NASA CONTRACTOR REPORT 177422

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

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2.4.1 COMBUSTION-BASED MASS BALANCE

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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
С	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.
н ₂	diatomic hydrogen
н ₂ О	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

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GLOSSARY

min	minimum
N ₂	diatomic nitrogen
N_2H_4	hydrazine
NASA	National Aeronautics and Space Administration
NH3	ammonia
0 ₂	diatomic oxygen
0&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
тос	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

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UNITS OF MEASURE

ftendl	footcandle
1 G	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
рН	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

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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.

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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.

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1.0 INTRODUCTION

1.1 OVERVIEW

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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

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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

					Heat	Launch
Ranking	<u>Weight</u>	<u>Volume</u>	Logistics	Power	<u>Rejection</u>	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 Subsystem						
Parameter	INCIN	<u>weto</u> x	s <u>cwo</u>	<u>VCD</u>	<u>times</u>	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		6	_5	_1			
Total	23	27	17	11	14	13	

WASTE MANAGEMENT SYSTEM PARAMETRIC EVALUATION

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.

	Inputs			Effluents					
Subsystem	<u>Water</u>	Solids	02	<u>Water</u>	Brine	Ash	<u>C02</u>	<u>N2</u>	<u>S02</u>
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

TABLE 1.6-3

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

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 1.6-4ECLSS CONFIGURATION RANKING SUMMARY

					Heat	Launch
Ranking	<u>Weight</u>	<u>Volume</u>	Logistics	Power	<u>Rejection</u>	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 They not only recover 100% of the water in the waste but also produce wastes. 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 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

	Gase	Gases (lb)		Water (lb)			
	02	<u>C02</u>	Potable	Hygiene	Wash	<u>Waste</u>	Total
Resupply	1,333	ο	4,867	30,672	ο	ο	36,872
Return	ο	1,584	ο	ο	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 Food preparation water Hand wash water Shower water Clothes wash water Dish wash water	lb/person-day lb/person-day lb/person-day lb/person-day lb/person-day lb/(8)crew-day	2.86 3.90 7.00 5.00 27.50 16.00	3.39 4.64
Metabolic produced water	lb/person-day	0.78	5.82
Perspiration/respiration H2O	lb/person-day	4.02	
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.

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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 , COand NH_3 gases in the effluent even with the use of a catalytic afterburner. The product



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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 preconcentration 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 posttreatment 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 2.2.1.2-1DRY INCINERATION EQUIPMENT LISTFrom 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	600xl 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	43xl hr each	l2 btuh (24 hr avg)	HSC interm.	
Ash storage Tank(90day)	2065 in3	30 lb	-	-	Estimated	
Insulation				180 btuh	Air cooled	
Revised tota	al 20 ft3 (45%pkg)	160 lb (12%pkg)	388 (24 hr avg)	350 btuh (24 hr avg)		
Consumes: O2		0.6 lb/	day/lb solid	s input		
Returns: Solids 0.11 lb/day/lb solids input						
COMMENTS:						
1. "-" denot	es that no	specific	information	was determin	ed for this	
point. 2. Subtotals	represent	paramete	ers determ	ined directl	y from the	
<pre>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).</pre>						

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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.





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2.2.2.2 Parametric Description

Table 2.2.2.2-1 lists the equipment and related parameters for a projected fourperson 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 N₂ and CO₂ 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 (1b)	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	ll 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/d	lay				
Returns Solids 0.3 lb/day							
COMMENTS:							
 "-" denotes that no specific information was determined for this point. Based upon 330 cc/hr feed rate (90% urine/10% feces) nominal four-person system with 25% overdesign factor (17.5 lb/day). Subtotals represent parameters determined directly from the literature. 							

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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. Α 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. Derived	3.2-1 S from SAE	UPERCRITICA Paper 8208 & Mode	L WATER OXII 72, Timberla 11, 1982	DATION EQUIP Ake, Hong, Si	MENT LIST Impson
Component	Volume (in3)	Weight (1b)	Power (w)	Heat rejection	Notes
Slurry pump	720	27	17	58 btuh	Air cooled
Reactor w/ htr and insul	985	17	840xl 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
O2 comp penalty	-	-	55	- 188 btuh	Air cooled
Extra heat reqd to sus- tain reaction	-	-	420	-	1240 deg F
Total	12 ft3 (45%pkg)	398 (12%pkg)	552	542 btuh 2381 btuh	Liq cooled Air cooled
Consuma	ables	Return to	Earth	To Mass Ba	lance
02 4.9	lb/day	Solids1.2SO20.3H2O63.3	lb/day lb/day lb/day	N2 0.4 1 CO2 4.9 1	b/day b/day
Comments:					
l. Based upon	eight-pe Wash	rson crew /(Urine (35.2 Feces (1.6 Brine (21.9 Trash (2.4	<pre>water), <so ()="" <1.04=""> () <0.56> () <1.20> () <1.07> () <1.07></so></pre>	lids>/ 24-hr	operation:
		TOLAT (01.1	.) + <3.90>	= 05 ID/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 selfsustaining 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. From	4.2-1 V Life Syst	APOR COMPRI ems, Inc. 1	ESSION DIST Letter FHS-2	LLATION EQUIPM 2-8, Feb. 14, 1	IENT LIST 983
Component	Volume (in3)	Weight (1b)	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:					
<pre>1. System as o waste at a 2. "-" denote point.</pre>	depicted 90% duty es that n	is sized t cycle, or o specific	o process an equivale information	35.6 lb/day nt rate of 40 was determine	of liquid lb/day. d for this



L

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 2.2.5.2-1TIMES II EQUIPMENT LISTFrom Hamilton Standard Report HSPC84T03, 1984						
Component	Volume (in3)	Weight (1b)	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:

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 N₂, N₂O, and water at 250 deg C and then catalytically reducing the N₂O to N₂ and O₂ 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 NH₃ 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



Figure 2.2.6.1-1. 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 waterquality 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 wastetreatment 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.

Component	Volume (in3)	Weight (lb)	Power (w)	Heareje	at ction	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)		Expendabl	les (p	per day	7)
O2 Antifoam pH adjust	0.3100 0.0022 0.0022	1b 1b 1b	Solids filter		0.03	52 lb
Comments:						

TABLE 2.2.6.2-2AUX. VPCAR EQUIPMENT LISTDerived 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	* 22xl 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 recirc	295 72	9.0 4.0	1.3 10.4	4.4 btuh 35.5 btuh	Estimated Estimated		
Feed control	-	-	-	-			
Feed storage tank	918	-	-	-			
Instruments	-	-	-	-			
Thermal insululation	-	-	-	-			
Total	26 ft3	235	68	2530 btuh 1570 btuh	INCIN (Avg) WETOX		
Consumables: O2 pH adjust	(Assummed 0.0022 lb/	included 'day	in upstream w	waste-treatmer	nt process)		
Expendables: Filter	0.0352 lb/	'day					
Comments:							
1. Factored fr	om system	designed	to treat 14	kg/day (30.8)	lb/day) or		
2. "-" denote point.	es that no	specific	information v	was determined	for this		

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

<u>Level</u>	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

		Waste	Manageme	nt Subs	ystem	
Parameter	(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) Volume (ft3)	81 4	87 3	62 0.6	23 2	33 2	66 2
D.Return to Earth Weight (lb) Volume	249 6	255 5	230 3	466 9	585 10	197 4
E.Power (w) AC DC Intermittent	760 0 16465	1263 0 0	550 0 836	32 82 0	13 144 1	118 0 86
F.Spec energy (1) (wh/lb)	485	416	231	43	58	27
G.Heat Rejection Air cooled (btuh Liq.cooled (btuh) 1623) 968	1508 2805	2370 540	387 0	534 0	402 0
H.Technology (1) assessment	4	4	3	6	5	3
Notes:						
1. This parameter is independent of	s based f crew s	on the esize.	quipment	lists :	in section	2.2 and
2. INCIN and WETO in the literature	X includ e and as	le an aux s evaluat	iliary VI ed in th:	PCAR per is repor	nalty as su ct.	iggested



- · ···



VPCAR. VPCAR.
 INCIN. WETOX.
 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 ft³. If this estimate were to become a not-toexceed 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 ft³) in relationship to the Shuttle cargo bay capacity (10,600 ft³) 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 SO₂ as wastes. If calcium carbonate, CACO₃, is used to collect this SO₂, then 50 lb of CACO₃ is required every 90 days for these processes and 25 lb of unreacted CACO₃ plus 34 lb of CASO₄ must be returned to Earth. This analysis assumes CACO₃ SO₂ absorbent. All other products are considered to be recoverable and reusable.





