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CONTROLLED ECOLOGICAL LIFE SUPPORT SYSTEMS (CELSS) PHYSIOCHEMICAL WASTE MANAGEMENT SYSTEMS EVALUATION

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CELSS

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GLOSSARY

ARC	Ames Research Center
AC	alternating current
BETS	Boeing Engineering Trade Study (computer program)
CELSS	controlled ecological life support system
CER	cost estimating relationships
C	carbon
CH_4	methane
CO_2	carbon dioxide
DDT&E	design development, test, and evaluation
DC	direct current
dia	diameter
ECS	environmental control system
ECLSS	environmental control and life support system
EDC	electrochemical depolarized cell (CO2 removal)
EM	engineering model
EPA	Environmental Protection Agency
EVA	extravehicular activity
FO	fiber optic
GARD, Inc.	General American Research Division, Inc.
H_2	diatomic hydrogen
H_2O	water
HID	high intensity discharge lamp
HSC	Hamilton Standard Company
HX	heat exchanger
HYG	hygiene water
I_2	diatomic iodine
IOC	initial operational capability
INCIN	dry incineration (system)
IVA	intravehicular activity
LEO	low Earth orbit
LSRF	life sciences research facility
LSS	life support system
LM	logistics module
LMSC	Lockheed Missiles and Space Company
max	maximum

GLOSSARY

min	minimum
N_2	diatomic nitrogen
N_2H_4	hydrazine
NASA	National Aeronautics and Space Administration
NH_3	ammonia
O_2	diatomic oxygen
O&C	operations and checkout
ORU	orbital replacement unit
PGU	plant growth unit
POT	potable water
RO	reverse osmosis (waste water process)
SCWO	supercritical water oxidation (system)
SO_2	sulfur dioxide
SS	Space Station
STS	Space Transportation System (Shuttle)
TIMES	thermoelectric integrated membrane evaporation system
TOC	total organic carbon
VAX	DEC minicomputer
VCD	vapor compression distillation (system)
VMS	Virtual Memory System (VAX operating system software)
VPCAR	vapor phase catalytic ammonia removal (system)
WETOX	wet oxidation (system)
wt	weight

UNITS OF MEASURE

btu	British thermal unit (unit of heat transfer)
btuh	btu per hour
cc	cubic centimeters
deg C	degrees centigrade
deg F	degrees Fahrenheit
ft^3	cubic feet
ft/min	feet per minute
ft	foot

UNITS OF MEASURE

ftcndl	footcandle
1G	Earth normal gravity
g	grams
hr	hour
hz	hertz (unit of frequency in cycles/sec)
kbps	kilobits per second
kg	kilograms
kw	kilowatts
kwh	kilowatt hour
K$	thousands of dollars
lb	pounds (unit of mass)
m^3	cubic meters
mbh	thousands of btu per hour mm millimeters
mmHg	millimeters of mercury (unit of pressure)
mm/m^2/sec	micromoles per square meter per second
pH	indication of acidity/alkalinity
ppm	parts per million
psia	pounds per square inch absolute (unit of pressure)
psig	pounds per square inch gauge (unit of pressure)
%	percent
<	less than
>	greater than

FOREWORD

The Conceptual Design Option Study-Controlled Ecological Life Support System (CELSS) Program Planning Support (contract NAS2- 11806) was modified by change order 2 dated April 30, 1985, to include a survey of six physiochemical waste management systems with potential CELSS applications. The contracting officer's representative is Dr. R. L. MacElroy. The study manager is Dr. Catherine Johnson.

This study was conducted by the Boeing Aerospace Company, Seattle, Washington.

ABSTRACT

This report compares parametric data for the following six waste management subsystems, as considered for use on the Space Station: (1) dry incineration, (2) wet oxidation, (3) supercritical water oxidation, (4) vapor compression distillation, (5) thermoelectric integrated membrane evaporation system, and (6) vapor phase catalytic ammonia removal. The parameters selected for comparison are on-orbit weight and volume, resupply and return to Earth logistics, power consumption, and heat rejection.

Trades studies are performed on subsystem parameters derived from the most recent literature. The Boeing Engineering Trade Study, (BETS), an environmental control and life support system (ECLSS) trade study computer program developed by Boeing Aerospace Company, is used to properly size the subsystems under study. The six waste treatment subsystems modeled in this program are sized to process the wastes for a 90-day Space Station mission with a crew of eight persons and an emergency supply period of 28 days. The resulting subsystem parameters are compared not only on an individual subsystem level but also as part of an integrated ECLSS.

Two factors affect the results of this trade study. One is the level of subsystem development. The four basic parameters studied in this report tend to be optimized during the later stages of equipment development. Therefore, subsystems in their later stages of development tend to exhibit lower parametric values than their earlier models. The other factor is the functional design of the subsystem. Systems designed to process a wider variety of wastes and to convert these wastes to more usable byproducts in general have higher process rates and therefore tend to be larger, weigh more, consume more power and reject more heat than waste treatment systems with lower process rates. These parametric liabilities are only offset when the parameters are weighed against the process rates and the overall ECLSS mass balance.

1.0 INTRODUCTION

1.1 OVERVIEW

Waste management subsystems are a key element in Controlled Ecological Life Support Systems (CELSS) operations. These subsystems recover the minerals needed for plant growth from waste products. These waste products are normally highly complex organics that are not directly assimilable by plants as nutrients. Converting these organics may be accomplished through biological or physiochemical processes. This study deals only with the physiochemical subsystems currently under consideration for space station waste management system. These subsystems are:

a. Incineration (INCIN).
b. Wet oxidation (WETOX).
c. Supercritical water oxidation (SCWO).
d. Vapor compression distillation (VCD).
e. Thermoelectric integrated membrane evaporation system (TIMES).
f. Vapor-phase catalytic ammonia removal (VPCAR).

Subsystems are sized, for comparison purposes, to support an eight-person crew waste load. These subsystems are to operate in a Space Station microgravity environment. They are configured to optimize weight, volume, and power demands. The designs are processed through the Boeing Engineering Trade Study (BETS) computer program to develop parametric data used in comparison analyses.

While this study deals solely with a parametric comparison of these subsystems, there are two important factors, not directly considered here, that should be kept in mind. One is the differences in the development stages among the six subsystems. As the development of a subsystem progresses past the demonstration of the design concept, design attention becomes more focused on optimizing power consumption, heat rejection, and weight and volume. Accordingly, it may be misleading to compare the parameters of subsystems in their early stages of design and testing, such as INCIN, WETOX, SCWO and VPCAR, with parameters of more developed subsystems, such as VCD and TIMES. The other factor is the functional design of the subsystem. INCIN, WETOX, and SCWO are designed to reduce both solid and liquid wastes while recovering reusable water and gases. VCD and TIMES are designed to process waste liquids only while recovering useful water. VPCAR is being developed to clean up the the water from the VCD unit but it could be used to process waste liquids and vapors as well.

1.2 BACKGROUND

Waste management was identified as enabling technology early in the course of the CELSS program planning study. NASA evaluation resulted in amendment of the contract (NAS2-11806) to examine physiochemical waste management subsystems.

1.3 STUDY OBJECTIVES

This study has four objectives:

a. Identify physiochemical waste water management subsystem designs suitable for use on Space Station-based CELSS.
b. Develop equipment listings and flow diagrams.
c. Develop mass flows using computerized modeling techniques.
d. Compare subsystems using trade-off analysis.

1.4 STUDY APPROACH

Seven sequential steps are used to meet the study objectives: (1) An extensive literature search for current waste water management subsystems was conducted (pertinent literature is listed in section 4.0). (2) Waste water subsystem schematics were extracted from the literature. These subsystem schematics were then modified as required for space flight. (3) An equipment listing was developed for each schematic. (4) A mass balance was calculated to ensure equipment and system flows were compatible with waste water load. (5) BETS parametric modeling algorithms were derived for each subsystem. Each subsystem was then processed through the BETS modeling program to generate parametric values for an eight-person crew. (6) The subsystems were compared based on their parametric values. (7) Overall ECLSS parametric comparisons were conducted. This process is presented in this attachment to the CELSS final report.

1.5 GUIDELINES AND ASSUMPTIONS

The same assumptions used in the Conceptual Design Option Study-Controlled Ecological Life Support Systems (CELSS) Program Planning Study are applicable to this attachment. These assumptions and guidelines are in section 1.5 of the final report.

1.6 INTRODUCTORY SUMMARY AND CONCLUSIONS

Six waste management systems with potential CELSS application are surveyed: (1) dry incineration (INCIN), (2) wet oxidation (WETOX), (3) supercritical water oxidation (SCWO), (4) vapor compression distillation (VCD), (5) thermoelectric integrated membrane evaporation system (TIMES), and 6) vapor phase catalytic ammonia removal (VPCAR).

Waste management systems are key elements in CELSS. They must recover and recycle inorganic nutrients and minerals from waste products to sustain plant growth. Waste management is also a key element for Space Station without the plant growth option. Solid and liquid wastes normally generated by the metabolic and hygienic activities of the Space Station crew must be processed, reduced, and stored for return to Earth. Without processing and reducing these wastes, the logistics requirements for the projected 90-day resupply of potable and hygiene water would total 57% of the Shuttle payload capacity. Wash and waste waters being returned to Earth would exceed the Shuttle landing payload capacity by 6197 lb.

All of the subsystems discussed in this report serve to close the (ECLSS) loop in differing degrees. INCIN, WETOX, and SCWO are designed to process solid and liquid wastes and thus reusable water, solid residues, and gases. VCD, TIMES, and VPCAR are designed to process liquid wastes only, producing reusable water. VPCAR may be able to process some dissolved solids while recovering additional water and gases.

INCIN was developed in 1972 by General American Research Division (GARD, Inc.) to incinerate human feces, urine, and nonhuman wastes. A four-man system for spacecraft use was built and tested by GARD, Inc.. The advantage of this subsystem is its production of sterile products. The disadvantages are its very dirty effluent requiring post treatment by catalytic oxidation, the requirement to preconcentrate the waste water, and the requirement to manually load the incinerator. The original schematic is modified in this report (fig. 2.2.1.1-1) to include a concentrator. For this study, auxiliary VPCAR parametric penalties are added to the process.

WETOX was developed in 1972 by the Lockheed Missiles and Space Co. (LMSC) to process human feces, urine, and miscellaneous spacecraft wastes at elevated temperature and pressure, recovering useful gases and water for recycling. A four-man prototype was designed and tested in the laboratory by LSMC. The advantages of this system include the ability to handle solid wastes as well as nondistilled liquid wastes, automatic operation, and its production of a sterile effluent. Disadvantages include high-temperature (550 deg F) and high-pressure (2200 psia) operation and the production of a very dirty effluent requiring post-treatment by catalytic oxidation. The original schematic (fig. 2.2.2.1-1) is not modified, but the addition of an auxiliary VPCAR is considered to be a requirement in this report.

SCWO is currently under development by Modar, Inc. This process involves the rapid oxidation of aqueous wastes containing (by weight) up to 30% solids above the critical temperature (705 deg F) and pressure (3208 psia) of water. There is good reason to believe that this process will be able to handle the 1% to 6% by weight of solids that are expected to be encountered in the Space Station waste water. High power and heat rejection rates are expected to be a concern with this system. A laboratory experiment has been set up and tested by Modar, Inc. to prove the basic concept. Data from this experiment are used in this report to derive component parameters for an eight-person Space Station subsystem. The advantages of this include ability to process solids, high oxidation efficiency resulting in relatively clean effluent, and a very short reaction time of 1 minute or less. Disadvantages include a very high operating temperature (1240 deg F) and pressure (3674 psia) resulting in designs with relatively high weight, volume, power and heat rejection penalties. A conceptual schematic (fig. 2.2.3.1-1) of a Space Station system was derived from data provided by Model, Inc..

VCD is being developed by Life Systems, Inc., is a phase-change process designed to recover potable water from urine and wash water by boiling off water at subatmospheric pressure in a compressor/evaporator/condenser. A second-generation, three-man system specifically designed for spacecraft use, was built and tested by Life Systems, Inc. Advantages of this process include low power consumption, high heat recovery, and high water recovery rate. Disadvantages include the inability to process solids and failure of the recovered water to meet NASA potable-water standards. No changes to the Life Systems, Inc. system schematic (fig. 2.2.4.1-1) are made in this report.

TIMES is being developed by Hamilton Standard. This also is a phase change process using a polysulfone hollow fiber membrane to evaporate water at subatmospheric pressure. A three-person prototype, specifically designed for spacecraft use, was built and tested by Hamilton Standard using urine concentrations of up to 12% (by weight). Advantages of this system include low level of complexity, low power consumption, high heat recovery, and high water recovery rate. Disadvantages include inability to process solids and low water quality. No changes to the Hamilton Standard system schematic (fig. 2.2.5.1-1) are made in this report.

Vapor phase catalytic ammonia removal is under development by GARD, Inc.. It is a hybrid process using a hollow fiber membrane to recover water as well as catalytic oxidizer reactors for reducing volatiles to useful water vapor and gases. This process was proven on a laboratory bench model by GARD, Inc. using untreated urine vapor as input. Advantages include ability to break down water vapor volatiles into reusable water and gases, high heat recovery, and the quality of recovered water. Disadvantages include inability to process suspended solids and high reactor temperatures (250 deg C and 450 deg C) resulting in volume, power, and heat rejection penalties. No changes in the proposed system schematic (fig. 2.2.6.1-1) are made in this report. However, this schematic is used to derive a schematic (fig. 2.2.6.1-2) and equipment parameters for an auxiliary VPCAR unit for addition to the INCIN and WETOX subsystems clean up their effluents.

The validity of subsystem trade analysis largely depends on the level of subsystem technology development. The more mature systems are optimized for power, weight, volume, and heat rejection. They therefore tend to come out better in parametric trade analyses when compared with less mature systems. Thus the parametric performance of the six subsystems would tend to reflect the maturity of development as listed below from most to least mature:

1. VCD.
2. TIMES.
3. INCIN.
4. WETOX.
5. VPCAR.
6. SCWO.

Considering these systems as independent entities that have no influence on the other ECLSS subsystems, they are ranked by the parameters evaluated in this report from best to least as shown in table 1.6-2 below.

TABLE 1.6-1

WASTE MANAGEMENT SYSTEM RANKING SUMMARY

Ranking	Weight	Volume	Logistics	Power	Heat Rejection	Launch Costs
1	TIMES	TIMES	VPCAR	VCD	VCD	VPCAR
2	VCD	VCD	SCWO	VPCAR	VPCAR	SCWO
3	SCWO	SCWO	INCIN	TIMES	TIMES	INCIN
4	VPCAR	VPCAR	WETOX	SCWO	INCIN	WETOX
5	INCIN	WETOX	VCD	INCIN	SCWO	VCD
6	WETOX	INCIN	TIMES	WETOX	WETOX	TIMES

It is apparent that the phase-change processes (VCD and TIMES) have the best weight, volume, power, and heat rejection characteristics but have the worst logistics requirements. The better characteristics are partially a result of the mature level of subsystem development. The fact that these processes were designed to recover water from only liquid wastes also contributes to the lower weight, volume, power, and heat rejection but results in higher logistics requirements.

The combustion processes (INCIN, WETOX, and SCWO) have the opposite characteristics. They exhibit relatively high weight, volume, power, and heat rejection but lower logistics requirements. The higher weight, volume, power and heat rejection rates are partially due to the lower maturity level of these subsystems and are also due to the increased mass processing rate, higher recovery rate and the nature of the processes that use high temperatures and pressures for combustion. The more favorable logistics requirements are due to the higher recovery rates of usable materials, requiring less resupply and return to Earth.

The VPCAR system is a hybrid using both phase-change and oxidation processes. Its parametric performance is therefore more mixed than for the other systems in this study. VPCAR displays the best logistics, good power consumption and heat rejection, but only fair weight and volume characteristics. Overall its performance is very good considering its relatively low technology level (figure 2.3-1).

It is difficult to determine a "best" subsystem from the above comparisons. Selecting a best subsystem depends on which parameters are considered to be the most important. The relative importance of the parameters depends on the mission requirements. For example, a short-mission space capsule may place maximum emphasis on weight, volume, power, and heat rejection. A long-mission lunar-base or Mars expedition may place maximum emphasis on reducing or eliminating logistics. The Space Station may place equal emphasis on all of the parameters with upper limits set for each one. Table 1.6-2 is a parametric evaluation of the subsystem where all parameters are considered to be equally important.

TABLE 1.6-2

WASTE MANAGEMENT SYSTEM PARAMETRIC EVALUATION

Parameter	Waste Management Subsystem					
	INCIN	WETOX	SCWO	VCD	TIMES	VPCAR
Weight	5	6	3	2	1	4
Volume	6	5	3	2	1	4
Logistics	3	4	2	5	6	1
Power	5	6	4	1	3	2
Heat Rejection	4	6	5	1	3	2
Total	23	27	17	11	14	13

The subsystems are given nominal values based on their relative ranking in each parametric category. Therefore, the TIMES subsystem weight parameter is given a value of 1 because it exhibited the best weight characteristics (sec. 2.3.1). The WETOX subsystem power parameter, however, is given a value of 6 because it exhibited the highest power consumption (sec. 2.3.3). Lower ranking values indicate lower parametric penalties and therefore better relative parametric standing. When the parametric values for each subsystem are summed, the following parametric ranking results:

1. VCD.
2. VPCAR.
3. TIMES.
4. SCWO.
5. INCIN.
6. WETOX.

When all parameters are considered equally, the phase-change processes come out on top and VCD is the best of these. Subsystem maturity and functional design have a lot to do with this result.

The NASA Space Station program places primary emphasis on costs. At this time there is not enough information on all of the subsystems to determine and compare them for life cycle costs. But, as demonstrated (table 2.3.5-1), there is enough parametric information derived from this report to determine and compare subsystem launch costs over a projected subsystem equipment life of 10 years. The launch costs in the table have subsystem power and heat rejection support required from the Space Station factored into them. The results reveal that if launch costs were the single most important selection criteria, then the subsystems would have to be ranked from most to least desirable as follows:

1. VPCAR.
2. SCWO.
3. INCIN.
4. WETOX.
5. VCD.
6. TIMES.

This is the same relative ranking as for the logistics comparison in section 2.3.2. This indicates that, when launch costs are considered over the life of the equipment, logistics becomes the single most important parameter overriding weight, volume, power, and heat rejection combined. The combustion-based subsystems have the best logistics characteristics, and, of these VPCAR and SCWO appear to be the best performers.

However, these waste treatment subsystems do not function independently. They are dependent up other ECLSS devices for waste and processing inputs as well as for additional processing of effluents. This affects the balance of materials required and produced by these subsystems and the balance of materials processed and stored by the rest of the ECLSS. Table 1.6-3 is a summary of the ECLSS daily materials balance for an eight-person Space Station mission for each of the six waste processes under study.

TABLE 1.6-3

ECLSS DAILY MATERIALS BALANCE (LB/DAY) (1)

Subsystem	Inputs			Effluents					
	Water	Solids	O_2	Water	Brine	Ash	CO_2	N_2	SO_2
INCIN	60.6	4.1	5.2	62.9	0	1.2	5.1	0.4	0.2
WETOX	60.6	4.1	5.2	62.9	0	1.2	5.1	0.4	0.2
SCWO	60.6	4.1	5.2	62.9	0	1.2	5.1	0.4	0.2
VCD (2)	60.5	2.4	0	58.0	5.0	0	0	0	0
TIMES (3)	60.5	2.4	0	57.6	6.1	0	0	0	0
VPCAR	60.6	2.4	0	61.7	0	0.8	2.8	0.3	0.2

Notes:

(1) Balanced to within 0.1 lb.

(2) 0.4 lb water vapor vented.

(3) 2.3 lb water vapor vented.

The above summary indicates that the combustion processes recover more water and require less storage for waste byproducts than the phase-change processes. This is done at the expense of requiring oxygen (O_2) from the Space Station supply system and requiring larger carbon dioxide (CO_2) collection and reduction by the combustion processes could be used for plant growth, eliminating the need to increase the size of the Space Station CO_2 reduction subsystem.

The ECLSS material balance suggests that in order to evaluate and compare the subsystems they should be considered as part of an integrated ECLSS. Using a common ECLSS baseline configuration (table 2.5-1) for each of the six subsystems results in the "ECLSS Configuration Ranking Summary" shown below for each of the four parameters. A Shuttle commode and trash compactor are added to the phase-change configurations (fig. 2.5-2) as penalties for storing solid wastes.

The parametric rankings obtained in section 2.5 for the six waste management subsystem ECLSS configurations provide the basis for the conclusions in this report. This is because the configuration rankings include consideration of individual subsystem parameters along with overall ECLSS material balances and ECLSS subsystem interdependence. Therefore, they provide a more complete picture of the end parametric affects of each of the six waste management subsystems. Table 1.6-4 below is a summary of Section 2.5.

TABLE 1.6-4

ECLSS CONFIGURATION RANKING SUMMARY

Ranking	Weight	Volume	Logistics	Power	Heat Rejection	Launch Costs
1	TIMES	SCWO	SCWO	VCD	VCD	INCIN
2	VCD	TIMES	INCIN	TIMES	TIMES	SCWO
3	SCWO	VCD	WETOX	VPCAR	VPCAR	WETOX
4	VPCAR	WETOX	VPCAR	SCWO	INCIN	VPCAR
5	INCIN	VPCAR	VCD	INCIN	SCWO	VCD
6	WETOX	INCIN	TIMES	WETOX	WETOX	TIMES

Several conclusions may be drawn from this summary. First, it highlights the optimum ECLSS configuration for each parameter. If on-orbit weight is considered to be the most important characteristic, then the TIMES configuration has the lowest weight. If logistics weight is considered to be the most important factor, then the SCWO configuration has the lowest logistics requirements.

Second, general trends related to process type appear. The summary reveals that the phase-change processes (VCD and TIMES) exhibit the best weight, volume (with the exception of SCWO), power, and heat rejection characteristics, but the worst logistics. The combustion processes (INCIN, WETOX, and SCWO) exhibit very good logistics, but the worst weight, volume, power, and heat rejection. The VPCAR results are more mixed since this subsystem is part phase change, with hollow fiber membrane evaporator, and part combustion (oxidation), with its NH_3 and N_2O catalytic oxidation reactors. These trends are due in part to the function of the processes and in part to their level of maturity. The phase-change processes handle only liquid wastes and can only recover 94% to 97% of the water in these wastes. Any solids in the wastes (and an equal amount of water by weight) are rejected as brine and stored for return to Earth. This handling of a limited amount of wastes keeps the on-orbit weight and volume, power consumption, and heat rejection rates relatively low, but the brine storage requirements keeps the logistics high. The combustion processes are designed to handle both solid and liquid wastes. They not only recover 100% of the water in the waste but also produce additional water in the oxidation reactions. The higher waste processing rate and the required higher operating temperatures and pressures (except for INCIN) tend to increase the subsystem weight, volume, power consumption, and heat rejection rates. Increased dependency on the other ECLSS subsystems for providing O_2 and for processing N_2, CO_2 and SO_2 tend to increase these same parameters for the supporting subsystems as well. However, the higher processing and recovery rates also tend to significantly reduce the ECLSS logistics requirements for water and N_2.

Third, relationships between the various parameters become visible. Power consumption and heat rejection rate have identical configuration rankings. This is because all of the power that is required by a subsystem is assumed to be converted to heat. If a fan motor draws 1 kw of electrical power, it is assumed that 1 kw of heat is passed to the cabin atmosphere by the motor. The exception to this assumption is the combustion processes. These generate additional heat, above their power consumption rate, in the exothermic oxidation reactions (fig. 2.4.1-1). Another relationship exists between configuration logistics and 10-year launch costs. When launch costs consider not only getting the equipment into orbit but also resupplying it every 90 days for an anticipated 10-year life, then logistics becomes the single most important cost factor. One relationship that is not evident in this summary but is evident in the consideration of individual subsystems (sec. 2.3, fig. 2.3.1-1) is the direct relationship between on-orbit weight and volume. This is not seen in the ECLSS configuration comparisons because the weight and volume values are too close to each other. The values are so close (within 4% to 9%) that they can be considered within the limits of estimating error and therefore not significant.

It is not obvious from table 2.5.5-1 which waste management subsystem is the best overall parametric performer. That judgment depends largely on which parameters are considered to be the most important. The relative importance of each parameter must be determined from the individual space-mission requirements. A short mission in a space capsule may emphasize low weight, volume, power, and heat rejection. A lunar base or Mars expedition may place higher priority on low logistics. A Space Station in Earth orbit may place equal importance on all. If all parameters are considered equally important, then the subsystems can be ranked as follows from best to least:

1. VCD.
2. TIMES.
3. SCWO.
4. VPCAR.
5. INCIN.
6. WETOX.

Because the phase-change processes rank highest in five out of the four separate parameters they have the best overall performance. VCD ranks the highest of these. The combustion processes rank the lowest, SCWO is the best of these.

However, NASA is placing primary importance on costs for the Space Station program. Although insufficient data have been found for calculating complete subsystem life cycle costs for this report, enough subsystem parametric data have been generated by BETS to estimate subsystem launch costs over a projected 10-year equipment life. When these costs, which are adjusted for the use of the IOC Space Station power and thermal systems, are compared for each ECLSS configuration, the following subsystem ranking from least to most expensive launch cost results:

1. INCIN.
2. SCWO.
3. WETOX.
4. VPCAR.
5. VCD.
6. TIMES.

This ranking is basically the same as for the logistics parameter, indicating that when launch costs are evaluated over the life of the equipment, logistics becomes the single most important factor. Logistics becomes so important that it overrides the weight, volume, power consumption, and heat rejection parameters combined. The combustion processes have the lowest logistics requirements. The cost figures are so close among the three combustion processes (within 5%) that no clear best performer is indicated.

2.0 WASTE MANAGEMENT SUBSYSTEM COMPARISON

2.1 WASTE PROCESSING

Normal operation of the Space Station will result in the generation of numerous contaminants and wastes. For the Station to continue operation and to provide a habitable environment for the crew, all of the contaminants and wastes must be collected and processed. Gaseous contaminants are expected to be generated primarily by crew metabolism and by material outgassing. These gases will be processed primarily by the Station CO_2 removal and reduction subsystems and by the trace contaminant removal subsystem. Liquid wastes are expected from crew metabolism and crew hygiene activities. In an open-loop water system, these wastes would simply be collected and stored for later return to Earth. In this case, storage requirements would be quite high. Solid wastes occur in the form of fecal solids and trash solids. Like the liquid wastes, if the solid wastes are not treated or reduced they must be collected and stored for return to Earth. A listing of generally accepted crew metabolic and hygiene requirements and outputs is given in table 2.1-1.

The purpose of a waste management subsystem is to process, reduce, and store waste products while converting some of them to reusable form. Simple storage of wastes is the most reliable technique but suffers the greatest logistics penalties in terms of weight and volume. For example, if a 90-day Space Station resupply period is assumed, using the crew loads listed in table 2.1-1 results in the Space Shuttle resupply and return to Earth weights as given in table 2.1-2.

TABLE 2.1-2
PARTIAL LOGISTICS FOR OPEN-LOOP ECLSS
Eight-Person Crew and 90-Day Resupply Period

	Gases (lb)		Water (lb)				
	O_2	CO_2	Potable	Hygiene	Wash	Waste	Total
Resupply	1,333	o	4,867	30,672	o	o	36,872
Return	o	1,584	o	o	30,007	6,606	38,197

Notes:

1. This table represents only a partial logistics picture. Actual Space Station open-loop resupply and return logistics would balance each other.
2. Wash and waste water figures in this table contain solids.

TABLE 2.1-1

AVERAGE LOADS FOR ECLSS

Parameter	Units	Average	Peak *
Metabolic oxygen	lb/person-day	1.84	3.65
Metabolic carbon dioxide	lb/person-day	2.20	4.41
Drinking water	lb/person-day	2.86	3.39
Food preparation water	lb/person-day	3.90	4.64
Hand wash water	lb/person-day	7.00	
Shower water	lb/person-day	5.00	
Clothes wash water	lb/person-day	27.50	
Dish wash water	lb/(8)crew-day	16.00	
Metabolic produced water	lb/person-day	0.78	
Perspiration/respiration H2O	lb/person-day	4.02	5.82
Fecal water	lb/person-day	0.20	
Urine (3.3) plus flush (1.1)	lb/person-day	4.40	
Food solids	lb/person-day	1.36	
Food water	lb/person-day	1.10	
Food preparation latent H2O	lb/person-day	0.06	
Trash solids	lb/person-day	0.13	
Trash water	lb/person-day	0.30	
Urine solids	lb/person-day	0.13	
Fecal solids	lb/person-day	0.07	
Sweat solids	lb/person-day	0.04	
EVA drinking water	lb/8-hr EVA	0.75	
EVA waste water	lb/8-hr EVA	2.00	
EVA oxygen	lb/8-hr EVA	1.32	
EVA carbon dioxide	lb/8-hr EVA	1.57	
Sensible metabolic heat	btu/person-day	7010.00	7900
Hygiene latent water	lb/person-day	0.94	
Laundry latent water	lb/person-day	0.13	
Hygiene water solids	% of H2O usage	0.13	
Waste wash water solids	% of H2O usage	0.44	
Airlock volume	ft3	150.00	
Cabin air leakage	lb/day-module	0.50	
Commode ullage volume	ft3/dump	0.00	
Charcoal (odor control)	lb/person-day	0.13	
Clothing weight	lb/person-day	2.50	

* Short term, high work load capacity.

Since the existing Space Transportation System is rated for a landing (return to Earth) payload of only 32,000 lb, table 2.1-2 shows that a completely open-loop environmental control and life support system (ECLSS) for an eight-person crew is not supportable at this time. A partial or a completely closed-loop system must therefore be considered. Generally, the more closed an integrated Station ECLSS becomes, the more reduced the logistics requirements become. The major drawback to the closed system is that the subsystems are very interdependent resulting in a lower overall system reliability than for an open-loop system. Subsystem and ECLSS reliabilities are not addressed further in this report due to the lack of sufficient subsystem reliability data.

There are some subsystems whose function is to reduce the volume of the wastes while not necessarily converting these wastes to useful byproducts. Such subsystems are, for example, the present commode aboard the Space Shuttle and a proposed trash compactor for the Space Station. Although these devices may serve necessary functions aboard the Space Station, they remain open-loop devices.

The six waste management subsystems considered in this study all serve to close the ECLSS loop. The Life Systems, Inc. vapor compression distillation (VCD) unit and the Hamilton Standard Inc. TIMES thermoelectric integrated membrane evaporation system (TIMES) unit are two of the most developed subsystems now under consideration by NASA for use aboard spacecraft. Both of these units are designed to recover water from waste and wash water sources through a phase change process. They both provide distilled water by boiling off water vapor at subatmospheric pressures. The solids left behind in these processes are concentrated into brines that then must be stored for later return to Earth.

The four other subsystems in this study: dry incineration (INCIN), wet oxidation (WETOX), supercritical water oxidation (SCWO), and vapor phase catalytic ammonia removal (VPCAR) are much less developed than the VCD or TIMES units. INCIN and WETOX units were last developed in the early 1970s, research continues to be done on them. SCWO and VPCAR are the two most recently developed technologies that have grown out of the earlier work on INCIN and WETOX. Both of these later subsystems are still in the laboratory development stage. INCIN, WETOX, and SCWO are designed to recover not only the water in the incoming waste and wash waters but also water formed by the combustion of solids contained in these inputs. Unlike VCD and TIMES, these subsystems can handle solid wastes in a liquid slurry with optimum solids concentrations at 10% to 30% weight.

VPCAR is somewhat of a hybrid between the phase-change and the combustion processes. It is designed to recover waste and wash water and any water formed from the oxidation of volatiles, such as ammonia, carried over from an evaporation process.

Suspended solids must be filtered out before entering this process but dissolved solids may be carried over with the water vapor and oxidized. The unusable byproducts from all of these combustion-oxidation processes are expected to be ash and some sulfur dioxide (SO_2) gas. These byproducts must be stored for later return to Earth.

A more detailed discussion on each of the above subsystems follows in section 2.2.

2.2 SUBSYSTEM DESCRIPTION

This section details each subsystem by functional description, schematic and equipment and parameter list. This information was drawn from the most recent reports and journal articles available. Revisions have been added for operating in a zero-G environment (i.e., water/gas separation devices) and for additional equipment deemed necessary for the subsystem to function as part of an integrated ECLSS (e.g., service valves, control valves, accumulators, and heat exchangers).

2.2.1 Incineration

This subsystem is based upon ASME publication 72-ENAv-2 written by L. J. Labak, G. A. Remus, and J. Shapira in 1972.

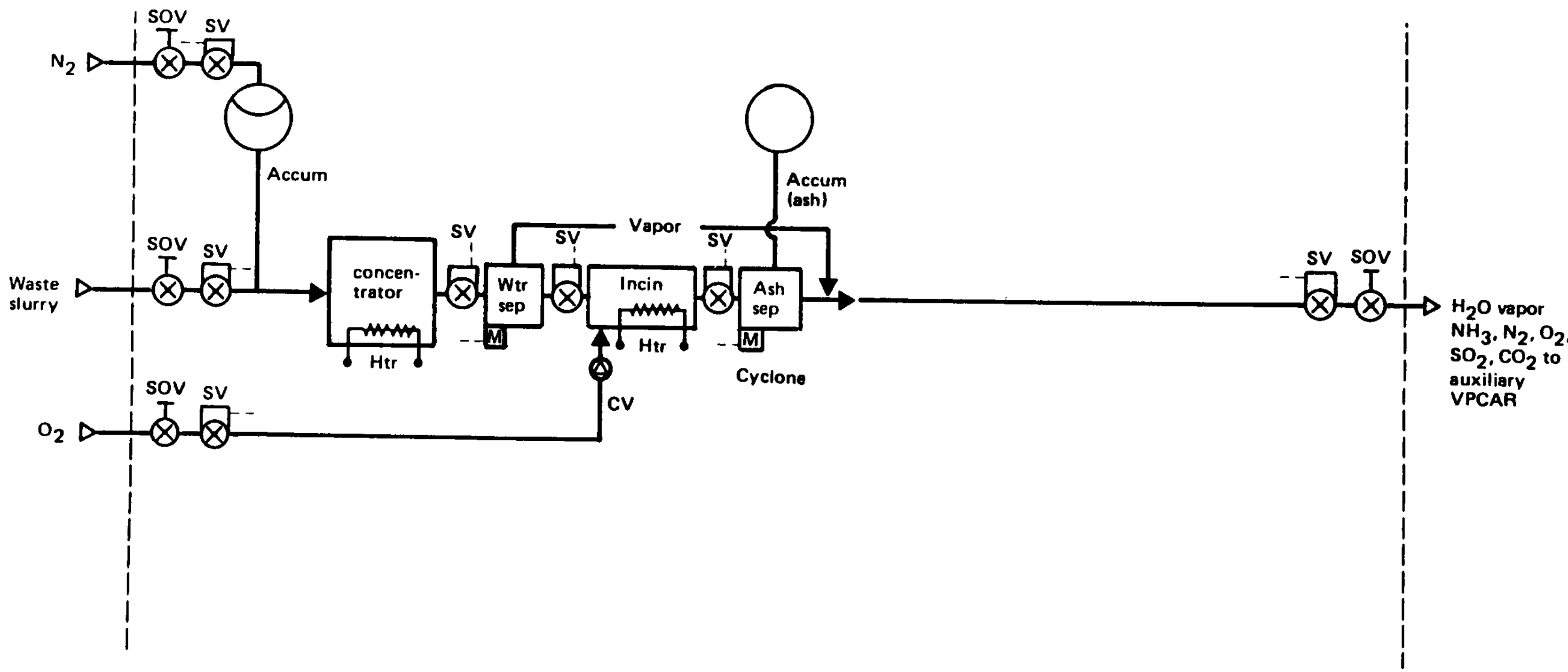
A system was developed to incinerate human feces, urine, distillate residue (50% solids by weight) and nonhuman wastes at 600 deg C. It is judged for the purposes of this report that this system reached a NASA technology level of 4 (table 2.3-1).

2.2.1.1 Subsystem Design

A four-man automatic incineration system for spacecraft use was built and tested. This design (fig. 2.2.1.1-1) consisted of an incinerator designed to operate at 600 deg C, a catalytic afterburner/oxidizer designed to operate at 300 deg C to 500 deg C. (not shown for reasons explained below), and a control and display unit. Incineration was improved by providing pure oxygen as opposed to air for combustion, adding an afterburner and varying the oxygen feed rate to the afterburner. Dual condensers and a gas collection device were shown on the report process diagram but were not included as an integral part of the system prototype.

This system was designed to process 1230/day of water containing 475 of solids. 5.0 kwh of electrical energy, and 0.6g of oxygen per gram of waste solids were required. The incineration process took 6.5 hr., 17.5 hr were required for cooldown resulting in a total cycle time of 24 hr.

Advantages of the design included selfsterilization and sterile products. Disadvantages of the design included incomplete combustion of wastes resulting in H_2, CH_4, CO and NH_3 gases in the effluent even with the use of a catalytic afterburner. The product



Legend:

Item	Description
Accum	Accumulator
Cat ox	Catalytic oxidizer
CV	Check valve
Htr	Electric heater
Incin	Incinerator
M	Fan motor
SOV	Shut off valve (manual)
SV	Solenoid valve
Wtr sep	Water separator

Figure 2.2.1.1-1. Incineration Waste Disposal System Space Station Application

water was yellow, had a pH of 9.5 and an electrical conductivity of 13 microohms. In addition, there were quantities of NH_4+, CL-, and $SO_4=$, carbon, and solids in the product water. Further water processing would be required to be able to use the effluent water and gases from this system. As configured, this system would require either a pre-concentration process for wash water and urine, additional power for concentrating these inputs, or heating the unconcentrated inputs to combustion temperatures.

An additional drawback to the as-designed configuration is the requirement to manually load wastes into the incinerator for processing. NASA wishes manpower on board the Space Station to be used primarily for customer support. Therefore, ECLSS subsystems should work automatically to minimize the amount of crew time required to support them. An additional benefit of making this process automatic would be the elimination of the cooldown time required between manual loadings of the incinerator.

The following devices were added to the basic process flow diagram as given in the ASME report:

a. Service and control valves for maintenance and automatic control.
b. Accumulators for system capacitance and ash storage.
c. A waste concentrator and a water/vapor separator as penalties for concentrating urine/flush water and wash water to 50% solids weight.
d. A solids separator for automatically removing ash from the incinerator effluent gases.
e. An auxiliary VPCAR (fig. 2.2.6-2) for posttreating and condensing the effluent (not shown).

The following devices were deleted from the basic process flow diagram:

a. The catalytic oxidizer/afterburner was replaced by an auxiliary VPCAR for more efficient and thorough oxidation of the effluent gases.
b. The condensers were replaced by the condenser on the auxiliary VPCAR post-treatment process.
c. A gas storage accumulator was deleted and assumed to be part of the postprocessing of these gases by other subsystems.