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.



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 ft³ for a resupply period of 90 days. In relation to the total Shuttle capacity of 10,603 ft³, 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

	System	(1) On-orbit wt (1b)	(1) Annual replacement wt (1b)	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
1 1 1	The first the first consist of the of i the of r	In an equi -year costs t-year res f the annua nflation. T eturn calcu	are the launch are the launch upply launch f l resupply lau his is a futur lation is not	t cost per th fees for tees. The c inch fees a te-value co being used	pound of about the system as osts for years s adjusted for mputation only. here.	well as the s 2 through 9 a 7% annual An Internal

WASTE MANAGEMENT SUBSYSTEM LAUNCH COSTS Subsystem On-orbit wt (1b) 90-Day resupply wt (1b) Subsystem power (kw) Subsystem heat reject (kw) (1) 10-year launch wt (1b) (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	TABLE 2.3.5-2						
SubsystemOn-orbit wt (1b)90-Day resupply wt (1b)Subsystem power (kw)Subsystem heat reject(1) 10-year launch wt (1b)(2) 10-year launch cost (\$)INCIN (3)1,0332490.760.7611,6203,701,410WETOX (3)1,2262551.261.2612,3774,219,027SCWO (3)3962300.550.8510,1162,767,098VCD1114660.110.1119,0814,261,344TIMES925850.160.1623,9205,308,622VPCAR5241970.120.128,5912,362,713Notes:		WAST	e Managemi	ent subsys	TEM LAUNCH	COSTS	
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 SCNO (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:	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 (\$)
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:	INCIN (3)	1,033	249	0.76	0.76	11,620	3,701,410
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:	WETOX (3)	1,226	255	1.26	1.26	12,377	4,219,027
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:	SCWO (3)	396	230	0.55	0.85	10,116	2,767,098
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:	VCD	111	466	0.11	0.11	19,081	4,261,344
VPCAR 524 197 0.12 0.12 8,591 2,362,713 Notes:	TIMES	92	585	0.16	0.16	23,920	5,308,622
Notes:	VPCAR	524	197	0.12	0.12	8,591	2,362,713
	Notes:		ہ ہے جب سے حد قاب ہے ج				

- 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 systems 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 systems used by the subsystem 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.





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.

					Heat	Launch
Ranking	<u>Weight</u>	Volume	Logistics	Power	Rejection	Costs
	MIN 10	<i></i>			VOD	
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

WASTE MANAGEMENT SYSTEM RANKING SUMMARY

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 M	ANAGEN	<u>MENT SU</u>	BSYSTEM	L
Parameter	INCIN	WETOX	<u>scwo</u>	<u>VCD</u>	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		6		_1		
Total	23	27	17	11	14	13

WASTE MANAGEMENT SYSTEM PARAMETRIC EVALUATION

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., "CO₂ 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 (SO₂) 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.





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.

	Amount of (1) (1) (1) (1) (1)	Material Required rial/lb solid lis	or Produced ted below)
- Material	Urine Solids	Fecal Solids	Hygiene and Wash Solids
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 release	d per pound of so	lids oxidized
-	5,285	13,089	9,498
Notes: The basic combusti	on reactions	are:	
C + O2 => CO2 2H2 + O2 => 2H2 S + O2 => SO2	$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$) btu/lb C) btu/lb H2) btu/lb S	

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



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



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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.



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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 ft³ with a standard deviation of 44 ft³ (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:

<u>WEIGHT</u>	VOLUME
1. TIMES	SCWO
2. VCD	TIMES
3. SCWO	VCD
4. VPCAR	WETOX

	JOB ID INCN ECLSS CONFIGURATION NO. 1	
	SUBSYSTEM SELECTION SUMMARY	
TEM NO.	SUBSYSTEM/COMPONENT	
1	HX & FANS - AIR COOLING	STAINLESS
70	HX & FANS - ODOR CONTROL	
2	HX - EQUIPMENT COLDPLATES	STATNI, ESS
5	CO2 DEMOVAL = EDC	OTATMIN 00
11	CO2 REDUCTION - BOSCH	
13	TRACE CONTAMINANT CONTROL	
14	ATMOSP MONITOR - MASS SPECTRMTR-	
61	02 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 HZO STORAGE & PRE-TREAT	
	WASH HZU STURAGE	
74 75	DEVERSE AND STORAGE	
68	H20 RECOVERY - INCINERATION	
76	PROCESSED H20 POST-TREATMENT HYG	
36	H2O OUALITY 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	
40	HEALTH & HIGIENE - OVEN	
48	HEALTH & HIGIENE - FOOD REFRIDGE HEALTH & HYGIENE - FOOD FREEZER-	
ADDI	TIONAL COMPONENTS PER MODULE	
	SUITS AND PLSS'S	
ō	PORTABLE OXYGEN SUPPLIES	
0	EMERGENCY ESCAPE SYSTEMS	

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B	OEING 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
/0	HX & FANS - ODOR CONTROL	
2	HX - EQUIPMENT COLDPLATES	STAINLESS
Л	CO2 REMOVAL - EDC	01114 MED 00
- 4 11	CO2 REDUCTION - BOSCH	
13	TRACE CONTAMINANT CONTROL	
14	ATMOSP MONITOR - MASS SPECTRMTR-	
61	02 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 H2U	
35	PROCESSED H20 POST-TREATMENT POT	
30 71	WASTE HZO STORAGE & PRE-IREAT	
74	HYGIENE H20 STORAGE	
75	REVERSE OSMOSIS - HYGIENE H2O	
34	H20 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 & HIGIENE - COMMODE/URINL	
44	HEALTH & HIGIENE - EMER WOIL COL URAIMU & UVCIENT - TRASH CONDACT	
45	HEALTH & HYGIENE - OVEN	
47	HEALTH & HYGIENE - FOOD REFRIDGE	
48	HEALTH & HYGIENE - FOOD FREEZER-	
ADD	ITIONAL COMPONENTS PER MODULE	
	0 SUITS AND PLSS'S	
	U PORTABLE OXYGEN SUPPLIES	
	U EMERGENCI ESCAPE SISTEMS	
TABLE	2.5-2 ECLSS WITH WASTE WATER PROCESSING	BY PHASE CHANGE

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TABLE 2.5-3

ECLSS CONFIGURATION PARAMETRIC SUMMARY for an Eight-Person Crew

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

in the literature and as evaluated in this report.



Figure 2.5.1-1. ECLSS Veight 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 ft³ 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 ft³ with a standard deviation of 93 ft³ (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-



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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 ft³. The return to Earth requirements for the configurations all fall within the Shuttle landing capacity of 32,000 lb and 10,600 ft³.

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.

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- 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



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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 10year 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 ft³) 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 onorbit 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.

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:								

TABLE 2.5.4-1

- 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

					Heat	Launch
Ranking	<u>Weight</u>	<u>Volume</u>	Logistics	Power	Rejection	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:

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*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 N₂, CO₂, and SO₂ 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

	Waste Management Subsystem						
<u>Parameter</u>	INCIN	W <u>etox</u>	SCWO	<u>VCD</u>	<u>TIMES</u>	V <u>PCAR</u>	
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_			
Total	22	25	14	12	13	19	

ECLSS CONFIGURATION PARAMETRIC EVALUATION

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.

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- 1. VCD.
- 2. TIMES.
- 3. SCWO.
- 4. VPCAR.
- 5. INCIN.

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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.
- $2. \quad SCWO.$
- 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.

Heat Launch Ranking Weight Volume Logistics Power rejection 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

ECLSS CONFIGURATION RANKING SUMMARY

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 NH₃ and N₂O 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

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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 longduration 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.