2.2.1.2 Parametric Description

Table 2.2.1.2-1 lists the dry incineration prototype equipment and parameters as originally specified in the ASME report. Additional equipment as deemed necessary has been added and a revised parameter total determined. This list, except for the heat rejection rate, does not reflect the addition of an auxiliary VPCAR to this subsystem. The parametric penalties for an auxiliary VPCAR are presented in table 2.2.6.2-2. When

TABLE 2.2.1.2-1 DRY INCINERATION EQUIPMENT LIST
From ASME 72-ENAv-2, Labak, Remus, Shapira

Component	Volume	Weight	Power (w)	Heat rejection	Notes
Incin-erator	2450 cc 149 in3	2625 g 5.86 lb	600x5.5 hr	-	
Catalytic aftrburner	500 cc 31 in3	1200 g 2.63 lb	600x1 hr interm.	-	Substitute aux VPCAR
Controls and panel	-	-	170x6.5 hr	157 btuh (24 hr avg)	Air cooled
Piping and	-	-		-	structure
Subtotal	10.4 ft3	90.5 lb	-	-	
Feed storage tank	550 in3	8 lb	-	-	Estimated
Feed Con-centrator (16 lb urine)	1200 in3	18 lb	4800x1 hr interm.	-	Estimated
Fan sepa-rators(2)	231 in3 each	5.6 lb each	43x1 hr each	12 btuh (24 hr avg)	HSC interm.
Ash storage Tank(90day)	2065 in3	30 lb	-	-	Estimated
Insulation				180 btuh	Air cooled
Revised total	20 ft3 (45%pkg)	160 lb (12%pkg)	388 (24 hr avg)	350 btuh (24 hr avg)	

Consumes:
O2 0.6 lb/day/lb solids input

Returns:
Solids 0.11 lb/day/lb solids input

COMMENTS:

1. "-" denotes that no specific information was determined for this point.
2. Subtotals represent parameters determined directly from the literature.
3. Based on incineration of 1230 g/day (2.7 lb/day) of wastes with 475 g solids. Represents wastes from a four-person crew (19.2 lb/day before concentration).

the parameters for an auxiliary VPCAR are added to the parameters of the incineration subsystem, the total heat rejected will be equivalent to the total power consumed. A summary of these parameters adjusted for an eight-person crew and including an auxiliary VPCAR is presented in section 2.3.

2.2.2 Wet Oxidation

This subsystem is based on ASME Publications 72-ENAv-3 written by R. B. Jagow in 1972 and 70-Av/SpT-1 written by R. B. Jagow, R. J. Jaffe, and C. G. Saunders in 1970. A system was under development to process human feces, urine, and other miscellaneous spacecraft wastes, recovering useful gases and water for recycling. It is judged for the purposes of this report that the development of this system reached a NASA technology level of 4 (table 2.3-1).

2.2.2.1 Subsystem Design

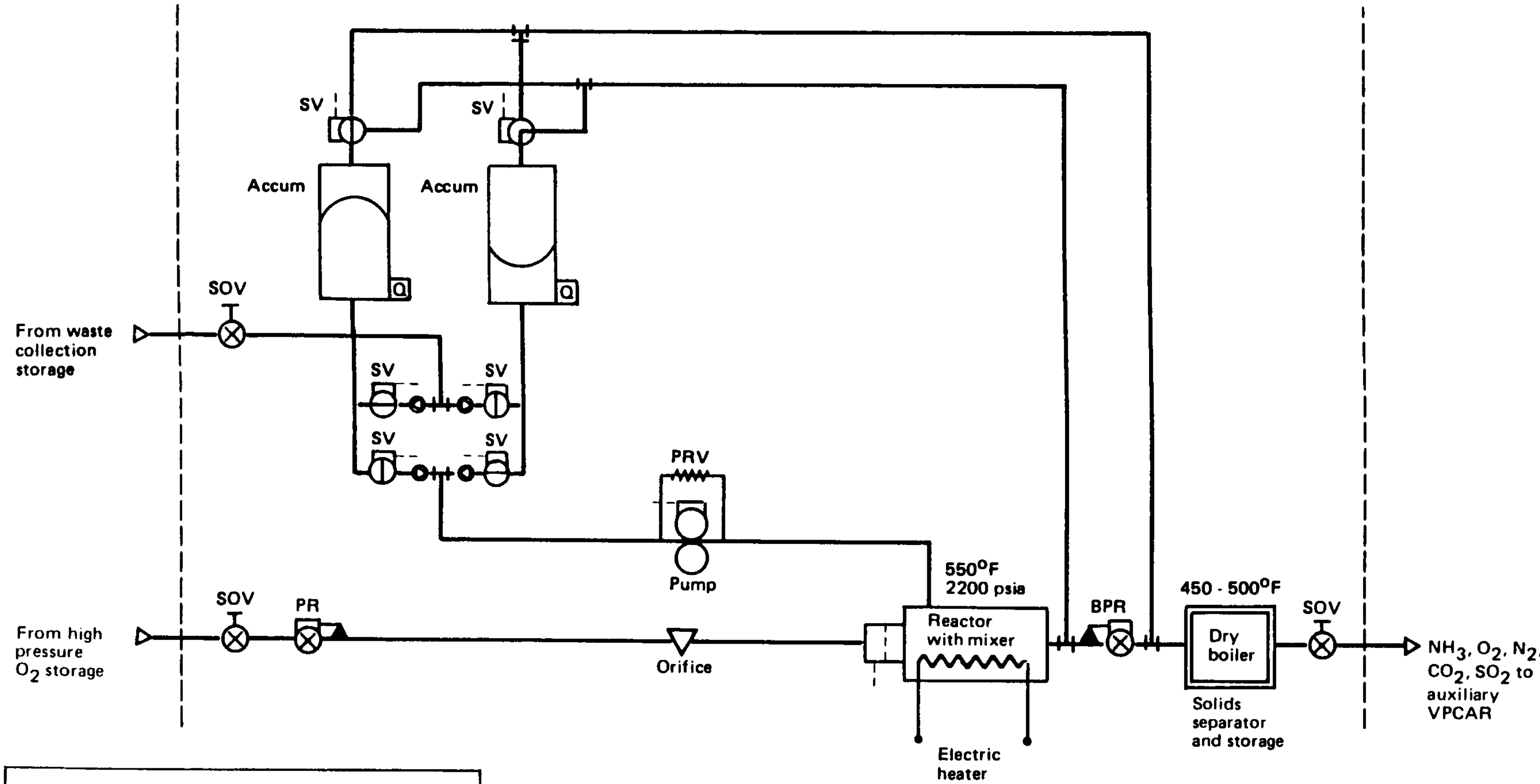
An initial, prototype four-man wet oxidation system was designed and tested in the laboratory. This design (figure 2.2.2.1-1) consisted of: dual slurry feed tanks, a slurry feed control valve, slurry pumps, a reactor operating at 550 deg F and 2200 psig, oxygen flow controls, a dry boiler, and controls and instrumentation.

This system was designed to process 330 cc/hr of a 10% feces/90% urine mixture by weight (four-man load with a 25% design margin). 1.3 kw of electrical energy and 28.4/hr of oxygen were required. Optimum reaction time appeared to be 1-1/2 hr. Improvements in the design included using oxygen rather than air for combustion, using a base metal oxide catalyst to reduce temperatures and to promote complete oxidation, and stirring the slurry.

Advantages of the wet oxidation system include the ability to handle solid waste and nondistilled waste water. The solids produced were reduced to a sterile nondegradable ash of very small volume.

Disadvantages included the high temperatures (550 deg F) and high pressures (2200 psig) required for the reaction. Incomplete combustion and reduction of wastes was a problem with this process as well. Experimental results showed quantities of NH_3, CO, and CH_4 in the effluent. The product water had a pH of 8.4 and very high conductivity indicating a large quantity of dissolved salts. An auxiliary VPCAR (see Sec. 2.2.6 and fig. 2.2.6.1-2) for post-treating and condensing the effluent water vapor and gases would be required with this system.

There were no devices either added to or deleted from the subsystem schematic as presented in the ASME papers.



Legend:

Item	Description
Accum	Accumulator (with/moving diaphram)
BPR	Back pressure regulator
PR	Pressure regulator
PRV	Pressure relief valve
SOV	Shut off valve (isolation)
SV	Solenoid valve

Figure 2.2.2.1-1. Wet Oxidation Subsystem Space Station Application

2.2.2.2 Parametric Description

Table 2.2.2.2-1 lists the equipment and related parameters for a projected four-person flight system as presented in ASME 70-Av/SpT-1. The only addition to this list is a power penalty adjustment for compressing both the slurry and the oxygen to the operating pressure of the reactor. This list, except for the heat rejection rate, does not reflect the addition of an auxiliary VPCAR. The parameters for an auxiliary VPCAR are listed in table 2.2.6.2-2. When the parameters for an auxiliary VPCAR are added to the parameters for the wet oxidation subsystem, the total heat rejection rate will be equivalent to the total power consumption. A summary of these parameters adjusted for an eight person crew and including an auxiliary VPCAR is presented in section 2.3.

2.2.3 Supercritical Water Oxidation

This concept is based upon SAE Paper 820872 written by Timberlake, Hong, Simson, and Modell in 1982. The process involves oxidation of aqueous wastes above the critical temperature (374 deg C) and the critical pressure (215 bar) of water. Organic oxidation is initiated spontaneously when oxygen and water are brought together at 400 deg C and 250 bar. The heat of combustion causes a rise in temperature to above 600 deg C. This process is said to oxidize organic materials at efficiencies greater than 99.99% with reaction times of less than 1 min. without the use of catalysts. As a result, organics, such as urea, are completely broken down to N_2 and CO_2 gases and water vapor. The solubility of inorganic salts is very low under these conditions and precipitate out as solids. For industrial processes treating aqueous wastes containing 1% to 20% organics by weight, supercritical water oxidation is less costly than incineration and more efficient than wet oxidation.

Although not specifically mentioned in the literature, there is good reason to believe that this process can handle the 1% to 6% solids likely to be encountered on board spacecraft, but not without a power penalty for generating enough heat to sustain the reaction. It is judged, for the purposes of this report, that supercritical water oxidation, as specifically developed for spacecraft use, has reached a NASA technology level of 3 (table 2.3-1).

2.2.3.1 Subsystem Design

A laboratory experiment was set up at Modar, Inc. to demonstrate the use of SCWO for urea destruction. A schematic of this system and a schematic of the general SCWO process were used to derive a probable SCWO spacecraft waste treatment subsystem capable of operating in 0-G environment. Figure 2.2.3.1-1 shows this system. A feed waste accumulator is used to provide system capacitance. A small piston slurry pump is

TABLE 2.2.2.2-1 WET OXIDATION EQUIPMENT LIST
From ASME 70-Av/SpT-1 by Jagow, Jaffe, and Saunders

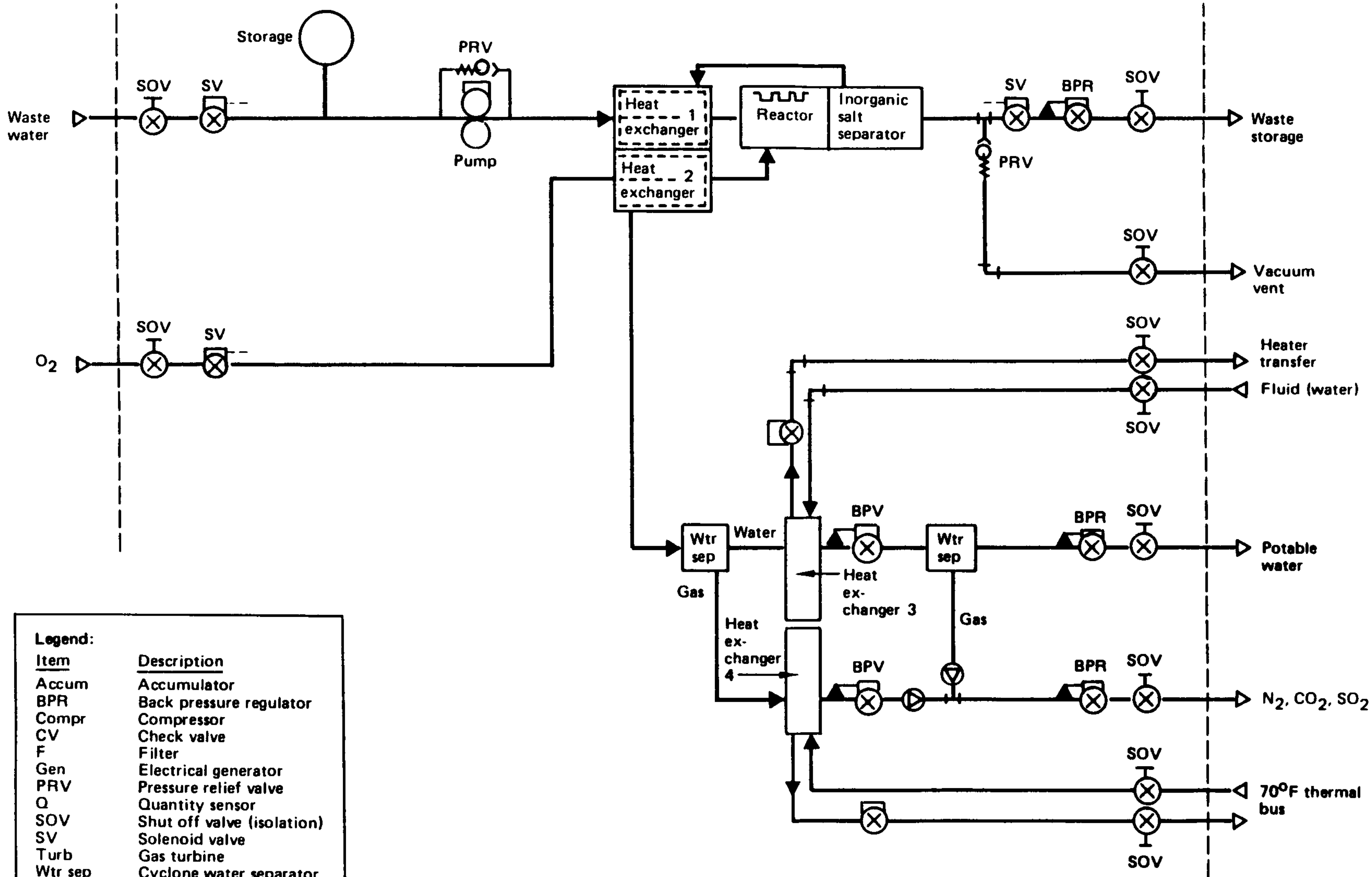
Component	Volume (in3)	Weight (lb)	Power (w)	Heat rejection	Notes
Slurry feed tanks	-	20	-	-	
Slurry valves	-	8	15	51 btuh	Air cooled
Slurry pump	-	4	15	51 btuh	Air cooled
Reactor	1140	70	250x24 hr	-	
Oxygen tank	-	3	-	-	Not required
Oxygen controls	-	5	-	-	
Dry boiler (ash sep)	-	30	-	95 btuh	Air cooled
Structure and plumbing	-	25	-	-	
Controls and instr	-	12	10	34 btuh	Air cooled
Subtotal	11 ft3 (45%Pkg)	198 (12%Pkg)	290	231 btuh	Rough estimate
O2/slurry compression penalty	-	-	13x24 hr	44 btuh	Air cooled
Revised Total	11 ft3	198	303	275 btuh	

Consumes:
O2 0.64 lb/day

Returns
Solids 0.3 lb/day

COMMENTS:

1. "-" denotes that no specific information was determined for this point.
2. Based upon 330 cc/hr feed rate (90% urine/10% feces) nominal four-person system with 25% overdesign factor (17.5 lb/day).
3. Subtotals represent parameters determined directly from the literature.



Legend:

Item	Description
Accum	Accumulator
BPR	Back pressure regulator
Compr	Compressor
CV	Check valve
F	Filter
Gen	Electrical generator
PRV	Pressure relief valve
Q	Quantity sensor
SOV	Shut off valve (isolation)
SV	Solenoid valve
Turb	Gas turbine
Wtr sep	Cyclone water separator

Figure 2.2.3.1-1. Supercritical Water Oxidation Space Station Application

used to pressurize to slurry to 250 bar. Pure oxygen is provided for oxidation at slightly above 250 bar from an existing spacecraft high pressure O_2 gas storage system (assumed to be at, or above 4000 psia). Heat recovery exchangers are provided to preheat the incoming slurry and O_2 to 400 deg C, preventing charring of the solids in the reactor. On initial start-up, when there is not yet any heat to recover, the slurry must be held and preheated in the reactor before the O_2 is introduced to initiate the oxidation process. Once the reaction is up to 670 deg C (full destruction of N_2O), 250 bar and the reaction time (< 1 min.) is satisfied, the reactor effluent is fed through the cyclone inorganic salt separator. Effluent water vapor and gases are then passed through the two heat recovery heat exchangers where the water vapor becomes partially condensed. A cyclone water separator separates the condensed water from the gases and these two streams are fed through two more heat exchangers to reduce their temperatures to 70 deg F. The water and gas streams are then reduced in pressure to within 1 bar of atmosphere and the water stream is passed through one more cyclone water separator to eliminate any remaining gases present. The effluent is reusable water with no further treatment required and a mixture of N_2, CO_2, and SO_2 (from the soap in the wash water) gases that must pass through several posttreatment processes to be reused and stored as required.

This system was designed to process 65 lb. per day of wastes containing 3.9 lb. of solids. The process would draw about 552 w of electrical power and require an estimated 1.26 lb of oxygen per pound of solids for stoichiometric oxidation. The process is assumed to be continuous over 24 hr minimizing startup preheat penalties.

An advantage of this process is high oxidation efficiency resulting in the need for very little post-processing of the water produced for reuse and no need for an auxiliary catalytic oxidation process for the effluent water vapor and gases. The reaction time of 1 min. or less lends itself to continuous operation.

Disadvantages include the need for very high temperatures and pressures to achieve the high oxidation efficiency. This results in weight penalties due to the increased structural strength required of the components and in volume due to the insulation required to keep surface temperatures down to 105 deg F as required by NASA Space Station Reference Configuration (reference 30). The pressures involved may dictate that this subsystem be located outside the pressured habitable volumes of the Space Station. This would make servicing difficult and replacement would most likely be on a unit basis.

2.2.3.2 Parametric Description

Table 2.2.3.2-1 lists the SCWO equipment and parameters as designed for Space Station use for this report. An O_2 compression penalty has been added along with both a

TABLE 2.2.3.2-1 SUPERCRITICAL WATER OXIDATION EQUIPMENT LIST
Derived from SAE Paper 820872, Timberlake, Hong, Simpson & Modell, 1982

Component	Volume (in3)	Weight (lb)	Power (w)	Heat rejection	Notes
Slurry pump	720	27	17	58 btuh	Air cooled
Reactor w/ htr and insul	985	17	840x1 hr interm	-	Start-up heater
Passive cyclone salt separator	985	17	-	-	
Passive cyclone water separators(2)	985	17	-	-	
Flow control valves (10)	220 each	5 each	6 each	205 btuh total	Air cooled
Waste storage	3450	110	-	-	
Heat exch (4)	985 each	25 each	-	542 btuh total	Liq cooled w/reclaim
O_2 comp penalty	-	-	55	- 188 btuh	Air cooled
Extra heat reqd to sustain reaction	-	-	420	-	1240 deg F
Total	12 ft3 (45%pkg)	398 (12%pkg)	552	542 btuh 2381 btuh	Liq cooled Air cooled

Consumables	Return to Earth	To Mass Balance
O_2 4.9 lb/day	Solids 1.2 lb/day	N_2 0.4 lb/day
	SO_2 0.3 lb/day	CO_2 4.9 lb/day
	H_2O 63.3 lb/day	

Comments:

1. Based upon eight-person crew /(water), <solids>/ 24-hr operation:

	(water)	<solids>
Urine	(35.2)	<1.04>
Feces	(1.6)	<0.56>
Wash Brine	(21.9)	<1.20>
Trash	(2.4)	<1.07>
Total	(61.1) +	<3.90> = 65 lb/day

2. 92 mbtu required in reactor: 25 mbtu generated by reaction; 34 mbtu added by heater; 33 mbtu recovered by preheater exchangers; 46 mbtu lost from insulated surfaces; 13 mbtu recovered by liquid cooling on a daily basis.

power and heat rejection penalty for heating the excess water to supercritical conditions. Heating the excess water is required due to the low percentage (<5%) of organics in the slurry. If a pretreatment distillation process were used to produce a 10% to 30% (by weight organic feed slurry to this process, the oxidation reaction would be self-sustaining and self-heating to the required temperatures. This kind of penalty is the same for any combustion/oxidation process, including dry incineration and wet oxidation. The heat rejection rate listed in table 2.2.3.2-1 includes the heat generated by the combustion of solids in the waste water.

2.2.4 Vapor Compression Distillation

The VCD subsystem as evaluated in this report is based on the Life Systems, Inc. VCD2 unit reported in NASA Test Report JSC 17694, CSD-SS-054 written by R. P. Reysa, C. D. Thompson, and A. T. Linton and dated September 30, 1983. VCD distillation is a phase-change process. The subsystem was designed to recover potable water from urine and wash water feed-stock. In this process, waste water is boiled off at low pressure in a rotating evaporator and the resultant water vapor is centrifugally separated from the liquid and pumped by a rotary lobe compressor to a condenser held at a slightly higher temperature and pressure. Heat is reclaimed in the process due to the common evaporator/condenser cylindrical wall. The condensed water is centrifugally collected and pumped to a post-treatment canister. Solids are not treated but are concentrated up to 50% by weight and stored in a recycle filter tank. It is judged, for the purposes of this report, that the development of this subsystem has reached a NASA technology level of 6 (table 2.3-1).

2.2.4.1 Subsystem Design

A three-person automatic VCD system specifically designed for spacecraft environment was built, tested, and revised for more efficient and reliable operation. Figure 2.2.4.1-1 is a schematic of this subsystem. This design consists of: a pressure-controlled waste tank for system capacitance, a recycle filter tank for collecting solids, a peristaltic pump assembly designed to handle all of the circulation requirements of the subsystem, a motor-driven compressor/evaporator/condenser, and the necessary valves and controllers to operate the unit automatically.

This system, as projected for a four-person flight unit per reference 15, is sized to process 35.6 lb/day of liquid wastes containing up to 8% solids at a 90% duty cycle or an equivalent of 1.65 lb/hr (40 lb/day). The recycle filter tank is sized to collect 0.26 lb per person day of solids. The unit would operate at 52 w and would reject 72 w of heat.

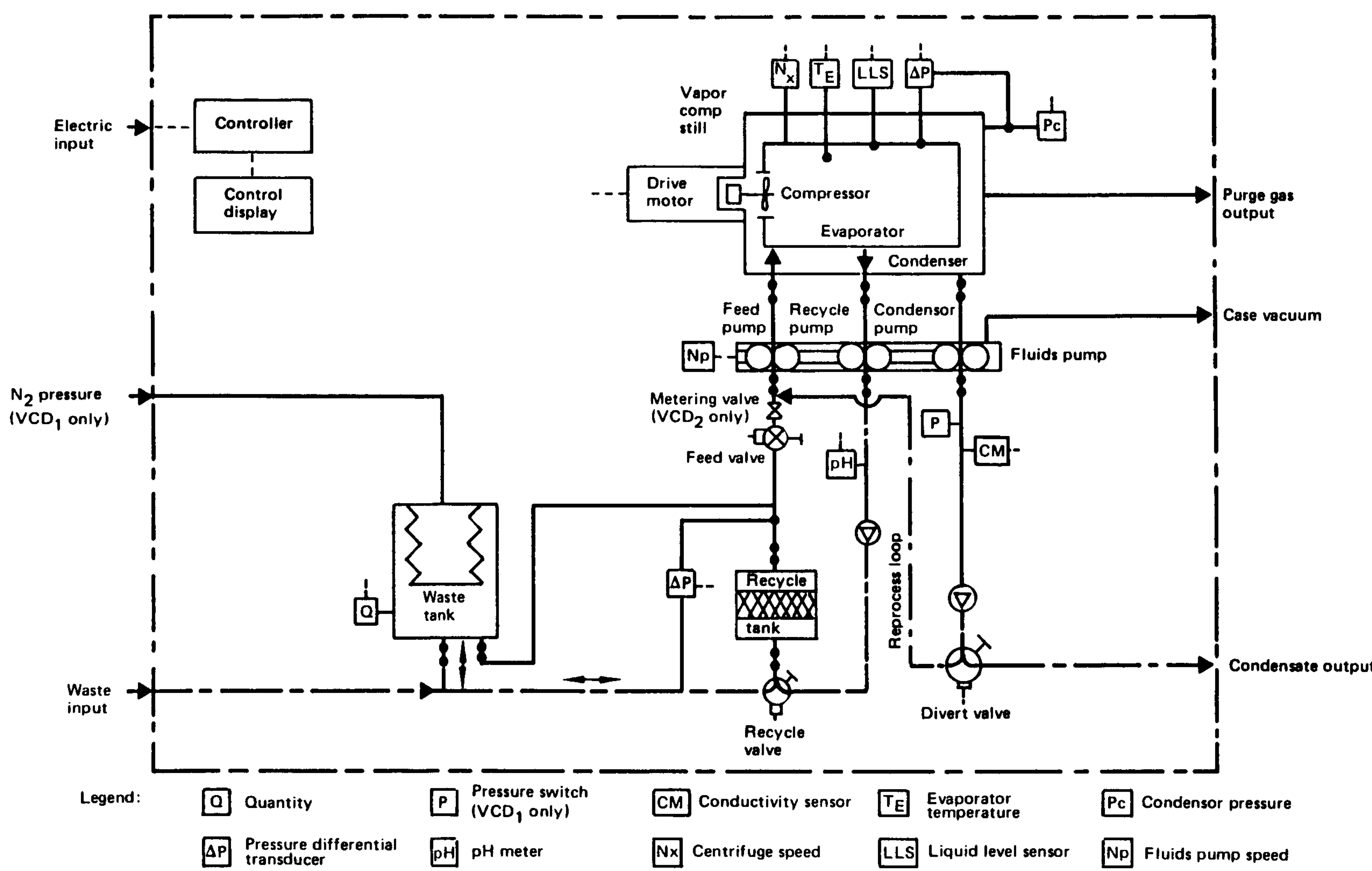


Figure 2.2.4.1-1. General VCD Subsystem Schematic

Advantages of the system include lower power consumption and less heat rejection than the oxidation process and much lower operating temperatures and pressures. The water recovery rate is about 96% by weight of the water in the incoming waste.

Disadvantages include the inability to process solids fed into it. These solids must be filtered out and disposed of with an equal weight of water. Accordingly, fecal solids and trash solids could not be fed to this system.

Although designed to produce potable water, the actual test results of the VCD effluent did not meet the NASA Potable Water Specification MSC-SPEC-SD-W-0020. These specifications are very tight but at its present stage of development VCD would require post-treatment for TOC, pH, conductivity, ammonia, trace metals, bacteria, fungus, odor, and taste to meet them. Posttreatment would require microbial check valves, charcoal, and deionizer beds, and UV/oxidation.

No changes in the Life System, Inc. VCD design were considered necessary for evaluation in this report.

2.2.4.2 Parametric Design

Table 2.2.4.2-1 lists the equipment and related parameters for a projected flight VCD subsystem designed to process 35.6 lb/day of liquid waste. A summary of these parameters adjusted for an eight-person crew is presented in section 2.3.

2.2.5 Thermoelectric Integrated Membrane Evaporation

The subsystem evaluated in this report is based on the Hamilton Standard Company unit described in Hamilton Standard Company report HSPC84T03, section 2.0, assumed to be written in 1984 and ASME Publication 80-ENAs-46 written by H. E. Winkler and G. J. Roebelen, Jr. in 1980. TIMES was originally developed on 1977 to provide water recovery with minimum complexity and positive liquid gas separation. The operation of the subsystem is insensitive to gravity, combining a hollow fiber polysulfone membrane evaporator that distills water under a partial vacuum with a thermoelectric heat pump that recovers the latent heat used to boil off the water in the evaporator. The system is proposed to handle wash water brine in addition to urine and flush water. For the purposes of this report, it is judged that this system has reached a NASA technology level of 5 (Table 2.3-1).

2.2.5.1 Subsystem Design

A three-person urine water recovery preprototype was designed and tested specifically for spacecraft use. This unit has been tested with pretreated urine at solids concentrations up to 12% by weight. By 1984 a second revision, TIMES II, incorporating

TABLE 2.2.4.2-1 VAPOR COMPRESSION DISTILLATION EQUIPMENT LIST
From Life Systems, Inc. Letter FHS-2-8, Feb. 14, 1983

Component	Volume (in3)	Weight (lb)	Power (w)	Heat Rejection (w)	Notes
Still	2039	44	43	43	
Recycle tank	2938	15	-	-	
Fluids pump	173	14	20	20	
Fluids control module	449	5	9	9	
Pressure control module	173	2	-	-	
Bacteria/flow check valve	17	1	-	-	
Total	4.9 ft3 (45%pkg)	91 (12%pkg)	72	72	

Comments:

1. System as depicted is sized to process 35.6 lb/day of liquid waste at a 90% duty cycle, or an equivalent rate of 40 lb/day.
2. "-" denotes that no specific information was determined for this point.

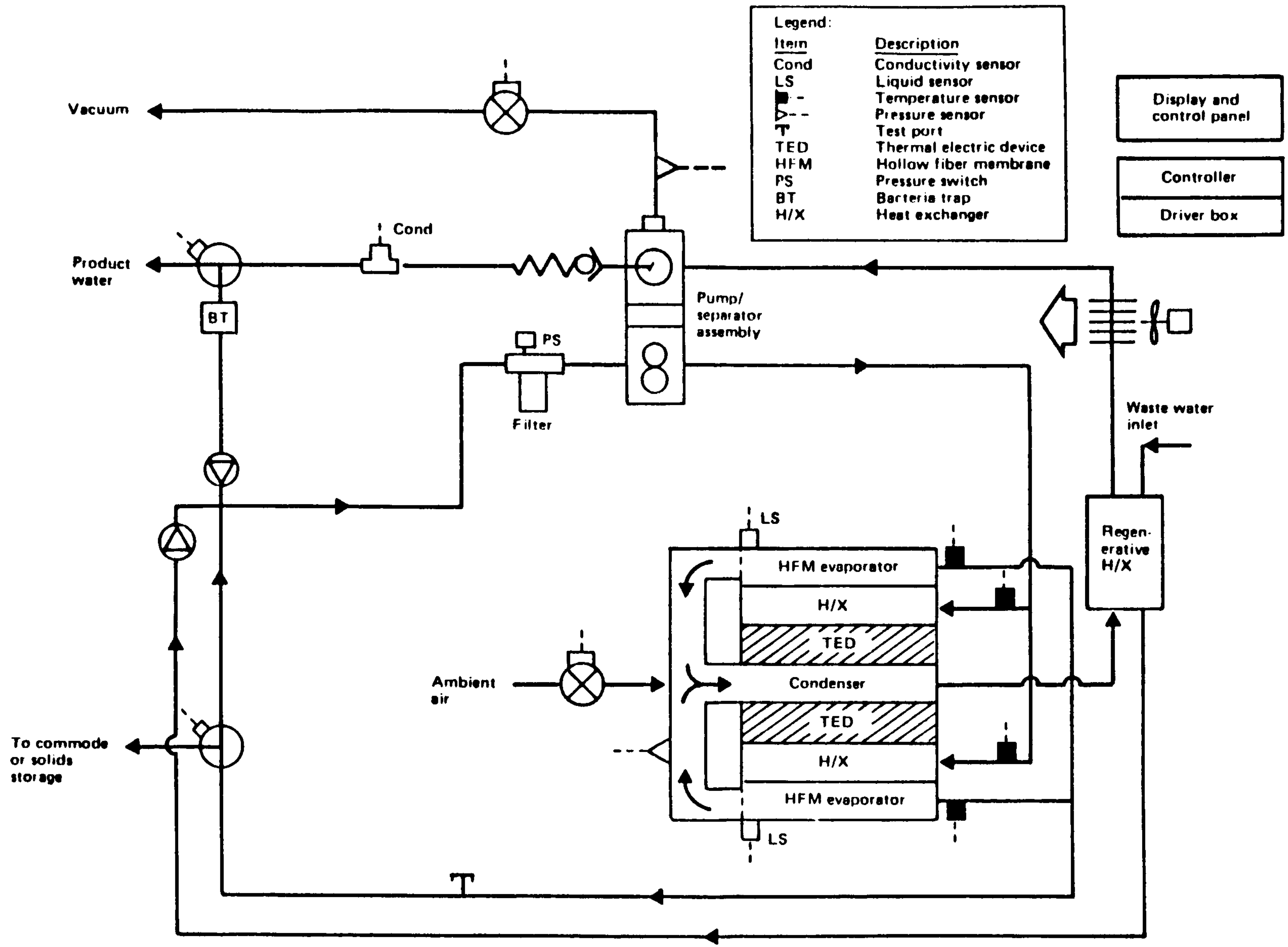


Figure 2.2.5.1-1. TIMES II Schematic

many design improvements was proposed. Figure 2.2.5.1-1 is a schematic of the proposed TIMES II waste-treatment subsystem. The design consists of: (1) a regenerative heat exchanger to cool the effluent product water while preheating the incoming waste water, (2) a filter assembly to trap solids, (3) a combination gas-liquid separator/recycle pump used to separate product water from gas vapor going to vacuum and to pump the waste water being processed around the recycle loop, (4) an integrated thermoelectric regenerator/HFM evaporator used to evaporate the waste water under a vacuum, recover the latent heat of evaporation and condense the recovered water vapor, (5) a forced air/liquid heat exchanger used to further cool the product water stream, and (6) the necessary control valves and controllers required for automatic operation.

The TIMES II system is proposed to recover 4.5 lb/hr of product water with a 95% water recovery rate at solids concentration up to 3% by weight. This solids concentration is compatible with that expected from urine, flush water, and pretreated wash and humidity condensate brines. This unit would operate at 249 w and reject about 852 btu of heat.

Advantages of this system include a low level of complexity, recovery of the heat of evaporation, continuous or batch operation, completely automatic operation and operation at near atmospheric temperatures (140 deg F) and pressures (1 atmosphere with occasional purges to vacuum to vent noncondensables).

Disadvantages of this design include the inability to process the solids fed into it. These solids must be filtered out and disposed of in a 60/40 weight percentage of water/solids. Therefore, fecal solids and trash solids could not be fed into this system. Product water quality was a problem with the original TIMES unit. Although it met generally accepted U.S. Health Department standards, it did not meet the NASA/JSC standards (sec. 2.2.4.1). Water quality was to be improved with the TIMES II unit by lowering the operating temperature, optimizing the operating cycle based on the solids, concentration and changing the urine pretreatment chemicals. Even so, the process will probably require postfiltration and bacteria traps. The Space Station requirement for zero venting to space vacuum will most likely impose a vacuum pump and a noncondensibles storage penalty upon the system as well.

No changes in the Hamilton Standard Company TIMES II design were considered necessary for evaluation in this report.

2.2.5.2 Parametric Design

Table 2.2.5.2-1 lists the equipment and related parameters for a projected TIMES II waste-treatment process. A summary of these parameters adjusted for an eight-person crew is presented in section 2.3.

TABLE 2.2.5.2-1 TIMES II EQUIPMENT LIST
From Hamilton Standard Report HSPC84T03, 1984

Component	Volume (in3)	Weight (lb)	Power (w)	Heat rejection	Notes
Check valves (2)	-	1.2	-	-	
Relief valve	-	0.6	-	-	
3-way valves (2) (5% duty)	-	4.4	0.9	3.07 btuh	5% Duty
2-way valve (2) (5% duty)	-	3.0	0.9	3.07 btuh	5% Duty
Microbial filter	-	0.5	-	-	
Recycle filter	-	3.0	-	-	
Pressure switch	-	0.2	-	-	
Temperature sensor (4)	-	0.4	-	-	
Pressure sensor (2)	-	0.5	-	-	
Evaporator liq sensor (2)	-	0.2	-	-	
Condensate conduct sensor	-	0.5	-	-	
Pump/separator	-	3.8	20.0	68.3 btuh	
Regenerative heat exchanger	-	3.0	-	-	
Condensate heat exchanger	-	5.0	-	-	
Conden fan	-	1.0	5.6	19.1 btuh	
Thermoelect heat pump	-	20.0	222.0	758 btuh	
Evaporator (2)	-	46.0	-	-	
Condenser	-	1.5	-	-	
Total	16286	120.8	248 w/reclaim	852 btuh	Incl pkg

Comments:

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1. Unit described is sized for 4.25 lb/hr water production.

2.2.6 Vapor Phase Catalytic Ammonia Removal

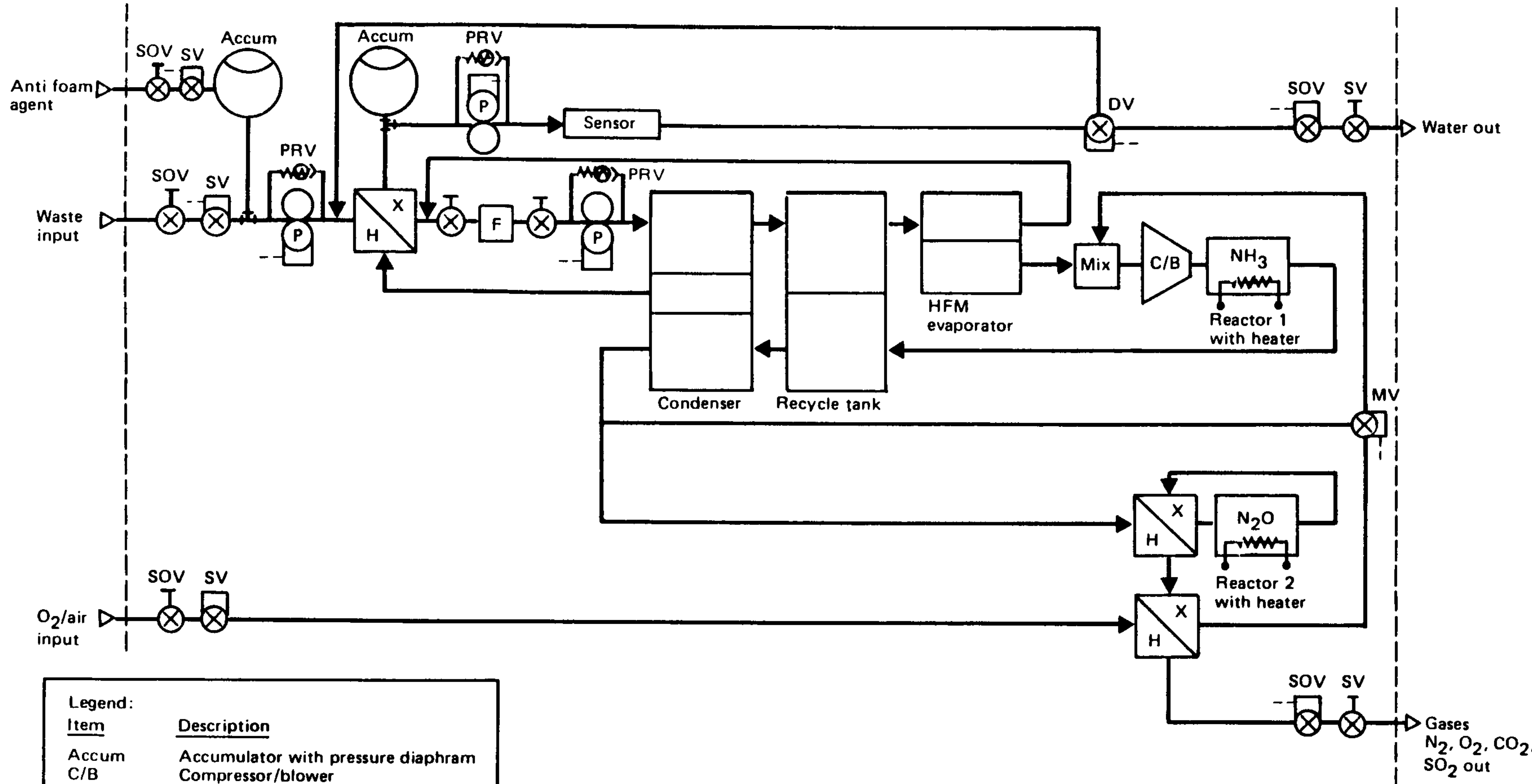
The VPCAR subsystem evaluated in this report is based on the GARD, Inc. "Catalytic Distillation Water Recovery Subsystem" proposal B1-258 written by P. Budininkas, submitted in May 1983 in response to NASA RFP2-31178. This process was designed specifically to recover water from untreated urine vapor by catalytically oxidizing the NH3 in the vapor to N_2, N_2O, and water at 250 deg C and then catalytically reducing the N_2O to N_2 and O_2 at 450 deg C. The catalyst used for the oxidation of ammonia is platinum. The catalyst used for the reduction of nitrous oxide is ruthenium. The proposed unit has been sized to handle urine, flush water, and reverse osmosis brine. For the purposes of this report, it is judged that this system has reached a NASA technology level of 3 (table 2.3-1).

2.2.6.1 Subsystem Design

The VPCAR process has been bench tested as a laboratory model using untreated urine vapor. A three-person system has been proposed to NASA by GARD, Inc. which is a refinement of the laboratory model. Figure 2.2.6.1-1 is a schematic of this system. The design consists of: (1) a pressure-controlled, waste-water feed accumulator and recovered-water accumulator for system capacitance; (2) a waste feed pump; (3) a heat recovery exchanger used to preheat the incoming waste water while cooling the outgoing product water; (4) a filter assembly for removing suspended solids from the recycled waste stream; (5) a specially constructed concentric recuperative condenser that uses the recycled waste stream to condense the product water vapor; (6) a duplex recycle tank, a hollow fiber membrane evaporator used to produce waste-water vapor; (7) a chamber for mixing the waste-water vapor with pure oxygen; (8) a compressor/blower to force the oxygen/fuel mixture through the reactors; (9) an NH_3 catalytic oxidation reactor with a heater to ensure a 250 deg C reaction temperature; (10) an N_2O catalytic oxidation reactor with a heater to ensure a 450 deg C reaction temperature; (11) heat recovery exchangers to use the N_2O reactor effluent to preheat the incoming vapor and the oxygen gas supply; and (12) the required isolation and control valves for automatic operation.

The VPCAR system is proposed to recover 14 kg/day (1.3 lb/hr) of waste water while operating at 120 w and rejecting 109 w of heat.

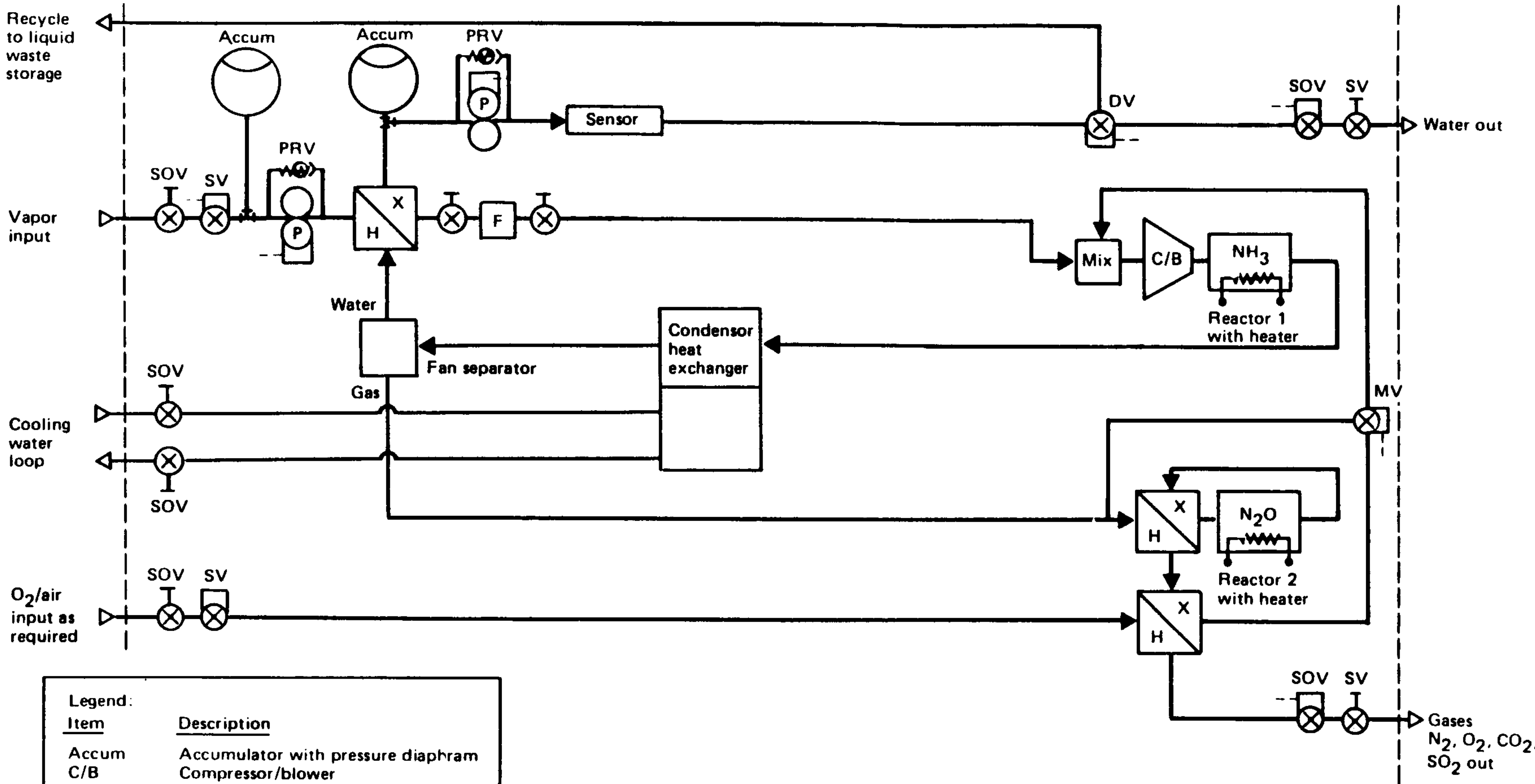
Advantages of this process are the ability to break down ammonia and N_2O into useful constituents, the ability to process untreated urine, the incorporation of an HFM evaporator that helps to purify as well as evaporate the effluent vapor, and the recovery of the vaporization heat and heats of reaction. Water recovered from untreated urine by the VPCAR preprototype meets U.S. drinking water standards with the exception of low



Legend:

Item	Description
Accum	Accumulator with pressure diaphram
C/B	Compressor/blower
DV	Diverting valve
F	Filter
HX	Heat exchanger
Mix	Mixing chamber
MV	Mixing valve
NH_3	Ammonia
N_2O	Nitrous oxide
P	Pump
PRV	Pressure relief valve
SOV	Shut off valve (manual)
SV	Solenoid valve

Figure 2.2.6.1-1. Vapor Phase Catalytic Ammonia Removal System Space Station Application



Legend:

Item	Description
Accum	Accumulator with pressure diaphram
C/B	Compressor/blower
DV	Diverting valve
F	Filter
HX	Heat exchanger
Mix	Mixing chamber
MV	Mixing valve
NH_3	Ammonia
N_2O	Nitrous oxide
P	Pump
PRV	Pressure relief valve
SOV	Shut off valve (manual)
SV	Solenoid valve

Figure 2.2.6.1-2. Auxiliary Vapor Phase Catalytic Ammonia Removal System Space Station Application

pH. This system, as shown in figure 2.2.6.1-1, could be used effectively to postprocess water from an R.O. unit, a VCD unit; or a TIMES II unit to help meet NASA/JSC water-quality standards. This system, as amended in figure 2.2.6.1-2, could be used to posttreat the water vapor from a dry incineration or wet oxidation waste-treatment process. In the latter use, no feed pumps and no evaporators would be required since the input to the system would already be in vapor form.

Disadvantages of the VPCAR system include the inability to process solid wastes. Solids must be filtered out of the waste stream before entering the evaporator. Therefore, no fecal solids or trash solids could be fed into this subsystem. The high reaction temperatures, 250 deg C and 450 deg C, penalize the system in terms of extra volume required for thermal insulation. Post-treatment of the recovered water would be required to raise the pH.

No changes in the GARD, Inc. VPCAR design were considered to be necessary for this report. However, an auxiliary VPCAR (fig. 2.2.6.1-2) was derived from the original GARD, Inc. design to post-process the water vapor effluent from the dry incineration and the wet oxidation processes. For the purposes of this report, auxiliary VPCAR's are considered necessary for these waste treatment processes and are included in the BETS parametric models of these subsystems.

2.2.6.2 Parametric Design

Tables 2.2.6.2-1 and 2.2.6.2-2 list the equipment and related parameters for projected VPCAR and auxiliary VPCAR subsystems, respectively. The list for the auxiliary VPCAR includes heat rejection rates that are dependent on the primary waste-treatment process, incineration or wet oxidation. A summary of the parameters for the base VPCAR subsystem sized for an eight-person Space Station crew is presented in section 2.3.

TABLE 2.2.6.2-1 VPCAR EQUIPMENT LIST
From GARD, Inc. Proposal B1-258 in Response to
NASA RFP2-31178 (BGB)

Component	Volume (in3)	Weight (lb)	Power (w)	Heat rejection	Notes
NH3 oxid react + Cat	33.5	5.5	1.1	3.75 btuh	
N2O oxid react + cat	293.6 w/insul	2.2	12.7	43.2 btuh	
Evaporator (HFM)	591.0	-	25.9	88.4 btuh	
Condenser	87.8	11.8	-	-	
Blower/ compressor	-	-	1.0	3.4 btuh	Air cooled
Heat exchangers	-	-	2.3	7.96 btuh	
Recycle tank	306.0	4.4	-	-	
Recycle pump	-	-	14.5	49.5 btuh	Air cooled
Solids filter	-	-	-	-	
Feed control	-	-	-	-	
Feed stor tank	918.0	13.3	-	-	
Instruments	-	-	-	-	
Total	28.3 ft3	256	57.5	196 btuh	With heat recovery

Consumables (per day)	
O2	0.3100 lb
Antifoam	0.0022 lb
pH adjust	0.0022 lb

Expendables (per day)	
Solids filter	0.0352 lb

Comments:

1. Based upon 14 kg/day (1.3 lb/hr) water recovered (three-persons)

TABLE 2.2.6.2-2 AUX. VPCAR EQUIPMENT LIST
Derived from GARD Proposal B1-258 in Response to
NASA RFP2-31178 (BGB)

Component	Volume	Weight	Power (w)	Heat rejection	Notes
NH3 oxid react + cat	33.5	5.5	* 22x1 hr	-	* If reqd
N2O oxid react + cat	293.6 w/insul	2.2	* 20x1 hr	-	* If reqd
Condenser/ cooler	87.8	11.8	-	2300 btuh 1335 btuh	INCIN (Avg) WETOX
Fan separator	230.9	5.6	56	190 btuh	HSC device
Blower/ compressor	-	-	0.1	0.3 btuh	Air cooled
Pumps: vapor	295	9.0	1.3	4.4 btuh	Estimated
recirc	72	4.0	10.4	35.5 btuh	Estimated
Feed control	-	-	-	-	
Feed storage tank	918	-	-	-	
Instruments	-	-	-	-	
Thermal insululation	-	-	-	-	
Total	26 ft3	235	68	2530 btuh 1570 btuh	INCIN (Avg) WETOX

Consumables:
O2 (Assummed included in upstream waste-treatment process)
pH adjust 0.0022 lb/day

Expendables:
Filter 0.0352 lb/day

Comments:

1. Factored from system designed to treat 14 kg/day (30.8 lb/day) or 1.3 lb/hr.
2. "-" denotes that no specific information was determined for this point.

2.3 SUBSYSTEM PARAMETRIC COMPARISON

The validity of subsystem trade analyses largely depends on the level of subsystem technology development. The level of technical development may be adequately defined using the existing NASA, crew systems technology level scale (table 2.3-1).

TABLE 2.3-1

NASA-CREW SYSTEMS TECHNOLOGY LEVELS

Level	Description
1	Basic principles observed and reported.
2	Conceptual design formulated.
3	Conceptual design tested analytically and experimentally.
4	Critical function/characteristic demonstrated.
5	Component/breadboard tested in relevant environment.
6	Prototype/engineering model tested in relevant environment.
7	Engineering model tested in space.
8	Operational.

This scale begins with a lowest rating (1) for basic principles observed and reported and ends with a highest rating (8) for a space flight operational system. Subsystems in the earliest stages of development tend to be laboratory test assemblies that have been built primarily to prove or to optimize a process. Accordingly, they lack the service valving, accumulators, 0-G specific hardware and microprocessor controls that would normally be required on a flight unit. Weight, volume, power, heat rejection, and service are not the most important design drivers at this early stage. Therefore, these parameters tend to be greater for laboratory and preprototype hardware than for prototype and flight-engineered units. In the later development stages, these parameters do become primary design drivers. In this study, the combustion/oxidation processes INCIN, WETOX, SCWO, and VPCAR are judged to be at the lower end of the technology level scale. SCWO and VPCAR are lowest at level 3 conceptual design tested analytically and experimentally. INCIN and WETOX are at the next highest level 4 critical function/characteristics demonstrated. Although none of the waste management subsystems studied for this report has reached flight unit status, the phase-change processes, TIMES II and VCD come the closest. The TIMES II unit has reached a level 5 component/breadboard tested in relevant environment. VCD has reached a level 6 prototype/engineering model tested in relevant environment. It would be expected from the above differences in subsystem technology development that a parametric ranking in order of best to least might show the following:

1. VCD.
2. TIMES II.
3. INCIN.
4. WETOX.
5. VPCAR.
6. SCWO.

This relationship is illustrated in figure 2.3-1. The overall evaluation results arrived at in section 2.6 do show VCD VCD and TIMES as the best parametric performers. This is judged to be a direct result of the technology level of the two subsystems. However, SCWO and VPCAR, although at lower stages in their development than INCIN or WETOX, came out better in the parametric evaluation. This is judged to be a result of the auxiliary VPCAR penalty levied against INCIN and WETOX.

Table 2.3-2 shows comparative data for the six waste water processing subsystems under study. The table summarizes the BETS data contained in appendix section 5.2 program analysis. Included are values for weight (1-G equivalent) and volume for the subsystems as installed on-orbit; weight (1-G equivalent) and volume of the resupply and return to Earth materials required at each 90-day resupply; electric power (both continuous and intermittent ac and dc power); specific energy (wh/lb of processed water); heat rejection (both air cooled as dissipated to the cabin atmosphere, and liquid cooled as dissipated to the Space Station thermal bus or to a heat recovery loop); and technology level as defined in table 2.3-1.

All six subsystems covered in this study are considered single unit sized to handle the wastes from an eight-person Space Station crew.

2.3.1 Weight and Volume

The fixed on-orbit weights and volumes for the six waste-management subsystems sized for an eight-person crew are listed as items A and B in table 2.3-2 and are displayed in figure 2.3.1-1. The bar chart shows the following order of subsystems according to optimum weight and volume characteristics from best to least:

	WEIGHT	VOLUME
1.	TIMES.	TIMES.
2.	VCD.	VCD.
3.	SCWO.	SCWO.

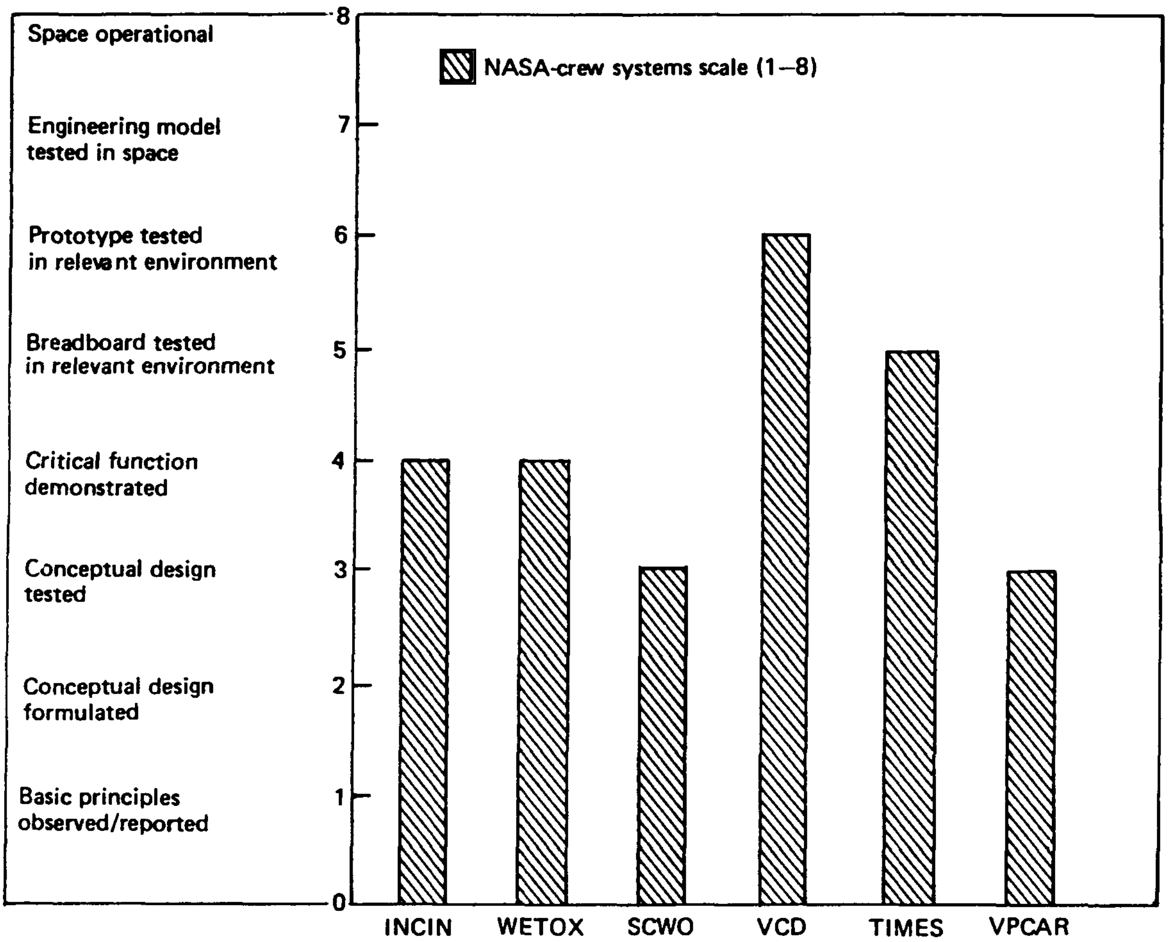


Figure 2.3-1. Waste Management System Technology Level

TABLE 2.3-2

WASTE MANAGEMENT SYSTEM PARAMETRIC SUMMARY
for an Eight-Person Crew

Parameter	Waste Management Subsystem					
	(2) INCIN	(2) WET OX	SCWO	VCD	TIMES	VPCAR
A. Weight (lb)	1033	1226	396	111	92	524
B. Volume (ft3)	122	95	12	7	5	58
C. Resupply (90-day)						
Weight (lb)	81	87	62	23	33	66
Volume (ft3)	4	3	0.6	2	2	2
D. Return to Earth						
Weight (lb)	249	255	230	466	585	197
Volume	6	5	3	9	10	4
E. Power (w)						
AC	760	1263	550	32	13	118
DC	0	0	0	82	144	0
Intermittent	16465	0	836	0	1	86
F. Spec energy (1) (wh/lb)	485	416	231	43	58	27
G. Heat Rejection						
Air cooled (btuh)	1623	1508	2370	387	534	402
Liq.cooled (btuh)	968	2805	540	0	0	0
H. Technology (1) assessment	4	4	3	6	5	3

Notes:

1. This parameter is based on the equipment lists in section 2.2 and is independent of crew size.

2. INCIN and WETOX include an auxiliary VPCAR penalty as suggested in the literature and as evaluated in this report.

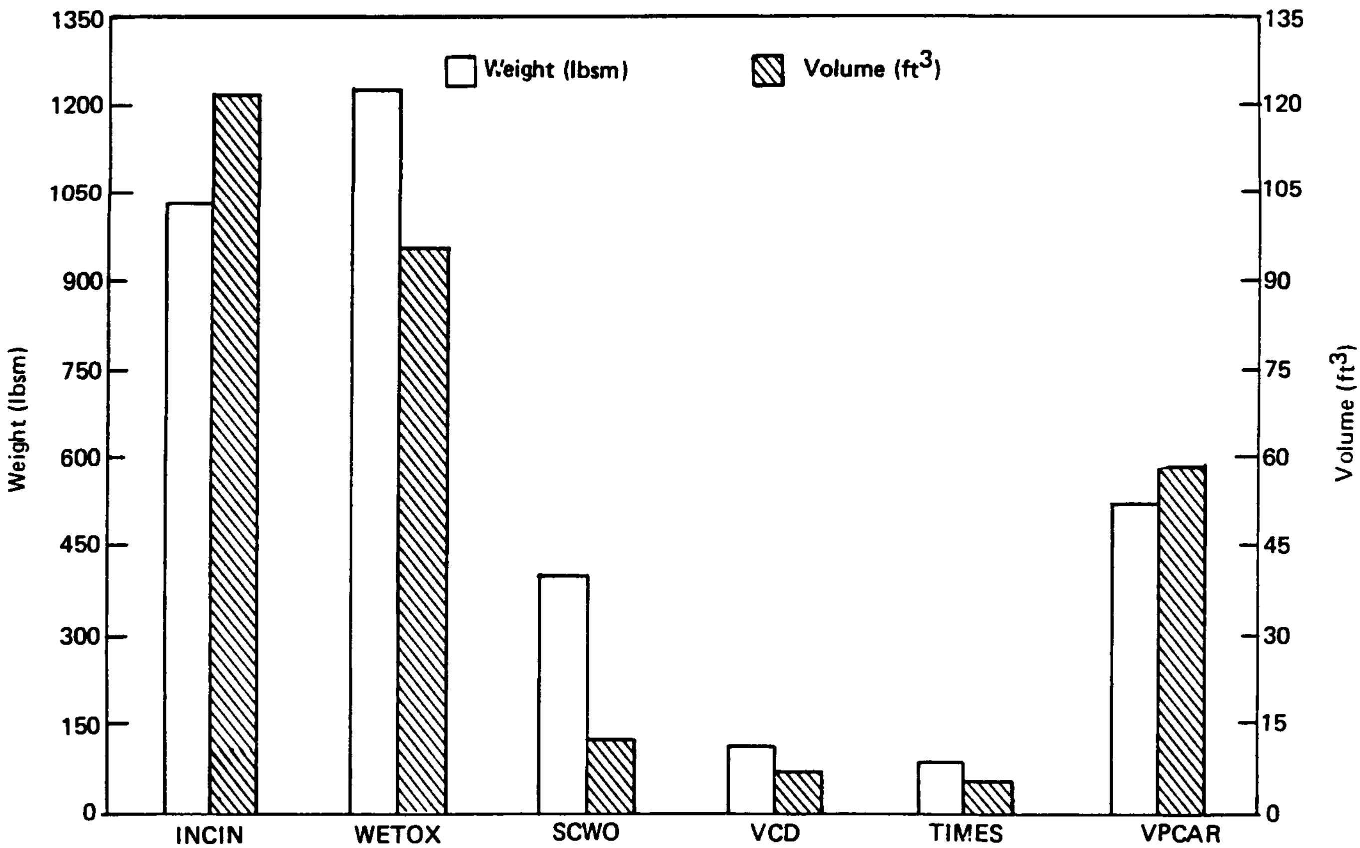


Figure 2.3.1-1. Waste Management System Weight and Volume Comparison

4. VPCAR. VPCAR.
5. INCIN. WETOX.
6. WETOX. INCIN.

Although weight might first appear to have minimal effect on objects in a weightless environment, it does impact Space Shuttle payload weight for getting those objects into orbit. The mass of an item also affects its inertia on orbit and hence the ability to handle it either inside or outside of the Space Station. The NASA Space Station Reference Configuration (reference 30) in table 4.4.6-3 lists a weight estimate for the waste-management subsystem at 500 lbm. If this estimate were to become a not-to-exceed requirement, the VPCAR subsystem would be considered marginal and INCIN and WETOX would be completely eliminated as candidates. INCIN and WETOX have the highest weights and volumes because they each include an auxiliary VPCAR as a requirement for producing reusable water and gases.

Volume becomes important from the standpoint of limited available space both on the Space Shuttle and especially within the Space Station. All of the systems, logistics, and structures compete for space. Subsystems, therefore must be packaged in compact serviceable units. The waste-management subsystem volume estimate listed in the above NASA reference and table is 40 ft^3. If this estimate were to become a not-to-exceed requirement, the SCWO subsystem would be considered marginal and the VPCAR, WETOX, and INCIN subsystems would be eliminated as candidates.

Using the previously mentioned NASA waste-management subsystem weight and volume estimates as guidelines leaves the following subsystems (by order of preference):

1. TIMES.
2. VCD.
3. SCWO.

It is believed that TIMES and VCD have the best showing primarily because of their high technology level. Conversely, SCWO and VPCAR are lower in this ranking because they share a much lower level of technology development. It is assumed that further development of the latter two subsystems will yield lower on-orbit weight and volume estimates.

2.3.2 Logistics

Logistics includes the resupply of subsystem replacement parts, expendables, such as filter cartridges and treatment chemicals, and consumables, such as gases and water. Logistics also includes return to Earth items, such as used spares and expendables, contaminant gases, waste water, trash, and excess fluids and gases that are not permitted to be vented to space. The weights and volumes of these resupply and return to Earth items are listed for each waste management subsystem as items C and D in table 2.3-2. The return to Earth logistics figures in table 2.3-2 include resupply logistics. It should be noted here that because no specific resupply data are available for SCWO, INCIN, WETOX, and VPCAR, an estimating factor of 10% of the fixed on-orbit weight is used for this study. Therefore, the resupply weight and volume figures for these subsystems tends to parallel their fixed on-orbit weights and volumes. More specific data exist for TIMES and VCD and is used in this report.

Return to Earth weights are compared in figure 2.3.2-1. Logistics volumes are so small (3 to 10 ft^3) in relationship to the Shuttle cargo bay capacity (10,600 ft^3) that they are not considered for comparison here. The subsystems are listed below in the order of the most to least optimum logistics weights from table 2.3-2.

1. VPCAR.
2. SCWO.
3. INCIN.
4. WETOX.
5. VCD.
6. TIMES.

VCD and TIMES show the highest return to Earth weight because they lose 50% and 60% by weight respectively of water to solids as brines that must be stored and shipped back to Earth. INCIN and WETOX have the next highest return to Earth weight due to their auxiliary VPCAR penalty. Generally, however, the combustion-based processes have the lowest return to Earth logistics because they process and recover more of the wastes produced aboard the Space Station than the phase-change processes. The return to Earth estimates for these subsystems include an estimated 10% factor of on-orbit weight and volume plus weights and volumes of waste materials stored and returned to Earth. The 10% factor is not used for VCD and TIMES. The VCD and TIMES units produce waste brines. INCIN, WETOX, SCWO, and VPCAR produce ash and SO_2 as wastes. If calcium carbonate, $CACO_3$, is used to collect this SO_2, then 50 lb of $CACO_3$ is required every 90 days for these processes and 25 lb of unreacted $CACO_3$ plus 34 lb of $CASO_4$ must be returned to Earth. This analysis assumes $CACO_3$ SO_2 absorbent. All other products are considered to be recoverable and reusable.

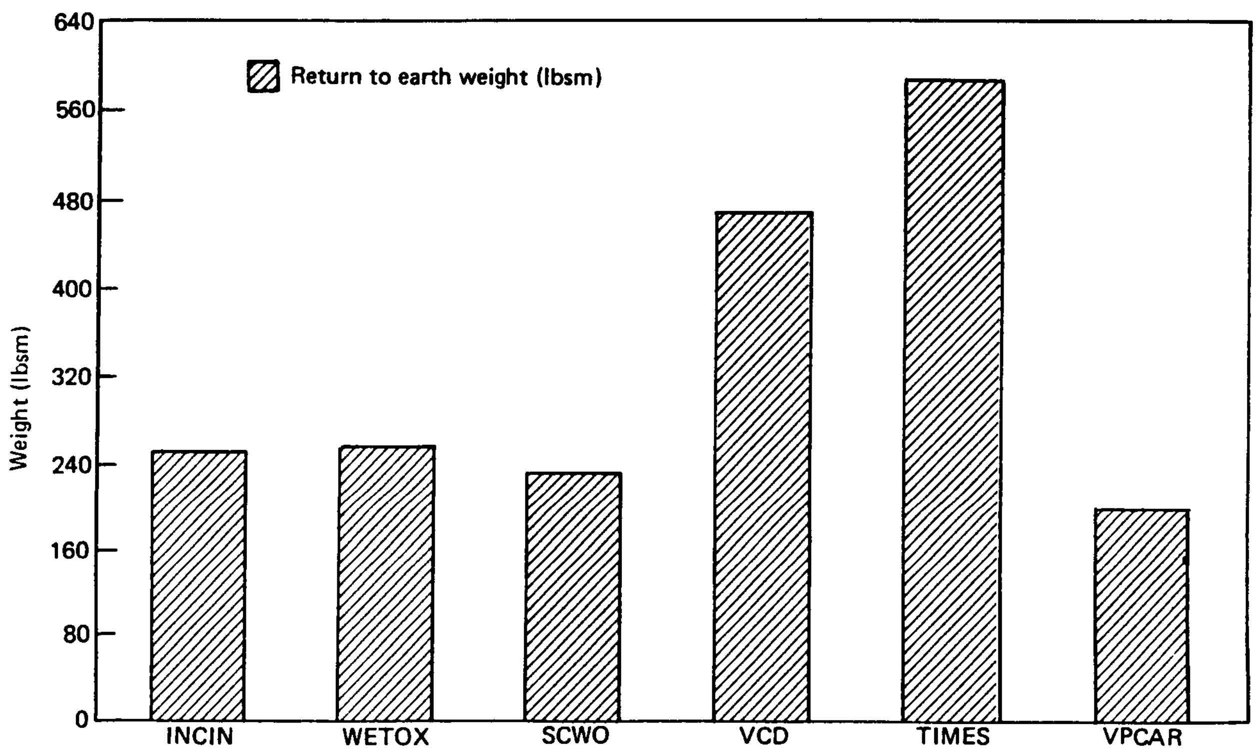


Figure 2.3.2-1. Waste Management System Logistics Comparison

2.3.3 Power

The ac, dc and intermittent subsystem power requirements are listed under item E in table 2.3-2. The sum of the ac and dc power requirements in total Watts and the specific energy characteristics of the subsystems in Watt-hours per pound of recovered water are compared in figure 2.3.3-1.

Subsystem power affects the size and weight of the Space Station power generating solar arrays and the Station power distribution system. For subsystems that must operate continuously during both the lightside and the darkside portions of the orbit, subsystem power also affects the size and weight of the power storage facilities. Power storage, although not considered directly by this report, would be required for INCIN and WETOX due to their extended process times (24 hr and 1-1/2 hr respectively). VCD and TIMES, although considered to be batch processes, would also require power storage since stopping them has been shown to result in the carryover of contaminants into the recovered water. Once started, they must run continuously until the batch has been completed.

Ranked in order of optimum power requirements from best to least, the subsystems would be listed as follows:

1. VCD.
2. VPCAR.
3. TIMES.
4. SCWO.
5. INCIN.
6. WETOX.

Specific energy is a measure of the process efficiency of a water recovery subsystem. It is defined in terms of Watt-hours required to recover 1 lbm of reusable water. Therefore, the most efficient water recovery subsystem is the one with the lowest specific energy. The second set of bars in figure 2.3.3-1 shows a comparison of the specific energy for the six waste-management processes. If ranked according to the most efficient, the subsystems would be listed as follows:

1. VPCAR.
2. VCD.
3. TIMES.
4. SCWO.
5. WETOX.
6. INCIN.

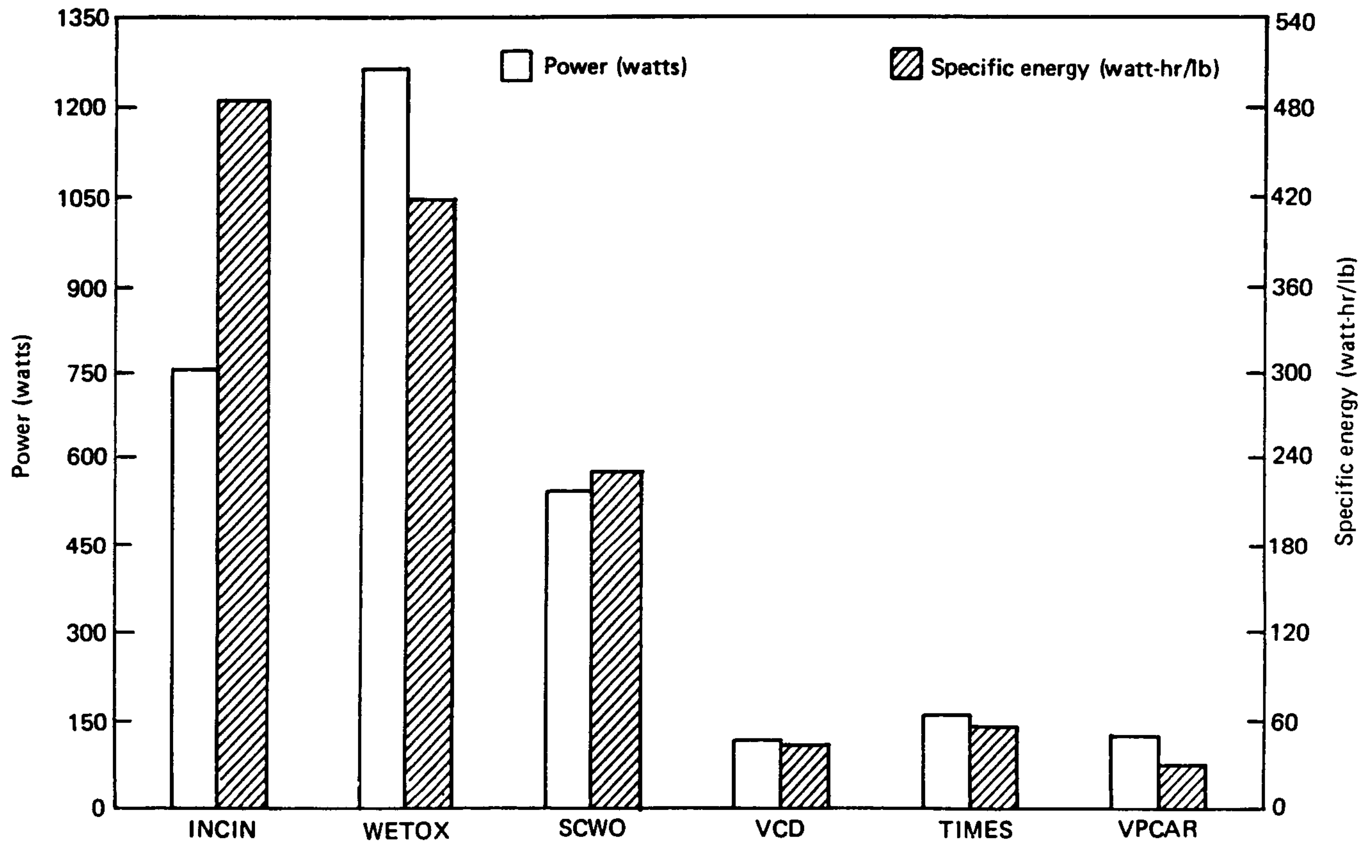


Figure 2.3.3-1. Waste Management System Power Comparison

VPCAR, VCD, TIMES, and SCWO are the more efficient subsystems because they all employ heat recovery to reduce their power requirements. SCWO is the highest power consumer of these due to high operating temperature (1240 deg F) and pressure (3672 psia). INCIN and WETOX are the least efficient subsystems due mainly to their auxiliary VPCAR penalty, they also operate at high temperatures. The three combustion processes would show lower power consumption and better specific energy characteristics if the solids concentration of their input waste waters were boosted to the 10% to 30% range. With more solids, these subsystems would generate more of their own heat during combustion and would depend less on electrically generated heat.

2.3.4 Heat Rejection

Both air cooled and liquid cooled heat rejection rates for the six waste-management subsystems are listed under item G in table 2.3-2 The sums of the air and liquid rates are given in figure 2.3.4-1. Air cooled heat rejection is that part of the process heat that is dissipated to the surrounding cabin air. Typical sources are electric motors and heat transmission losses through thermally insulated hot surfaces. Liquid cooled heat rejection is that portion of the process heat load that is not recovered for reuse by the process and is therefore removed in a process cooling heat exchanger using liquid as a coolant. Subsystem heat rejection is important because, whether it is air cooled or liquid cooled, it ultimately affects the size and mass of the Space Station radiators and thermal bus. The subsystems are listed below in the order of lesser to greater heat rejection requirements:

1. VCD.
2. VPCAR.
3. TIMES.
4. INCIN.
5. SCWO.
6. WETOX.

Like the subsystem power characteristics, this ranking reflects the degree of heat recovery employed in the subsystem designs as well as the auxiliary VPCAR penalties imposed on INCIN and WETOX. SCWO heat rejection is relatively high due to extremely high operating temperature (124 deg F).

2.3.5 Launch Cost Analysis

Subsystem parameters considered in this report, on-orbit weight and volume, logistics weight and volume, power consumption, and heat rejection, can be used

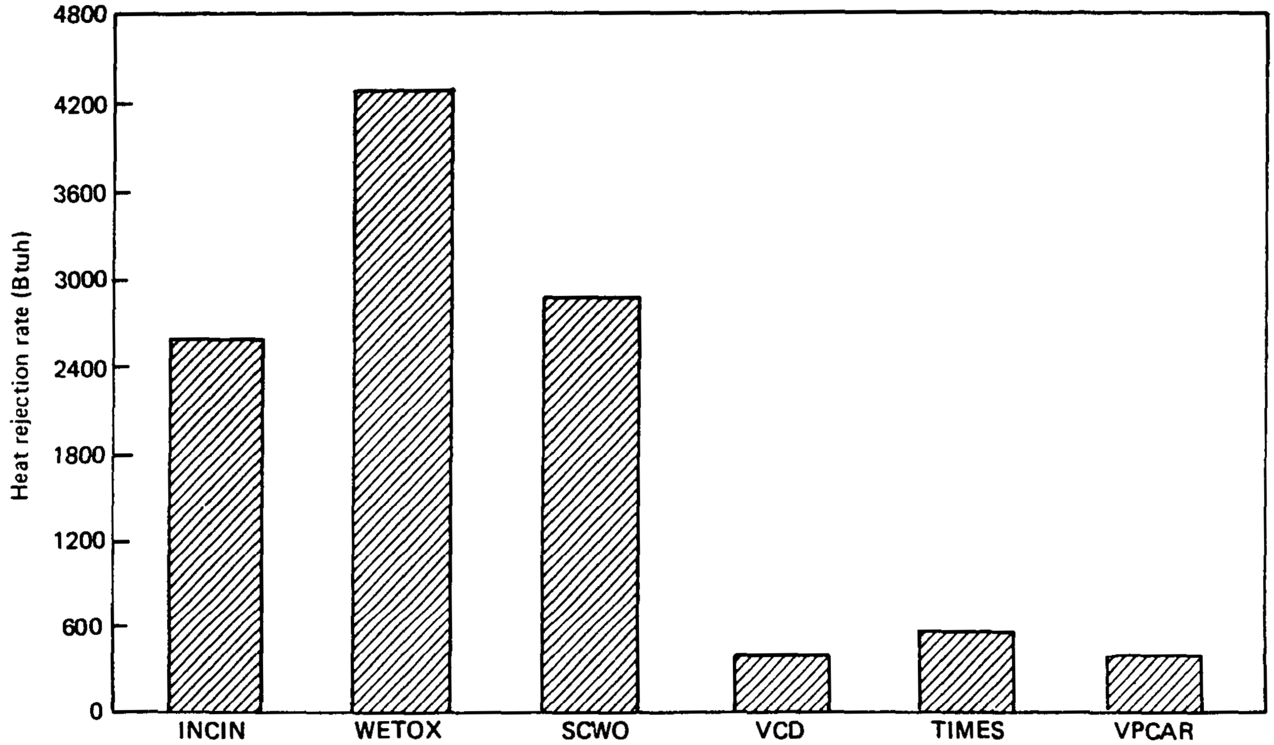


Figure 2.3.4-1. Waste Management Subsystem Heat Rejection (btuh)

together in estimating the best individual waste-management subsystem by equating each parameter to a 10-year launch cost. These parametric launch costs are then added to yield total 10-year launch costs for each subsystem. The exceptions to this approach are the on-orbit and resupply volume characteristics. However, the subsystem on-orbit volumes closely track the on-orbit weight characteristics (figure 2.3.1-1). The return to Earth volumes for each subsystem are all very small, ranging from 4 to 10 ft^3 for a resupply period of 90 days. In relation to the total Shuttle capacity of 10,603 ft^3, these values are considered to be too small to justify comparison.