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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. This page intentionally left blank

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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

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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



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AVERAGE LOADS FOR ECLSS

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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 TRAD JO	ES STUDY - (BETS) B ID INCN ICUPATION NO 1	24-SEP-85
ECLSS CONF	IGURATION NO. I	
SPECIFI	C MISSION DATA	
PARAMETER	UNITS	VALUE
MODIILE		
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 PERIC	DD 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
/0	HX & FANS - ODOR CONTROL	
2	HX - EQUIPMENT COLDPLATES HX & FANS - HIMIDITY CONTROL	STATNI, ESS
4	CO2 REMOVAL - EDC	DIVIUPUOD
11	CO2 REDUCTION - BOSCH	
13	TRACE CONTAMINANT CONTROL	
14	ATMOSP MONITOR - MASS SPECTRMTR-	
61	O2 SUPPLY - STATIC FEED ELECTR	
22	OZ STORAGE – HI PRESS EMERG	
24 25	NZ SUPPLY - NZH4 DECOMPOSITION	
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	
/1	WASH H2O STORAGE	
74	HYGIENE HZO STORAGE	
68	H20 RECOVERY - INCINERATION	
76	PROCESSED H20 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 HEALTH & HYGIENE - CITH WASH/DDY	
44	HEALTH & HYGIENE - CHIN WASH/DRI HEALTH & HYGIENE - EMER WSTE COL	
46	HEALTH & HYGIENE - OVEN	
47	HEALTH & HYGIENE - FOOD REFRIDGE	
48	HEALTH & HYGIENE - FOOD FREEZER-	
ž	ADDITIONAL COMPONENTS PER MODULE	
-	A SULTES AND PLSS'S	
	0 PORTABLE OXYGEN SUPPLIES	
	0 EMERGENCY ESCAPE SYSTEMS	
TAB	LE 5.1.1-1 ECLSS WITH WASTE WATER PROCESSING	BY COMBUSTION

	BOEING ENGINEERING TRADES STUDY - (BET	S) 24-SEP-85
	JOB ID VCD ECLSS CONFIGURATION NO.	2
	SUBSYSTEM SELECTION SUMMA	RY
ITEM	NO. SUBSYSTEM/COMPONENT	
1	HX & FANS - AIR COOLING	STAINLESS
70	HX & FANS - ODOR CONTROL	
2	HX - EQUIPMENT COLDPLATES	CHATNE FOC
3	HX & FANS - HUMIDITY CONTROL	STAINLESS
17	CO2 REMOVAL - EDC	
13	TRACE CONTAMINANT CONTROL	
1/	ATMOST MONITOR - MASS SPECTRMTR-	
61	02 SUPPLY - STATIC FEED ELECTR. -	
22	02 STORAGE - HI PRESS EMERG	
24	N2 SUPPLY - N2H4 DECOMPOSITION	
25	N2 STORAGE - HI PRESS EMERG	
26	CABIN PRESSURE CONTROL	
28	POT. H20 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	
/5	REVERSE OSMOSIS - HYGIENE HZO	Tet
34	HZU RECOVERI - VCD	LSI
26	PROCESSED HZU POST-TREATMENT HIG	
20	HEATTH & HYCIENE - HAND WASH	
32	HEALTH & HYGIENE - HOT H20 SPLY-	
30	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-	
i	ADDITIONAL COMPONENTS PER MODULE	· ·
	0 SUITS AND PLSS'S	
	0 PORTABLE OXYGEN SUPPLIES	
	0 EMERGENCY ESCAPE SYSTEMS	
TABL	0 PORTABLE OXYGEN SUPPLIES 0 EMERGENCY ESCAPE SYSTEMS B 5.1.1-2 ECLSS WITH WASTE WATER PROCESS	SING BY PHASE CHAN

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

3

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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		SPACE STAT	10 N		FCTSE CEASE	CO FLEE ENGLIC		
	MODULES Module Site Creveerscas L'IIIAL Supply pef	1 4010 0 FT3 5 ~5 ~5	AFSUPELY PEPIC AFSUPELY PEPIC LTGFTSLOE DARKSTDF	HIN 0.05	CC2 RFFTC1 CC2 RFFTC1 C2 GENERAT		. 11 또 1 > 는 La 1 - 또 도 II	
SUBSYSTFL	• DATA TER TAIL - 1	1 REGUTRED FOR ST					1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
	PCNER (VATIS)			U T		ري 		
		LTGP	JISICE	759.6		с . с		
		DARK Ilte	'STDE Britteri	759.6 16465.5		د د د د		
	HFAT LCAL - SFASI	RLF (3TU°S)		ŭΓv	ата тено	LJ 3012	LIGUID IFER	
				ļ				
		1917	TEIDE	1623.2	CAPLY ALR	959.4	4)-45 F	
		L T T T T T T T T T T T T T T T T T T T	SIVE Rrittert	5.5,01 989 .1	MIS THUS	55738. ⁶		
	PAYLCAD		2	4EIGHT (LAS)		логоме (Е13)		
		FIXF Inlt	D DR-LEAIS & AXE. .Ith States & AXE.	153.5		123.0 13.4		
			SUPIČIAL	1186.2		 		
		UNER UNER	17714 SFARF3 & EN 184 TO EARTH	(F 91.0 219.4		ຍ ເ. • ແ ທີ່ແ		
SUBSYETER	CESIGN CHITERIA					6 7 7 8 7 8 8 8 8 8 8 8 8	8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	
SUREYETER	« MASS EALALCE DATA	PER UMIT (LA/DAY	(.				8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	
	MATERIALS REGULAEL	6	PATERIALS DRC	DRICEN	14. 70	TENIALS LOST		
	VASTE VATER= 54. CXYGEN= 54.		1111111111111111111111111111111111111	Z= f2.853 5.226 C.396	;			
			SUTFUR DICYIC	DE= 0.176				

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TABLE 5.2-1 INCINERATION/AUX. VPCAR SUBSYSTEM SUMMARY

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(SIAO) - ADDIS STOPPES LUCK - (PEIS)

IMCH SPACE STATIÓN EGLES CÓUPATION NG. – I SUNNAR SMEEL – PAGE 3 8 man crem 1 moeule – Ihiliad Supply Period = 90.0 fays, regupply period = 90.0 days

				TOTAL WEI	GHT (LA)			TCTAL VCI	.UME (FT3)	1
N G A L T E K	SHASYSTEM OR COMPONENT	UKITS Deco	FIXED ON-CRBIT	INTTAL SPR+FXP	DESUPPLY SPR+EXP	RETURU TC FARTY	FIXED DA-CRETT	TNTTIAL Septement	aya+sas Yuqubar	RETURN TO FARTU
	HX & FANS - ALP COLLING		57.0.	0.0	0.5	0 5	6.1	C . J	U • U	0.0
70	HX & FANS - DOOR CONTREL	Ļ	81.6	73.0	146.0	146.0	с - 4	4.0	3°0	6.8
61	HX - EGUTPMENT COLOPLATES	22	261.8	0.0	0°0	0.0	۰ • • •	0.0	د• ن	0.0
m	HX & FANS - HUMIDITY CONTROL	-	207.6	0.0	C. !	0.1	75.7	0.0	υ • υ	0.0
4	roz Removal - Euc	•-	310.6	31.1	6 •5	6°3	14.7	1.5	د • ۵	0.4
11	CC2 PEDUCTION - RUSCH	•	522.6	360.7	372.5	5f1.5	53.5	50.5	5°, 5	59.4
ŝ	TAACE COMTAMINANI CONTROL	-	176.3	9.8 °	с • - 2 2	9.69	13P.C	4 . 3	4 ° 5	4.8
14	AIMDSP MCNITOR - NASS SPECTRVIR-	-	0.75	7.7	2.3	2.3	Э • 5	с . Э	• • •	0.1
61 6	02 SUPPLY - STATIC FEED ELECTR	-	271.7	166.1	166.1	166.1	ر • ب	2.6	א. א	2.6
22	12 STOPAGE - HI PRESS EMERG	•	111.4	C*0	42.3	42.3	94.4	د. ن	ч . С	÷*2
24	NZ SUPPLY - N2H4 DECAMPOSITICN	-	0°C	0.0	د • ،	0.0	د• د	د. ب	C•J	0.0
25	N2 STORAGE - HI PRESS ERERG	1	143.7	0.0	د.،	4 •3	10.5	0.1	۳ ° 0	6. 3
26	CABIN PRESSURE CONTROL	F	142.6	0.0	2.9	2.9	2.5	0.0	0 . 1	0.1
28	PCT. H2C STORAGE - CLOSEE LOCP	-	663.7	66.4	19.9	19.5	24.F	2.5	C.7	0.1
29	PCT. H20 STURAGE - EMERGENCY	15	3187.5	0.0	υ°0	0.0	101.3	0. 0	د • ی	0.0
63	REVERSE CSMOSIS - FUTAPLE H2C	-	260.2	2.6	2.5	2.6	6.2	23.4	25.1	25.1
35	PRCCESSED H20 POST-IREATVENT PCT	-	0 . 2	0.0	ເ [•] ບ	0°0	0.0	0.0	0°0	0.0
30	WASTE H2C STORAGE & PRE-IREAT	•	211.0	16.7	- 16	101.0	25.5	1.0	15.0	13.5
11	WASH H20 STORAGE	-	5°06	5°6	с. •	э ° С	13.5	1.4	ч. С	0.4
74	HIGIENE H20 STORAGF	-	148.5	14.9	√: •₽	4.5	20.3	2.4	0 . 6	0.0
75	REVERSE CS40SIS - FIGIENE H2C	un,	1644.6	16.2	15.2	16.2	80.7	720.9	5.275	778.9
68	H20 RECOVERY - INCINERATION	•	1037.9	153.3	81 . 0	249.4	122.0	12.5	5 . 5	6°9
76	PROCESSED 420 DOST-IREATVENT HYG	•	1.5	0.3	r' • 0	0°0	د . ی	0.0	0.0	0.0
36	H20 CUALITY YONITORING	-	6 u • U	22.5	1.1	+	с• च	1.5	0.1	0.1
37	HEALTH & HYGIENE - HANT WASH	-	25°n	2.5	ŋ . 3	9.0		0.3	ن • ۱	0.1
38	HEALTH & HYGIENE - HOT H2C SPLY-	**1	22.8	1.3	6°0	6°0	۳. د	0.4	J C	0.1
6 E	HEALTH & HYGIENE - COLT H2C SPLN	•	20.0	1.3	0° 2	0.0	0 •	0.1		0.1
40	НЕАТТН 5 НҮСІЕЙЕ - ВОСУ СИСЛЕК	-	105.0	10.5	3.7	3.2	47.3	4.7	1.1	1.1
7 T	HEALTH & HYGTENE - DISCHASHER	*	78.0	7.8	2.3	2.3	V * °	8.0	د. د	0.3
42	HEALTH & HYGTENE - CLTF WASH/DR1	-	C . C .	7.8	2.3	2.3	т. • с	0 . 8	۳. د	e.0
44	PEALTH & HYGIENE - EWER WSTE COL	m	45. م	0°0	د. د	0.0	د . ۳		с • с	0.0
46	HEALTH & HYGIENE - CVEN	-	40°	4.0		1.2	2.5	6.3	0.1	0.1
47	PEALTH & HYGTENE - FOCT REFRIDGE	-	141.9	14.2	و م	4.3	24,3	2.4	L • J	0.7
4 B	HEALTH & HYGIENE - FOOD FREEZER-	-	385.3	38,5	11.6	11.t	84.1	F • C	2.5	2.5
			*							
	TCIALS	ł	11912.6	1118.0	1082.5	1549.2	3 5 5 5	852.7	1°-0°6	606