The launch costs for the subsystem on-orbit and logistics weight and the launch costs for the prorated power and thermal systems weight penalties can be totalled for each subsystem and compared. Table 2.3.5-1 is a breakdown of the Initial Operational Capability (I.O.C.) Space Station power and thermal system launch weights and equivalent costs over a 10-year system life. This information was derived from reference 30, tables 3.1-1 and 4.2.4-6. Table 2.3.5-2 compares the 10-year launch costs, including prorated power and thermal system penalties, for each of the six subsystems, figure 2.3.5-1 is a bar chart of the results. This evaluation results in the following ranking of the six subsystems from least expensive to most expensive 10-year launch costs.

1. VPCAR.
2. SCWO.
3. INCIN.
4. WETOX.
5. VCD.
6. TIMES.

Comparing this result with the previous logistics comparison in section 2.3.2 reveals that when subsystems are compared individually on a 10-year launch cost basis logistics becomes the most important cost factor.

Launch cost penalties for subsystem on-orbit weight and logistics weight can be derived by considering the FY 89 Shuttle launch charge of $71.4 million divided equally among the full Shuttle launch payload of 65,000 lb. This approach results in an equivalent launch cost per pound of payload of $1098.46. When considering launch costs over a projected 10-year subsystem equipment life, the annual resupply launch costs require an adjustment for inflation. A figure of 7% per year is presently being used by The Boeing Company in financial analyses. It is used here as well.

As mentioned in section 2.3, subsystem power consumption affects the size and weight of the Space Station power system. The subsystems will draw power from the main bus. Higher subsystem power requirements necessitate a larger Energy Conversion

TABLE 2.3.5-1

IOC SPACE STATION POWER AND THERMAL SYSTEMS LAUNCH COSTS

System	(1) On-orbit wt (lb)	(1) Annual replacement wt (lb)	10-year launch wt (lb)	(2) 10-year launch cost ($)	10-year cost per kw ($/kw)
(3) 75 kw power	22,744	1,585	38,594	28,408,341	378,778
(4) 95.8 kw thermal	10,818	144	12,258	12,194,318	162,591

Notes:

1. Weight figures are taken from Reference 30, Tables 3.1-1 and 4.2.4-6.

2. Costs are based on a FY89 Shuttle customer launch cost of $71,400,000 as announced by NASA Administrator James Beggs in 1985. Assuming a full cargo bay payload of 65,000 lb and assuming that the total launch costs are apportioned equally among the payloads according to weight, results in an equivalent launch cost per pound of about $1,098.46 The first-year costs are the launch fees for the system as well as the the first-year resupply launch fees. The costs for years 2 through 9 consist of the annual resupply launch fees as adjusted for a 7% annual rate of inflation. This is a future-value computation only. An Internal rate of return calculation is not being used here.

3. This is the baseline power system consisting of a photovoltaic energy conversion system (ECS), a fuel cell energy storage system (ESS), and a power management and distribution system (PMAD).

4. This is the baseline thermal control system consisting of a two-phase ammonia external bus and a two-phase water thermal transport system including radiators, heat exchangers, coldplates, piping, and pumps.

TABLE 2.3.5-2

WASTE MANAGEMENT SUBSYSTEM LAUNCH COSTS

Subsystem	On-orbit wt (lb)	90-Day resupply wt (lb)	Subsystem power (kw)	Subsystem heat reject (kw)	(1) 10-year launch wt (lb)	(2) 10-year launch cost ($)
INCIN (3)	1,033	249	0.76	0.76	11,620	3,701,410
WETOX (3)	1,226	255	1.26	1.26	12,377	4,219,027
SCWO (3)	396	230	0.55	0.85	10,116	2,767,098
VCD	111	466	0.11	0.11	19,081	4,261,344
TIMES	92	585	0.16	0.16	23,920	5,308,622
VPCAR	524	197	0.12	0.12	8,591	2,362,713

Notes:

1. This weight includes on-orbit and resupply weight penalties for the power used and heat rejected by the subsystem as derived from table 2.3.5-1.

2. The first-year costs consist of the launch fees for the subsystem plus the launch fees for that portion of the power and thermal systems used by the subsystem as well as the first-year subsystem resupply launch fees plus the resupply launch fees for that portion of the power and thermal sysems used by the subsystem. The costs for years 2 through 9 consist of the annual resupply launch fees for the subsystem and for that portion of the power and thermal systems used by the subsystem, adjusted for a 7% annual rate of inflation.

3. The heat rejection for INCIN, WETOX, and SCWO includes the heat of combustion.

4. Power and heat rejection rates assume continuous subsystem operation over a 24 hr period. This is consistent with the sizing criteria applied to the subsystems in this report.

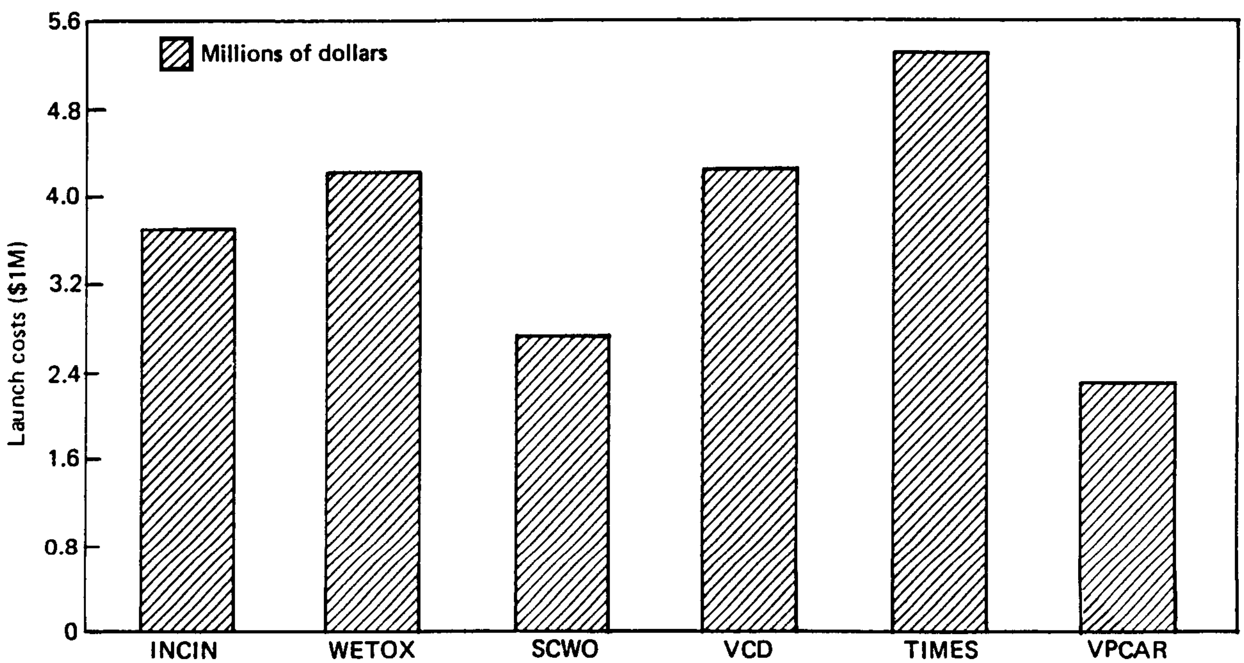


Figure 2.3.5-1. Waste Management System Launch Costs Over 10 Years

System, (ECS) Energy Storage System, (ESS) (for operation during the darkside of the orbit) and Power Management and Distribution System. Accordingly, it is reasonable to penalize the subsystems with a portion of the power system weight and resupply weight in direct relation to the power they consume. If a subsystem draws 7.5 kw and the IOC Space Station power system supplies 75 kw, the subsystem is penalized 10% of the total power system weight and logistics weight. These weight penalties are converted to 10-year launch costs in the same manner as the subsystem on-orbit and logistics weights.

Likewise subsystem heat rejection affects the size and weight of the Space Station thermal control system. The subsystems ultimately reject heat to the Space Station thermal bus. Higher subsystem heat rejection rates require larger radiator surfaces and a larger thermal transport system including heat exchangers, cold plates, piping, and pumps. Therefore, it is reasonable to penalize the subsystems with a portion of the thermal system weight and logistics weight in direct relation to the heat rejected. If a subsystem rejects 9.58 kw of heat and the IOC Space Station thermal system is sized for 95.8 kw, the subsystem is penalized for 100% of the total thermal system weight and logistics weight. These weight penalties are converted to ten year launch costs in the same manner as the power system weight penalties and the subsystem on-orbit weights and logistics weights.

2.3.6 Summary

Table 2.3.6-1 summarizes the subsystem parametric comparisons made in this section.

TABLE 2.3.6-1

WASTE MANAGEMENT SYSTEM RANKING SUMMARY

Ranking	Weight	Volume	Logistics	Power	Heat Rejection	Launch Costs
1	TIMES	TIMES	VPCAR	VCD	VCD	VPCAR
2	VCD	VCD	SCWO	VPCAR	VPCAR	SCWO
3	SCWO	SCWO	INCIN	TIMES	TIMES	INCIN
4	VPCAR	VPCAR	WETOX	SCWO	INCIN	WETOX
5	INCIN	WETOX	VCD	INCIN	SCWO	VCD
6	WETOX	INCIN	TIMES	WETOX	WETOX	TIMES

Table 2.3.6-1 that the phase-change processes (VCD and TIMES) have the best weight, volume, power, and heat rejection characteristics but have the worst logistics requirements. The better characteristics are partially a result of the mature level of subsystem development. The fact that these processes were designed to recover water from only liquid wastes also contributes to the lower weight, volume, power, and heat rejection but results in higher logistics requirements.

The combustion processes (INCIN, WETOX, and SCWO) have the opposite characteristics. They exhibit relatively high weight, volume, power and heat rejection but lower logistics requirements. The higher weight volume, power, and heat rejection rates are partially a result of the lower maturity level of these subsystems but are also due to the increased mass processing rate, higher recovery rate, and the nature of the processes themselves that high temperatures and pressures for combustion. The more favorable logistics requirements are due to the higher recovery rates of usable materials, requiring less resupply and return to Earth logistics.

The VPCAR system is a hybrid using both phase-change and oxidation processes, its parametric performance is therefore more mixed than for the other systems in this study. VPCAR displays the best logistics, good power consumption and heat rejection, but only fair weight and volume characteristics. Overall, the performance is very good considering its relatively low technology level (figure 2.3-1).

It is difficult to determine a "best" subsystem from the above comparisons. Selecting a best subsystem depends upon which parameters are considered to be most important. The relative importance of the parameters depends on the mission requirements. For example, a short-mission space capsule may place maximum emphasis on weight, volume, power, and heat rejection. A long-mission lunar base or Mars expedition may place maximum emphasis on reducing or eliminating logistics. The Space Station may place equal emphasis on all of the parameters with upper limits set for each one. Table 2.3.6-2 is a parametric evaluation of the subsystem where all parameters are considered to be equally important.

TABLE 2.3.6-2

WASTE MANAGEMENT SYSTEM PARAMETRIC EVALUATION

Parameter	WASTE MANAGEMENT SUBSYSTEM					
	INCIN	WETOX	SCWO	VCD	TIMES	VPCAR
Weight	5	6	3	2	1	4
Volume	6	5	3	2	1	4
Logistics	3	4	2	5	6	1
Power	5	6	4	1	3	2
Heat Reject	4	6	5	1	3	2
Total	23	27	17	11	14	13

In table 2.3.6-2 the subsystems are given nominal values based on their relative ranking in each parametric category. Therefore, the TIMES subsystem weight parameter is given a value of 1 because TIMES exhibited the best weight characteristics (section 2.3.1). The WETOX subsystem power parameter, however, is given a value of 6 it exhibited the highest power consumption (section 2.3.3). Lower ranking values in this Table indicate lower parametric penalties and therefore better relative parametric standing. When the parametric values for each subsystem are summed, the following parametric ranking results:

1. VCD.
2. VPCAR.
3. TIMES.
4. SCWO.
5. INCIN.
6. WETOX.

When all parameters are considered equally, the phase-change processes come out on top and VCD is the best of these. Subsystem maturity and functional design have a lot to do with this result.

NASA Space Station program places primary emphasis on costs. At this time there is not enough information on all of the subsystems to determine and compare them for life cycle costs. But, as demonstrated in table 2.3.5-1, there is enough parametric information derived from this report to determine and compare subsystem launch costs over a projected subsystem equipment life of 10 years. The launch costs in this table have subsystem power and heat rejection support required from the space station factored into them. The results reveal that if launch costs were to be the single most important selection criteria, then the subsystems would have to be ranked from most to least desirable as follows:

1. VPCAR.
2. SCWO.
3. INCIN.
4. WETOX.
5. VCD.
6. TIMES.

This is the same relative ranking as the logistics comparison in section 2.3.2. This indicates that when launch costs are considered over the life of the equipment, logistics becomes the single most important parameter. Logistics becomes so important that it overrides weight, volume, power, and heat rejection combined. The combustion-based subsystems have the best logistics characteristics and, of these, VPCAR and SCWO appear to be the best performers.

2.4 IMPACT ON OVERALL ECLSS

As part of an integrated Space Station ECLSS, the waste-treatment process does not operate as an independent entity. It depends on inputs from other ECLSS subsystems for operation (e.g., power, waste water, oxygen). It must also have outputs that other ECLSS subsystems can process (e.g., solids, concentrated waste water, recovered water and gases) at operating temperatures and pressures that the other subsystems are designed to tolerate. Types and quantities of the materials required and produced by the waste-treatment process therefore affect the balance of materials processed and stored by the rest of the ECLSS. This interdependency influences the process rates of certain other subsystems (e.g., increased O_2 generation rate for the static-feed water electrolysis oxygen system when a combustion or oxidation based waste-management subsystem is used). These process rate changes may require upsizing or downsizing of certain dependent subsystems. Therefore, it can be assumed that each type of waste management subsystem imprints its own unique character upon the balance of materials handled by the ECLSS and, therefore, upon the parameters of the ECLSS in which it operates. Accordingly, overall ECLSS mass balances have been determined for each waste treatment process in this report and are discussed below.

2.4.1 Combustion-Based Mass Balance

Figure 2.4.1-1 illustrates the impact of a combustion-based waste treatment subsystem assuming that the product water meets NASA Potable Water Specification MSC-SPEC-SD-W-0020 (it does not meet this specification at this time). The upper part of the figure represents the baseline ECLSS configuration (as listed in table 2.5-1). Baseline subsystems are represented in individual functional blocks (i.e., "CO_2 Removal EDC"). The middle portion represents ECLSS storage requirements within circular tanks, noting the storage item and quantity to be stored in pounds per day (i.e., "Carbon Storage <6.2>"). When no values are listed within these circles, no net storage either for resupply or return to Earth is required. The lower portion represents both the waste-management subsystem under consideration as well as any required auxiliary devices in functional blocks.

This analysis is valid for INCIN and for WETOX provided with auxiliary VPCAR, as well as for SCWO. These processes require the upsizing of the oxygen generation and the carbon dioxide collection and reduction subsystems. They also require storage for ash and sulfur dioxide (SO_2) gas. Nitrogen released by combustion could provide the necessary makeup for module leakage and subsystem ullage loss. Enough potable water is produced to overcome deficits in the hygiene water production subsystems with some excess water that would have to be stored and returned to Earth during resupply.

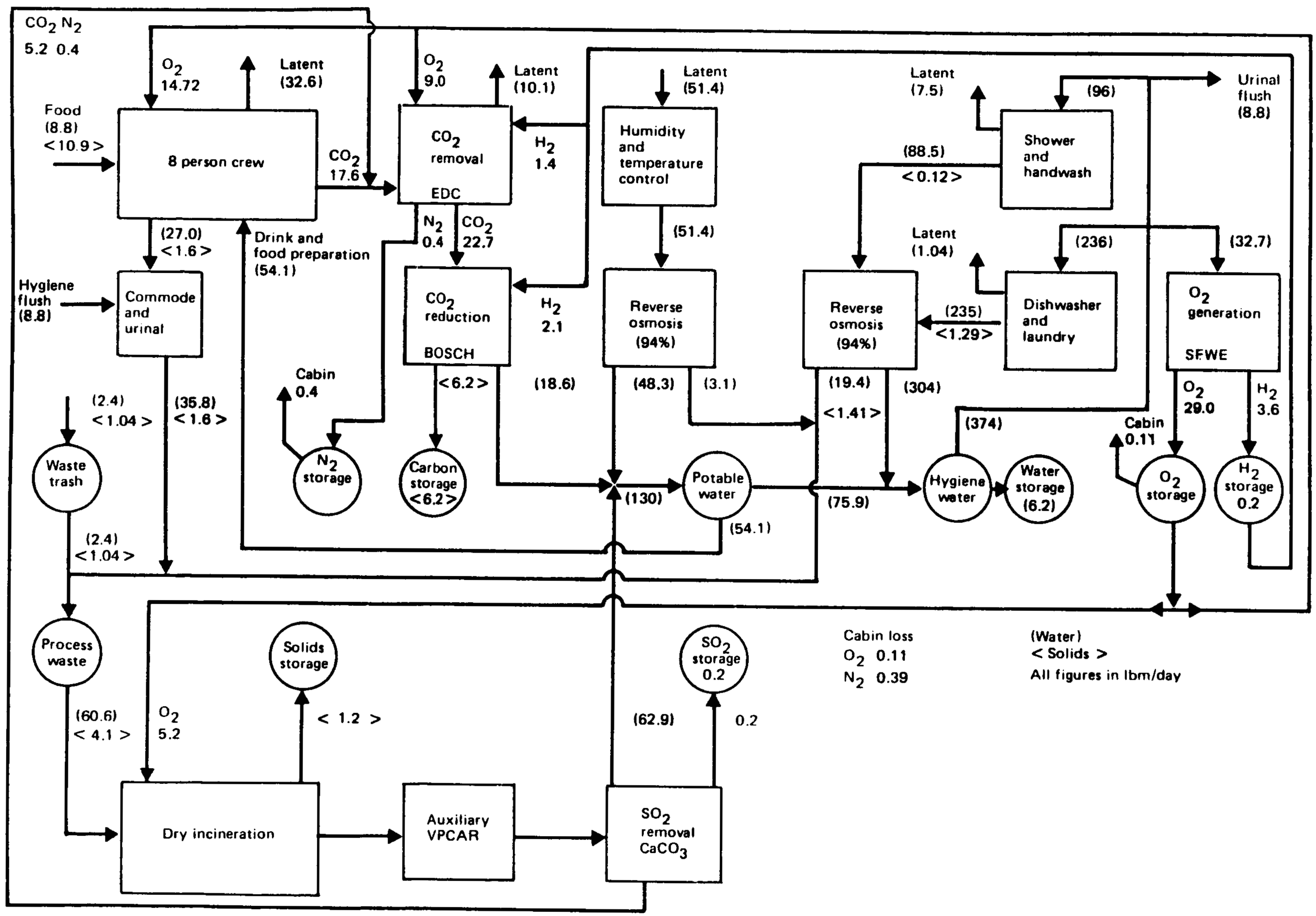


Figure 2.4.1-1. ECLSS Daily Mass Balance Using Combustion-Based Waste Management

A combustion analysis was performed particularly for analyzing the SCWO subsystem using urine composition data from reference 26 and fecal and wash water composition data from reference 25. Insufficient data were found for what might be the chemical constituents of Space Station trash. Therefore, trash was assumed to be similar in composition to wash solids. Trash quantities were derived from reference 13. The resulting combustion analysis is shown in table 2.4.1-1. It applies to any of the oxidation processes assuming complete oxidation of solids takes place.

2.4.2 VCD-Based Mass Balance

Figure 2.4.2-1 illustrates the impact of a VCD phase-change process on the Space Station materials balance assuming that the recovered water meets the NASA potable water specification (it does not at this time). Unlike the combustion processes, VCD can not handle solids directly. Suspended solids must be separated by filtration. Dissolved solids are concentrated into a brine that is 50% solids by weight. Because this subsystem is not designed to treat solid wastes, fecal and trash solids must be separated from their waters, stored, and returned to Earth. In the process of recovering water, VCD also loses water in the formation of brine. In the ECLSS configuration selected for this report, this brine becomes waste that does not undergo further processing and therefore must be returned to Earth. Even so, VCD recovers enough water to make up the deficit in hygiene water production with a couple of extra pounds per day left over requiring storage for later return to Earth. VCD does not impact any of the other ECLSS subsystems.

2.4.3 TIMES-Based Mass Balance

Figure 2.4.3-1 is a representation of the TIMES phase-change process impact on the overall ECLSS, assuming that the recovered water meets the NASA potable water specification (it does not at this time). Since TIMES, like VCD, is a phase-change process it filters out suspended solids and concentrates dissolved solids in a brine. This brine is lower in solids concentration for the TIMES than for the VCD. Six pounds of water are lost for every 4 lb of solids removed. Therefore, less water is recovered by the TIMES subsystem and more is returned to Earth as brine. This difference in brine concentration is enough to allow a deficit in the hygiene water supply system, requiring extra water supplies to be brought on board and stored at initial supply and resupply times. Fecal and trash solids must be removed from their waters, stored, and returned to Earth. TIMES does not impact any of the other ECLSS subsystems.

TABLE 2.4.1-1 WASTE SOLIDS COMBUSTION ANALYSIS
Assumes Complete Combustion / Oxidation of Fuel

Material	Urine Solids	Fecal Solids	Hygiene and Wash Solids
	Amount of Material Required or Produced (lb material/lb solid listed below)		
I Required:			
Oxygen	0.614	1.83	1.43
II Produced:			
Carbon dioxide	0.70	1.73	1.39
Water vapor	0.36	0.90	0.54
Nitrogen	0.22	0.08	0.05
Sulfur dioxide	0.008	0.0	0.12
Solids (ash)	0.32	0.13	0.33
	Btu released per pound of solids oxidized		
	5,285	13,089	9,498

Notes:

The basic combustion reactions are:

$$C + O_2 \Rightarrow CO_2 + 14{,}600 \text{ btu/lb } C$$
$$2H_2 + O_2 \Rightarrow 2H_2O + 62{,}000 \text{ btu/lb } H_2$$
$$S + O_2 \Rightarrow SO_2 + 4{,}050 \text{ btu/lb } S$$

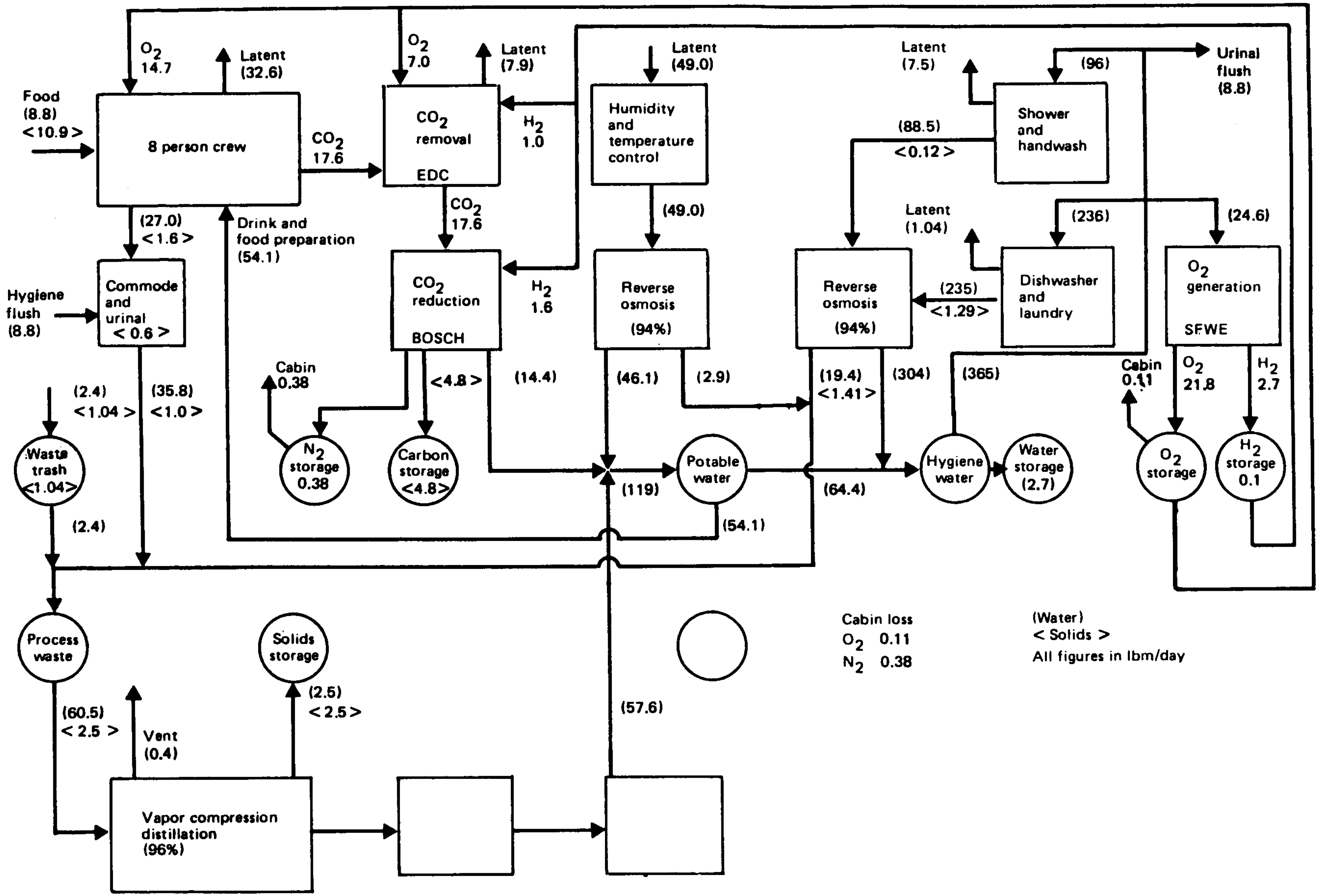


Figure 2.4.2-1. ECLSS Daily Mass Balance Vapor Compression Distillation Impact

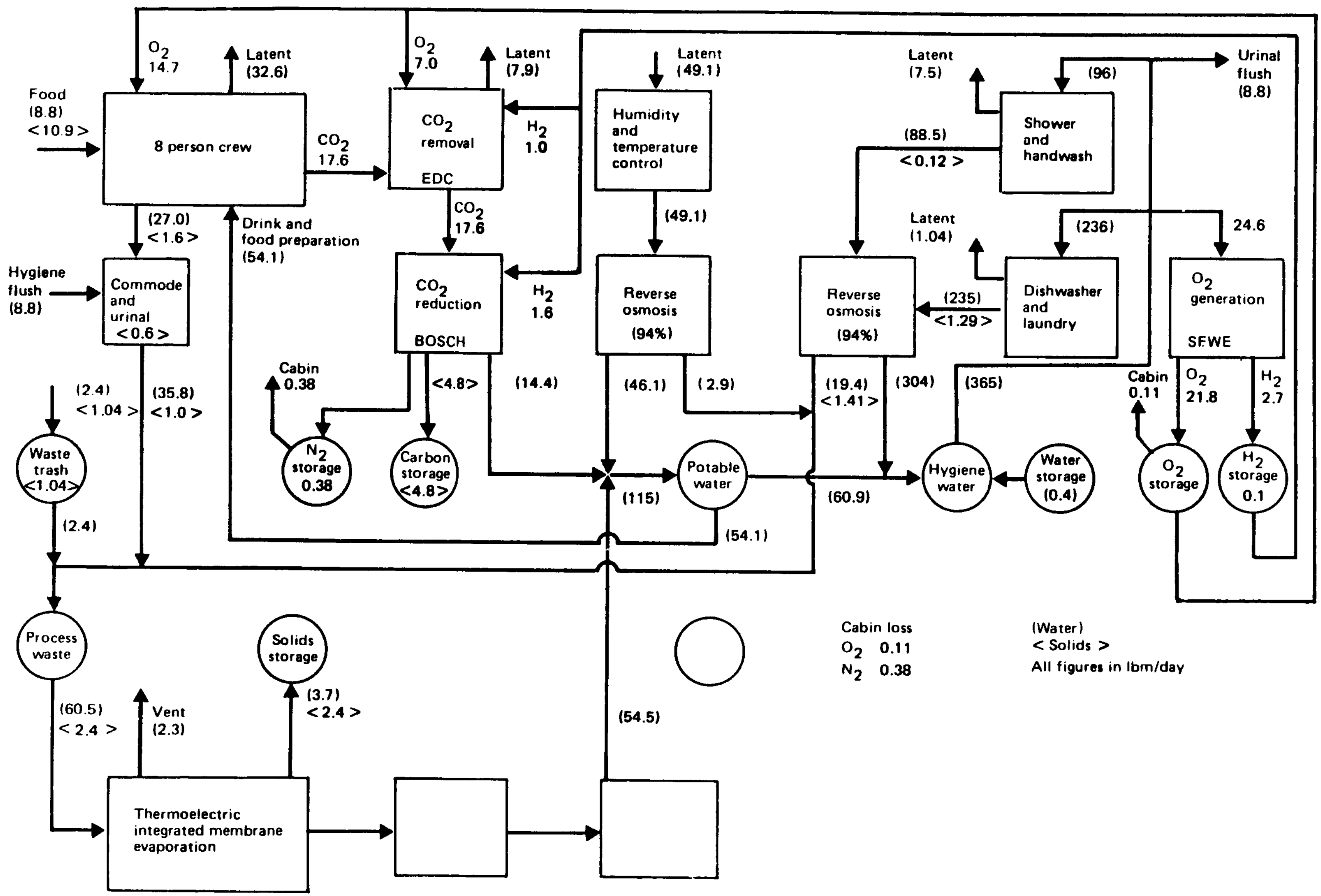


Figure 2.4.3-1. ECLSS Daily Mass Balance Thermoelectric Integrated Membrane Evaporation Impact

2.4.4 VPCAR-Based Mass Balance

Figure 2.4.4-1 depicts the impact of the VPCAR waste-management subsystem on the Space Station materials balance, assuming that the product water meets the NASA potable water specification (it does not at this time). As mentioned earlier, VPCAR is somewhat of a hybrid between the phase-change and combustion processes. It filters out suspended solids and concentrates dissolved solids in an evaporator. However, volatiles, such as ammonia, which are carried over into the water vapor side are oxidized and reformed into reusable vapor and gases such as H_2O and N_2. Fecal and trash solids must be separated from their waters, stored, and returned to Earth. It has been assumed for the purposes of this mass balance that dissolved solids are carried over into the vapor side and catalytically oxidized. This process requires the upsizing of the oxygen generation and the carbon dioxide collection and reduction subsystems, although not to the same degree as the combustion processes due to the inability to handle suspended solids. Ash and SO_2 collection and storage is required to handle the oxidation waste products. The nitrogen released by the oxidation process is not enough to make up for module leakage and subsystem ullage loss. Therefore, additional nitrogen is required either as stored gas or liquid or by a nitrogen generation subsystem. Enough usable water is produced by the VPCAR to make up the deficit in the hygiene water production subsystem with several pounds per day excess requiring storage for later return to Earth.

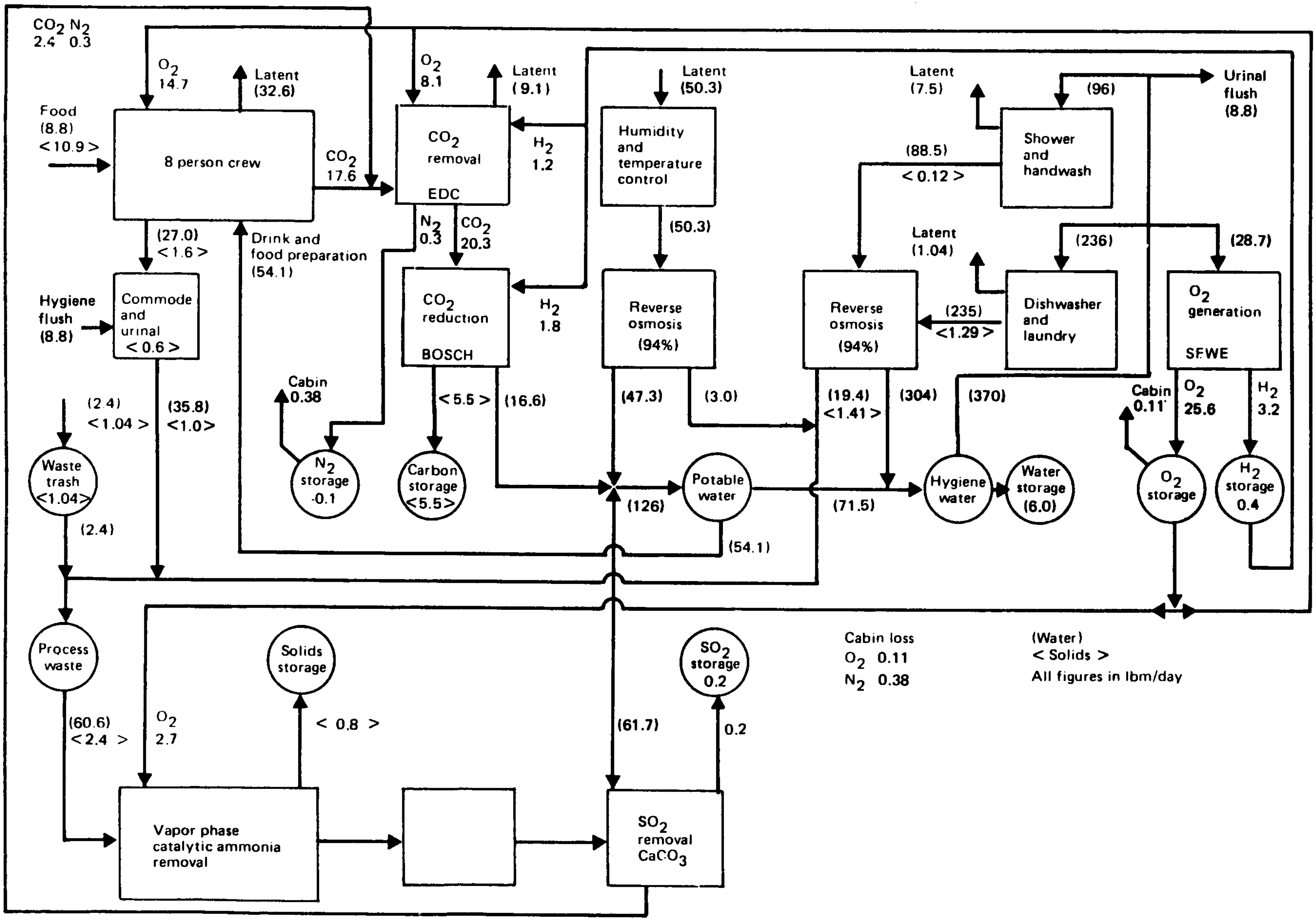


Figure 2.4.4-1. ECLSS Daily Mass Balance Vapor Phase Catalytic Ammonia Removal Impact

2.5 ECLSS PARAMETRIC COMPARISON

In order to more completely assess the parameters of the six waste-management subsystems involved in this study, it was felt that each subsystem should be "placed" into a common Space Station ECLSS configuration and that the resulting ECLSS parameters should be evaluated and compared. Using this approach, additional parametric penalties, such as sizing changes in interdependent ECLSS subsystems, water system resupply and waste return to Earth become more apparent. The ECLSS mass balances discussed in section 2.4 were derived from this evaluation. The results are more fully discussed in this section.

The common ECLSS configurations into which the waste-management subsystems were placed are shown in tables 2.5-1 and 2.5-2. Table 2.5-1 is a listing of supporting subsystems selected for the combustion-based waste-treatment processes. Table 2.5-2 is a listing of supporting subsystems selected for the phase-change waste- treatment processes and for VPCAR. The difference between these two tables is the inclusion of a Shuttle commode and a trash compactor in table 2.5-2 as a penalty for the inability of phase-change processes to handle fecal and trash solids. Otherwise, the temperature control, air revitalization, supporting water processing, and the health and hygiene subsystems are the same.

Table 2.5-3 shows comparative data for the complete ECLSS associated with each type of waste-management subsystem. The parameters listed are similar to those presented in table 2.3-2, which was used for the individual subsystem comparisons.

2.5.1 WEIGHT AND VOLUME

The fixed on-orbit weights and volumes for the six waste management ECLSS configurations, sized for a one module Space Station mission with an eight-person crew, are listed as items A and B in table 2.5-3 and are compared in figure 2.5.1-1. This figure shows only slight differences among the configurations. The mean system weight is 11,512 lb with a standard deviation of 458 lb (4% of the mean). The mean system volume is 948 ft^3 with a standard deviation of 44 ft^3 (5% of the mean). However slight the differences may be, ranking these configurations on the basis of the most to least preferred on-orbit weight and volume would yield the following list:

WEIGHT	VOLUME
1. TIMES	SCWO
2. VCD	TIMES
3. SCWO	VCD
4. VPCAR	WETOX

BOEING ENGINEERING TRADES STUDY - (BETS) 24-SEP-85

JOB ID INCN
ECLSS CONFIGURATION NO. 1

SUBSYSTEM SELECTION SUMMARY

ITEM NO.	SUBSYSTEM/COMPONENT	
1	HX & FANS - AIR COOLING---------	STAINLESS
70	HX & FANS - ODOR CONTROL--------	
2	HX - EQUIPMENT COLDPLATES-------	
3	HX & FANS - HUMIDITY CONTROL----	STAINLESS
4	CO2 REMOVAL - EDC---------------	
11	CO2 REDUCTION - BOSCH-----------	
13	TRACE CONTAMINANT CONTROL-------	
14	ATMOSP MONITOR - MASS SPECTRMTR-	
61	O2 SUPPLY - STATIC FEED ELECTR.-	
22	O2 STORAGE - HI PRESS EMERG-----	
24	N2 SUPPLY - N2H4 DECOMPOSITION--	
25	N2 STORAGE - HI PRESS EMERG-----	
26	CABIN PRESSURE CONTROL----------	
28	POT. H2O STORAGE - CLOSED LOOP--	
29	POT. H2O STORAGE - EMERGENCY----	
63	REVERSE OSMOSIS - POTABLE H2O---	
35	PROCESSED H2O POST-TREATMENT POT	
30	WASTE H2O STORAGE & PRE-TREAT---	
71	WASH H2O STORAGE----------------	
74	HYGIENE H2O STORAGE-------------	
75	REVERSE OSMOSIS - HYGIENE H2O---	
68	**H2O RECOVERY - INCINERATION ----**	
76	PROCESSED H2O POST-TREATMENT HYG	
36	H2O QUALITY MONITORING----------	
37	HEALTH & HYGIENE - HAND WASH----	
38	HEALTH & HYGIENE - HOT H2O SPLY-	
39	HEALTH & HYGIENE - COLD H2O SPLY	
40	HEALTH & HYGIENE - BODY SHOWER--	
41	HEALTH & HYGIENE - DISHWASHER---	
42	HEALTH & HYGIENE - CLTH WASH/DRY	
44	HEALTH & HYGIENE - EMER WSTE COL	
46	HEALTH & HYGIENE - OVEN---------	
47	HEALTH & HYGIENE - FOOD REFRIDGE	
48	HEALTH & HYGIENE - FOOD FREEZER-	

ADDITIONAL COMPONENTS PER MODULE

0 SUITS AND PLSS'S
0 PORTABLE OXYGEN SUPPLIES
0 EMERGENCY ESCAPE SYSTEMS

TABLE 2.5-1 ECLSS WITH WASTE WATER PROCESSING BY COMBUSTION

BOEING ENGINEERING TRADES STUDY - (BETS) 24-SEP-85

JOB ID VCD

ECLSS CONFIGURATION NO. 2

SUBSYSTEM SELECTION SUMMARY

ITEM NO.	SUBSYSTEM/COMPONENT	
1	HX & FANS - AIR COOLING---------	STAINLESS
70	HX & FANS - ODOR CONTROL--------	
2	HX - EQUIPMENT COLDPLATES-------	
3	HX & FANS - HUMIDITY CONTROL----	STAINLESS
4	CO2 REMOVAL - EDC---------------	
11	CO2 REDUCTION - BOSCH-----------	
13	TRACE CONTAMINANT CONTROL-------	
14	ATMOSP MONITOR - MASS SPECTRMTR-	
61	O2 SUPPLY - STATIC FEED ELECTR.-	
22	O2 STORAGE - HI PRESS EMERG-----	
24	N2 SUPPLY - N2H4 DECOMPOSITION--	
25	N2 STORAGE - HI PRESS EMERG-----	
26	CABIN PRESSURE CONTROL----------	
28	POT. H2O STORAGE - CLOSED LOOP--	
29	POT. H2O STORAGE - EMERGENCY----	
63	REVERSE OSMOSIS - POTABLE H2O---	
35	PROCESSED H2O POST-TREATMENT POT	
30	WASTE H2O STORAGE & PRE-TREAT---	
71	WASH H2O STORAGE----------------	
74	HYGIENE H2O STORAGE-------------	
75	REVERSE OSMOSIS - HYGIENE H2O---	
34	**H2O RECOVERY - VCD--------------**	**LSI**
76	PROCESSED H2O POST-TREATMENT HYG	
36	H2O QUALITY MONITORING----------	
37	HEALTH & HYGIENE - HAND WASH----	
38	HEALTH & HYGIENE - HOT H2O SPLY-	
39	HEALTH & HYGIENE - COLD H2O SPLY	
40	HEALTH & HYGIENE - BODY SHOWER--	
41	HEALTH & HYGIENE - DISHWASHER---	
42	HEALTH & HYGIENE - CLTH WASH/DRY	
43	**HEALTH & HYGIENE - COMMODE/URINL**	
44	HEALTH & HYGIENE - EMER WSTE COL	
45	**HEALTH & HYGIENE - TRASH COMPACT**	
46	HEALTH & HYGIENE - OVEN---------	
47	HEALTH & HYGIENE - FOOD REFRIDGE	
48	HEALTH & HYGIENE - FOOD FREEZER-	

ADDITIONAL COMPONENTS PER MODULE

0 SUITS AND PLSS'S
0 PORTABLE OXYGEN SUPPLIES
0 EMERGENCY ESCAPE SYSTEMS

TABLE 2.5-2 ECLSS WITH WASTE WATER PROCESSING BY PHASE CHANGE

TABLE 2.5-3

ECLSS CONFIGURATION PARAMETRIC SUMMARY
for an Eight-Person Crew

Parameter	(1) INCIN	(1) WETOX	SCWO	VCD	TIMES	VPCAR
	Waste Management Subsystem					
A.Weight (lb)	11913	12104	11280	11047	11029	11696
B.Volume (ft3)	995	968	885	925	923	991
C.Resupply (90-day)						
Weight (lb)	1082	1088	1064	1664	1674	1735
Volume (ft3)	853	908	906	979	979	980
D.Return to Earth						
Weight (lb)	1849	1855	1830	3656	3774	3414
Volume (ft3)	910	909	906	1079	1080	1074
E.Power (w)						
AC	2902	3396	2754	1943	1936	2099
DC	5880	5880	5880	4589	4651	5229
Intermittent	22295	5829	6665	6512	6513	6587
F.Heat Rejection						
Air cooled (btuh)	9365	9216	10322	7493	7681	7662
Liq cooled (btuh)	36245	37932	36773	29639	29828	31793

Notes:

1. INCIN and WETOX include an auxiliary VPCAR penalty as suggested in the literature and as evaluated in this report.

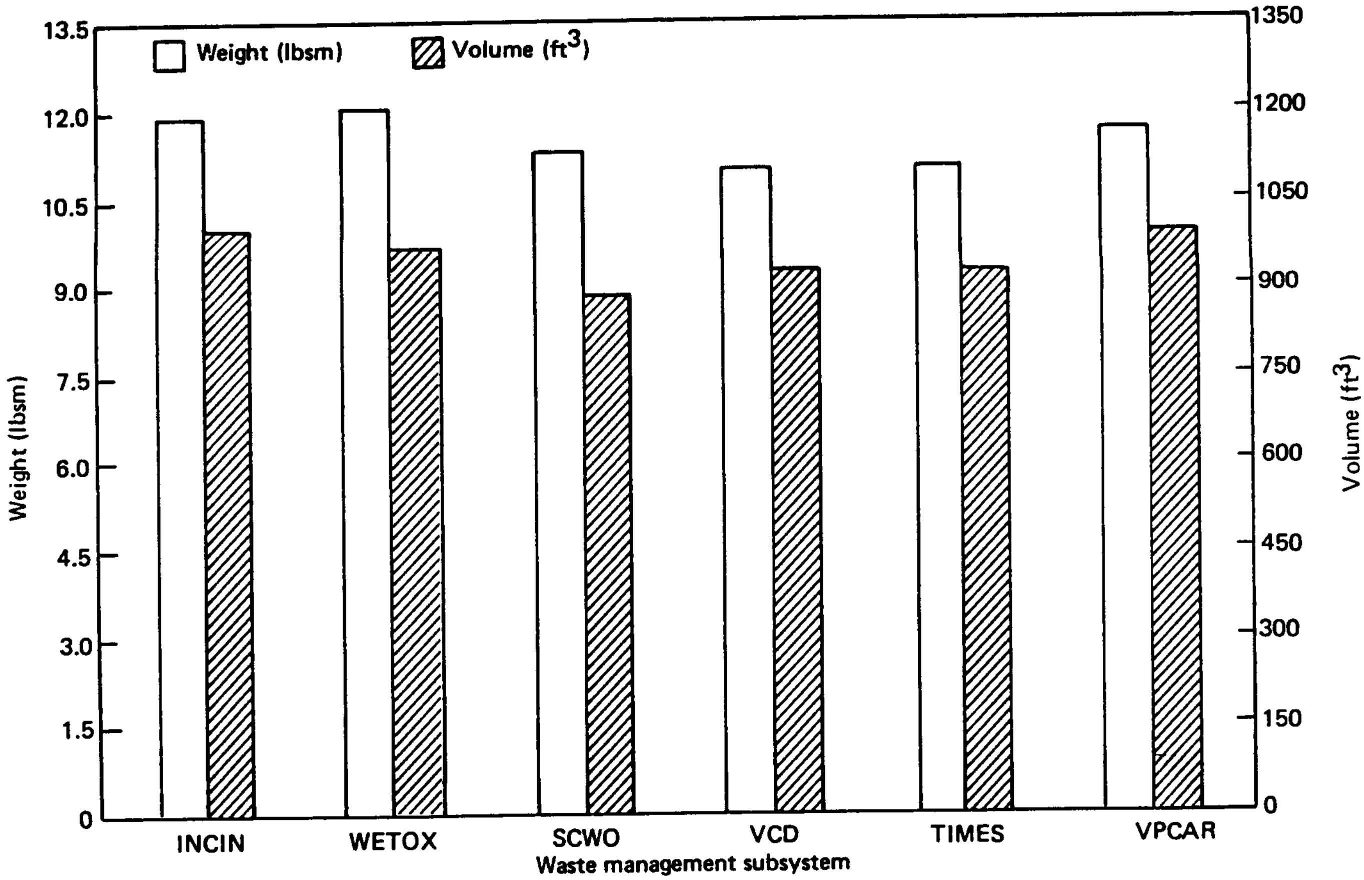


Figure 2.5.1-1. ECLSS Weight and Volume Comparison

5. INCIN	VPCAR
6. WETOX	INCIN

The differences in configuration weights and volumes reflect not only the sizing of the individual waste-treatment subsystems but also any size adjustments required for the supporting subsystems. Although the range of differences in the system weights and volumes is not as great as the range of differences in the subsystem weights and volumes (table 2.3-1), the ranking is the same in both cases. This is due primarily to the fact that TIMES and VCD are optimally designed to begin with. Additionally, these same two subsystems do not require sizing changes in their companion ECLSS subsystems. SCWO, VPCAR, INCIN, and WETOX have much more mass and volume as individual subsystems than TIMES and VCD. The four subsystems do require sizing adjustments in the supporting ECLSS subsystems. The INCIN and WETOX configurations are at the bottom of the ranking due to their auxiliary VPCAR penalty. It should be noted that all six configurations exceed the NASA estimates of 9,271 lb and 773 ft^3 for the total ECLSS, including extravehicular activity (EVA) servicing and safe-haven provisions as given in reference 30, table 4.4.6-3.

2.5.2 LOGISTICS

Configuration resupply and return to Earth weights and volumes are listed as items C and D in table 2.5-3. The return to Earth logistics figures include resupply logistics. Configuration resupply and return to Earth weights, only, are compared in figure 2.5.2-1.

The data in table 2.5-3 indicate that there is very little difference among the configuration logistics volumes. The mean logistics volume is 993 ft^3 with a standard deviation of 93 ft^3 (9% of the mean). Therefore, only the weights are used in this comparison. Ranked in the order of the most desirable logistics weights, the configurations are listed as follows:

1. SCWO.
2. INCIN.
3. WETOX.
4. VPCAR.
5. VCD.
6. TIMES.

The combustion-based ECLSS show the most favorable logistics requirements because these subsystems process and recover more waste materials than the phase-

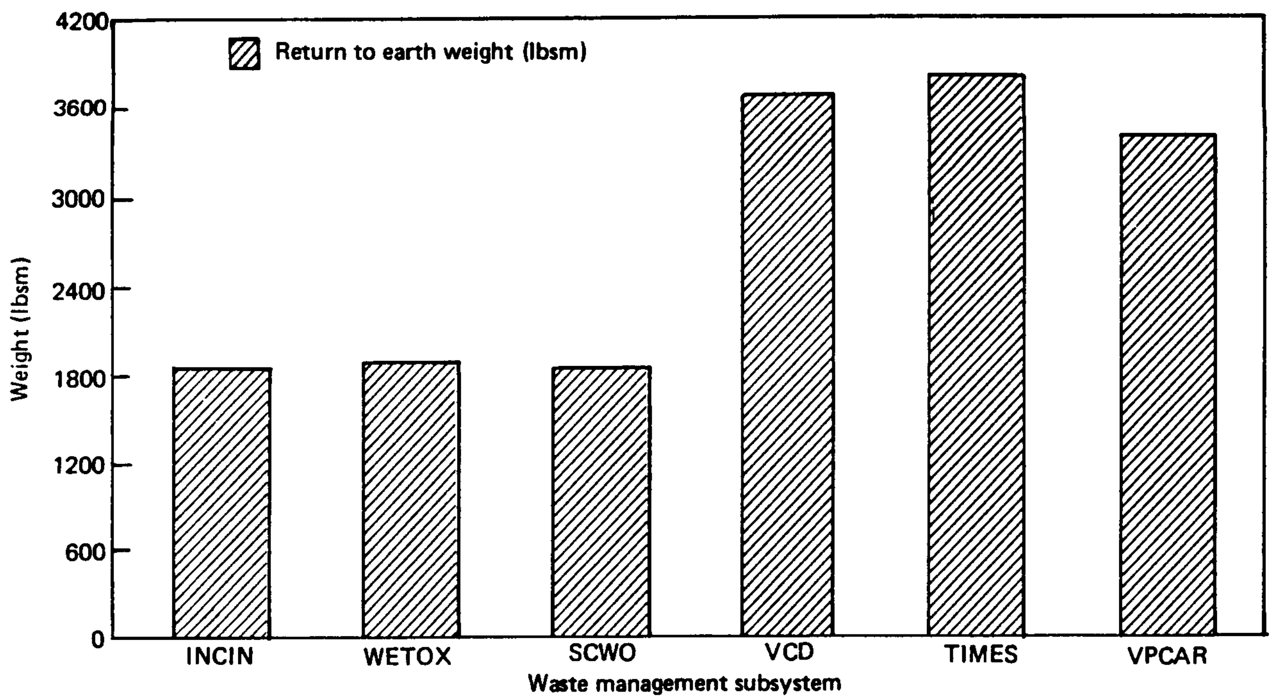


Figure 2.5.2-1. ECLSS Configuration Logistics Comparison

change based systems. Therefore, less resupply and return to Earth items are required. The differences among the logistics weights for the combustion-based systems are insignificant, having a mean return to Earth weight of 1845 lb with a standard deviation of only 13 lb (0.7% of the mean).

The VPCAR requires the least overall logistics of the phase-change based ECLSS configurations. This is due to its combustion-like (oxidation) characteristics in reducing a greater quantity of waste and recovering more water and gases. The logistics are less than for the VCD and TIMES configurations even though VPCAR requires more support from the rest of the ECLSS subsystems (e.g., O_2 supply, CO_2 recovery, etc.). VPCAR also does not produce a brine as do VCD and TIMES. Brines for VCD and TIMES tie up at least an equal quantity of water to solids removed in the waste-management subsystem. This water becomes unrecoverable waste and must be returned to Earth. The VCD configuration requires less logistics than the TIMES configuration because it does not lose as much water to the production of brine as does the TIMES.

All of the resupply requirements for the six ECLSS configurations fall within the Shuttle launch capacity of 65,000 lb and 10,600 ft^3. The return to Earth requirements for the configurations all fall within the Shuttle landing capacity of 32,000 lb and 10,600 ft^3.

2.5.3 POWER CONSUMPTION AND HEAT REJECTION

ECLSS configuration power consumption (w) and heat rejection (btuh) are listed as items E and F, respectively, in table 2.5-3. Configuration total power consumption (kw) and total heat rejection (thousands of btuh) are compared in figure 2.5.3-1. When ranked according to optimal power consumption, the six ECLSS configurations are as follows:

1. VCD.
2. TIMES.
3. VPCAR.
4. SCWO.
5. INCIN.
6. WETOX.

The VCD and TIMES power consumption rates are very close to each other not only because of the similarity of their processes but also because of the high degree of heat recovery designed into these subsystems. Their ECLSS configurations also consume less power than the others because phase-change processes have minimal impact on companion ECLSS subsystems. The VPCAR process uses phase-change and employs heat

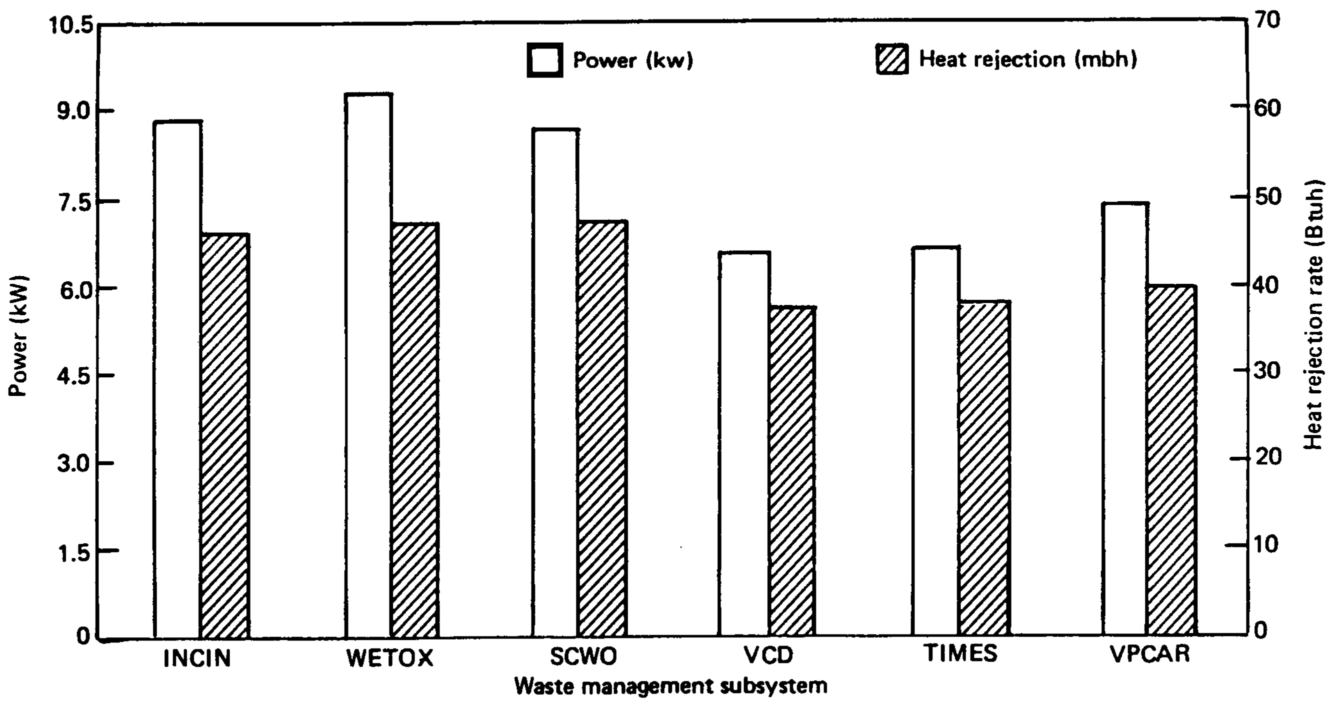


Figure 2.5.3-1. ECLSS Power Consumption and Heat Rejection

recovery as well, but requires high temperatures (250 deg C and 450 deg C) for catalytic oxidation and impacts the sizing of supporting ECLSS subsystems.

The combustion based configurations consume the most power because they process and recover more materials, operate at higher temperatures, and require more support from other ECLSS subsystems. Less power would be required if the solids concentration of the waste water to be processed by these subsystems were boosted to 10% to 30% by weight. This would result in additional heat being evolved by the combustion process, which could then be recovered to preheat the incoming slurry and oxygen gas. The WETOX system has higher power consumption than the INCIN system primarily due to high operating pressure (2200 psia). It consumes more power than the SCWO system due the use of less heat recovery in the primary process.

When ranked according to optimum heat rejection, the six waste treatment based ECLSS configurations are as follows:

1. VCD.
2. TIMES.
3. VPCAR.
4. INCIN.
5. SCWO.
6. WETOX.

The VCD and the TIMES configurations show the least heat rejection requirements because of their built-in heat recovery. They are nearly equal in this respect. The VPCAR configuration, however, operates at higher temperature and impacts supporting ECLSS subsystems resulting in a higher heat rejection rate.

The combustion-based ECLSS all show considerably more heat rejection requirements. Again, this is because they process and recover more waste materials, operate at higher temperatures, and require more support from companion ECLSS subsystems than the other configurations.

2.5.4 LAUNCH COST ANALYSIS

The ECLSS configuration parameters, like the parameters for the individual waste management subsystems considered in section 2.3, can be used together for estimating the best ECLSS waste-management configuration by equating each parameter with a 10-year launch cost. However, discussion of launch costs focuses on weight parameters and generally does not address volume issues. Therefore, on-orbit and logistics volumes are left out of this type of analysis. Is this valid? As shown in sections 2.5.1 and 2.5.2, there are small relative differences in both the on-orbit (the standard deviation is 5% of the mean) and logistics (the standard deviation is 9% of the mean) volumes among the six ECLSS configurations. Because of these small differences and the fact that even the largest volume (1080 ft^3) amounts to only 1/10 of the shuttle cargo bay capacity, volumes are not considered to be significant enough to be of concern here.

Launch costs for the on-orbit and logistics weight and the launch costs for the ECLSS configuration power and thermal systems weight penalties are totalled and compared, as in section 2.3.5. Table 2.5.4-1 is a listing of the 10-year ECLSS configuration launch costs. Figure 2.5.4-1 is a bar chart of the results. This evaluation results in the following ranking of the six configurations from least to most expensive 10-year launch costs:

1. INCIN.
2. SCWO.
3. WETOX.
4. VPCAR.
5. VCD.
6. TIMES.

When this ranking is compared with the results of the logistics weight ranking in section 2.5.2, it becomes evident that logistics becomes the single most important parameter affecting 10-year launch costs. It becomes so important that it overrides on-orbit weight, power consumption, and heat rejection combined. This is the same conclusion reached in section 2.3.5 where 10-year launch costs are compared for the individual subsystems.

Configuration launch costs and launch cost penalties for configuration power use and heat dissipation are determined on the same basis as for the individual subsystems in section 2.3.5.

TABLE 2.5.4-1

ECLSS CONFIGURATION LAUNCH COSTS

ECLSS config	On-orbit wt (lb)	90-day resupply wt (lb)	Subsystem power (kw)	Subsystem heat reject (kw)	(1) 10-year launch wt (lb)	(2) 10-year launch cost ($)
INCIN (3)	11,913	1,849	5.91	13.36	91,651	33,228,675
WETOX (3)	12,104	1,855	9.28	13.81	93,877	34,824,823
SCWO (3)	11,280	1,830	8.63	13.80	91,703	33,453,127
VCD	11,047	3,656	6.53	10.88	164,071	48,032,048
TIMES	11,029	3,774	6.59	10.99	168,883	49,083,087
VPCAR	11,696	3,414	7.33	11.56	155,404	47,013,784

Notes:

1. This weight includes on-orbit and resupply weight penalties for the power used and heat rejected by the subsystem as derived from table 2.3.5-1.

2. The first-year costs consist of the launch fees for the ECLSS plus the launch fees for that portion of the power and thermal systems used by the ECLSS, as well as the first-year ECLSS resupply launch fees plus the resupply launch fees for that portion of the power and thermal sysems used by the ECLSS. The costs for years 2 through 9 consist of the annual resupply launch fees for the ECLSS and that portion of the power and thermal systems used by the ECLSS, adjusted for a 7% annual rate of inflation.

3. The heat rejection for INCIN, WETOX, and SCWO includes the heat of combustion.

4. Power and heat rejection rates assume continuous subsystem operation over a 24 hr period. This is consistent with the sizing criteria applied to the subsystems in this report.

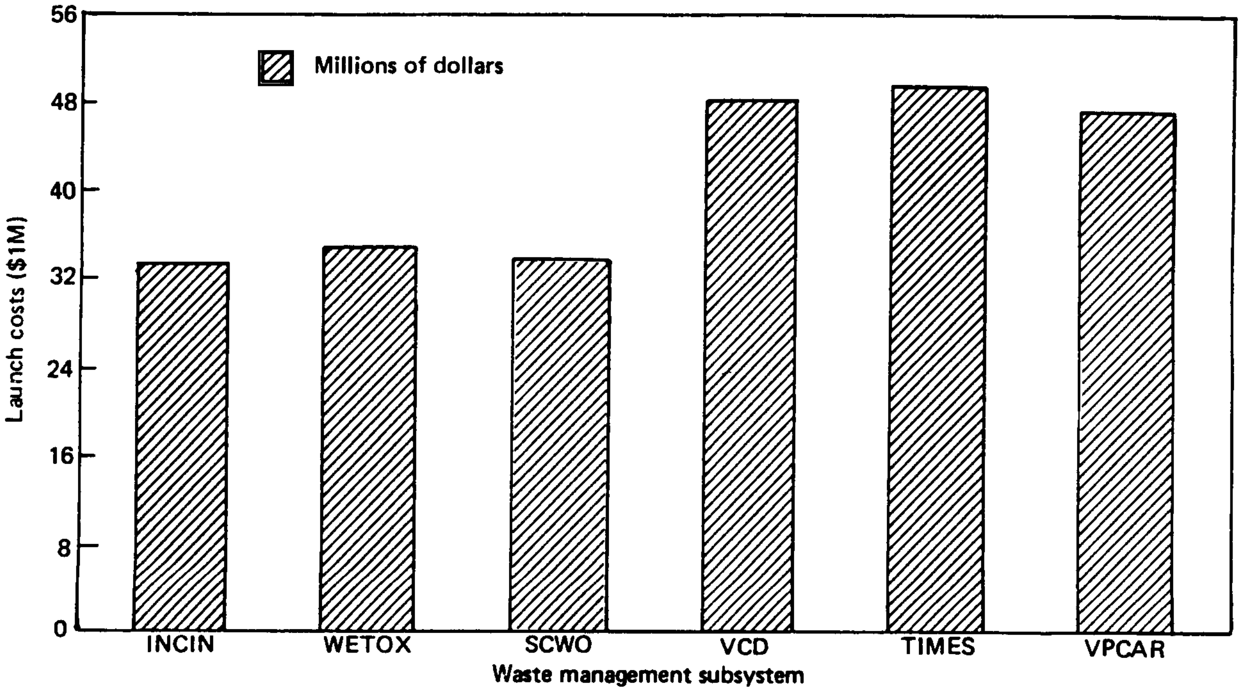


Figure 2.5.4-1. ECLSS Configuration Launch Costs Over 10 Years

2.5.5 SUMMARY

Table 2.5.5-1 summarizes the ECLSS configuration parametric comparisons made in section 2.5.

TABLE 2.5.5-1

ECLSS CONFIGURATION RANKING SUMMARY

Ranking	Weight	Volume	Logistics	Power	Heat Rejection	Launch Costs
1	TIMES	*SCWO	*SCWO	VCD	VCD	*INCIN
2	VCD	*TIMES	*INCIN	*TIMES	*TIMES	SCWO
3	SCWO	*VCD	*WETOX	*VPCAR	*VPCAR	*WETOX
4	VPCAR	*WETOX	*VPCAR	SCWO	INCIN	VPCAR
5	INCIN	*VPCAR	VCD	INCIN	SCWO	VCD
6	WETOX	INCIN	TIMES	WETOX	WETOX	TIMES

Notes:
*Indicates a difference in ranking from the individual subsystem comparisons in section 2.3.

Table 2.5.5-1 shows the same general parametic trends for the ECLSS configurations as does table 2.3.6-1 for the individual subsystem parameters. That is, the phase-change based configurations (VCD and TIMES) exhibit lower weight, volume, power consumption, and heat rejection characteristics, even with waste storage penalties, than the combustion-based configurations (INCIN, WETOX and SCWO). This is understandable not only from an individual subsystem standpoint, as discussed in section 2.3.6, but also from the standpoint of subsystem interdependency. The phase-change processes require very little support from the other ECLSS subsystems. Therefore, there are very few supporting subsystem sizing adjustments, with the related additional weight, volume, power, and heat rejection, required.

The combustion-based configurations, however, have the best logistics characteristics but the worst weight, volume (with the exception of SCWO), power consumption, and heat rejection. This is due not only to the individual subsystem design characteristics (as discussed in section 2.3.6) but it is also due to the extent of subsystem interdependency. The combustion-based processes require oxygen and produce N_2, CO_2, and SO_2 gases as well as water. These gases must be handled by other subsystems. The extra capacity requirements levied on these supporting subsystems result in higher subsystem weight, volume, power, and heat rejection. This, in turn, results in higher overall configuration weight, volume, power, and heat rejection than is contributed by the waste-treatment subsystem alone.

The VPCAR does not compare as well with the other subsystems when evaluated as part of an overall ECLSS. Being a hybrid system, part phase-change and part combustion (oxidation), its ranking is mixed. However, its combustion characteristics with its higher dependency on other subsystems become a dominant factor. It ranks third in power and heat rejection, fourth in weight and logistics and fifth in volume.

If all the parameters are weighted equally important, as may be the case for the Space Station, the ECLSS configurations can be evaluated as shown in table 2.5.5-2 below.

TABLE 2.5.5-2

ECLSS CONFIGURATION PARAMETRIC EVALUATION

	Waste Management Subsystem					
Parameter	INCIN	WETOX	SCWO	VCD	TIMES	VPCAR
Weight	5	6	3	2	1	4
Volume	6	4	1	3	2	5
Logistics	2	3	1	5	6	4
Power	5	6	4	1	2	3
Heat Rejection	4	6	5	1	2	3
Total	22	25	14	12	13	19

Table 2.5.5-2 assigns values to the configuration parameters equal to the relative ranking of each configuration for each parameter considered. For example, the TIMES configuration weight is assigned a value of 1 because it has the lowest weight of the six configurations (section 2.5.1). The WETOX configuration heat rejection, however, is assigned a value of 6 because it has the highest heat rejection rate of the six configurations (section 2.5.3). Therefore, the lower values in this table represent better parametric performance. The following configuration ranking is derived from summing the parametric values for each configuration.

C-2

1. VCD.
2. TIMES.
3. SCWO.
4. VPCAR.
5. INCIN.
6. WETOX.

As is the result when the subsystems are considered individually, when the parameters are equally weighed the phase-change processes come out on top and the VCD is the best of these. However, when compared with the summary of the individual subsystems in section 2.3.6, VPCAR ranks differently. As part of an ECLSS, VPCAR ranks fourth. It ranks second as an individual subsystem. As mentioned earlier, this is due to its dependency on other ECLSS subsystems.

If primary emphasis is placed on configuration launch costs (section 2.5.4), the configuration ranking changes to the following:

1. INCIN.
2. SCWO.
3. WETOX.
4. VPCAR.
5. VCD.
6. TIMES.

This is very close to the ECLSS configuration logistics ranking in section 2.5.2. It indicates that, when launch costs are considered over the lifetime of the ECLSS equipment, logistics become the single most important parameter. It becomes so important that it overrides weight, volume, power, and heat rejection combined. The combustion-based ECLSS configurations have the best logistics. Of these, INCIN and SCWO appear to be the best performers. Yet the launch cost figures are so close among INCIN, WETOX, and SCWO it can only be concluded that combustion-based waste treatment processes are more launch cost effective than the phase-change based processes.

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3.0 CONCLUSION

The parameteric rankings obtained in section 2.5 for the six waste management subsystem ECLSS configurations provide the basis for the conclusions in this report. This is because the configuration rankings include consideration of individual subsystem parameters along with overall ECLSS materials balances and ECLSS subsystem interdependence. Therefore, they provide a more complete picture of the end parametric effects of each of the six waste-management subsystems. Table 2.5.5-1 is repeated here as a summary of section 2.5.

ECLSS CONFIGURATION RANKING SUMMARY

Ranking	Weight	Volume	Logistics	Power	Heat rejection	Launch costs
1	TIMES	SCWO	SCWO	VCD	VCD	INCIN
2	VCD	TIMES	INCIN	TIMES	TIMES	SCWO
3	SCWO	VCD	WETOX	VPCAR	VPCAR	WETOX
4	VPCAR	WETOX	VPCAR	SCWO	INCIN	VPCAR
5	INCIN	VPCAR	VCD	INCIN	SCWO	VCD
6	WETOX	INCIN	TIMES	WETOX	WETOX	TIMES

Several conclusions may be drawn from this summary. First, it highlights the optimum ECLSS configuration for each parameter. If on-orbit weight is considered to be the most important characteristic, then the TIMES configuration has the lowest weight. If logistics weight is considered to be the most important factor, then the SCWO configuration has the lowest logistics requirements.

Second, general trends related to process type appear. The summary reveals that the phase-change processes (VCD and TIMES) exhibit the best weight, volume (with the exception of SCWO), power, and heat rejection characteristics, but the worst logistics. The combustion processes (INCIN, WETOX, and SCWO) exhibit very good logistics, but the worst weight, volume, power, and heat rejection. The VPCAR results are more mixed because this subsystem is part phase-change, with its hollow fiber membrane evaporator, and part combustion (oxidation), with its NH_3 and N_2O catalytic oxidation reactors. These trends are due in part to the function of the processes and due in part to their level of maturity. The phase-change processes handle only liquid wastes and can only recover 94% to 97% of the water in these wastes. Any solids in the wastes and an equal amount of water by weight are rejected as brine and stored for return to Earth. Handling a limited amount of wastes keeps the on-orbit weight and volume, power consumption, and heat rejection rates relatively low, but the brine storage requirements keep the return to Earth logistics high. The combustion processes are designed to handle both solid and liquid wastes. They not only recover 100% of the water in the waste but also produce additional water in the oxidation reactions. The higher waste-processing rate and the higher operating temperatures and pressures (except INCIN) required for this rate tend to increase the subsystem weight, volume, power consumption, and heat rejection rates. Increased dependency on the other ECLSS subsystems for providing O_2 and for processing N_2, CO_2, and SO_2 tend to increase these same parameters for the supporting subsystems as well. However, the higher processing and recovery rates also tend to significantly reduce the ECLSS logistics requirements for water and N_2.

Third, relationships between the various parameters become visible. Power consumption and heat rejection rates have identical configuration rankings because all of the power required by a subsystem is assumed to be converted to heat. If a fan motor draws 1 kw of electrical power, it is assumed that 1 kw of heat is passed to the cabin atmosphere by the motor. The exception to this assumption is the combustion processes. These generate additional heat, above their power consumption rate, in the exothermic oxidation reactions (figure 2.4.1-1). Another relationship exists between configuration logistics and 10-year launch costs. When launch costs consider not only getting the equipment into orbit but also resupplying it every 90 days over an anticipated 10-year life, logistics becomes the single most important cost factor. One relationship that is not evident in this summary but is evident in the consideration of individual subsystems (section 2.3, figure 2.3.1-1) is the direct relationship between on-orbit weight and volume. This is not seen in the ECLSS configuration comparisons because the weight and volume values are too close to each other. The values are so close (within 4% to 9%) that they can be considered within the limits of estimating error and therefore not significant.

It is not obvious from table 2.5.5-1 which waste-management subsystem is the best overall parametric performer. That judgment depends largely on which parameters are considered to be the most important. The relative importance of each parameter must be determined from the individual space mission requirements. A short mission in a space capsule may emphasize low weight, volume, power, and heat rejection. A long-duration lunar base or Mars expedition may place higher priority on low logistics. A Space Station in Earth orbit may place equal importance on all. If all parameters are considered equally important, then the subsystems can be ranked as follows from best to least:

1. VCD.
2. TIMES.

3. SCWO.
4. VPCAR.
5. INCIN.
6. WETOX.

Because the phase-change processes rank highest in four out of the five separate parameters they have the best overall performance. VCD ranks the highest of these. The combustion processes rank the lowest, but SCWO is the best of these.

NASA is placing primary importance on costs for the Space Station program. Although insufficient data have been found for calculating complete subsystem life cycle costs for this report, enough subsystem parametric data have been generated by the BETS to estimate subsystem launch costs over a projected 10-year equipment life. When these costs, which are adjusted for the use of the IOC Space Station power and thermal systems, are compared for each ECLSS configuration, the following subsystem ranking from least to most expensive launch cost results.

1. INCIN.
2. SCWO.
3. WETOX.
4. VPCAR.
5. VCD.
6. TIMES.

This ranking is basically the same as for the logistics parameter, indicating that when launch costs are evaluated over the life of the equipment, logistics becomes the single most important factor. Logistics becomes so important that it overrides the weight, volume, power consumption, and heat rejection parameters combined. The combustion processes have the lowest logistics requirements. The cost figures are so close among the three combustion processes (within 5%) that no clear best performer is indicated.

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5.0 THE BETS PROGRAM AND PROGRAM RESULTS

5.1 THE BETS PROGRAM

The BETS (Boeing Engineering Trade Study) program employed in this study calculates characteristics of an ECLSS system configured by the user. The program considers the interactions between the selected subsystems and bases calculations on average process rates taken as steady state. A flow chart of the main program is shown in figure 5.1-1. The BETS program contains average loads assumed generated by the crew and the non-ECLSS Space Station equipment (table 5.1-1), as well as mission data assumed for the Space Station (table 5.1-2). These data are representative of current projections for Space Station operation. The exceptions in this study will be that no EVA is considered and that the entire inhabited volume is considered as a single module.

5.1.1 COMPARISON PROCEDURE

A representative ECLSS system configuration sized to handle the loads from an eight-person crew was selected as the baseline for the comparison of the subject water reclamation subsystems. However, a commode for the storage of fecal solids and a trash compactor for the processing of dry garbage has been added to the VCD, TIMES and VPCAR ECLSS analyses as penalties for the inability of these systems to handle solid wastes. Tables 5.1.1-1 and 5.1.1-2 summarize the ECLSS subsystems selected along with the combustion-based and the phase-change based waste treatment processes, respectively.

The BETS subroutines for INCIN, WETOX, SCWO, and VCD were developed as linear extrapolations from single point data found in or derived from the current literature. The TIMES subroutine was developed from parametric data supplied by Hamilton Standard to Boeing Aerospace Company. The VCD subroutine was developed by fitting curves derived from Hamilton Standard parametric data to single point data supplied by Life Systems Inc. to Boeing.

INCIN, WETOX, and SCWO subroutines all intake urine/flush water, reverse osmosis brines (condensate and wash water), fecal solids and fecal water, trash solids and trash water, and oxygen. They all produce water, CO_2 gas, N_2 gas, SO_2 gas (primarily from the soap in the wash water brine), and solids. The INCIN and WETOX processes are considered to output water too dirty to be used directly. These subroutines, therefore, carry parametric penalties for an auxiliary VPCAR as an integral cleanup process.