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

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BOEIMG ENGIMEEFING TAADUS STUDY - (HFTS)

1

INCH SPACE STATION ECLSS COHFIGURATION MC. I STHWARY SHEET - PAGE 1 8 Maw Crew 1 Motule - Initial Subply Perion = 90.0 Dáys, resepely periou = 90.0 Jays

TOIAL ELECTRICAL POWER (WATTS)

3.0							
	11 ATTS					ບ ດ	
3. SUBSYSTEM OR COMPONENT	REG	ΓS	LS 1	TNI			
HX & FANS - AIR COLING		824.22	821.2	<u>, г</u>	0 0	0.0	• •
HX & FANS - DOOR CONTREL		с ° С	0.0	ບີບ ບ	0-0		
HX - ECUIPWENT CCLDPLATES	22		0.0		0.0		
HX & FANS - HUMICITY CONTRU	1	176.0	176-0				
CO2 REMOVAL - EDC		205.0	265.0				יי גי גי
CO2 REFUCTION - PESCH		101					
LULLACU FRANTARENCI DUACE					130.8	130.4	1307.5
「「「「」」」」、「「」」」、「「」」、「」」、「」」、「」」、「」」、「」」		200°4	260.4	ა • 0	304.5	3.4.5	с . Э
ALTONY MURITUR - RAGO SPECT	3 4 L 8 - 1	0.0	0°0	0°0	0.0	ς ζ	115.0
CZ SUPELY - STATIC FFEC ELF.	CTR 1	156.6	156.6	υ°0	5326.b	5326.6	
02 STORAGE - HI FRESS FMERC		0°0	0.0	υ ΄ υ	0.0		
N2 SUPPLY - N244 DECCMPCSIT.	10N 1	0.0	0.0	6-0	0		
NZ STUFAGE - HI FRESS EMERC		c.0	0-0			. C	
CAPIN PRESSURE CONTROL		0.0	0-0				
POT. H20 STORAGE - CLOSED T	1 400	c		, c			> ·
POT. HZD STORAGE - EWERGENC							
SEVERSE DAMOSIA - DOTABLE V					6 0		0 • •
		0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	1. O U	5	5°0	c	0°)
ADERADERENDE ONDE ADDUCTUUM DE ADERENDE ADDUCTUUM DE AD UCADOUCTUUM DE ADDUCTUUM DE			0.0	5°0	0.5	0.5	с. С
NAMLE FAU DIURAGE & FREETRE		0 • 0 0	0.0	J "UE	0.0	с ° 0	0.0
		с ° С	0.0	50°C	0.0	0.0	350.7
HYGIERE HZU STURAGE====		0.0	0.0	ບີບຄ	0-0	c c	7 C C 7
REVEPSE OSHOSIS - MYCIENE H	20 5	230.1	230.1	0.0	. · ·	0.0	
H2C RECOVERY - INCTRERATION		759.6	759.0	16455.6			
PRCCESSED H20 POSI-TREATMEN	L HVG 1	0.0	c • o				
H2C OUALITY MONITORING		0.0	0.0		7		
HEALTH & HYGIENE - HAND WASH		0					
HEALTH & HYGIENE - HET HOD	5 . Y. T						
	1 1 1 2 2					5°°01	0.)
CORPARE A CARLEND A TRAVER					•••	6.5	ن ت
		C.	0.0	220°C	0.0	د	15.0
	••••	ر • ن	0.0	745.C	ः •	0 ° 0	15.0
TEALIN & AYGIENE - CITE MASI		0°0	0.0	U " 1 F E	0°0	с•с	15.0
HEALTH & HYGIENE - EVER 4STI	CCL 3	0°C	0.0	ບ ໍ ບ	0.0	c c	0
HEALTH & HYGIENE - OVEN		0 •0	0.0	C • 14	0.0	, c , c	10.075
HEALTH & HYGIENE - FOOE REFI	LDGE 1	0°0	0.0	ت " ت	15.0	15.0	
HEALTH & HYGIENE - FCCT FREI	2255- 1	د د	0.0	ບ ໍ ບ	15.	15.0	1350.0
101		2902	5-0066	17830 5	RCCO /	. 0.03	

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

17-CC1-25 C5:33

POEING ENCLAFEPING THADES SIMEY - (SEIS)

THOR SPACE STATION ELLSS CONFIGURATION AC. I SPENARS SHEEL - PAGE 2 6 Man Crew 1 Monule - Juiting Supply Perion = 50.0 days, Mesterly Perion = 90.0 Uars