The VCD, TIMES II, and VPCAR subroutines all intake urine/flush water, reverse osmosis brines (condensate and wash water), fecal water, and trash water. The VPCAR subroutine includes terms for intake oxygen, antifoam agent, pH adjustment agent, and

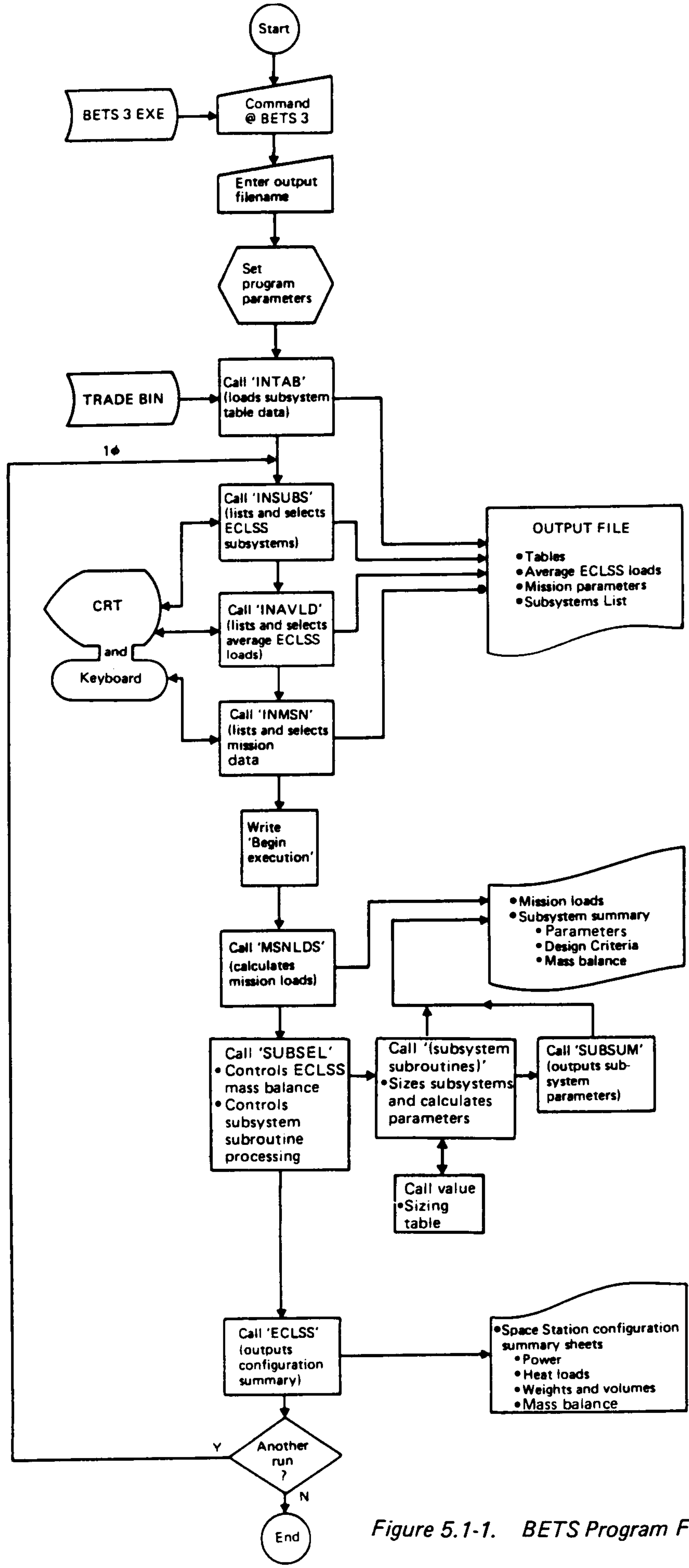

Figure 5.1-1. BETS Program Flow Chart

BOEING ENGINEERING TRADES STUDY - (BETS)   24-SEP-85

AVERAGE LOADS FOR ECLSS

PARAMETER	UNITS	AVERAGE
METABOLIC OXYGEN	LB/PERSON-DAY	1.84
METABOLIC CARBON DIOXIDE	LB/PERSON-DAY	2.20
DRINKING WATER	LB/PERSON-DAY	2.86
FOOD PREPARATION WATER	LB/PERSON-DAY	3.90
HAND WASH WATER	LB/PERSON-DAY	7.00
SHOWER WATER	LB/PERSON-DAY	5.00
CLOTHES WASH WATER	LB/PERSON-DAY	27.50
DISH WASH WATER	LB/(8) CREW-DAY	16.00
METABOLIC PRODUCED WATER	LB/PERSON-DAY	0.78
PERSPIRATION/RESPIRATION WATER	LB/PERSON-DAY	4.02
URINE (3.3) AND FLUSH (1.1)	LB/PERSON-DAY	4.40
FOOD SOLIDS	LB/PERSON-DAY	1.36
FOOD WATER	LB/PERSON-DAY	1.0
FOOD PREPARATION LATENT WATER	LB/PERSON-DAY	0.06
URINE SOLIDS	LB/PERSON-DAY	0.13
FECAL SOLIDS	LB/PERSON-DAY	0.07
SWEAT SOLIDS	LB/PERSON-DAY	0.04
EVA DRINK WATER	LB/8-HR EVA	0.75
EVA WASTE WATER	LB/8-HR EVA	2.00
EVA OXYGEN	LB/8-HR EVA	1.32
EVA CARBON DIOXIDE	LB/8-HR EVA	1.7
SENSIBLE METABOLIC HEAT	BTU/PERSON-DAY	7010.00
HYGIENE LATENT WATER	LB/PERSON-DAY	0.94
LAUNDRY LATENT WATER	LB/PERSON-DAY	0.13
HYGIENE WATER SOLIDS	% OF H2O USAGE	0.13
WASTE WASH WATER SOLIDS	% OF H2O USAGE	0.44
AIRLOCK VOLUME	FT3	150.00
CABIN AIR LEAKAGE	LB/DAY-MODULE	0.50
COMMODE ULLAGE VOLUME	FT3/DUMP	0.00
CHARCOAL (ODOR CONTROL)	LB/PERSON-DAY	0.13
CLOTHING WEIGHT	LB/PERSON-DAY	0.00

TABLE 5.1-1

BOEING ENGINEERING TRADES STUDY - (BETS) 24-SEP-85
JOB ID INCN
ECLSS CONFIGURATION NO. 1

SPECIFIC MISSION DATA

PARAMETER	UNITS	VALUE
MODULE		
NUMBER OF MODULES	TOTAL	1
NUMBER OF CREWPERSONS	TOTAL	8
AVERAGE FREE VOLUME	FT3 PER MODULE	4010.00
PRESSURIZATION	(PER MODULE)	
TOTAL MODULE PRESSURE	PSIA	14.70
O2 PARTIAL PRESSURE	PSIA	3.00
CO2 PARTIAL PRESSURE	MMHG	3.00
NO. OF RE-PRESSURIZATIONS	PER RESUPPLY PERIOD	1
HEAT LOADS	(PER MODULE)	
LIGHTING & DISPLAYS	BTU/DAY	25000.00
EXPERIMENTAL		
SENSIBLE	BTU/DAY	0.00
LATENT H2O	LB/DAY	0.00
EVA		
NUMBER OF EVA	PER WEEK	0
AVERAGE EVA DURATION	HOURS	8.00
AIRLOCK USED	PER WEEK	0
AIRLOCK DUMP PRESSURE	PSIA	2.00
RESUPPLY		
INITIAL SUPPLY PERIOD	DAYS	90.00
RESUPPLY PERIOD	DAYS	90.00
EMERG. SUPPLIES ALLOCATION	DAYS	28.00
ORBIT		
LIGHTSIDE DURATION	MIN	56.00
DARKSIDE DURATION	MIN	36.00

TABLE 5.1-2

BOEING ENGINEERING TRADES STUDY - (BETS) 24-SEP-85

JOB ID INCN
ECLSS CONFIGURATION NO. 1

SUBSYSTEM SELECTION SUMMARY

ITEM NO.	SUBSYSTEM/COMPONENT	
1	HX & FANS - AIR COOLING---------	STAINLESS
70	HX & FANS - ODOR CONTROL--------	
2	HX - EQUIPMENT COLDPLATES-------	
3	HX & FANS - HUMIDITY CONTROL----	STAINLESS
4	CO2 REMOVAL - EDC---------------	
11	CO2 REDUCTION - BOSCH-----------	
13	TRACE CONTAMINANT CONTROL-------	
14	ATMOSP MONITOR - MASS SPECTRMTR-	
61	O2 SUPPLY - STATIC FEED ELECTR.-	
22	O2 STORAGE - HI PRESS EMERG-----	
24	N2 SUPPLY - N2H4 DECOMPOSITION--	
25	N2 STORAGE - HI PRESS EMERG-----	
26	CABIN PRESSURE CONTROL----------	
28	POT. H2O STORAGE - CLOSED LOOP--	
29	POT. H2O STORAGE - EMERGENCY----	
63	REVERSE OSMOSIS - POTABLE H2O---	
35	PROCESSED H2O POST-TREATMENT POT	
30	WASTE H2O STORAGE & PRE-TREAT---	
71	WASH H2O STORAGE----------------	
74	HYGIENE H2O STORAGE-------------	
75	REVERSE OSMOSIS - HYGIENE H2O---	
68	**H2O RECOVERY - INCINERATION ----**	
76	PROCESSED H2O POST-TREATMENT HYG	
36	H2O QUALITY MONITORING----------	
37	HEALTH & HYGIENE - HAND WASH----	
38	HEALTH & HYGIENE - HOT H2O SPLY-	
39	HEALTH & HYGIENE - COLD H2O SPLY	
40	HEALTH & HYGIENE - BODY SHOWER--	
41	HEALTH & HYGIENE - DISHWASHER---	
42	HEALTH & HYGIENE - CLTH WASH/DRY	
44	HEALTH & HYGIENE - EMER WSTE COL	
46	HEALTH & HYGIENE - OVEN---------	
47	HEALTH & HYGIENE - FOOD REFRIDGE	
48	HEALTH & HYGIENE - FOOD FREEZER-	

ADDITIONAL COMPONENTS PER MODULE

0 SUITS AND PLSS'S
0 PORTABLE OXYGEN SUPPLIES
0 EMERGENCY ESCAPE SYSTEMS

TABLE 5.1.1-1 ECLSS WITH WASTE WATER PROCESSING BY COMBUSTION

BOEING ENGINEERING TRADES STUDY - (BETS)   24-SEP-85

JOB ID VCD
ECLSS CONFIGURATION NO. 2

SUBSYSTEM SELECTION SUMMARY

ITEM NO.	SUBSYSTEM/COMPONENT	
1	HX & FANS - AIR COOLING---------	STAINLESS
70	HX & FANS - ODOR CONTROL--------	
2	HX - EQUIPMENT COLDPLATES-------	
3	HX & FANS - HUMIDITY CONTROL----	STAINLESS
4	CO2 REMOVAL - EDC---------------	
11	CO2 REDUCTION - BOSCH-----------	
13	TRACE CONTAMINANT CONTROL-------	
14	ATMOSP MONITOR - MASS SPECTRMTR-	
61	O2 SUPPLY - STATIC FEED ELECTR.-	
22	O2 STORAGE - HI PRESS EMERG-----	
24	N2 SUPPLY - N2H4 DECOMPOSITION--	
25	N2 STORAGE - HI PRESS EMERG-----	
26	CABIN PRESSURE CONTROL----------	
28	POT. H2O STORAGE - CLOSED LOOP--	
29	POT. H2O STORAGE - EMERGENCY----	
63	REVERSE OSMOSIS - POTABLE H2O---	
35	PROCESSED H2O POST-TREATMENT POT	
30	WASTE H2O STORAGE & PRE-TREAT---	
71	WASH H2O STORAGE----------------	
74	HYGIENE H2O STORAGE-------------	
75	REVERSE OSMOSIS - HYGIENE H2O---	
34	H2O RECOVERY - VCD--------------	LSI
76	PROCESSED H2O POST-TREATMENT HYG	
36	H2O QUALITY MONITORING----------	
37	HEALTH & HYGIENE - HAND WASH----	
38	HEALTH & HYGIENE - HOT H2O SPLY-	
39	HEALTH & HYGIENE - COLD H2O SPLY	
40	HEALTH & HYGIENE - BODY SHOWER--	
41	HEALTH & HYGIENE - DISHWASHER---	
42	HEALTH & HYGIENE - CLTH WASH/DRY	
43	HEALTH & HYGIENE - COMMODE/URINL	
44	HEALTH & HYGIENE - EMER WSTE COL	
45	HEALTH & HYGIENE - TRASH COMPACT	
46	HEALTH & HYGIENE - OVEN---------	
47	HEALTH & HYGIENE - FOOD REFRIDGE	
48	HEALTH & HYGIENE - FOOD FREEZER-	

ADDITIONAL COMPONENTS PER MODULE

0 SUITS AND PLSS'S
0 PORTABLE OXYGEN SUPPLIES
0 EMERGENCY ESCAPE SYSTEMS

TABLE 5.1.1-2 ECLSS WITH WASTE WATER PROCESSING BY PHASE CHANGE

filter material. All these subroutines produce water. The VPCAR also outputs CO_2 gas, N_2 gas, SO_2 gas and solids as byproducts of the catalytic oxidation process. The VCD and TIMES produce a concentrated brine (40% to 50% solids by weight) that must go to waste storage.

5.2 COMPARISON RESULTS

Tables 5.2-1 through 30 are the outputs of BETS for the six waste treatment subsystems in their appropriate ECLSS environments. Each of the six waste processes has five BETS output pages associated with it. The first page is a parametric summary for the particular waste treatment subsystem. Power, weight, volume, heat rejection, and subsystem mass balance are calculated for an eight-person crew and printed out on this page. This information is used in section 2.2 subsystem comparison analysis. The second page is a logistics summary for the entire ECLSS configuration. The third page is an ECLSS electrical power summary. The fourth page is a heat load summary sheet for the ECLSS. The fifth page is an ECLSS mass balance summary. Negative values in the mass balance columns represent the use or removal of a material by the subsystems listed on the left side of the page. Positive values represent materials output or produced by a particular subsystem. Values for solids are not represented in either the wash or waste water columns.

The outputs from the INCIN system are printed in tables 5.2-1 through 5.

The outputs from the WETOX system are printed in tables 5.2-6 through 10.

The outputs from the SCWO system are printed out in tables 5.2-11 through 15.

The outputs from the VCD system are printed out in tables 5.2-16 through 20.

The outputs from the TIMES system are printed out in tables 5.2-21 through 25.

The outputs from the VPCAR systems are printed out in tables 5.2-26 through 30.

The ECLSS outputs are summarized in section 2.5.

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SUBSYSTEM F8 H2O RECOVERY - INCINERATION ---- ECLSS CONFIGURATION NO. 1

MISSION DATA

SPACE STATION				ECLSS CLOSED LOOP FUNCTIONS	
MODULES	1	RESUPPLY PERIOD	90.0 DAYS	CO2 REDUCTION	H2O RECOVERY
MODULE SIZE	4010.0 FT3	ORBIT		O2 GENERATION	CONDENSATE
CREWPERSONS	8	LIGHTSIDE	56.0 MIN		WASH WATER
INITIAL SUPPLY PERIOD	90.0 DAYS	DARKSIDE	36.0 MIN		URINE

SUBSYSTEM DATA PER UNIT - 1 REQUIRED FOR STATION

POWER (WATTS)

	AC	DC
LIGHTSIDE	759.6	0.0
DARKSIDE	759.6	0.0
INTERMITTENT	16465.6	0.0

HEAT LOAD - SENSIBLE (BTU'S)

	AIR	AIR TEMP	LIQUID	LIQUID TEMP
LIGHTSIDE	1623.2	CABIN AIR	968.4	40-45 F
DARKSIDE	1623.2	CABIN AIR	968.4	40-45 F
INTERMITTENT	989.1		55298.0	

PAYLOAD

	WEIGHT (LBS)	VOLUME (FT3)
FIXED ON-ORBIT	1032.9	122.0
INITIAL SPARES & EXP	153.3	12.5
SUBTOTAL	1186.2	134.5
RESUPPLY SPARES & EXP	81.0	3.9
RETURN TO EARTH	219.4	6.0

SUBSYSTEM DESIGN CRITERIA

SUBSYSTEM MASS BALANCE DATA PER UNIT (LB/DAY)

MATERIALS REQUIRED		MATERIALS PRODUCED		MATERIALS LOST
WASTE WATER=	64.703	POTABLE WATER=	62.853	
OXYGEN=	5.215	CO2=	5.226	
		NITROGEN=	0.396	
		SULFUR DIOXIDE=	0.178	
		SOLIDS=	1.215	

TABLE 5.2-1 INCINERATION/AUX. VPCAR SUBSYSTEM SUMMARY

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INCH SPACE STATION ECLSS CONFIGURATION NO. 1 SUMMARY SHEET - PAGE 3
8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL WEIGHT (LB) FIXED ON-ORBIT	INITIAL SPR+EXP	RESUPPLY SPR+EXP	RETURN TO EARTH	TOTAL VOLUME (FT3) FIXED ON-ORBIT	INITIAL SPR+EXP	RESUPPLY SPR+EXP	RETURN TO EARTH
1	HX & FANS - AIR COOLING---------	1	57.0	0.0	0.5	0.5	1.9	0.0	0.0	0.0
70	HX & FANS - ODOR CONTROL--------	1	80.0	73.0	146.0	146.0	4.0	4.0	8.0	8.0
2	HX - EQUIPMENT COLDPLATES-------	22	261.8	0.0	0.0	0.0	0.1	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	207.6	0.0	0.1	0.1	75.7	0.0	0.0	0.0
4	CO2 REMOVAL - EDC---------------	1	310.8	31.1	9.3	9.3	14.7	1.5	0.4	0.4
11	CO2 REDUCTION - BOSCH-----------	1	522.6	360.7	372.5	961.5	53.5	55.5	59.8	59.8
13	TRACE CONTAMINANT CONTROL-------	1	176.3	88.8	88.8	88.8	138.0	4.8	4.8	4.8
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	77.0	7.7	2.3	2.3	3.5	0.3	0.1	0.1
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	271.7	166.1	166.1	166.1	6.0	2.6	2.6	2.6
22	O2 STORAGE - HI PRESS EMERG-----	1	1411.4	0.0	42.3	42.3	94.4	0.0	2.8	2.8
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	143.7	0.0	4.3	4.3	10.5	0.0	0.3	0.3
26	CABIN PRESSURE CONTROL----------	1	142.6	0.0	2.9	2.9	2.5	0.0	0.1	0.1
28	POT. H2O STORAGE - CLOSED LOOP--	1	663.7	66.4	19.9	19.9	24.6	2.5	0.7	0.7
29	POT. H2O STORAGE - EMERGENCY----	15	3187.5	0.0	0.0	0.0	101.3	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	260.2	2.6	2.6	2.6	6.2	23.4	25.1	25.1
35	PROCESSED H2O POST-TREATMENT POT	1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	211.0	16.7	91.5	101.0	25.5	1.0	15.0	13.5
71	WASH H2O STORAGE----------------	1	99.0	9.9	3.0	3.0	13.5	1.4	0.4	0.4
74	HYGIENE H2O STORAGE-------------	1	148.5	14.9	4.5	4.5	20.3	2.0	0.6	0.6
75	REVERSE OSMOSIS - HYGIENE H2O---	5	1644.6	16.2	16.2	16.2	89.7	720.9	778.9	778.9
68	H2O RECOVERY - INCINERATION ----	1	1032.9	153.3	81.0	249.4	122.0	12.5	3.9	6.0
76	PROCESSED H2O POST-TREATMENT HYG	1	1.5	0.3	0.3	0.0	0.0	0.0	0.0	0.0
36	H2O QUALITY MONITORING----------	1	60.0	22.5	1.4	1.4	4.0	1.5	0.1	0.1
37	HEALTH & HYGIENE - HAND WASH----	1	25.0	2.5	0.8	0.6	3.5	0.3	0.1	0.1
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	22.8	1.3	0.9	0.9	0.8	0.9	0.1	0.1
39	HEALTH & HYGIENE - COLD H2O SPLY	1	20.0	1.3	0.6	0.6	0.8	0.1	0.1	0.1
40	HEALTH & HYGIENE - BODY SHOWER--	1	105.0	10.5	3.2	3.2	47.3	4.7	1.4	1.4
41	HEALTH & HYGIENE - DISHWASHER---	1	78.0	7.8	2.3	2.3	8.4	0.8	0.3	0.3
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	78.0	7.8	2.3	2.3	8.4	0.8	0.3	0.3
44	HEALTH & HYGIENE - EMER WSTE COL	3	45.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN---------	1	40.0	4.0	1.2	1.2	2.5	0.3	0.1	0.1
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	141.9	14.2	4.3	4.3	24.3	2.4	0.7	0.7
48	HEALTH & HYGIENE - FOOD FREEZER-	1	385.3	38.5	11.6	11.6	84.1	5.4	2.5	2.5
	TOTALS -----		11912.6	1118.0	1082.6	1549.2	994.8	852.7	909.1	909.7

TABLE 5.2-2 INCINERATION/AUX. VPCAR ECLSS LOGISTICS SUMMARY

INCH SPACE STATION ECLSS CONFIGURATION NO. 1 SUMMARY SHEET - PAGE 1
6 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL ELECTRICAL POWER (WATTS) AC LS	AC DS	AC INT	DC LS	DC DS	DC INT
1	HX & FANS - AIR COOLING----------	1	821.2	821.2	0.0	0.0	0.0	0.0
70	HX & FANS - ODOR CONTROL---------	1	0.0	0.0	0.0	0.0	0.0	0.0
2	HX - EQUIPMENT COLDPLATES--------	22	0.0	0.0	0.0	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL-----	1	176.0	176.0	0.0	0.0	0.0	0.0
4	CO2 REMOVAL - EDC----------------	1	265.9	265.9	0.0	0.0	0.0	0.0
11	CO2 REDUCTION - BOSCH------------	1	196.1	196.1	0.0	130.8	130.8	1307.5
13	TRACE CONTAMINANT CONTROL--------	1	260.4	260.4	0.0	304.5	304.5	0.0
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.0	0.0	0.0	0.0	0.0	115.0
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	156.6	156.6	0.0	5326.6	5326.6	0.0
22	O2 STORAGE - HI PRESS EMERG------	1	0.0	0.0	0.0	0.0	0.0	15.0
24	N2 SUPPLY - N2H4 DECOMPOSITION---	1	0.0	0.0	0.2	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG------	1	0.0	0.0	0.0	0.0	0.0	15.0
26	CABIN PRESSURE CONTROL-----------	1	0.0	0.0	0.0	30.0	30.0	0.0
28	POT. H2O STORAGE - CLOSED LOOP---	1	0.0	0.0	0.0	0.0	0.0	0.0
29	POT. H2O STORAGE - EMERGENCY-----	15	0.0	0.0	100.0	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O----	1	36.4	36.4	0.0	0.0	0.0	0.0
35	PROCESSED H2O POST-TREATMENT POT	1	0.0	0.0	0.0	0.5	0.5	0.0
30	WASTE H2O STORAGE & PRE-TREAT----	1	0.0	0.0	30.0	0.0	0.0	0.0
71	WASH H2O STORAGE-----------------	1	0.0	0.0	20.0	0.0	0.0	356.7
74	HYGIENE H2O STORAGE--------------	1	0.0	0.0	30.0	0.0	0.0	393.3
75	REVERSE OSMOSIS - HYGIENE H2O----	5	230.1	230.1	0.0	0.0	0.0	0.0
68	H2O RECOVERY - INCINERATION -----	1	759.6	759.6	16465.6	0.0	0.0	0.0
76	PROCESSED H2O POST-TREATMENT HYG	1	0.0	0.0	0.0	3.1	3.1	0.0
36	H2O QUALITY MONITORING-----------	1	0.0	0.0	0.0	40.0	40.0	0.0
37	HEALTH & HYGIENE - HAND WASH-----	1	0.0	0.0	100.0	0.0	0.0	15.0
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	0.0	0.0	200.0	15.0	15.0	0.0
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.0	0.0	0.0	0.0	0.0	0.0
40	HEALTH & HYGIENE - BODY SHOWER---	1	0.0	0.0	250.0	0.0	0.0	15.0
41	HEALTH & HYGIENE - DISHWASHER----	1	0.0	0.0	240.0	0.0	0.0	15.0
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.0	0.0	340.0	0.0	0.0	15.0
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.0	0.0	0.0	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN----------	1	0.0	0.0	45.0	0.0	0.0	370.0
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.0	0.0	0.0	15.0	15.0	476.0
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.0	0.0	0.0	15.0	15.0	1350.0
	TOTALS -----		2902.3	2902.3	17820.8	5880.4	5880.4	4474.0

TABLE 5.2-3 INCINERATION/AUX. VPCAR ECLSS ELECTRICAL POWER SUMMARY

17-OCT-85 09:38 BOEING ENGINEERING TRADES STUDY - (BETS)

TECH SPACE STATION ECLSS CONFIGURATION NO. 1 SUMMARY SHEET - PAGE 2

8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL SENSIBLE HEAT LOAD (BTU/HR) AIR LS	AIR DS	AIR INT	LIQUID LS	LIQUID DS	LIQUID INT
1	HX & FANS - AIR COOLING---------	1	2802.9	2802.9	0.0	12742.9	12712.9	7909.0
70	HX & FANS - ODOR CONTROL--------	1	0.0	0.0	0.0	0.0	0.0	0.0
2	HX - EQUIPMENT COLDPLATES-------	22	0.0	0.0	0.0	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	-824.0	-824.0	0.0	8575.5	8575.5	0.0
4	CO2 REMOVAL - EDC---------------	1	509.9	509.5	0.0	1613.4	1613.4	0.0
11	CO2 REDUCTION - BOSCH-----------	1	1232.0	1232.0	4402.7	691.1	691.1	0.0
13	TRACE CONTAMINANT CONTROL-------	1	2201.1	2201.1	0.0	0.0	0.0	0.0
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.0	0.0	392.5	0.0	0.0	0.0
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	607.8	607.8	0.0	11548.1	11548.1	0.0
22	O2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	51.2	0.0	0.0	0.0
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.0	0.0	0.7	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	51.2	0.0	0.0	0.0
26	CABIN PRESSURE CONTROL----------	1	102.4	102.4	0.0	0.0	0.0	0.0
28	POT. H2O STORAGE - CLOSED LOOP--	1	0.0	0.0	0.0	0.0	0.0	0.0
29	POT. H2O STORAGE - EMERGENCY----	15	0.0	0.0	341.3	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	124.3	124.3	0.0	0.0	0.0	0.0
35	PROCESSED H2O POST-TREATMENT PCT	1	1.7	1.7	0.0	0.0	0.0	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.0	0.0	102.4	0.0	0.0	0.0
71	WASH H2O STORAGE----------------	1	0.0	0.0	1285.6	0.0	0.0	0.0
74	HYGIENE H2O STORAGE-------------	1	0.0	0.0	1463.5	0.0	0.0	0.0
75	REVERSE OSMOSIS - HYGIENE H2O---	5	785.3	785.3	0.0	0.0	0.0	0.0
68	H2O RECOVERY - INCINERATION ----	1	1623.2	1623.2	989.1	968.4	968.4	552[illegible].0
76	PROCESSED H2O POST-TREATMENT HYG	1	10.4	10.4	0.0	0.0	0.0	0.0
36	H2O QUALITY MONITORING----------	1	136.5	136.5	0.0	0.0	0.0	0.0
37	HEALTH & HYGIENE - HAND WASH----	1	0.0	0.0	392.5	0.0	0.0	0.0
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	51.2	51.2	687.6	0.0	0.0	0.0
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.0	0.0	0.0	0.0	0.0	600.0
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.0	0.0	904.5	0.0	0.0	0.0
41	HEALTH & HYGIENE - DISHWASHER---	1	0.0	0.0	2079.3	0.0	0.0	0.0
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.0	0.0	1211.6	0.0	0.0	0.0
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.0	0.0	0.0	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN---------	1	0.0	0.0	1416.4	0.0	0.0	0.0
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.0	0.0	0.0	51.2	51.2	1624.6
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.0	0.0	0.0	51.2	51.2	4641.7
	TOTALS -----		9364.6	9364.6	15918.0	36245.0	36245.0	69933.3

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TABLE 5.2-4 INCINERATION/AUX. VPCAR ECLSS HEAT REJECTION SUMMARY

17-OCT-85 09:39 BOEING ENGINEERING TRADES STUDY - (BETS)

INCN SPACE STATION ECLSS CONFIGURATION NO. 1 SUMMARY SHEET - PAGE 4
8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	MASS BALANCE FOR GASSES (LB/DY) OXYGEN	NITROGEN	CARBON DIOXIDE	HYDROGEN	MASS BALANCE FOR WATER (LB/DY) CONDENSATE	POTABLE	WASH	WASTE	HYGIENE
	BASIC CREW AND MODULE-----------		-14.833	-0.387	17.600	N/A	41.200	-54.080	323.440	38.160	-340.800
1	HX & FANS - AIR COOLING---------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70	HX & FANS - ODOR CONTROL--------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	HX - EQUIPMENT COLDPLATES-------	22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	HX & FANS - HUMIDITY CONTROL----	1	0.000	0.000	0.000	0.000	-51.400	0.000	0.000	0.000	0.000
4	CO2 REMOVAL - EDC---------------	1	-9.067	0.000	[illegible]	[illegible]	[illegible]	0.000	0.000	0.000	0.000
11	CO2 REDUCTION - BOSCH-----------	1	0.000	0.000	-22.809	-2.074	0.000	18.662	0.000	0.000	0.000
13	TRACE CONTAMINANT CONTROL-------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	29.115	0.000	0.000	3.639	0.000	-32.755	0.000	0.000	0.000
22	O2 STORAGE - HI PRESS EMERG-----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.000	0.006	0.000	0.001	0.000	0.000	0.000	0.000	0.000
25	N2 STORAGE - HI PRESS EMERG-----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	CABIN PRESSURE CONTROL----------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	PCT. H2O STORAGE - CLOSED LOOP--	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	PCT. H2O STORAGE - EMERGENCY----	15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63	REVERSE OSMOSIS - POTABLE H2O---	1	0.000	0.000	0.000	0.000	0.000	48.316	0.000	3.084	0.000
35	PROCESSED H2O POST-TREATMENT PCT	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
71	WASH H2O STORAGE----------------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
74	HYGIENE H2O STORAGE-------------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
75	REVERSE OSMOSIS - HYGIENE H2O---	5	0.000	0.000	0.000	0.000	0.000	0.000	-323.440	19.406	304.034
68	H2O RECOVERY - INCINERATION ----	1	-5.215	0.396	5.228	0.000	0.000	62.853	0.000	-60.657	0.000
76	PROCESSED H2O POST-TREATMENT HYG	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36	H2O QUALITY MONITORING----------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	HEALTH & HYGIENE - HAND WASH----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
41	HEALTH & HYGIENE - DISHWASHER---	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	HEALTH & HYGIENE - OVEN---------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	SUBSYSTEM ULLAGE (CUMULATIVE)---		0.000	-0.015	-0.019	-0.002	0.000	0.000	0.000	0.000	0.000
	TOTALS -----		0.000	0.000	0.000	0.205	0.000	42.997	0.000	0.000	-36.766

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TABLE 5.2-5 INCINERATION/AUX. VPCAR ECLSS MASS BALANCE SUMMARY

```
17-OCT-85   09:43                    BOEING ENGINEERING TRADES STUDY - (BETS)

SUBSYSTEM 65  H2O RECOVERY - WET OXIDATION----              ECLSS CONFIGURATION NO.  1                          JOB TO BETX

    MISSION DATA-----------------------------------------------------------------------------------------------------------

                              SPACE STATION                                     ECLSS CLOSED LOOP FUNCTIONS
          ------------------------------------------------------------------    ----- ------ ---- ---------
          MODULES                     1           RESUPPLY PERIOD  90.0 DAYS     CO2 REDUCTION H2O RECOVERY
          MODULE SIZE            4010.0 FT3       ORBIT                          O2 GENERATION    CONDENSATE
          CREWPERSONS                 8             LIGHTSIDE      56.0 MIN                       WASH WATER
          INITIAL SUPPLY PERIOD 90.0 DAYS           DARKSIDE       36.0 MIN                       URINE

    SUBSYSTEM DATA PER UNIT -  1 REQUIRED FOR STATION----------------------------------------------------------------------

          POWER (WATTS)                                     AC                             DC
                                                            --                             --
                                     LIGHTSIDE           1263.1                           0.0
                                     DARKSIDE            1263.1                           0.0
                                     INTERMITTENT           0.0                           0.0

          HEAT LOAD - SENSIBLE (BTU'S)                      AIR        AIR TEMP          LIQUID       LIQUID TEMP
                                                            ---        --- ----          ------       ------ ----
                                     LIGHTSIDE           1507.6        CABIN AIR         2804.5         40-45 F
                                     DARKSIDE            1507.6        CABIN AIR         2804.5         40-45 F
                                     INTERMITTENT           0.0                             0.0

          PAYLOAD                                      WEIGHT (LBS)                    VOLUME (FT3)
                                                       ------ -----                    ------ -----
                                     FIXED ON-ORBIT       1225.7                           95.3
                                     INITIAL SPARES & EXP  172.6                            9.8
                                                        ------                          -----
                                        SUBTOTAL          1398.3                          105.1

                                     RESUPPLY SPARES & EXP  96.8                            3.1
                                     RETURN TO EARTH       255.2                            5.2

    SUBSYSTEM DESIGN CRITERIA----------------------------------------------------------------------------------------------

    SUBSYSTEM MASS BALANCE DATA PER UNIT (LB/DAY)--------------------------------------------------------------------------

          MATERIALS REQUIRED                 MATERIALS PRODUCED                  MATERIALS LOST
          ------------------                 ------------------                  --------------
          WASTE WATER=     64.703            POTABLE WATER=       62.853
          OXYGEN=           5.215            CO2=                  5.278
                                             NITROGEN=             0.396
                                             SULFUR DIOXIDE=       0.178
                                             SOLIDS=               1.215
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TABLE 5.2-6 WET OXIDATION/AUX. VPCAR SUBSYSTEM SUMMARY

WETX SPACE STATION ECLSS CONFIGURATION NO. 1 SUMMARY SHEET - PAGE 3

8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL WEIGHT (LB) FIXED ON-ORBIT	INITIAL SPR+EXP	RESUPPLY SPR+EXP	RETURN TO EARTH	TOTAL VOLUME (FT3) FIXED ON-ORBIT	INITIAL SPR+EXP	RESUPPLY SPR+EXP	RETURN TO EARTH
1	HX & FANS - AIR COOLING----------	1	56.4	0.0	0.5	0.5	1.9	0.0	0.0	0.0
70	HX & FANS - ODOR CONTROL---------	1	80.0	73.0	146.0	146.0	4.0	4.0	8.0	8.0
2	HX - EQUIPMENT COLDPLATES--------	22	261.8	0.0	0.0	0.0	0.1	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL-----	1	207.6	0.0	0.1	0.1	75.7	0.0	0.0	0.0
4	CO2 REMOVAL - EDC----------------	1	310.8	31.1	9.3	9.3	14.7	1.5	0.4	0.4
11	CO2 REDUCTION - BOSCH------------	1	522.6	360.7	372.5	961.5	53.5	55.5	59.8	59.8
13	TRACE CONTAMINANT CONTROL--------	1	176.3	88.8	88.8	88.8	138.0	4.8	4.8	4.8
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	77.0	7.7	2.3	2.3	3.5	0.3	0.1	0.1
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	271.7	166.1	166.1	166.1	6.0	2.6	2.6	2.6
22	O2 STORAGE - HI PRESS EMERG-----	1	1411.4	0.0	42.3	42.3	94.4	0.0	2.8	2.8
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	143.7	0.0	4.3	4.3	10.5	0.0	0.3	0.3
26	CABIN PRESSURE CONTROL----------	1	142.6	0.0	2.9	2.9	2.5	0.0	0.1	0.1
28	PCT. H2O STORAGE - CLOSED LOOP--	1	663.7	66.4	19.9	19.9	24.6	2.5	0.7	0.7
29	PCT. H2O STORAGE - EMERGENCY----	15	3187.5	0.0	0.0	0.0	101.3	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	260.2	2.6	2.6	2.6	6.2	23.4	25.1	25.1
35	PROCESSED H2O POST-TREATMENT PCT	1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	211.0	16.7	91.5	101.0	25.5	1.0	15.0	13.5
71	WASH H2O STORAGE----------------	1	99.0	9.9	3.0	3.0	13.5	1.4	0.4	0.4
74	HYGIENE H2O STORAGE-------------	1	148.5	14.9	4.5	4.5	20.3	2.0	0.6	0.6
75	REVERSE OSMOSIS - HYGIENE H2O---	5	1644.6	16.2	16.2	16.2	89.7	720.9	778.9	778.8
65	H2O RECOVERY - WET OXIDATION----	1	1225.7	172.6	86.8	255.2	95.3	9.3	3.1	5.2
76	PROCESSED H2O POST-TREATMENT HYG	1	1.5	0.3	0.3	0.0	0.0	0.0	0.0	0.0
36	H2O QUALITY MONITORING----------	1	60.0	22.5	1.4	1.4	4.0	1.5	0.1	0.1
37	HEALTH & HYGIENE - HAND WASH----	1	25.0	2.5	0.8	0.8	3.5	0.3	0.1	0.1
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	22.8	1.3	0.9	0.9	0.8	0.9	0.1	0.1
39	HEALTH & HYGIENE - COLD H2O SPLY	1	20.0	1.3	0.6	0.6	0.8	0.1	0.1	0.1
40	HEALTH & HYGIENE - BODY SHOWER--	1	105.0	10.5	3.2	3.2	47.3	4.7	1.4	1.4
41	HEALTH & HYGIENE - DISHWASHER---	1	78.0	7.8	2.3	2.3	8.4	0.8	0.3	0.3
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	78.0	7.8	2.3	2.3	8.4	0.8	0.3	0.3
44	HEALTH & HYGIENE - EMER WSTE COL	3	45.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN---------	1	40.0	4.0	1.2	1.2	2.5	0.3	0.1	0.1
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	141.9	14.2	4.3	4.3	24.3	2.4	0.7	0.7
48	HEALTH & HYGIENE - FOOD FREEZER-	1	385.3	38.5	11.6	11.6	84.1	8.4	2.5	2.5
	TOTALS -----		12104.9	1137.3	1088.4	1855.0	968.1	650.0	908.3	906.9

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TABLE 5.2-7 WET OXIDATION/AUX. VPCAR ECLSS LOGISTICS SUMMARY

WETX SPACE STATION ECLSS CONFIGURATION NO. 1 SUMMARY SHEET - PAGE 1

6 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL ELECTRICAL POWER (WATTS) AC LS	AC DS	AC INT	DC LS	DC DS	DC INT
1	HX & FANS - AIR COOLING---------	1	811.7	811.7	0.0	0.0	0.0	0.0
70	HX & FANS - ODOR CONTROL--------	1	0.0	0.0	0.0	0.0	0.0	0.0
2	HX - EQUIPMENT COLDPLATES-------	22	0.0	0.0	0.0	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	176.0	176.0	0.0	0.0	0.0	0.0
4	CO2 REMOVAL - EDC---------------	1	265.9	265.9	0.0	0.0	0.0	0.0
11	CO2 REDUCTION - BOSCH-----------	1	196.1	196.1	0.0	130.8	130.8	1307.5
13	TRACE CONTAMINANT CONTROL-------	1	260.4	260.4	0.0	304.5	304.5	0.0
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.0	0.0	0.0	0.0	0.0	115.0
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	156.6	156.6	0.0	5326.6	5326.6	0.0
22	O2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	0.0	0.0	0.0	15.0
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.0	0.0	0.2	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	0.0	0.0	0.0	15.0
26	CABIN PRESSURE CONTROL----------	1	0.0	0.0	0.0	30.0	30.0	0.0
28	POT. H2O STORAGE - CLOSED LOOP--	1	0.0	0.0	0.0	0.0	0.0	0.0
29	POT. H2O STORAGE - EMERGENCY----	15	0.0	0.0	100.0	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	36.4	36.4	0.0	0.0	0.0	0.0
35	PROCESSED H2O POST-TREATMENT PCT	1	0.0	0.0	0.0	0.5	0.5	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.0	0.0	30.0	0.0	0.0	0.0
71	WASH H2O STORAGE----------------	1	0.0	0.0	20.0	0.0	0.0	356.7
74	HYGIENE H2O STORAGE-------------	1	0.0	0.0	30.0	0.0	0.0	398.8
75	REVERSE OSMOSIS - HYGIENE H2O---	5	230.1	230.1	0.0	0.0	0.0	0.0
65	H2O RECOVERY - WET OXIDATION----	1	1263.1	1263.1	0.0	0.0	0.0	0.0
76	PROCESSED H2O POST-TREATMENT HYG	1	0.0	0.0	0.0	3.1	3.1	0.0
36	H2O QUALITY MONITORING----------	1	0.0	0.0	0.0	40.0	40.0	0.0
37	HEALTH & HYGIENE - HAND WASH----	1	0.0	0.0	100.0	0.0	0.0	15.0
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	0.0	0.0	200.0	15.0	15.0	0.0
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.0	0.0	0.0	0.0	0.0	0.0
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.0	0.0	250.0	0.0	0.0	15.0
41	HEALTH & HYGIENE - DISHWASHER---	1	0.0	0.0	240.0	0.0	0.0	15.0
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.0	0.0	340.0	0.0	0.0	15.0
44	HEALTH & HYGIENE - EMER WSTE CCL	3	0.0	0.0	0.0	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN---------	1	0.0	0.0	45.0	0.0	0.0	370.0
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.0	0.0	0.0	15.0	15.0	476.0
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.0	0.0	0.0	15.0	15.0	1360.0
	TOTALS -----		3396.3	3396.3	1355.2	5880.4	5880.4	4474.0

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TABLE 5.2-8 WET OXIDATION/AUX. VPCAR ECLSS ELECTRICAL POWER SUMMARY

WETX SPACE STATION ECLSS CONFIGURATION NO. 1 SUMMARY SHEET - PAGE 2

8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL SENSIBLE HEAT LOAD (BTU/HR) AIR LS	AIR DS	AIR INT	LIQUID LS	LIQUID DS	LIQUID INT
1	HX & FANS - AIR COOLING---------	1	2770.3	2770.3	0.0	12594.7	12594.7	7414.5
70	HX & FANS - DOCK CONTROL--------	1	0.0	0.0	0.0	0.0	0.0	0.0
2	HX - EQUIPMENT COLDPLATES-------	22	0.0	0.0	0.0	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	-824.0	-824.0	0.0	8578.5	8578.5	0.0
4	CO2 REMOVAL - EDC---------------	1	509.9	509.9	0.0	1013.4	1013.4	0.0
11	CO2 REDUCTION - BOSCH-----------	1	1232.0	1232.0	4462.7	691.1	691.1	0.0
13	TRACE CONTAMINANT CONTROL-------	1	2201.1	2201.1	0.0	0.0	0.0	0.0
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.0	0.0	392.5	0.0	0.0	0.0
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	607.8	607.8	0.0	11548.1	11548.1	0.0
22	O2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	51.2	0.0	0.0	0.0
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.0	0.0	0.7	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	51.2	0.0	0.0	0.0
26	CABIN PRESSURE CONTROL----------	1	102.4	102.4	0.0	0.0	0.0	0.0
28	POT. H2O STORAGE - CLOSED LOOP--	1	0.0	0.0	0.0	0.0	0.0	0.0
29	POT. H2O STORAGE - EMERGENCY----	15	0.0	0.0	341.3	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	124.3	124.3	0.0	0.0	0.0	0.0
35	PROCESSED H2O POST-TREATMENT PCT	1	1.7	1.7	0.0	0.0	0.0	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.0	0.0	102.4	0.0	0.0	0.0
71	WASH H2O STORAGE----------------	1	0.0	0.0	1285.6	0.0	0.0	0.0
74	HYGIENE H2O STORAGE-------------	1	0.0	0.0	1463.5	0.0	0.0	0.0
75	REVERSE OSMOSIS - HYGIENE H2O---	5	785.3	785.3	0.0	0.0	0.0	0.0
65	H2O RECOVERY - WET OXIDATION----	1	1507.6	1507.6	0.0	2804.5	2804.5	0.0
76	PROCESSED H2O POST-TREATMENT HYG	1	10.4	10.4	0.0	0.0	0.0	0.0
36	H2O QUALITY MONITORING----------	1	136.5	136.5	0.0	0.0	0.0	0.0
37	HEALTH & HYGIENE - HAND WASH----	1	0.0	0.0	392.5	0.0	0.0	0.0
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	51.2	51.2	682.6	0.0	0.0	0.0
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.0	0.0	0.0	0.0	0.0	600.0
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.0	0.0	904.5	0.0	0.0	0.0
41	HEALTH & HYGIENE - DISHWASHER---	1	0.0	0.0	2070.3	0.0	0.0	0.0
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.0	0.0	1211.6	0.0	0.0	0.0
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.0	0.0	0.0	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN---------	1	0.0	0.0	1416.4	0.0	0.0	0.0
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.0	0.0	0.0	51.2	51.2	1624.5
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.0	0.0	0.0	51.2	51.2	4641.7
	TOTALS -----		9216.3	9216.3	14829.9	37932.8	37932.8	14280.7

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TABLE 5-2-9 WET OXIDATION/AUX. VPCAR ECLSS HEAT REJECTION SUMMARY

WETX SPACE STATION ECLSS CONFIGURATION NO. 1 SUMMARY SHEET - PAGE 4

8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	MASS BALANCE FOR GASSES (LB/DY)				MASS BALANCE FOR WATER (LB/DY)				
			OXYGEN	NITROGEN	CARBON DIOXIDE	HYDROGEN	CONDENSATE	POTABLE	WASH	WASTE	HYGIENE
	BASIC CREW AND MODULE-----------		-14.833	-0.387	17.600	N/A	41.200	-54.080	323.440	38.160	-340.800
1	HX & FANS - AIR COOLING---------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70	HX & FANS - ODOR CONTROL--------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	HX - EQUIPMENT COLDPLATES-------	22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	HX & FANS - HUMIDITY CONTROL----	1	0.000	0.000	0.000	0.000	-51.400	0.000	0.000	0.000	0.000
4	CO2 REMOVAL - EDC---------------	1	-9.067	0.000	0.000	-1.360	10.200	0.000	0.000	0.000	0.000
11	CO2 REDUCTION - BOSCH-----------	1	0.000	0.000	-22.809	-2.074	0.000	18.662	0.000	0.000	0.000
13	TRACE CONTAMINANT CONTROL-------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	29.115	0.000	0.000	3.639	0.000	-32.755	0.000	0.000	0.000
22	O2 STORAGE - HI PRESS EMERG-----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.000	0.006	0.000	0.001	0.000	0.000	0.000	0.000	0.000
25	N2 STORAGE - HI PRESS EMERG-----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	CABIN PRESSURE CONTROL----------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	PCT. H2O STORAGE - CLOSED LOOP--	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	PCT. H2O STORAGE - EMERGENCY----	15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63	REVERSE OSMOSIS - POTABLE H2O---	1	0.000	0.000	0.000	0.000	0.000	48.316	0.000	3.084	0.000
35	PROCESSED H2O POST-TREATMENT PCT	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
71	WASH H2O STORAGE----------------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
74	HYGIENE H2O STORAGE-------------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
75	REVERSE OSMOSIS - HYGIENE H2O---	5	0.000	0.000	0.000	0.000	0.000	0.000	-323.440	19.406	304.034
65	H2O RECOVERY - WET OXIDATION----	1	-5.215	0.396	5.228	0.000	0.000	62.853	0.000	-60.650	0.000
76	PROCESSED H2O POST-TREATMENT HYG	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36	H2O QUALITY MONITORING----------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	HEALTH & HYGIENE - HAND WASH----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
41	HEALTH & HYGIENE - DISHWASHER---	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	HEALTH & HYGIENE - OVEN---------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	SUBSYSTEM ULLAGE (CUMULATIVE)---		0.000	-0.015	-0.019	-0.002	0.000	0.000	0.000	0.000	0.000
	TOTALS -----		0.000	0.000	0.000	0.205	0.000	42.997	0.000	0.000	-36.756

TABLE 5.2-10 WET OXIDATION/AUX. VPCAR ECLSS MASS BALANCE SUMMARY

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17-OCT-85   09:45                    BOEING ENGINEERING TRADES STUDY - (BETS)

SUBSYSTEM 66  H2O RECOVERY - S.C.W.O. --------              ECLSS CONFIGURATION NO.  1                JOB ID SCWO

      MISSION DATA-------------------------------------------------------------------------------------------

                              SPACE STATION                                ECLSS CLOSED LOOP FUNCTIONS
              -------------------------------------------------------      ----- ------ ---- ---------
              MODULES                 1          RESUPPLY PERIOD  90.0 DAYS  CO2 REDUCTION H2O RECOVERY
              MODULE SIZE        4010.0 FT3      ORBIT                       O2 GENERATION  CONDENSATE
              CREWPERSONS             8            LIGHTSIDE      56.0 MIN                  WASH WATER
              INITIAL SUPPLY PERIOD 90.0 DAYS      DARKSIDE       36.0 MIN                  URINE

      SUBSYSTEM DATA PER UNIT -  1 REQUIRED FOR STATION------------------------------------------------------

              POWER (WATTS)                                AC                        DC
                                                           --                        --
                                    LIGHTSIDE            549.5                      0.0
                                    DARKSIDE             549.5                      0.0
                                    INTERMITTENT         830.2                      0.0

              HEAT LOAD - SENSIBLE (BTU'S)                 AIR      AIR TEMP        LIQUID     LIQUID TEMP
                                                           ---      --- ----        ------     ------ ----
                                    LIGHTSIDE           2370.1      CABIN AIR        539.5       40-45 F
                                    DARKSIDE            2370.1      CABIN AIR        539.5       40-45 F
                                    INTERMITTENT           0.0                         0.0

              PAYLOAD                               WEIGHT (LBS)                VOLUME (FT3)
                                                    ------ -----                ------ -----
                                    FIXED ON-ORBIT        396.2                      11.9
                                    INITIAL SPARES & EXP   99.6                       1.5
                                                         ------                     -----
                                       SUBTOTAL           495.9                      13.4

                                    RESUPPLY SPARES & EXP  61.9                       0.6
                                    RETURN TO EARTH       230.3                       2.7

      SUBSYSTEM DESIGN CRITERIA------------------------------------------------------------------------------

      SUBSYSTEM MASS BALANCE DATA PER UNIT (LB/DAY)----------------------------------------------------------

              MATERIALS REQUIRED             MATERIALS PRODUCED                 MATERIALS LOST
              ------------------             ------------------                 --------------
              WASTE WATER=   64.703          POTABLE WATER=     62.853
              OXYGEN=         5.215          CO2=                5.226
                                             NITROGEN=           0.396
                                             SULFUR DIOXIDE=     0.178
                                             SOLIDS=             1.215
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TABLE 5.2-11 SUPERCRITICAL WATER OXIDATION SUBSYSTEM SUMMARY

SCWO SPACE STATION ECLSS CONFIGURATION NO. 1 SUMMARY SHEET - PAGE 3
8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

			TOTAL WEIGHT (LB)				TOTAL VOLUME (FT3)			
ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	FIXED ON-ORBIT	INITIAL SPR+EXP	RESUPPLY SPR+EXP	RETURN TO EARTH	FIXED ON-ORBIT	INITIAL SPR+EXP	RESUPPLY SPR+EXP	RETURN TO EARTH
1	HX & FANS - AIR COOLING---------	1	60.9	0.0	0.6	0.6	2.0	0.0	0.0	0.0
70	HX & FANS - ODOR CONTROL--------	1	80.0	73.0	146.0	146.0	4.0	4.0	8.0	8.0
2	HX - EQUIPMENT COLDPLATES-------	22	261.8	0.0	0.0	0.0	0.1	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	207.6	0.0	0.1	0.1	75.7	0.0	0.0	0.0
4	CO2 REMOVAL - EDC---------------	1	310.8	31.1	9.3	9.3	14.7	1.5	0.4	0.4
11	CO2 REDUCTION - BOSCH-----------	1	522.6	360.7	372.5	961.5	53.5	55.5	59.8	59.8
13	TRACE CONTAMINANT CONTROL-------	1	176.3	88.8	88.8	88.8	138.0	4.8	4.8	4.8
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	77.0	7.7	2.3	2.3	3.5	0.3	0.1	0.1
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	271.7	166.1	166.1	166.1	6.0	2.6	2.6	2.6
22	O2 STORAGE - HI PRESS EMERG-----	1	1411.4	0.0	42.3	42.3	94.4	0.0	2.8	2.8
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	143.7	0.0	4.3	4.3	10.5	0.0	0.3	0.3
26	CABIN PRESSURE CONTROL----------	1	142.6	0.0	2.9	2.9	2.5	0.0	0.1	0.1
28	PCT. H2O STORAGE - CLOSED LOOP--	1	663.7	66.4	19.9	19.9	24.6	2.5	0.7	0.7
29	PCT. H2O STORAGE - EMERGENCY----	15	3187.5	0.0	0.0	0.0	101.3	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	260.2	2.6	2.6	2.6	6.2	23.4	25.1	25.1
35	PROCESSED H2O POST-TREATMENT PCT	1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	211.0	16.7	91.5	101.0	25.5	1.0	15.0	13.5
71	WASH H2O STORAGE----------------	1	99.0	9.9	3.0	3.0	13.5	1.4	0.4	0.4
74	HYGIENE H2O STORAGE-------------	1	148.5	14.9	4.5	4.5	20.3	2.0	0.6	0.6
75	REVERSE OSMOSIS - HYGIENE H2O---	5	1644.6	16.2	16.2	16.2	89.7	720.9	778.8	779.8
66	H2O RECOVERY - S.C.W.O. --------	1	396.2	89.6	61.9	230.3	11.9	1.5	0.6	2.7
76	PROCESSED H2O POST-TREATMENT HYG	1	1.5	0.3	0.3	0.0	0.0	0.0	0.0	0.0
36	H2O QUALITY MONITORING----------	1	60.0	22.5	1.4	1.4	4.0	1.5	0.1	0.1
37	HEALTH & HYGIENE - HAND WASH----	1	25.0	2.5	0.8	0.8	3.5	0.3	0.1	0.1
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	22.8	1.3	0.9	0.9	0.8	0.9	0.1	0.1
39	HEALTH & HYGIENE - COLD H2O SPLY	1	20.0	1.3	0.6	0.6	0.8	0.1	0.1	0.1
40	HEALTH & HYGIENE - BODY SHOWER--	1	105.0	10.5	3.2	3.2	47.3	4.7	1.4	1.4
41	HEALTH & HYGIENE - DISHWASHER---	1	78.0	7.8	2.3	2.3	8.4	0.8	0.3	0.3
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	78.0	7.8	2.3	2.3	8.4	0.8	0.3	0.3
44	HEALTH & HYGIENE - EMER WSTE COL	3	45.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN---------	1	40.0	4.0	1.2	1.2	2.5	0.3	0.1	0.1
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	141.9	14.2	4.3	4.3	24.3	2.4	0.7	0.7
48	HEALTH & HYGIENE - FOOD FREEZER-	1	385.3	38.5	11.6	11.6	84.1	8.4	2.5	2.5
	TOTALS -----		11279.9	1054.3	1063.5	1830.1	884.9	841.7	905.8	906.4

TABLE 5.2-12 SUPERCRITICAL WATER OXIDATION ECLSS LOGISTICS SUMMARY

SCVC SPACE STATION ECLSS CONFIGURATION NO. 1 SUMMARY SHEET - PAGE 1

8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL ELECTRICAL POWER (WATTS) AC LS	AC DS	AC INT	DC LS	DC DS	DC INT
1	HX & FANS - AIR COOLING---------	1	882.9	882.9	0.0	0.0	0.0	0.0
70	HX & FANS - ODOR CONTROL--------	1	0.0	0.0	0.0	0.0	0.0	0.0
2	HX - EQUIPMENT COLDPLATES-------	22	0.0	0.0	0.0	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	176.0	176.0	0.0	0.0	0.0	0.0
4	CO2 REMOVAL - EDC---------------	1	265.9	265.9	0.0	0.0	0.0	0.0
11	CO2 REDUCTION - BOSCH-----------	1	196.1	196.1	0.0	130.8	130.8	1307.5
13	TRACE CONTAMINANT CONTROL-------	1	260.4	260.4	0.0	304.5	304.5	0.0
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.0	0.0	0.0	0.0	0.0	115.0
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	156.6	156.6	0.0	5326.6	5326.6	0.0
22	O2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	0.0	0.0	0.0	15.0
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.0	0.0	0.2	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	0.0	0.0	0.0	15.0
26	CABIN PRESSURE CONTROL----------	1	0.0	0.0	0.0	30.0	30.0	0.0
28	POT. H2O STORAGE - CLOSED LOOP--	1	0.0	0.0	0.0	0.0	0.0	0.0
29	POT. H2O STORAGE - EMERGENCY----	15	0.0	0.0	100.0	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	36.4	36.4	0.0	0.0	0.0	0.0
35	PROCESSED H2O POST-TREATMENT POT	1	0.0	0.0	0.0	0.5	0.5	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.0	0.0	30.0	0.0	0.0	0.0
71	WASH H2O STORAGE----------------	1	0.0	0.0	20.0	0.0	0.0	356.7
74	HYGIENE H2O STORAGE-------------	1	0.0	0.0	30.0	0.0	0.0	398.8
75	REVERSE OSMOSIS - HYGIENE H2O---	5	230.1	230.1	0.0	0.0	0.0	0.0
66	H2O RECOVERY - S.C.W.O. --------	1	549.5	549.5	836.2	0.0	0.0	0.0
76	PROCESSED H2O POST-TREATMENT HYG	1	0.0	0.0	0.0	3.1	3.1	0.0
36	H2O QUALITY MONITORING----------	1	0.0	0.0	0.0	40.0	40.0	0.0
37	HEALTH & HYGIENE - HAND WASH----	1	0.0	0.0	100.0	0.0	0.0	15.0
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	0.0	0.0	200.0	15.0	15.0	0.0
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.0	0.0	0.0	0.0	0.0	0.0
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.0	0.0	250.0	0.0	0.0	15.0
41	HEALTH & HYGIENE - DISHWASHER---	1	0.0	0.0	240.0	0.0	0.0	15.0
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.0	0.0	340.0	0.0	0.0	15.0
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.0	0.0	0.0	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN---------	1	0.0	0.0	45.0	0.0	0.0	370.0
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.0	0.0	0.0	15.0	15.0	476.0
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.0	0.0	0.0	15.0	15.0	1360.0
	TOTALS -----		2753.9	2753.9	2191.4	5880.4	5880.4	4474.0

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TABLE 5.2-13 SUPERCRITICAL WATER OXIDATION ECLSS ELECTRICAL POWER SUMMARY

17-OCT-85 09:45 BOEING ENGINEERING TRADES STUDY - (BETS)

SCWO SPACE STATION ECLSS CONFIGURATION NO. 1 SUMMARY SHEET - PAGE 2
8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL SENSIBLE HEAT LOAD (BTU/HR) AIR LS	AIR DS	AIR INT	LIQUID LS	LIQUID DS	LIQUID INT
1	HX & FANS - AIR COOLING---------	1	3013.5	3013.5	0.0	13700.4	13700.4	7414.5
70	HX & FANS - ODOR CONTROL--------	1	0.0	0.0	0.0	0.0	0.0	0.0
2	HX - EQUIPMENT COLDPLATES-------	22	0.0	0.0	0.0	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	-824.0	-824.0	0.0	8578.5	8578.5	0.0
4	CO2 REMOVAL - EDC---------------	1	509.8	509.8	0.0	1613.4	1613.4	0.0
11	CO2 REDUCTION - BOSCH-----------	1	1232.0	1232.0	4462.7	691.1	691.1	0.0
13	TRACE CONTAMINANT CONTROL-------	1	2201.1	2201.1	0.0	0.0	0.0	0.0
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.0	0.0	392.5	0.0	0.0	0.0
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	607.8	607.8	0.0	11548.1	11548.1	0.0
22	O2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	51.2	0.0	0.0	0.0
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.0	0.0	0.7	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	51.2	0.0	0.0	0.0
26	CABIN PRESSURE CONTROL----------	1	102.4	102.4	0.0	0.0	0.0	0.0
28	POT. H2O STORAGE - CLOSED LOOP--	1	0.0	0.0	0.0	0.0	0.0	0.0
29	POT. H2O STORAGE - EMERGENCY----	15	0.0	0.0	341.3	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	124.3	124.3	0.0	0.0	0.0	0.0
35	PROCESSED H2O POST-TREATMENT POT	1	1.7	1.7	0.0	0.0	0.0	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.0	0.0	102.4	0.0	0.0	0.0
71	WASH H2O STORAGE----------------	1	0.0	0.0	1285.6	0.0	0.0	0.0
74	HYGIENE H2O STORAGE-------------	1	0.0	0.0	1463.5	0.0	0.0	0.0
75	REVERSE OSMOSIS - HYGIENE H2O---	5	785.3	785.3	0.0	0.0	0.0	0.0
66	H2O RECOVERY - S.C.W.O. --------	1	2370.1	2370.1	0.0	539.5	539.5	0.0
76	PROCESSED H2O POST-TREATMENT HYG	1	10.4	10.4	0.0	0.0	0.0	0.0
36	H2O QUALITY MONITORING----------	1	136.5	136.5	0.0	0.0	0.0	0.0
37	HEALTH & HYGIENE - HAND WASH----	1	0.0	0.0	392.5	0.0	0.0	0.0
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	51.2	51.2	682.6	0.0	0.0	0.0
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.0	0.0	0.0	0.0	0.0	600.0
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.0	0.0	904.5	0.0	0.0	0.0
41	HEALTH & HYGIENE - DISHWASHER---	1	0.0	0.0	2073.3	0.0	0.0	0.0
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.0	0.0	1211.6	0.0	0.0	0.0
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.0	0.0	0.0	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN---------	1	0.0	0.0	1416.4	0.0	0.0	0.0
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.0	0.0	0.0	51.2	51.2	1624.6
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.0	0.0	0.0	51.2	51.2	4341.7
	TOTALS -----		10322.1	10322.1	14828.9	36773.5	36773.5	14280.7

TABLE 5.2-14 SUPERCRITICAL WATER OXIDATION ECLSS HEAT REJECTION SUMMARY

SCWO SPACE STATION ECLSS CONFIGURATION NO. 1 SUMMARY SHEET - PAGE 4

8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	MASS BALANCE FOR GASSES (LB/DY)				MASS BALANCE FOR WATER (LB/DY)				
			OXYGEN	NITROGEN	CARBON DIOXIDE	HYDROGEN	CONDENSATE	POTABLE	WASH	WASTE	HYGIENE
	BASIC CREW AND MODULE-----------		-14.833	-0.387	17.600	N/A	41.200	-54.080	323.440	38.160	-340.800
1	HX & FANS - AIR COOLING---------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70	HX & FANS - ODOR CONTROL--------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	HX - EQUIPMENT COLDPLATES-------	22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	HX & FANS - HUMIDITY CONTROL----	1	0.000	0.000	0.000	0.000	-51.400	0.000	0.000	0.000	0.000
4	CO2 REMOVAL - EDC---------------	1	-9.067	0.000	0.000	-1.360	10.200	0.000	0.000	0.000	0.000
11	CO2 REDUCTION - BOSCH-----------	1	0.000	0.000	-22.809	-2.074	0.000	18.662	0.000	0.000	0.000
13	TRACE CONTAMINANT CONTROL-------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	29.115	0.000	0.000	3.639	0.000	-32.755	0.000	0.000	0.000
22	O2 STORAGE - HI PRESS EMERG-----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.000	0.006	0.000	0.001	0.000	0.000	0.000	0.000	0.000
25	N2 STORAGE - HI PRESS EMERG-----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	CABIN PRESSURE CONTROL----------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	POT. H2O STORAGE - CLOSED LOOP--	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	POT. H2O STORAGE - EMERGENCY----	15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63	REVERSE OSMOSIS - POTABLE H2O---	1	0.000	0.000	0.000	0.000	0.000	48.316	0.000	3.684	0.000
35	PROCESSED H2O POST-TREATMENT POT	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
71	WASH H2O STORAGE----------------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
74	HYGIENE H2O STORAGE-------------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
75	REVERSE OSMOSIS - HYGIENE H2O---	5	0.000	0.000	0.000	0.000	0.000	0.000	-323.440	19.406	304.034
66	H2O RECOVERY - S.C.W.O. --------	1	-5.215	0.396	5.228	0.000	0.000	62.953	0.000	-60.650	0.000
76	PROCESSED H2O POST-TREATMENT HYG	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36	H2O QUALITY MONITORING----------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	HEALTH & HYGIENE - HAND WASH----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
41	HEALTH & HYGIENE - DISHWASHER---	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	HEALTH & HYGIENE - OVEN---------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	SUBSYSTEM ULLAGE (CUMULATIVE)---		0.000	-0.015	-0.019	-0.002	0.000	0.000	0.000	0.000	0.000
	TOTALS -----		0.000	0.000	0.000	0.205	0.000	42.997	0.000	0.000	-36.766

TABLE 5.2-15 SUPERCRITICAL WATER OXIDATION ECLSS MASS BALANCE SUMMARY

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SUBSYSTEM 34  H2O RECOVERY - VCD--------------          ECLSS CONFIGURATION NO. 2                VCD TO VCD

MISSION DATA------------------------------------------------------------------------------------------------

                          SPACE STATION                                     ECLSS CLOSED LOOP FUNCTIONS
          ------------------------------------------------------------     ----- ------ ---- --------
          MODULES                      1           RESUPPLY PERIOD   90.0 DAYS    CO2 REDUCTION H2O RECOVERY
          MODULE SIZE            4010.0 FT3        ORBIT                          O2 GENERATION   CONDENSATE
          CREWPERSONS                  8             LIGHTSIDE        56.0 MIN                    WASH WATER
          INITIAL SUPPLY PERIOD 90.0 DAYS            DARKSIDE         36.0 MIN                    URINE

SUBSYSTEM DATA PER UNIT -  1 REQUIRED FOR STATION-----------------------------------------------------------

          POWER (WATTS)                                      AC                        DC
                                                             --                        --
                                   LIGHTSIDE                31.5                      81.9
                                   DARKSIDE                 31.5                      81.9
                                   INTERMITTENT              0.0                       0.0

          HEAT LOAD - SENSIBLE (BTU'S)                      AIR       AIR TEMP       LIQUID      LIQUID TEMP
                                                            ---       --- ----       ------      ------ ----
                                   LIGHTSIDE               386.8     CABIN AIR        0.0         40-45 F
                                   DARKSIDE                386.8     CABIN AIR        0.0         40-45 F
                                   INTERMITTENT              0.0                      0.0

          PAYLOAD                                     WEIGHT (LBS)                VOLUME (FT3)
                                                      ------ -----                ------ -----
                                   FIXED ON-ORBIT          110.5                       6.6
                                   INITIAL SPARES & EXP     12.3                       0.7
                                                          ------                     -----
                                        SUBTOTAL           122.8                       7.3

                                   RESUPPLY SPARES & EXP    22.5                       2.3
                                   RETURN TO EARTH         465.9                       9.4

SUBSYSTEM DESIGN CRITERIA-----------------------------------------------------------------------------------

SUBSYSTEM MASS BALANCE DATA PER UNIT (LB/DAY)---------------------------------------------------------------

          MATERIALS REQUIRED                MATERIALS PRODUCED                  MATERIALS LOST
          ------------------                ------------------                  --------------
          INPUT WATER  = 62.963             PROCESSED WATER = 58.037
                                            VCD BRINE =        4.926
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TABLE 5.2-16 VAPOR COMPRESSION DISTILLATION SUBSYSTEM SUMMARY

VCD SPACE STATION ECLSS CONFIGURATION NO. 2 SUMMARY SHEET - PAGE 3

8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL WEIGHT (LB) FIXED ON-ORBIT	INITIAL SPR+EXP	RESUPPLY SPR+EXP	RETURN TO EARTH	TOTAL VOLUME (FT3) FIXED ON-ORBIT	INITIAL SPR+EXP	RESUPPLY SPR+EXP	RETURN TO EARTH
1	HX & FANS - AIR COOLING----------	1	49.3	0.0	0.5	0.5	1.6	0.0	0.0	0.0
70	HX & FANS - ODOR CONTROL--------	1	80.0	73.0	146.0	146.0	4.0	4.0	8.0	8.0
2	HX - EQUIPMENT COLDPLATES-------	22	261.8	0.0	0.0	0.0	0.1	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	198.4	0.0	0.1	0.1	72.3	0.0	0.0	0.0
4	CO2 REMOVAL - EDC---------------	1	250.5	25.1	7.5	7.5	12.2	1.2	0.4	0.4
11	CO2 REDUCTION - BOSCH-----------	1	522.6	360.7	372.5	961.5	53.5	55.5	59.8	59.8
13	TRACE CONTAMINANT CONTROL-------	1	176.3	88.8	88.8	88.8	138.0	4.8	4.8	4.8
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	77.0	7.7	2.3	2.3	3.5	0.3	0.1	0.1
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	223.0	124.5	124.5	124.5	5.2	1.9	1.9	1.9
22	O2 STORAGE - HI PRESS EMERG-----	1	1068.4	0.0	32.1	32.1	71.3	0.0	2.1	2.1
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	161.9	0.0	4.9	4.9	11.9	0.0	0.4	0.4
26	CABIN PRESSURE CONTROL----------	1	142.6	0.0	2.9	2.9	2.5	0.0	0.1	0.1
28	POT. H2O STORAGE - CLOSED LOOP--	1	663.7	66.4	19.9	19.9	24.6	2.5	0.7	0.7
29	POT. H2O STORAGE - EMERGENCY----	14	2975.0	0.0	0.0	0.0	94.5	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	249.4	2.5	2.5	2.5	6.1	22.3	24.0	24.0
35	PROCESSED H2O POST-TREATMENT POT	1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	211.0	16.7	91.5	101.0	25.5	1.0	15.0	13.5
71	WASH H2O STORAGE----------------	1	99.0	9.9	3.0	3.0	13.5	1.4	0.4	0.4
74	HYGIENE H2O STORAGE-------------	1	148.5	14.9	4.5	4.5	20.3	2.0	0.6	0.6
75	REVERSE OSMOSIS - HYGIENE H2O---	5	1644.6	16.2	16.2	16.2	89.7	720.9	778.8	778.8
34	H2O RECOVERY - VCD--------------	1	110.5	12.3	22.5	465.8	6.6	0.7	2.3	9.4
76	PROCESSED H2O POST-TREATMENT HYG	1	1.5	0.3	0.3	0.0	0.0	0.0	0.0	0.0
36	H2O QUALITY MONITORING----------	1	60.0	22.5	1.4	1.4	4.0	1.5	0.1	0.1
37	HEALTH & HYGIENE - HAND WASH----	1	25.0	2.5	0.8	0.8	3.5	0.3	0.1	0.1
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	22.8	1.3	0.9	0.9	0.8	0.9	0.1	0.1
39	HEALTH & HYGIENE - COLD H2O SPLY	1	20.0	1.3	0.6	0.6	0.8	0.1	0.1	0.1
40	HEALTH & HYGIENE - BODY SHOWER--	1	105.0	10.5	3.2	3.2	47.3	4.7	1.4	1.4
41	HEALTH & HYGIENE - DISHWASHER---	1	78.0	7.8	2.3	2.3	8.4	0.8	0.3	0.3
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	78.0	7.8	2.3	2.3	8.4	0.8	0.3	0.3
43	HEALTH & HYGIENE - COMMODE/URINL	4	691.6	0.0	691.6	893.2	74.0	0.0	74.0	74.0
44	HEALTH & HYGIENE - EMER WSTE COL	3	45.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0
45	HEALTH & HYGIENE - TRASH COMPACT	1	40.0	4.0	1.2	750.0	7.0	0.4	0.3	93.9
46	HEALTH & HYGIENE - OVEN---------	1	40.0	4.0	1.2	1.2	2.5	0.3	0.1	0.1
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	141.9	14.2	4.3	4.3	24.3	2.4	0.7	0.7
48	HEALTH & HYGIENE - FOOD FREEZER-	1	385.3	38.5	11.6	11.6	84.1	8.4	2.5	2.5
	TOTALS -----		11047.0	933.3	1663.5	3655.5	925.0	839.4	979.3	1078.5

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TABLE 5.2-17 VAPOR COMPRESSION DISTILLATION ECLSS LOGISTICS SUMMARY

VCC SPACE STATION ECLSS CONFIGURATION NO. 2 SUMMARY SHEET - PAGE 1

8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

			TOTAL ELECTRICAL POWER (WATTS)					
			AC			DC		
ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	LS	DS	INT	LS	DS	INT
1	HX & FANS - AIR COOLING---------	1	700.6	700.6	0.0	0.0	0.0	0.0
70	HX & FANS - ODOR CONTROL--------	1	0.0	0.0	0.0	0.0	0.0	0.0
2	HX - EQUIPMENT COLDPLATES-------	22	0.0	0.0	0.0	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	164.7	164.7	0.0	0.0	0.0	0.0
4	CO2 REMOVAL - EDC---------------	1	205.0	205.0	0.0	0.0	0.0	0.0
11	CO2 REDUCTION - BOSCH-----------	1	196.1	196.1	0.0	130.8	130.8	1307.5
13	TRACE CONTAMINANT CONTROL-------	1	260.4	260.4	0.0	304.5	304.5	0.0
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.0	0.0	0.0	0.0	0.0	115.0