		i	τι T	TAL SEVE	3H JTUT	AT LOAD (67	(1HP)	
		U E	٨I	- - - - -			STADIT	
• D:4	SPESISTEM OR COMPONENT RE		1		147	LS	20	I.Y.I
-	HX & FANS - AIR CODLING	1 2807	4 2802.	5	ن • ن	12742.9	12712.9	0.679.67
70	HX & FANS - ODOR CONTREL	1	· · · · · · · · · · · · · · · · · · ·	0	ບ ໍ ບ	0.0	ů°ů	0.0
7	HX - ECUTPWENT CCLOPLATES 2	2	°0 0°	Û	ບ. ເ	0.0	с. с	0°0
m	HX & FANS - HUWITITY CONTRUL	1 - 524	• - 824 •	0	ບີ ເ	F575.5	857a . 5	0°0
4	ru2 RE*UVAt 5pC	1 ב () כ	• a 200.	г	ບ ໍ ້	1613.4	1¢13°1	0°0
11	CO2 RELUCTION - RESCHARTER	1 1232	e.n 1232.	0 41	162.7	1.190	691 . 1	r.• n
E I	TRACE COWFANINANT CONTROL	1 2201	•1 22°1.	-1	ر * ر	J. J	ٿ ٿ	0.0
14	ALYOSP MONITUR - MASS SPECTARIP-	1	· u 0 0 •	0 0	392.5	0°0	د. د	0.0
61	02 SUPPLY - STATIC FFED FLECTR	1 607	. 8 607.	8	ر • ر	11548.1	11548.1	0.0
22	02 STORAGE - HI FRESS EMERG	, ,	.0 0.	ن	51.2	0.0	د د	0.0
24	N2 SUPPLY - M2H4 DECTMPCSITICH++	1	· · · · · · · · · · · · · · · · · · ·	0	r • 1	0.0	ں ۔ 0	0.0
25	N2 STGFAGE - HI PRESS ERERG		° 0 0.	0	51.2	0.0	с• с	0.0
26	CAFIN FRESSURE CONTREL	1 107	2.4 102.	•7	ວ ໍ ບ	ാ ം റ	0°0	0°0
26	POT. HZO STURAGE - CLOSED LOCP-+		o.o	0	c. c	0°0	с• с	0.0
29	POT. H2C STORAGE - EVERGENCY 1	5	0.0	0	341.3	0.0	с . 0	0.0
63	REVERSE OSMOSIS - POTAPLE H2C	1 124	1.3 124.	٣	ن • 6	0.0	د. د	0.0
35	PRECESSED H20 POST-TFEATMENT PCT	1	1.7 1.	7	ر. د	0.0	°°°	0.0
3 O E	WASTE H20 STORAGE & FRE-TRFAT	1	0°0	0	102.4	0.0	0°0	0.0
71	WASH H20 STORAGE	1	°° °°	0	285.6	0.0	с . с	0.0
74	HYGIENE H20 STCRAGE	1	•0 0•0		453.5	0.0	د • ۲	0.0
75	REVERSE CSMCSIS - HYCIERE H2C	5 765	5.3 785.	m	υ • υ	0.0	с с	0°
5 3	H2C RECOVERY - INCINERATION	1 162	3.2 1673.		1.189	968 . 4	968.4	55270.0
76	PRECESSED H20 POST-TREATVENT HYG	1 1(0.4 10.		υ. 0	0.0	с• С	0.0
30	42C CUALITY MONITCRING	1 136	5.5 136.	с С	ບໍ ເ	0.0	0°0	0.0
37	HEALTH & HYGIENE - HANT WASH	1	0°u	0	392.5	ം •	0°°	0.0
36	4EALTH & HYGIENE - HIT H20 SPLY-	1 5	1.2 51.	7	682.5	3°0	0°0	0.0
5	HEALTH & HYGIENE - CLLE HZC SPLY	-	0°0	0	ບ ໍ ບ	0°0	د د	603 . 0
40	HEALTH & HYGIEVE - BCCY SHCKER	1	0°0	c	904.5	0°0	د د	0.0
41	HEALTH & HYGTENE - LISPHASHEP	-	0°u	.0 2	070.3	0°0	د• ٥	0.0
42	HEALTH & HYGTENE - CITH WASH/DRY		۰° ۰°	.0 T	211.6	0	د • د	0°0
44	HEALTH & HYGIEVE - EVER HSTE COL	۲ ۳	۰° ۵۰	c	ر • د	0°0	с. С	0.0
0 7	HEALTH & HYGTENE - CVEN		0°0		416.4	ာ ု ၀	ເ ເ	0.0
47	HEALTH & HYGIEVE - FLOT REFRINGE	-	ں ۔ ں 0.	c	ບ ໍ ເ	51.2	51.2	1624.0
48	HEALTH & HYGTEVE - FROT FREEZER-		0° - 0	0	ι. 6	51.2	51.2	4641.7
		1		i !			8 6 7 9 1	
	TOTALS	9361	4.6 G364.	• 15	318°C	36245.0	36245°0	5.58990

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

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PUELMG EMGINEERING INADES STUCY - (METS)

NC. 1 STARAET SUEET - PLOF & 90.0 DAYS, RESTPELY PEPICL = 90.0 DAYS THCA SPACE STATION ECLES CONFIGURATION 5 "LA" CREW 1 MOTULE 1411111, SUPPLY PERION =

	AND	PALANCE FU	R GASSES	(LE/ÙY)	Р. А. С. Ч. Ч. А. С. Ч. Ч. А. С. Ч. А. С. Ч. А. Ч.				
COMPENSAT RED	TS DXVGFN	NITRCGEN	DARBON DTOXIDE	HYDRUGEN	CC 4D BNSN FE	PCTACLE	4 D G H	BLOVE	HYGIEVE
MCDULE	-14.833	-0.387	17.600	NZA	41.200	-54.080	323.440	35,167	-340,800
COCLING1	0.0000	0.000	0000	C.CUT	00000	0.00	000.0	101°u	0,000
R CCNTRCL 1	0000	0000	0.000	C. COT	00000	000	0.010	000 °0	000.0
COLDFLATES 22	0-0-0	000 0	000.0	0000	0.000	0.000	0,000	00000	000.0
IDITY CONTROL 1	0.000	000 * 0	000.0	000.0	-51.400	000°0	00000	000 0	0.000
1	-9.067	ύΩ υ °ύ	0.00		0.JZ*^.	0,0,0	0.000	00000	006.0
- BOSCH	00000	0.000	-72.8n3	-2.074	0.000	12.662	0,000	000.0	0,010
ANT CONTROL 1	0000	00000	0.000	000°0	0.000	0.00.0	000"0	000.0	0.0.0
- MASS SPECTRNTF- 1	00000	000 0	0.00.0	00000	0.000	00000	00000	000-0	0000"0
ATIC FEEL ELECTR 1	29.115	000*0	0.00.0	3.635	0.000	-32.755	0.000	0.00	0.000
I PRESS FMERG	0000	000°0	00000	000*0	0.00	ບ ບ ບ ບ	00000	10° 1	0.000
H4 DECOMPOSITICH- 1	0.000	C.006	00000	100.0	0.000	0,000	0.000	0,00,0	0.0.0
I PRESS FMERG 1	00000	000.0	0.000	0°00	0.603	0,00,0	0.000	000 0	0.000
CONTROL 1	0000	000 0	0,000	000'0	0.00	000°0	00000	000-0	000.0
IGE - CLOSED LOCP 1	0.000	00000	0.00.0	00000	6000	000.0	0,000	000.0	0.000
1GE - EMERGENCY 15	0-0-0	000 0	0.00.0	0000	0000	000	0,00,0	0.00	0.000
IS - FCTAELE H2C 1	00000	000°i	0.000	00000	0.000	49.315	00000	1.134	0.000
POST+TPEAINENT POT 1	00000	000 0	00000	00000	0,000	000"0	0,000	000 0	0.000
RAGE & PRE-TREAT 1	0.000	0.00	000 • 0	0, 000	0.000	000°0	0000	00000	0,000
AGE	0.0.0	000.0	0.00.0	101.0	0,000	0°00'0	0,000	0000	0.000
TPRAGE	00000	000 0	0.00.0	505.5	0.000	0,060	000000	000.0	0.000
IS - FYGIENE H2C 5	000°0	000-0	0.00	000000	0.00.0	000.0	-323.440	19.405	374.034
- INCINERATION 1	-5.215	C.39E	5.228	000-0	0.000	62,553	0°00	-9°, 650	0.000
POST+IREATVENT HYG 1	0.00	000-0	0.000	1, 100	0.000	000°u	000"0	000"0	0000
ISWIGOLINC	000.0	000 .	00000	000.0	000000	0.000	ÚUO ° O	000"0	0.000
INE - HAND WASH	6.000	000°J	0000	0.00.0	0.00.0	0,000	0.0.0	00000	00000
E4E - HOT H2C SPLY- 1	0.00.0	c•000	000"0	000.0	0.000	0.00.0	0.000	0°000	0.000
ENE - COLE F2C SPLY 1	0,000	r.000	0.005	000.0	0.000	000.0	0.0.0	ເວ້າ.	0.000
ENE - BODY SHCWER J	000000	000°5	0000.0	ບັງບີບ	0.00.0	000.0	0.000	ບານ"ນ	0-0-0
CVE - DISEWASHER 1	0.0.0	r. 000	0.000	0.000	0.000	00000	0.000	300°0	0000
EWE - CLT4 WASH/DRY 1	000 0	6.000	0.00	000.0	0.000	000.0	0.010	100° J	0.090
ENE - EVER WSTE COL 3	0.00	000 0	0000	000 0	0.00	0.00°0	0.000	0,000	0000
ENE - CVEN 1	0000	000 0	0.000	000 0	0.000	unu"0	0.000	60υ° υ	0000
EVE - FOOT REFRIDGE 1	00000	000 0	0.0.0	000-0	0.000	00000	0,010	006-0	0.040
CNE - FOCC FREEZER- 1	0.00.0	000.0	0.000	20202	0.000	u00"u	0.040	r.000	0.000
AGE (CUMULATIVE)	000	510-0-	<u>-</u> 0.019	-c°003	0.000	u00°0	0.0.0	000°u	000.0
	0.000	000.0	0.0.0	C. 205	0.000	~ プロ・マウ	0.010	r.roo	- 16.766