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	120.0	120.0	0.0	3953.5	3953.5	0.0
22	O2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	0.0	0.0	0.0	15.0
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.1	0.1	14.4	0.1	0.1	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	0.0	0.0	0.0	15.0
26	CABIN PRESSURE CONTROL----------	1	0.0	0.0	0.0	30.0	30.0	0.0
28	POT. H2O STORAGE - CLOSED LOOP--	1	0.0	0.0	0.0	0.0	0.0	0.0
29	POT. H2O STORAGE - EMERGENCY----	14	0.0	0.0	93.3	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	34.8	34.8	0.0	0.0	0.0	0.0
35	PROCESSED H2O POST-TREATMENT POT	1	0.0	0.0	0.0	0.5	0.5	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.0	0.0	30.0	0.0	0.0	0.0
71	WASH H2O STORAGE----------------	1	0.0	0.0	20.0	0.0	0.0	356.7
74	HYGIENE H2O STORAGE-------------	1	0.0	0.0	30.0	0.0	0.0	398.8
75	REVERSE OSMOSIS - HYGIENE H2O---	5	230.1	230.1	0.0	0.0	0.0	0.0
34	H2O RECOVERY - VCD--------------	1	31.5	31.5	0.0	81.9	81.9	0.0
76	PROCESSED H2O POST-TREATMENT HYG	1	0.0	0.0	0.0	3.1	3.1	0.0
36	H2O QUALITY MONITORING----------	1	0.0	0.0	0.0	40.0	40.0	0.0
37	HEALTH & HYGIENE - HAND WASH----	1	0.0	0.0	100.0	0.0	0.0	15.0
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	0.0	0.0	200.0	15.0	15.0	0.0
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.0	0.0	0.0	0.0	0.0	0.0
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.0	0.0	250.0	0.0	0.0	15.0
41	HEALTH & HYGIENE - DISHWASHER---	1	0.0	0.0	240.0	0.0	0.0	15.0
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.0	0.0	340.0	0.0	0.0	15.0
43	HEALTH & HYGIENE - COMMODE/URINL	4	0.0	0.0	480.0	0.0	0.0	60.0
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.0	0.0	0.0	0.0	0.0	0.0
45	HEALTH & HYGIENE - TRASH COMPACT	1	0.0	0.0	120.0	0.0	0.0	15.0
46	HEALTH & HYGIENE - OVEN---------	1	0.0	0.0	45.0	0.0	0.0	370.0
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.0	0.0	0.0	15.0	15.0	476.0
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.0	0.0	0.0	15.0	15.0	1360.0
	TOTALS -----		1943.2	1943.2	1962.7	4589.2	4589.2	4549.0

TABLE 5.2-18 VAPOR COMPRESSION DISTILLATION ECLSS ELECTRICAL POWER SUMMARY

17-OCT-85 09:49

BOEING ENGINEERING TRADES STUDY - (BETS)

VCD SPACE STATION ECLSS CONFIGURATION NO. 2 SUMMARY SHEET - PAGE 2

8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL SENSIBLE HEAT LOAD (BTU/HR) AIR LS	AIR DS	AIR INT	LIQUID LS	LIQUID DS	LIQUID INT
1	HX & FANS - AIR COOLING---------	1	2391.1	2391.1	0.0	10870.9	10870.9	8579.3
70	HX & FANS - ODOR CONTROL--------	1	0.0	0.0	0.0	0.0	0.0	0.0
2	HX - EQUIPMENT COLDPLATES-------	22	0.0	0.0	0.0	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	-798.1	-798.1	0.0	8188.9	8189.9	0.0
4	CO2 REMOVAL - EDC---------------	1	424.3	424.3	0.0	1275.4	1275.4	0.0
11	CO2 REDUCTION - BOSCH-----------	1	1232.0	1232.0	4462.7	691.1	691.1	0.0
13	TRACE CONTAMINANT CONTROL-------	1	2201.1	2201.1	0.0	0.0	0.0	0.0
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.0	0.0	392.5	0.0	0.0	0.0
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	447.9	447.9	0.0	8510.7	8510.7	0.0
22	O2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	51.2	0.0	0.0	0.0
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	1.3	1.3	49.2	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	51.2	0.0	0.0	0.0
26	CABIN PRESSURE CONTROL----------	1	102.4	102.4	0.0	0.0	0.0	0.0
28	POT. H2O STORAGE - CLOSED LOOP--	1	0.0	0.0	0.0	0.0	0.0	0.0
29	POT. H2O STORAGE - EMERGENCY----	14	0.0	0.0	318.5	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	118.6	118.6	0.0	0.0	0.0	0.0
35	PROCESSED H2O POST-TREATMENT PCT	1	1.6	1.6	0.0	0.0	0.0	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.0	0.0	102.4	0.0	0.0	0.0
71	WASH H2O STORAGE----------------	1	0.0	0.0	1285.6	0.0	0.0	0.0
74	HYGIENE H2O STORAGE-------------	1	0.0	0.0	1463.5	0.0	0.0	0.0
75	REVERSE OSMOSIS - HYGIENE H2O---	5	785.3	785.3	0.0	0.0	0.0	0.0
34	H2O RECOVERY - VCD--------------	1	386.8	386.8	0.0	0.0	0.0	0.0
76	PROCESSED H2O POST-TREATMENT HYG	1	10.4	10.4	0.0	0.0	0.0	0.0
36	H2O QUALITY MONITORING----------	1	136.5	136.5	0.0	0.0	0.0	0.0
37	HEALTH & HYGIENE - HAND WASH----	1	0.0	0.0	392.5	0.0	0.0	0.0
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	51.2	51.2	687.6	0.0	0.0	0.0
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.0	0.0	0.0	0.0	0.0	600.0
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.0	0.0	904.5	0.0	0.0	0.0
41	HEALTH & HYGIENE - DISHWASHER---	1	0.0	0.0	2070.3	0.0	0.0	0.0
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.0	0.0	1211.6	0.0	0.0	0.0
43	HEALTH & HYGIENE - COMMODE/URINL	4	0.0	0.0	1943.2	0.0	0.0	0.0
44	HEALTH & HYGIENE - EMER WSTE CCL	3	0.0	0.0	0.0	0.0	0.0	0.0
45	HEALTH & HYGIENE - TRASH COMPACT	1	0.0	0.0	460.8	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN---------	1	0.0	0.0	1416.4	0.0	0.0	0.0
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.0	0.0	0.0	51.2	51.2	1024.5
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.0	0.0	0.0	51.2	51.2	4641.7
	TOTALS -----		7492.6	7492.6	17158.6	29639.4	29639.4	15445.6

TABLE 5.2-19 VAPOR COMPRESSION DISTILLATION ECLSS HEAT REJECTION SUMMARY

ORIGINAL PAGE IS OF POOR QUALITY

VCD SPACE STATION ECLSS CONFIGURATION NO. 2 SUMMARY SHEET - PAGE 4
8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	MASS BALANCE FOR GASSES (LB/DY) OXYGEN	NITROGEN	CARBON DIOXIDE	HYDROGEN	MASS BALANCE FOR WATER (LB/DY) CONDENSATE	POTABLE	WASH	WASTE	HYGIENE
	BASIC CREW AND MODULE-----------		-14.833	-0.387	17.600	N/A	41.200	-54.080	323.440	39.160	-340.800
1	HX & FANS - AIR COOLING---------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70	HX & FANS - ODOR CONTROL--------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	HX - EQUIPMENT COLDPLATES-------	22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	HX & FANS - HUMIDITY CONTROL----	1	0.000	0.000	0.000	0.000	-49.065	0.000	0.000	0.000	0.000
4	CO2 REMOVAL - EDC---------------	1	-6.991	0.000	0.000	-1.049	7.865	0.000	0.000	0.000	0.000
11	CO2 REDUCTION - BOSCH-----------	1	0.000	0.000	-17.582	-1.598	0.000	13.385	0.000	0.000	0.000
13	TRACE CONTAMINANT CONTROL-------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	21.825	0.000	0.000	2.728	0.000	-24.553	0.000	0.000	0.000
22	O2 STORAGE - HI PRESS EMERG-----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.000	0.400	0.000	0.052	0.000	0.000	0.000	0.000	0.000
25	N2 STORAGE - HI PRESS EMERG-----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	CABIN PRESSURE CONTROL----------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	PCT. H2O STORAGE - CLOSED LOOP--	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	PCT. H2O STORAGE - EMERGENCY----	14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63	REVERSE OSMOSIS - POTABLE H2O---	1	0.000	0.000	0.000	0.000	0.000	46.121	0.000	2.944	0.000
35	PROCESSED H2O POST-TREATMENT POT	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
71	WASH H2O STORAGE----------------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
74	HYGIENE H2O STORAGE-------------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
75	REVERSE OSMOSIS - HYGIENE H2O---	5	0.000	0.000	0.000	0.000	0.000	0.000	-323.440	19.406	304.034
34	H2O RECOVERY - VCD--------------	1	0.000	0.000	0.000	0.000	0.000	59.037	0.000	-60.519	0.000
76	PROCESSED H2O POST-TREATMENT HYG	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36	H2O QUALITY MONITORING----------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	HEALTH & HYGIENE - HAND WASH----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
41	HEALTH & HYGIENE - DISHWASHER---	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
43	HEALTH & HYGIENE - COMMODE/URINL	4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45	HEALTH & HYGIENE - TRASH COMPACT	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	HEALTH & HYGIENE - OVEN---------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	SUBSYSTEM ULLAGE (CUMULATIVE)---		0.000	-0.014	-0.013	-0.008	0.000	0.000	0.000	0.000	0.000
	TOTALS -----		0.000	0.000	0.000	0.125	0.000	39.911	0.000	0.000	-36.766

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TABLE 5.2-20 VAPOR COMPRESSION DISTILLATION ECLSS MASS BALANCE SUMMARY

SUBSYSTEM 33 H2O RECOVERY - TIMES — ECLSS CONFIGURATION NO. 2 — [illegible]

MISSION DATA

SPACE STATION				ECLSS CLOSED LOOP FUNCTIONS	
MODULES	1	RESUPPLY PERIOD	90.0 DAYS	CO2 REDUCTION	H2O RECOVERY
MODULE SIZE	4010.0 FT3	ORBIT		O2 GENERATION	CONDENSATE
CREWPERSONS	8	LIGHTSIDE	56.0 MIN		WASH WATER
INITIAL SUPPLY PERIOD	90.0 DAYS	DARKSIDE	36.0 MIN		URINE

SUBSYSTEM DATA PER UNIT - 1 REQUIRED FOR STATION

POWER (WATTS)

	AC	DC
LIGHTSIDE	12.5	144.0
DARKSIDE	12.5	144.0
INTERMITTENT	0.0	1.0

HEAT LOAD - SENSIBLE (BTU'S)

	AIR	AIR TEMP.	LIQUID	LIQUID TEMP
LIGHTSIDE	534.0	CABIN AIR	0.0	40-45 F
DARKSIDE	534.0	CABIN AIR	0.0	40-45 F
INTERMITTENT	3.6		0.0	

PAYLOAD

	WEIGHT (LBS)	VOLUME (FT3)
FIXED ON-ORBIT	92.1	4.8
INITIAL SPARES & EXP	0.0	0.0
SUBTOTAL	92.1	4.8
RESUPPLY SPARES & EXP	33.3	1.5
RETURN TO EARTH	595.2	10.4

SUBSYSTEM DESIGN CRITERIA

CONTINUOUS OPERATION ONLY.

SUBSYSTEM MASS BALANCE DATA PER UNIT (LB/DAY)

MATERIALS REQUIRED	MATERIALS PRODUCED	MATERIALS LOST
INPUT WATER = 62.963	PROCESSED WATER = 54.538	VENTED WATER = 2.293
	BRINE = 6.132	

TABLE 5.2-21 THERMOELECTRIC INTEGRATED MEMBRANE EVAP. SUBSYSTEM SUMMARY

TIME SPACE STATION ECLSS CONFIGURATION NO. 2 SUMMARY SHEET - PAGE 3
8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

			TOTAL WEIGHT (LB)				TOTAL VOLUME (FT3)			
ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	FIXED ON-ORBIT	INITIAL SPR+EXP	RESUPPLY SPR+EXP	RETURN TO EARTH	FIXED ON-ORBIT	INITIAL SPR+EXP	RESUPPLY SPR+EXP	RETURN TO EARTH
1	HX & FANS - AIR COOLING---------	1	50.0	0.0	0.5	0.5	1.7	0.0	0.0	0.0
70	HX & FANS - ODOR CONTROL--------	1	80.0	73.0	146.0	146.0	4.0	4.0	8.0	8.0
2	HX - EQUIPMENT COLDPLATES-------	22	261.8	0.0	0.0	0.0	0.1	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	198.4	0.0	0.1	0.1	72.3	0.0	0.0	0.0
4	CO2 REMOVAL - EDC---------------	1	250.6	25.1	7.5	7.5	12.2	1.2	0.4	0.4
11	CO2 REDUCTION - BOSCH-----------	1	522.6	360.7	372.5	961.5	53.5	55.5	59.8	59.8
13	TRACE CONTAMINANT CONTROL-------	1	176.3	88.8	88.8	86.8	138.0	4.8	4.8	4.8
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	77.0	7.7	2.3	2.3	3.5	0.3	0.1	0.1
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	223.0	124.5	124.5	124.5	5.2	1.9	1.9	1.9
22	O2 STORAGE - HI PRESS EMERG-----	1	1068.4	0.0	32.1	32.1	71.3	0.0	2.1	2.1
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	161.9	0.0	4.9	4.9	11.9	0.0	0.4	0.4
26	CABIN PRESSURE CONTROL----------	1	142.6	0.0	2.9	2.9	2.5	0.0	0.1	0.1
28	PCT. H2O STORAGE - CLOSED LOOP--	1	663.7	66.4	19.9	19.9	24.6	2.5	0.7	0.7
29	PCT. H2O STORAGE - EMERGENCY----	14	2975.0	0.0	0.0	0.0	94.5	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	248.4	2.5	2.5	2.5	6.1	22.3	24.0	24.0
35	PROCESSED H2O POST-TREATMENT POT	1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	211.0	16.7	91.5	101.0	25.5	1.0	15.0	13.5
71	WASH H2O STORAGE----------------	1	99.0	9.9	3.0	3.0	13.5	1.4	0.4	0.4
74	HYGIENE H2O STORAGE-------------	1	148.5	14.9	4.5	4.5	20.3	2.0	0.6	0.6
75	REVERSE OSMOSIS - HYGIENE H2O---	5	1644.6	16.2	16.2	16.2	69.7	720.9	778.9	778.8
33	H2O RECOVERY - TIMES------------	1	97.1	0.0	33.3	585.2	4.8	0.0	1.6	10.4
76	PROCESSED H2O POST-TREATMENT HYG	1	1.5	0.3	0.3	0.0	0.0	0.0	0.0	0.0
36	H2O QUALITY MONITORING----------	1	60.0	22.5	1.4	1.4	4.0	1.5	0.1	0.1
37	HEALTH & HYGIENE - HAND WASH----	1	25.0	2.5	0.8	0.8	3.5	0.3	0.1	0.1
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	22.8	1.3	0.9	0.9	0.8	0.9	0.1	0.1
39	HEALTH & HYGIENE - COLD H2O SPLY	1	20.0	1.3	0.6	0.6	0.8	0.1	0.1	0.1
40	HEALTH & HYGIENE - BODY SHOWER--	1	105.0	10.5	3.2	3.2	47.3	4.7	1.4	1.4
41	HEALTH & HYGIENE - DISHWASHER---	1	78.0	7.8	2.3	2.3	8.4	0.8	0.3	0.3
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	78.0	7.8	2.3	2.3	8.4	0.6	0.3	0.3
43	HEALTH & HYGIENE - COMMODE/URINL	4	691.6	0.0	691.6	693.2	74.0	0.0	74.0	74.0
44	HEALTH & HYGIENE - EMER WSTE COL	3	45.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0
45	HEALTH & HYGIENE - TRASH COMPACT	1	40.0	4.0	1.2	750.0	7.0	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN---------	1	40.0	4.0	1.2	1.2	2.5	0.4	0.3	93.9
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	141.9	14.2	4.3	4.3	24.3	0.3	0.1	0.1
48	HEALTH & HYGIENE - FOOD FREEZER-	1	385.3	38.5	11.6	11.6	84.1	2.4	0.7	0.7
	TOTALS -----		11029.4	921.0	1674.8	3774.9	923.2	838.7	978.5	1079.5

TABLE 5.2-22 THERMOELECTRIC INTEGRATED MEMBRANE EVAP. ECLSS LOGISTICS SUMMARY

24-OCT-85 07:30 BOEING ENGINEERING POWER STUDY - (ETIS)

TIME SPACE STATION ECLSS CONFIGURATION NO. 2 SUMMARY SHEET - PAGE 1
8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL ELECTRICAL POWER (WATTS) AC LS	AC DS	AC INT	DC LS	DC DS	DC INT
1	HX & FANS - AIR COOLING----------	1	712.8	712.8	0.0	0.0	0.0	0.0
70	HX & FANS - ODOR CONTROL---------	1	0.0	0.0	0.0	0.0	0.0	0.0
2	HX - EQUIPMENT COLDPLATES--------	22	0.0	0.0	0.0	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	164.7	164.7	0.0	0.0	0.0	0.0
4	CO2 REMOVAL - EDC---------------	1	205.0	205.0	0.0	0.0	0.0	0.0
11	CO2 REDUCTION - BOSCH-----------	1	196.1	196.1	0.0	130.8	130.8	1307.5
13	TRACE CONTAMINANT CONTROL-------	1	260.4	260.4	0.0	304.5	304.5	0.0
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.0	0.0	0.0	0.0	0.0	115.0
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	120.0	120.0	0.0	3953.5	3953.5	0.0
22	O2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	0.0	0.0	0.0	15.0
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.1	0.1	14.3	0.1	0.1	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	0.0	0.0	0.0	15.0
26	CABIN PRESSURE CONTROL----------	1	0.0	0.0	0.0	30.0	30.0	0.0
28	POT. H2O STORAGE - CLOSED LOOP--	1	0.0	0.0	0.0	0.0	0.0	0.0
29	POT. H2O STORAGE - EMERGENCY----	14	0.0	0.0	93.3	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	34.8	34.8	0.0	0.0	0.0	0.0
35	PROCESSED H2O POST-TREATMENT POT	1	0.0	0.0	0.0	0.5	0.5	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.0	0.0	30.0	0.0	0.0	0.0
71	WASH H2O STORAGE----------------	1	0.0	0.0	20.0	0.0	0.0	356.7
74	HYGIENE H2O STORAGE-------------	1	0.0	0.0	30.0	0.0	0.0	398.8
75	REVERSE OSMOSIS - HYGIENE H2O---	5	230.1	230.1	0.0	0.0	0.0	0.0
33	H2O RECOVERY - TIMES------------	1	12.5	12.5	0.0	144.0	144.0	1.0
76	PROCESSED H2O POST-TREATMENT HYG	1	0.0	0.0	0.0	3.1	3.1	0.0
36	H2O QUALITY MONITORING----------	1	0.0	0.0	0.0	40.0	40.0	0.0
37	HEALTH & HYGIENE - HAND WASH----	1	0.0	0.0	100.0	0.0	0.0	15.0
38	HEALTH & HYGIENE - HOT H2O SPLY-	2	0.0	0.0	200.0	15.0	15.0	0.0
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.0	0.0	0.0	0.0	0.0	0.0
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.0	0.0	250.0	0.0	0.0	15.0
41	HEALTH & HYGIENE - DISHWASHER---	1	0.0	0.0	240.0	0.0	0.0	15.0
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.0	0.0	340.0	0.0	0.0	15.0
43	HEALTH & HYGIENE - COMMODE/URINL	4	0.0	0.0	480.0	0.0	0.0	60.0
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.0	0.0	0.0	0.0	0.0	0.0
45	HEALTH & HYGIENE - TRASH COMPACT	1	0.0	0.0	120.0	0.0	0.0	15.0
46	HEALTH & HYGIENE - OVEN---------	1	0.0	0.0	45.0	0.0	0.0	370.0
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.0	0.0	0.0	15.0	15.0	476.0
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.0	0.0	0.0	15.0	15.0	1360.0
	TOTALS -----		1936.4	1936.4	1967.7	4651.3	4651.3	4550.1

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TABLE 5.2-23 THERMOELECTRIC INTEGRATED MEMBRANE EVAP. ECLSS ELECTRICAL POWER SUMMARY

TIME SPACE STATION ECLSS CONFIGURATION NO. 2 SUMMARY SHEET - PAGE 2
8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

TOTAL SENSIBLE HEAT LOAD (BTU/HR)

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	AIR LS	AIR DS	AIR INT	LIQUID LS	LIQUID DS	LIQUID INT
1	HX & FANS - AIR COOLING---------	1	2432.6	2432.6	0.0	11059.6	11059.6	8591.1
70	HX & FANS - ODOR CONTROL--------	1	0.0	0.0	0.0	0.0	0.0	0.0
2	HX - EQUIPMENT COLDPLATES-------	22	0.0	0.0	0.0	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	-798.1	-798.1	0.0	8188.9	8188.9	0.0
4	CO2 REMOVAL - EDC---------------	1	424.3	424.3	0.0	1275.4	1275.4	0.0
11	CO2 REDUCTION - BOSCH-----------	1	1232.0	1232.0	4462.7	591.1	591.1	0.0
13	TRACE CONTAMINANT CONTROL-------	1	2201.1	2201.1	0.0	0.0	0.0	0.0
14	ATMOSE MONITOR - MASS SPECTROMTR-	1	0.0	0.0	392.5	0.0	0.0	0.0
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	447.9	447.9	0.0	8510.7	8510.7	0.0
22	O2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	51.2	0.0	0.0	0.0
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	1.3	1.3	49.2	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	51.2	0.0	0.0	0.0
26	CABIN PRESSURE CONTROL----------	1	102.4	102.4	0.0	0.0	0.0	0.0
28	POT. H2O STORAGE - CLOSED LOOP--	1	0.0	0.0	0.0	0.0	0.0	0.0
29	POT. H2O STORAGE - EMERGENCY----	14	0.0	0.0	318.5	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	118.6	118.6	0.0	0.0	0.0	0.0
35	PROCESSED H2O POST-TREATMENT POT	1	1.6	1.6	0.0	0.0	0.0	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.0	0.0	102.4	0.0	0.0	0.0
71	WASH H2O STORAGE----------------	1	0.0	0.0	1285.6	0.0	0.0	0.0
74	HYGIENE H2O STORAGE-------------	1	0.0	0.0	1463.5	0.0	0.0	0.0
75	REVERSE OSMOSIS - HYGIENE H2O---	5	785.3	785.3	0.0	0.0	0.0	0.0
33	H2O RECOVERY - TIMES------------	1	534.0	534.0	3.6	0.0	0.0	0.0
76	PROCESSED H2O POST-TREATMENT HYG	1	10.4	10.4	0.0	0.0	0.0	0.0
36	H2O QUALITY MONITORING----------	1	136.5	136.5	0.0	0.0	0.0	0.0
37	HEALTH & HYGIENE - HAND WASH----	1	0.0	0.0	392.5	0.0	0.0	0.0
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	51.2	51.2	632.5	0.0	0.0	0.0
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.0	0.0	0.0	0.0	0.0	600.0
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.0	0.0	904.5	0.0	0.0	0.0
41	HEALTH & HYGIENE - DISHWASHER---	1	0.0	0.0	2070.3	0.0	0.0	0.0
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.0	0.0	1211.6	0.0	0.0	0.0
43	HEALTH & HYGIENE - COMMODE/URINL	4	0.0	0.0	1843.2	0.0	0.0	0.0
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.0	0.0	0.0	0.0	0.0	0.0
45	HEALTH & HYGIENE - TRASH COMPACT	1	0.0	0.0	460.8	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN---------	1	0.0	0.0	1416.4	0.0	0.0	0.0
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.0	0.0	0.0	51.2	51.2	1624.6
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.0	0.0	0.0	51.2	51.2	4641.7
	TOTALS -----		7681.3	7681.3	17162.7	29828.1	29828.1	15447.4

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TABLE 5.2-24 THERMOELECTRIC INTEGRATED MEMBRANE EVAP. ECLSS HEAT REJECTION SUMMARY

TIME SPACE STATION ECLSS CONFIGURATION NO. 2 SUMMARY SHEET - PAGE 4

8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	MASS BALANCE FOR GASSES (LB/DY) OXYGEN	NITROGEN	CARBON DIOXIDE	HYDROGEN	MASS BALANCE FOR WATER (LB/DY) CONDENSATE	POTABLE	WASH	WASTE	HYGIENE
	BASIC CREW AND MODULE-----------		-14.833	-0.387	17.600	N/A	41.200	-54.080	323.440	38.160	-340.800
1	HX & FANS - AIR COOLING---------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70	HX & FANS - ODOR CONTROL--------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	HX - EQUIPMENT COLDPLATES--------	22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	HX & FANS - HUMIDITY CONTROL----	1	0.000	0.000	0.000	0.000	-49.065	0.000	0.000	0.000	0.000
4	CO2 REMOVAL - EDC---------------	1	-6.991	0.000	0.000	-1.049	7.865	0.000	0.000	0.000	0.000
11	CO2 REDUCTION - BOSCH-----------	1	0.000	0.000	-17.582	-1.590	0.000	14.365	0.000	0.000	0.000
13	TRACE CONTAMINANT CONTROL-------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	21.825	0.000	0.000	2.728	0.000	-24.553	0.000	0.000	0.000
22	O2 STORAGE - HI PRESS EMERG-----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.000	0.400	0.000	0.052	0.000	0.000	0.000	0.000	0.000
25	N2 STORAGE - HI PRESS EMERG-----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	CABIN PRESSURE CONTROL----------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	POT. H2O STORAGE - CLOSED LOOP--	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	POT. H2O STORAGE - EMERGENCY----	14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63	REVERSE OSMOSIS - POTABLE H2O---	1	0.000	0.000	0.000	0.000	0.000	46.121	0.000	2.944	0.000
35	PROCESSED H2O POST-TREATMENT PCT	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
71	WASH H2O STORAGE----------------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
74	HYGIENE H2O STORAGE-------------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
75	REVERSE OSMOSIS - HYGIENE H2O---	5	0.000	0.000	0.000	0.000	0.000	0.000	-323.440	19.406	304.034
33	H2O RECOVERY - TIMES------------	1	0.000	0.000	0.000	0.000	0.000	54.539	0.000	-60.510	0.000
76	PROCESSED H2O POST-TREATMENT HYG	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36	H2O QUALITY MONITORING----------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	HEALTH & HYGIENE - HAND WASH----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
41	HEALTH & HYGIENE - DISHWASHER---	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
43	HEALTH & HYGIENE - COMMODE/URINL	4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45	HEALTH & HYGIENE - TRASH COMPACT	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	HEALTH & HYGIENE - OVEN---------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	SUBSYSTEM ULLAGE (CUMULATIVE)---		0.000	-0.014	-0.016	-0.008	0.000	0.000	0.000	0.000	0.000
	TOTALS -----		0.000	0.000	0.000	0.125	0.000	36.417	0.000	0.000	-36.766

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TABLE 5.2-25 THERMOELECTRIC INTEGRATED MEMBRANE EVAP. ECLSS MASS BALANCE SUMMARY

SUBSYSTEM 67 H2O RECOVERY - V.P.C.A.R. ------ ECLSS CONFIGURATION NO. 2 JOB ID VCAR

MISSION DATA

SPACE STATION				ECLSS CLOSED LOOP FUNCTIONS	
MODULES	1	RESUPPLY PERIOD	90.0 DAYS	CO2 REDUCTION	H2O RECOVERY
MODULE SIZE	4010.0 FT3	ORBIT		O2 GENERATION	CONDENSATE
CREWPERSONS	8	LIGHTSIDE	56.0 MIN		WASH WATER
INITIAL SUPPLY PERIOD	90.0 DAYS	DARKSIDE	36.0 MIN		URINE

SUBSYSTEM DATA PER UNIT - 1 REQUIRED FOR STATION

POWER (WATTS)		AC	DC
	LIGHTSIDE	117.7	0.0
	DARKSIDE	117.7	0.0
	INTERMITTENT	96.0	0.0

HEAT LOAD - SENSIBLE (BTU'S)		AIR	AIR TEMP	LIQUID	LIQUID TEMP
	LIGHTSIDE	401.7	CABIN AIR	0.0	40-45 F
	DARKSIDE	401.7	CABIN AIR	0.0	40-45 F
	INTERMITTENT	0.0		0.0	

PAYLOAD		WEIGHT (LBS)	VOLUME (FT3)
	FIXED ON-ORBIT	524.0	57.7
	INITIAL SPARES & EXP	102.4	6.0
	SUBTOTAL	626.4	63.3
	RESUPPLY SPARES & EXP	65.7	2.0
	RETURN TO EARTH	196.7	3.5

SUBSYSTEM DESIGN CRITERIA

SUBSYSTEM MASS BALANCE DATA PER UNIT (LB/DAY)

MATERIALS REQUIRED		MATERIALS PRODUCED		MATERIALS LOST
WASTE WATER	= 63.039	POTABLE WATER	= 61.723	
OXYGEN	= 2.703	CO2	= 2.814	
ANTIFOAM	= 0.005	NITROGEN	= 0.299	
PH ADJUSTER	= 0.005	SULFUR DIOXIDE	= 0.178	
FILTER	= 0.072	SOLIDS	= 0.799	

TABLE 5.2-26 VAPOR PHASE CATALYTIC AMMONIA REMOVAL SUBSYSTEM SUMMARY

VCAR SPACE STATION ECLSS CONFIGURATION NO. 2 SUMMARY SHEET - PAGE 3

8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL WEIGHT (LB) FIXED ON-ORBIT	INITIAL SPR+EXP	RESUPPLY SPR+EXP	RETURN TO EARTH	TOTAL VOLUME (FT3) FIXED ON-ORBIT	INITIAL SPR+EXP	RESUPPLY SPR+EXP	RETURN TO EARTH
1	HX & FANS - AIR COOLING---------	1	50.0	0.0	0.5	0.5	1.7	0.0	0.0	0.0
70	HX & FANS - ODOR CONTROL--------	1	80.0	73.0	146.0	146.0	4.0	4.0	8.0	8.0
2	HX - EQUIPMENT COLDPLATES-------	22	261.8	0.0	0.0	0.0	0.1	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	203.3	0.0	0.1	0.1	74.1	0.0	0.0	0.0
4	CO2 REMOVAL - EDC---------------	1	283.0	28.3	8.5	8.5	13.5	1.4	0.4	0.4
11	CO2 REDUCTION - BOSCH-----------	1	522.6	360.7	372.5	961.5	53.5	55.5	59.8	59.9
13	TRACE CONTAMINANT CONTROL-------	1	176.3	88.8	88.8	86.8	138.0	4.8	4.8	4.5
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	77.0	7.7	2.3	2.3	3.5	0.3	0.1	0.1
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	248.5	146.3	146.3	146.3	5.6	2.2	2.2	2.2
22	O2 STORAGE - HI PRESS EMERG-----	1	1248.2	0.0	37.4	37.4	83.4	0.0	2.5	2.5
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	148.2	0.0	4.4	4.4	10.9	0.0	0.3	0.3
26	CABIN PRESSURE CONTROL----------	1	142.6	0.0	2.9	2.9	2.5	0.0	0.1	0.1
28	PCT. H2O STORAGE - CLOSED LOOP--	1	663.7	66.4	19.9	19.9	24.6	2.5	0.7	0.7
29	PCT. H2O STORAGE - EMERGENCY----	14	2975.0	0.0	0.0	0.0	94.5	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	254.8	2.5	2.5	2.5	6.2	22.9	24.6	24.6
35	PROCESSED H2O POST-TREATMENT PCT	1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	211.0	16.7	91.5	101.0	25.5	0.0	0.0	0.0
71	WASH H2O STORAGE----------------	1	99.0	9.9	3.0	3.0	13.5	1.0	15.0	13.5
74	HYGIENE H2O STORAGE-------------	1	148.5	14.9	4.5	4.5	20.3	1.4	0.4	0.4
75	REVERSE OSMOSIS - HYGIENE H2O---	5	1644.6	16.2	16.2	16.2	89.7	2.0	0.6	0.6
67	H2O RECOVERY - V.P.C.A.R. ------	1	524.0	102.4	65.7	196.7	57.7	720.9	778.6	778.8
76	PROCESSED H2O POST-TREATMENT HYG	1	1.5	0.3	0.3	0.0	0.0	0.0	2.0	3.5
36	H2O QUALITY MONITORING----------	1	60.0	22.5	1.4	1.4	4.0	0.0	0.0	0.0
37	HEALTH & HYGIENE - HAND WASH----	1	25.0	2.5	0.8	0.8	3.5	1.5	0.1	0.1
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	22.8	1.3	0.9	0.9	0.8	0.3	0.1	0.1
39	HEALTH & HYGIENE - COLD H2O SPLY	1	20.0	1.3	0.6	0.6	0.8	0.9	0.1	0.1
40	HEALTH & HYGIENE - BODY SHOWER--	1	105.0	10.5	3.2	3.2	47.3	0.1	0.1	0.1
41	HEALTH & HYGIENE - DISHWASHER---	1	78.0	7.8	2.3	2.3	8.4	4.7	1.4	1.4
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	78.0	7.8	2.3	2.3	8.4	0.8	0.3	0.3
43	HEALTH & HYGIENE - COMMODE/URINL	4	691.6	0.0	691.6	893.2	74.0	0.8	0.3	0.3
44	HEALTH & HYGIENE - EMER WSTE COL	3	45.0	0.0	0.0	0.0	3.0	0.0	74.0	74.0
45	HEALTH & HYGIENE - TRASH COMPACT	1	40.0	4.0	1.2	750.0	7.0	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN---------	1	40.0	4.0	1.2	1.2	2.5	0.4	0.3	93.9
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	141.9	14.2	4.3	4.3	24.3	0.3	0.1	0.1
48	HEALTH & HYGIENE - FOOD FREEZER-	1	385.3	38.5	11.6	11.6	84.1	2.4	0.7	0.7
								3.4	2.5	2.5
	TOTALS -----		11696.3	1048.5	1734.6	3414.2	990.8	845.8	990.3	1073.9

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TABLE 5.2-27 VAPOR PHASE CATALYTIC AMMONIA REMOVAL ECLSS LOGISTICS SUMMARY

VCAR SPACE STATION ECLSS CONFIGURATION NO. 2 SUMMARY SHEET - PAGE 1
8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL ELECTRICAL POWER (WATTS) AC LS	AC DS	AC INT	DC LS	DC DS	DC INT
1	HX & FANS - AIR COOLING---------	1	711.5	711.5	0.0	0.0	0.0	0.0
70	HX & FANS - ODOR CONTROL--------	1	0.0	0.0	0.0	0.0	0.0	0.0
2	HX - EQUIPMENT COLDPLATES-------	22	0.0	0.0	0.0	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL----	1	170.7	170.7	0.0	0.0	0.0	0.0
4	CO2 REMOVAL - EDC---------------	1	237.8	237.8	0.0	0.0	0.0	0.0
11	CO2 REDUCTION - BOSCH-----------	1	196.1	196.1	0.0	130.8	130.8	1307.5
13	TRACE CONTAMINANT CONTROL-------	1	260.4	260.4	0.0	304.5	304.5	0.0
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.0	0.0	0.0	0.0	0.0	115.0
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	139.2	139.2	0.0	4673.0	4673.0	0.0
22	O2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	0.0	0.0	0.0	15.0
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.0	0.0	3.7	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG-----	1	0.0	0.0	0.0	0.0	0.0	15.0
26	CABIN PRESSURE CONTROL----------	1	0.0	0.0	0.0	30.0	30.0	0.0
28	POT. H2O STORAGE - CLOSED LOOP--	1	0.0	0.0	0.0	0.0	0.0	0.0
29	POT. H2O STORAGE - EMERGENCY----	14	0.0	0.0	93.3	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O---	1	35.6	35.6	0.0	0.0	0.0	0.0
35	PROCESSED H2O POST-TREATMENT POT	1	0.0	0.0	0.0	0.5	0.5	0.0
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.0	0.0	30.0	0.0	0.0	0.0
71	WASH H2O STORAGE----------------	1	0.0	0.0	20.0	0.0	0.0	356.7
74	HYGIENE H2O STORAGE-------------	1	0.0	0.0	30.0	0.0	0.0	398.8
75	REVERSE OSMOSIS - HYGIENE H2O---	5	230.1	230.1	0.0	0.0	0.0	0.0
67	H2O RECOVERY - V.P.C.A.R. ------	1	117.7	117.7	86.0	0.0	0.0	0.0
76	PROCESSED H2O POST-TREATMENT HYG	1	0.0	0.0	0.0	3.1	3.1	0.0
36	H2O QUALITY MONITORING----------	1	0.0	0.0	0.0	40.0	40.0	0.0
37	HEALTH & HYGIENE - HAND WASH----	1	0.0	0.0	100.0	0.0	0.0	15.0
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	0.0	0.0	200.0	15.0	15.0	0.0
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.0	0.0	0.0	0.0	0.0	0.0
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.0	0.0	250.0	0.0	0.0	15.0
41	HEALTH & HYGIENE - DISHWASHER---	1	0.0	0.0	240.0	0.0	0.0	15.0
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.0	0.0	340.0	0.0	0.0	15.0
43	HEALTH & HYGIENE - COMMODE/URINL	4	0.0	0.0	480.0	0.0	0.0	60.0
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.0	0.0	0.0	0.0	0.0	0.0
45	HEALTH & HYGIENE - TRASH COMPACT	1	0.0	0.0	120.0	0.0	0.0	15.0
46	HEALTH & HYGIENE - OVEN---------	1	0.0	0.0	45.0	0.0	0.0	370.0
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.0	0.0	0.0	15.0	15.0	476.0
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.0	0.0	0.0	15.0	15.0	1360.0
	TOTALS -----		2099.2	2099.2	2038.0	5226.8	5226.8	4519.0

TABLE 5.2-28 VAPOR PHASE CATALYTIC AMMONIA REMOVAL ECLSS ELECTRICAL POWER SUMMARY

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17-OCT-85 09:57 BOEING ENGINEERING TRADES STUDY - (BETS)

VCAR SPACE STATION ECLSS CONFIGURATION NO. 2 SUMMARY SHEET - PAGE 2
8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	TOTAL SENSIBLE HEAT LOAD (BTU/HR) AIR LS	AIR DS	AIR INT	LIQUID LS	LIQUID DS	LIQUID INT
1	HX & FANS - AIR COOLING	1	2428.5	2428.5	0.0	11040.8	11040.8	8561.0
70	HX & FANS - ODOR CONTROL	1	0.0	0.0	0.0	0.0	0.0	0.0
2	HX - EQUIPMENT COLDPLATES	22	0.0	0.0	0.0	0.0	0.0	0.0
3	HX & FANS - HUMIDITY CONTROL	1	-812.3	-812.3	0.0	8398.6	8398.6	0.0
4	CO2 REMOVAL - EDC	1	470.3	470.3	0.0	1457.3	1457.3	0.0
11	CO2 REDUCTION - BOSCH	1	1232.0	1232.0	4462.7	691.1	691.1	0.0
13	TRACE CONTAMINANT CONTROL	1	2201.1	2201.1	0.0	0.0	0.0	0.0
14	ATMOSP MONITOR - MASS SPECTRMTR	1	0.0	0.0	392.5	0.0	0.0	0.0
61	O2 SUPPLY - STATIC FEED ELECTR.	1	531.7	531.7	0.0	10102.3	10102.3	0.0
22	O2 STORAGE - HI PRESS EMERG	1	0.0	0.0	51.2	0.0	0.0	0.0
24	N2 SUPPLY - N2H4 DECOMPOSITION	1	0.3	0.3	12.5	0.0	0.0	0.0
25	N2 STORAGE - HI PRESS EMERG	1	0.0	0.0	51.2	0.0	0.0	0.0
26	CABIN PRESSURE CONTROL	1	102.4	102.4	0.0	0.0	0.0	0.0
28	POT. H2O STORAGE - CLOSED LOOP	1	0.0	0.0	0.0	0.0	0.0	0.0
29	POT. H2O STORAGE - EMERGENCY	14	0.0	0.0	318.5	0.0	0.0	0.0
63	REVERSE OSMOSIS - POTABLE H2O	1	121.7	121.7	0.0	0.0	0.0	0.0
35	PROCESSED H2O POST-TREATMENT PCT	1	1.6	1.6	0.0	0.0	0.0	0.0
30	WASTE H2O STORAGE & PRE-TREAT	1	0.0	0.0	102.4	0.0	0.0	0.0
71	WASH H2O STORAGE	1	0.0	0.0	1285.6	0.0	0.0	0.0
74	HYGIENE H2O STORAGE	1	0.0	0.0	1463.5	0.0	0.0	0.0
75	REVERSE OSMOSIS - HYGIENE H2O	5	785.3	785.3	0.0	0.0	0.0	0.0
67	H2O RECOVERY - V.P.C.A.R.	1	401.7	401.7	0.0	0.0	0.0	0.0
76	PROCESSED H2O POST-TREATMENT HYG	1	10.4	10.4	0.0	0.0	0.0	0.0
36	H2O QUALITY MONITORING	1	136.5	136.5	0.0	0.0	0.0	0.0
37	HEALTH & HYGIENE - HAND WASH	1	0.0	0.0	392.5	0.0	0.0	0.0
38	HEALTH & HYGIENE - HOT H2O SPLY	1	51.2	51.2	682.6	0.0	0.0	0.0
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.0	0.0	0.0	0.0	0.0	600.0
40	HEALTH & HYGIENE - BODY SHOWER	1	0.0	0.0	904.5	0.0	0.0	0.0
41	HEALTH & HYGIENE - DISHWASHER	1	0.0	0.0	2070.3	0.0	0.0	0.0
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.0	0.0	1211.6	0.0	0.0	0.0
43	HEALTH & HYGIENE - COMMODE/URINL	4	0.0	0.0	1843.7	0.0	0.0	0.0
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.0	0.0	0.0	0.0	0.0	0.0
45	HEALTH & HYGIENE - TRASH COMPACT	1	0.0	0.0	460.8	0.0	0.0	0.0
46	HEALTH & HYGIENE - OVEN	1	0.0	0.0	1416.4	0.0	0.0	0.0
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.0	0.0	0.0	51.2	51.2	1574.6
48	HEALTH & HYGIENE - FOOD FREEZER	1	0.0	0.0	0.0	51.2	51.2	4641.7
	TOTALS		7662.4	7662.4	17122.0	31792.5	31792.5	15427.2

TABLE 5.2-29 VAPOR PHASE CATALYTIC AMMONIA REMOVAL ECLSS HEAT REJECTION SUMMARY

VCAR SPACE STATION ECLSS CONFIGURATION NO. 2 SUMMARY SHEET - PAGE 4

8 MAN CREW 1 MODULE INITIAL SUPPLY PERIOD = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

ITEM NO.	SUBSYSTEM OR COMPONENT	UNITS REQ'D	MASS BALANCE FOR GASSES (LB/DY) OXYGEN	NITROGEN	CARBON DIOXIDE	HYDROGEN	MASS BALANCE FOR WATER (LB/DY) CONDENSATE	POTABLE	WASH	WASTE	HYGIENE
	BASIC CREW AND MODULE-----------		-14.833	-0.387	17.600	N/A	41.200	-54.060	323.440	38.160	-340.800
1	HX & FANS - AIR COOLING---------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70	HX & FANS - ODOR CONTROL--------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	HX - EQUIPMENT COLDPLATES-------	22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	HX & FANS - HUMIDITY CONTROL----	1	0.000	0.000	0.000	0.000	-50.322	0.000	0.000	0.000	0.000
4	CO2 REMOVAL - EDC---------------	1	-8.108	0.000	0.000	-1.716	9.122	0.000	0.000	0.000	0.000
11	CO2 REDUCTION - BOSCH-----------	1	0.000	0.000	-20.395	-1.854	0.000	16.687	0.000	0.000	0.000
13	TRACE CONTAMINANT CONTROL-------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	ATMOSP MONITOR - MASS SPECTRMTR-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
61	O2 SUPPLY - STATIC FEED ELECTR.-	1	25.645	0.000	0.000	3.206	0.000	-29.950	0.000	0.000	0.000
22	O2 STORAGE - HI PRESS EMERG-----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	N2 SUPPLY - N2H4 DECOMPOSITION--	1	0.000	0.102	0.000	0.013	0.000	0.000	0.000	0.000	0.000
25	N2 STORAGE - HI PRESS EMERG-----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	CABIN PRESSURE CONTROL----------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	PCT. H2O STORAGE - CLOSED LOOP--	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	PCT. H2O STORAGE - EMERGENCY----	14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63	REVERSE OSMOSIS - POTABLE H2O---	1	0.000	0.000	0.000	0.000	0.000	47.302	0.000	3.019	0.000
35	PROCESSED H2O POST-TREATMENT PCT	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	WASTE H2O STORAGE & PRE-TREAT---	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
71	WASH H2O STORAGE----------------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
74	HYGIENE H2O STORAGE-------------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
75	REVERSE OSMOSIS - HYGIENE H2O---	5	0.000	0.000	0.000	0.000	0.000	0.000	-323.440	19.406	304.034
67	H2O RECOVERY - V.P.C.A.R. ------	1	-2.703	0.299	2.814	0.000	0.000	61.723	0.000	-60.586	0.000
76	PROCESSED H2O POST-TREATMENT HYG	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36	H2O QUALITY MONITORING----------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	HEALTH & HYGIENE - HAND WASH----	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
38	HEALTH & HYGIENE - HOT H2O SPLY-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39	HEALTH & HYGIENE - COLD H2O SPLY	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40	HEALTH & HYGIENE - BODY SHOWER--	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
41	HEALTH & HYGIENE - DISHWASHER---	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
42	HEALTH & HYGIENE - CLTH WASH/DRY	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
43	HEALTH & HYGIENE - COMMODE/URINL	4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
44	HEALTH & HYGIENE - EMER WSTE COL	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45	HEALTH & HYGIENE - TRASH COMPACT	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	HEALTH & HYGIENE - OVEN---------	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	HEALTH & HYGIENE - FOOD REFRIDGE	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	HEALTH & HYGIENE - FOOD FREEZER-	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	SUBSYSTEM ULLAGE (CUMULATIVE)---		0.000	-0.015	-0.019	-0.003	0.000	0.000	0.000	0.000	0.000
	TOTALS -----		0.000	0.000	0.000	0.145	0.000	42.782	0.000	0.000	-36.766

TABLE 5.2-30 VAPOR PHASE CATALYTIC AMMONIA REMOVAL ECLSS MASS BALANCE SUMMARY

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16. Abstract

This report compares parametric data for the following six waste management subsystems, as considered for use on the Space Station: 1) dry incineration, 2) wet oxidation, 3) supercritical water oxidation, 4) vapor compression distillation, 5) thermoelectric integrated membrane evaporation system, and 6) vapor phase catalytic ammonia removal. The parameters selected for comparison are on-orbit weight and volume, resupply and return to Earth logistics, power consumption, and heat rejection.

Trades studies are performed on subsystem parameters derived from the most recent literature. The Boeing Engineering Trade Study, (BETS), an environmental control and life support system (ECLSS) trade study computer program developed by Boeing Aerospace Company, is used to properly size the subsystems under study. The six waste treatment subsystems modeled in this program are sized to process the wastes for a 90-day Space Station mission with a crew of eight persons and an emergency supply period of 28 days. The resulting subsystem parameters are compared not only on an individual subsystem level but also as part of an integrated ECLSS.

Two factors affect the results of this trade study. One is the level of subsystem development. The four basic parameters studied in this report tend to be optimized during the later stages of equipment development. Therefore, subsystems in their later stages of development tend to exhibit lower parametric values that their earlier models. The other factor is the functional design of the subsystem. Systems designed to process a wider variety of wastes and to convert these wastes to more usable byproducts in general have higher process rates and therefore tend to be larger, weigh more, consume more power and reject more heat than waste treatment systems with lower process rates. These parametric liabilities are only offset when the parameters are weighed against the process rates and overall ECLSS mass balance.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
CELSS, Waste processing, supercritical water oxidation, wet oxidation, incineration, vapor compression dist. catalytic ammonia removal, trade studies	Unclassified - Unlimited STAR Category 54

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