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

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		2 0 4 5 7 7 8 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8				
	SPAC	CE STATION		ECLSS CLUSE	ITDVUT TOOL US	0;:S
L C L C L C L C L C L C L C L C L C L C	ULFS ULFS SIZE 4010.0 F RFFRSGKS 800.0 00.0 C	RESUPPLY FEALOF RESUPPLY FEALOF LIGHTSIDE DAYS DARKSIDF	90.0 DAYS 56.0 HIN 36.0 HIN	002 REFUC	1104 820 RFCTV 1104 820 RFCTV 7104 8454 84 01145 84	1111 1111 1111 1111
SUESYSTEN DAT	A FEP UNIT - 1 PEOULPED	FOR STATICH	,			
POd	ER (HATTS)		AC		50	
		LIGHTSIDE	1263.1		c	
		DARKSIDE Inter'ittent	1253.1 0.U			
HEA	T LOAC - SFNSIELE (8TU'S)		ALF	ALA TEMP	LIGUID	LIGUTO TENF
		LIGHTSIDE DAKKSIDE	1507.6 1507.6	CAPIN AIF CAPIN AIR	2804.5 2804.5 0.0	11 10 4 10 4 11 10 4 11 10 4
		TNJEKWITIENT	0.0		•	
YAY	LOAC	3	EIGHT (185)		VOLUME CET	<u> </u>
		FIXED ON-CREIT	1225.7		95.3	
		LPITIAL SFARES & EXP	172.é		u 1	
		SUPICIAL	1396.3		105.1	
		RESUPPLY SPARES & EX Return to earth	P 96.8 255.2		9	
SUBSYSTER DFS	SIGN CRITERIA					1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
SUBSYSTEN MAS	SE PALANCE CATA PER UNIT	(TB/DAY)				1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Lvx	FERTALS REGUTEED	MATERIALS PRO	D1JCED	<i>T</i> 1	ALERIALS LCST	
, v, ⊼ ₹ X ₹ U	515 målfre 64.703 166m 5.215 166m	PUTAPLE MATER CO2= NITRFGEWE SULFUR DICKID SCLIDS=	1.215			

TABLE 5.2-6 WET OXIDATION/AUX. VPCAR SUBSYSTEM SUMMARY

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EUFING ENGINFERING TOADES SIUDY - (BEIS)

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WETX SPACE STATION ECLES'CONFIGURATION NG. – I SUMMAPY SHET - PAGE 3 в MAN CREM і Module – Initial Supply Perion = 90.0 days, fesupely periol = 93.0 days

				TOTAL WEI	GHT (LB)			TCTAL VGL	UVE (FI3)	
ITEN		UNTTS	FIXED	INTIAL	PESUPPLY	RETURN	FIYED	INTIAL	PESUPPLY	RETURN
	SUBSYSTEM DR COMPONENT	REQ D	LIBAD-NO	SPE+EXP	SPR+EXP	TC EAPTH	LIBHO-40	SPR+EXP	SPA+5XP	TO EARIF
-	HITTHING I DOL HIN - DALA S XH	F	54.4	0.0	0.5	0.5	6°	0.0	0°0	0.0
10	HX & FANS - NDCR CCMTHCL	-	50°0‡	73.0	146.0	146.0	C. Þ	4.0	с " В	9°9
2	HX - ECUIPMENT CCURFLATES	22	261.8	0.0	°.'	0.0	0.1	0.0	0.0	с ° 0
m	PX & FARS - HUMIRITY CONTROL	1	207.6	0.0	0.1	c.1	75.7	0°C	ن• 0	0.0
4	CC2 FEMOVAL - EDC	-	310.8	31.1	د ••	٤.6	14.7	1.5	0.4	0.4
11	CC2 FERUCTION - BOSCH	•1	522.6	360.7	372.5	561 . 5	53,5	55.5	59.5	59.8
13	TRACE CONTANINANT CONTROL	-	176.3	8.64	6°33	88.9	138.0	4 - 6	5 . 9	10°5
14	ATMOSP MCNITOR - MASS SPECTRMIF-	-	77.0	r. r	2.3	2,3	3°2	0.3	ں * ا	0.1
61	C2 SUPPLY - STATIC FEET FLECTR	÷	271.7	166.1	166.1	166.1	6.0	2.6	2.6	2.6
22	C2 STGFAGE - HI PRESS FMERG	-1	1411.4	0.0	42.3	42.3	0° v 6	0.0	2.8	3.8
24	N2 SUPPLY - N2H4 DECOMFOSITION	-	0.0	0.0	ن • ۵	0.0	c° C	0.0	0.0	с . 0
25	N2 STCRAGE - HI FRESS EMERG	•	143.7	0.0	4.3	£.3	10.5	0.0		. O
26	CARIN PRESSURE CONTROL	-	142.6	0.0	2.9	2.9	2.5	0.0	0	0.1
28	PCT. H2C STORAGE - CLOSED LOCP	1	663.7	66.4	10,0	19,9	24.6	2.5	г. С	0.7
29	PCT. H2D STURAGE - EMERGENCY	15	3167.5	0.0	c 0	0.0	101.3	0.0	ی ، د	0.0
69	PEVERSE CSMOSIS - FOTAPLE H2C	•1	260.2	2.6	2.6	2.6	6.2	23.4	25.1	25.1
9 9	PROCESSEE HZO POST-TREATMENT PCT		r.2	0.0	0.0	0.0	0.0	0 0	0	0.0
ЭC	WASTE H2C STORAGE & PRE-IREAT	-	211.0	16.7	91.5	101.0	25.5	0 1	15.0	13.5
11	WASH H2C STORAGE	-	U°66	6.9	0°0	0.6	13.5	1.4	0.4	
74	HYGIENE F20 STORAGE	•	148.5	14.9	4.5	4.5	20.3	2.0	ن ن	0.6
15	REVERSE CSMOSIS - HYGIFNE P2C	ŝ	1644.6	16.2	16.2	16.2	80.7	720.9	778.0	778.8
65	H20 RECUVERY - WET OXICATION	•••	1225.7	172.6	86.A	255.2	95,3	6°3		5.2
76	PROCESSED H20 PUST-IPEATVENT HYG	÷	1.5	0.3	C°3	0.0	с. с	0.0	2°C	0.0
36	H20 GUALITY MOWITCHING	-	60°J	22.5	1.4	1.4	r.4	1.5	c	0 1
37	HEALTH & HYGIENE - HAND WASH		25° n	2.5	0 . 9	0.8	3 . 5	0.3	0.1	0.1
80 M	HEALTH & HYGIENE - HOT HZC SPLY-		22 . P	1.3	0°9	6*0	0 * 8	ũ . 9	0.1	.0
5. M	HEALTH & HYGIENE - COLU F2C SPLY	-	50°U	1.3	9°0	0.6	0.8	0.1	1°•0	0.1
40	HEALTH & HYGTENE - BODY SHOWER	-	105.0	10.5	с; м	3.2	47.3	4.7	1.4	1.4
41	HEALTH & HYGTENE - UTSUMASHER	-	10°02	7.8	2.3	2.3	v° a	0.ê		E 0
42	PEALTH & HYGIENE - CUTP WASH/DPY	-	75.0	7.6	2.3	2.3	R . 4	0.8		0.3
44	HEALTH & HYGIENE - EMER WSTE COL	m	45.A	0.0	с• °	с• о	3.0	0.0	с С	0.0
40	HERLIH & HYGIENE - CVEN	•	4u•0	4.0	1.2	1.2	2.5	0.3	C.1	0.1
47	HEALTH & HYGIENE - FOOT REFRIDGE		141.9	14.2	4°.3	4.3	24.3	2.4	C°0	C.7
48	PEALTH & HYGTEME - FOOD FREEZER-	-1	365.3	38.5	11.6	11.6	E4.1	ч т • СЭ	2.5	2.5
				1						
	TCIALS	:	12104.9	1137.3	1,089.4	1955.0	962.1	650.0	£°±0ъ	6"9'06

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

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POFING ENGINEERING TRADES SINCY - (METS)

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E MAN CREN. 1 MCTULE STATION ECLES'CONFIGURATION NC. 1 SUMMARY SHEFT - PAGE 1 E MAN CREN. 1 MCTULE 14111AL SUPFLY PERION = 90.C CAYS, REGUPPLY PERIOE = 90.9 DAYS

TOTAL ELECTRICAL POWER (*ATTS)

				βC			50	
	ITEW		S	***********				
	×0.	SUBSYSTEM DR COMPANY RED.	D LS	LS	TAT	ts	20	LNT
	-1	HX & FANS - AJF COCUTAG1	611°	611.7	ບ" ບ	0.0	0°0	0.0
	70	HX & FANS - ODCR CONTRCL 1	0.0	0.0	5°0	0.0	с ° с	0.0
	2	HX - EGUIPMEWT CCLOPLATES 22	с ° С	0.0	ະ ເ	0.0	c.°0	0.0
	· ~	HX & FANS - HUMIFITY CONTROL 1	175. n	176.0	0.0	(0	υ " υ	0.0
	4	CO2 PEPOVAL, - EDC	265.9	265.9	ວ ° 0	0.0	с ° 0	0.0
	11	CO2 PERUCTION - POSCH1	196.1	196.1	0.0	130.6	130.8	1377.5
	E I	TRACE CONTAWIMANT CONTREL 1	260.4	260.4	5°0	304.5	304.5	0.0
	4	ATMOSP MOWITOR - MASS SPECTRMIR- 1	0.0	0.0	0°C	0.0	0.0	115.0
	61	02 SUPELY - SIATIC FEED ELECTR 1	156.6	156.6	J 0	5326.0	5326.6	0.0
	22	02 STOFAGE - HI FRESS EVERG 1	د د	0.0	υ - υ	0.0	J.C	15.0
	24	N2 SUPELY - F2H4 DECEMPCSITION 1	c c	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	с ° 0	15.0
	26	CAPIN FRESSUPE CENTREL 1	C°C C	0.0	0°0	30.0	30.0	0.0
	28	POT. HZO STCRAGE - CLOSED LOOP 1	0°0	0.0	ວ ໍ ເ	0.0	0.0	0.0
	29	POT. H20 STORAGE - EVERGENCY 15	0.0	0.0	100.0	U°U	0°0	0.0
	63	REVEPSE DSMCSIS - PCTARLE H2C 1	36.4	36.4	0°C	0.0	6. 0	0.0
	35	PRCCESSED H20 PCT-IFEATMENT PCT 1	0 °0	0.0	0° 0	0.5	0.5	0.0
	30	WASTE F20 STORAGE & PRE-TREAT 1	0°0	0.0	30°08	0.0	0.0	0.0
	71	WASH H20 STGRAGE	u•0	0.0	29.C	0.0	0.0	356.7
	74	HYGIENE H27 STCRAGE	с•с с	0.0	3°°C	0.0	0°0	398,8
(75	REVERSE OSMOSIS - HIGIFRE R2C 5	230.1	230.1	2°0	0.0	0°0	0.0
21	65	H2C RECOVERY - MET CXICATICH 1	1263.1	1263.1	ິບ	0.0	с• С	0.0
Ł	76	PRCCESSED 420 POST-TREATMENT 4YG 1	0°0	0.0	ι. c	3.1	3.1	0.0
G	36	H2C CUPLITY MONITCRIFG 1	د . ت	0.0	0°0	40.0	40.0	0.0
D	37	HEALTH & HYGIEVE - HAND WASH 1	0.0	0.0	100.0	0.0	u•0	15.0
Į,	38	HEALTH & HYGTENE - HOT H20 SPLY- 1	ν°0	0.0	200.0	15.0	15.0	0.0
L. F.	39	HEALTH & HYGTENE - CFLC H2C SPLY 1	0.0	0 . 0	0°0	0"0	0.0	0.0
	40	HEALTA & HYGIENE - ECDY SHOWER- 1	د •ی	0.0	250.55	0.0	0.0	15.0
р	41	HEALTH & HYGIENE - CISPWASHER 1	0°0	0.0	240.0	0.0	0.0	15.0
À	42	HEALTH & HYGIERE - CLTF WASH/DRY 1	ς ° υ	0.0	340,6	0.0	0°0	15.0
G	44	HEALTH & HYGIENE - EVER WSTE CCL 3	ί°υ	0.0	0°0	0.0	د • ٥	0.0
1	46	HEALTH & HYGTENE - CVEN1	0°0	0.0	15.0	0.0	0.0	370.0
	47	PEALTH & HYGTELE - FOUT REFRIDGE 1	с•°0	0.0	ა - ი	15.0	15.0	470.0
rs.	43	HEALTH & HYGIEVE - FOGD FREEZER- 1	0 °0	0.0	ن . ن	15.0	15.1	1360.0
				5 8 8 5 8 8				
		TOTALS	- 3396.3	3356.3	1355.2	5880.4	5580.4	4474.0

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

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PUTING ENGTHEERING TRADES STUDY - (PETS)

METX SPACE STATION ECLAS-COMFIGUPATION NC. I SUMMARY SWEET - PAGE 2 R MAN CHEW I MCTULE INITIAL SUPPLY PEALON = 90.5 CAYS, RESUPPLY DERICU = 90.5 LAYS

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	=	U E #		A18	• • • • • • • • • • • • • • • • • • • •			6 8 9 9 9 8 8 8 8 8 8 8
20.2	SUASYSTEN OR CONFIGENT	50,D3	ΓS		1771 1771			1210-121-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1
-	HX & FAWS - AIR COOLING	-	277053	2770.3		12594.7	12594.7	7414.5
70	HX & FAWS - DOCK CONTRCL	÷	0 ° 0	0.0	C C	0 0		0.0
2	HX - EGUIPHENT CCLPPLATES	22	с•0	0.0	С • с	0.0		0 • • •
rn i	PX & FANS - PUMILITY CONTROL	t	-824.0	- 324.0	υ. 	8578.5	8578 5	0.0
4	COZ PERGVAL - FLC	•	200	5,9,5	`. د		4.61c1	0
	CUZ REEUCTION - FOSCH	-	1232.0	1232.0	4462.7	091.1	691.1	0.0
	TRACE CONTARINANT CONTROL	-	2201.1	2201.1	J • 0	(°))	6 • 0	0
14	AT*CSP MUNITUR - MASS SPECTRMTF-	•1	u" 0	0.0	392.5	0.0	с. с	(·)
- C 0	UZ SUPELY - STATIC FFET ELECTA	••	£07.8	607.8	0°C	11548.1	11548.1	0.0
7	UZ STUPAGE - HI FRESS FRERG+++		ن• ن	0 0	51.2	0.0	د • د	0.0
+ L N 0	NZ SFPFLI = 5284 DECTAFCSITION=+	•	с•°	6°0	2.0	0.0	۰° ۲	0.0
0 v N 1	NZ STURAGE - HI FREES EMERC		°.°	3°0	51.2	0.0	u*0	0.0
0 (N 1	CAPIN PRESSURE CONTROL	-	102.4	102.4	0°C	0.0	с•с	0
20 C	PUT. HZU STURAGE - CLUSED LOCP-+	-	د د	0.0	0°0	0.0	0.0	0.0
5.6	POT. HZC STUPAGE - EMERGENCY	15	د . د	0.0	341.3	0.0	c. 0	0.0
	REVERSE USMCSIS - POTABLE F2C	-1	124.3	124.3	い 0	(°•)	0°0	0.0
ה ה הי	PRUCESSEU HZG POST-TREATMENT PCT	•	1.7	1.7	0°0	0.0	0°0	0.0
	MARTE HZU STURAGE & PRE-TREAT	*"	с ° 0	c•0	102.4	0.0	С° 0	0.0
	#ASH HIO STORAGETTTTTTTTTTTTTTTTTTT	-	6°u	0.0	1285.6	0.0	с . с	0.0
41	HYGIERE HZO STORAGE	- 1	د •م	0.0	1463.5	0.0	с • с	0.0
5	REVERSE OSMOSIS - HYGIEWE H2G	ഹ	785.3	785.3	ن• د	0°0	0.0	0.0
65 1	H2C PECOVERY - WEI CXICATICH	•1	1507.6	1507.5	3.0	2804.5	2,04,5	0 0
16	PRCCESSED H20 POST-TREATWENT HYG		10.4	10.4	ت • ۲	0.0	с•°С	0.0
0 t 7 t	HZC OUALITY MONITCRING	-	136.5	136.5	ن• 0	0.0	0.0	0.0
~ (HEALTH & HYGIENE - HAND WASH	-1	د•0	0.0	392.5	0.0	c • 0	0.0
ກ ເ	HEALTH & HYGIEVE - HOT H20 SPLY-		51.2	51.2	632.6	0.0	0°0	0.0
ი. ე.	HEALTH & HYGIERE - COLU H2C SPLY	-	د •0	0.0	L .	0.0	0°0	0°0'9
0.	HEALTH & HYGIEVE - BICY SHOWER	-1	0°.	0.0	9.14 E	ċ° 0	c° c	0.0
10	HEALTH & HYGIENE - UISFWASPER	-1	د د	0°0	2070.3	0.0	0.0	0.0
	HEALTH & NYGIENE - CITH WASH/DRY	-	ں• 0	0.0	1211.6	0.0	0.0	ن• ن
4	HEALTH & HYGIENE - ENER WSTE CCL	m	0°0	0.0	د ° ر	0.0	0°C	6.9
4 •	HEALTH & HYGJERE - OVEN	-	0.0	0.0	1416.1	0.0	6°0	0.0
4 - 6	HEALTH & HYGIENE - FOOD REFRIDGE	-	с -	0.0	ມ ີ ເ	51.2	51.7	1624.5
P 4	HEALTH & HYGIERE - FCCT FREEZER-	-	υ•υ	0.0	ບ ໍ ເ	51.2	51.2	4011.7
					* * * * *			8 8 9 1 9 1
	TOTALS	;	9216.3	5216.3	14229.9	37932.8	37032.8	14290.7

ORIGINAL PAGE IS OF POOR QUALITY

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

65:43 17-CCT-85

BOEIMG EMGINFERING TRADES SIMDY - (HEIS)

WETX SPACE STATION ECUSS CENTION NO. I SUMMARY SUBET - PAGE 4 F Man CPSW I WORULE IMITAE SUPPLY PERTON = 90.°° DAYS, RESUPPLY PERIOD = 93.0 UAYS

			MASS F.	ALANCE FOR	LASSES	(%4/41)		S RALANCE	FGR %ÅT6	F (LB/FY	
ITE	-	UkITS	DXYGEN	NITECGEN	CARPON	HYCRCGEN	CONDENSATE	PCIABLE	エクマメ	WASTE	HYGTEKE
U X	SUBSYSTER OR COMPONENT	REC'D			DTCXIPE	к у Х	11 200			000000	
•	READER CREW AND SOUCHARTELETE										
-	THE PERSONNEL SOLUTION AND A VE										
2 (THE PERSON AND AND THE A AT	- C C									
4 r	したしたししいは、大学ができると、「「「「「」」というには、「」というに、「」」、「」、「」、「」、「」、「」、「」、「」、「」、「」、「」、「」、「」	7 7									
. .	THE ADVENUE AT TOTADE - ANAL & VE										
":	A CONTRACTOR AND A CONT								000 0	.000	0.00.0
	THE THE TOP AND THE TOP AND THE ADDRESS OF THE TOP ADDRESS OF T	••			000		000	000.0	0.000		0.00.0
	TATACTICS NAME OF CONTROL SOUTH AND ADDRESS OF TATACTICS NAME OF TATACTICS ADDRESS OF TATACTI							000			
# 4	T CHUCHU LULU CHERES - ACCOUNTS -	- •						- 30 - 755			
- 6	THE SERVICE AND ALL THE SERVICES OF THE SERVIC	-1 -	000 3								
7 C	TERULEISUBACUAR DESCRIPTION OF A CONTRACTURE SUBACUAR ANDRES ANDRES ANDRES ANDRES ANDRES AND			000			0.000	00000	0.000	0000	000.0
- 4 - 6		• •			0.000	0000	0.00	00000	000000	00000	00000
9 ° °		• •	000	000-0	0.000	000	0.00.0	0.00	0-0-0	000-0	0000
28	PCT. HOC STERAGE - CLOSED LUCP	4	0000	000	0.000	0.000	0.000	0,00	0.000	0.00	0.00.0
29	PCT_ H20 STORAGE - EMERGENCY	15	0.000	000 0	0.000	0.000	0000	0,000	0.00.0	000.0	0,000
63	I PEVERSE CSMOSIS - FOTAULE H2C	1	0°00	000*0	0.000	000	000	48.316	0.010	3.041	0.000
35	<pre>PROCESSED H20 POST-IREALMENT POT</pre>	1	0.0.0	00000	0.00.0	0.060	(-00-0	0,000	0.000	0.000	0,010
30	HASTE F2C STORAGE & PRF-TREAT	-	0.0.0	000-0	0.000	0000	0.000	0.001	0.0.0	000 0	0.000
71	. WASH H20 STORAGE	-1	000 0	000°0	0.000	000°0	0,000	0,00	0.00.0	000°u	0,000
74	HYGIENE F20 STORAGE	¥1	0.000	000.0	0.000	200-2	0.000	0.00°°0	00000	000°u	0.000
75	REVERSE CSMOSIS - PYGIFNE H2C	ß	00000	00000	00000	000.0	0000	- COU-0	323,440	19.405	304.034
65	H2D RECOVERY - WET CXIDATION	-	-5.215	n.396	5.228	000.0	0.000	62.P3	0-070	099°00-	0.000
76	PROCESSED H20 POST-IPEATMENT HYG	1	0.000	000.00	0.000	000-0	0.0.0	000.0	0000	00000	0.000
ŝ	H20 QUALITY MCNITORING	7	0.000	0.000	0.000	0000	0,000	00000	0000.0	00000	000.0
37	HEALTH & HYGIENE - HANC WASH	-	0.000	000.0	0.0.0	0.000	0.000	0,00,0	0.000	000 0	0.00.0
36	HEALTH & HYGIENE - HOT H2C SPLY-	-1	0.000	000.0	0.000	0,000	000.0	000.0	0,000	00000	0.000
56	HEALTH & HYGTENE - COLT F2C SPLY	•	0.000	0.000	0.00	000.0	0.000	000°-	000°0	0.000	0.00.0
40) HEALTH & HYGIENE - ECCY SHCHER	••••	0.000	000.0	0.00	575°0	0.000				000.0
41	HEALTH & HYGIEVE - DISPARSHEP	-	0.000	100°-1	0.000	000.0	00000		0.000	0°0000	000.0
24	2 HEALTH & HYGIENE - CLTH WASH/JRY		0,00.0	000.0	000.0	000°0	0.00	0 0 0 0 0	0.000	7.007 0.007	000.0
44	PEALTH & HYGIENE - EMER WSTE COL	m	0.000	00000	0.000	0,000	0.000	0,000 0,000	0000.000	0 0 0 0 0 0 0	000.0
10	HEALTH & HYGIENE - CVENHILLE		0.000	0.000	0.00.0	ວງວ ະ ບ	000.0	000°0			
4	/ HEALTH & HIGTENE - FOOT REFRIDCE	-	0000	C 0 0 0	0.000	000°0	0.00		000000		
40	HEALTH & HYGIENE - FOGT FREEZER-	•	0.0.0	000.0	0.000						00000
Ĭ	SURSISTER ULDAGE (COMULATIVE)	_	000		610.0-						
() (°)						1000 1000		40.047	000		
RIGULL PAGE I I POOR QUALIT		: 5.2-10	WET OXID	ATION/AUX.	VPCAR B	CLSS MASS]	BALANCE SUMM	ARY	• • •	•	
s V											

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	10% NG. 1 JOP 10 SC.	ciss Cuesta the substance	CC2 RECUCTION H2C RECOVERV CC2 RECUCTION H2C RECOVERV C2 GENERATION CUNDENSATE URIER		U U	:		0 • 0 0 • 0	R TEAP LIGHID LIGHID TEAP		1.157-07 1.5750 1.1571 1.1571 1.1570 1.1571 1.1570 1.1570 1.1571 1.1571 1.1571 1.1571 1.1571 1.1571 1.1571 1.15	VOLUME (ET3)		1.5	L 3. d	с. с.			HATFRIALS LOST		
GUEING ENGTHERING TAANES SIUDY - (FFIS	ECLSS CCHFIGURAT	CE STATION	FI3 URULT PEALOD 90.0 DAYS FI3 URULT FEALOD 90.0 DAYS LIGFTEIDE 56.0 MIN CAVS UPEKSIDE 36.0 MIN	FDR STÄTIS%	AC		LIGHTSIDE 549.5 Darkstdf fan faa f	INTERVITIENT 830.2) AIR AI	LIGPISIDE 2370-1 CAR	DARYSIDE 2370.1 CAR INTERVITIENT 2370.1 CAR	(SEI) THEIGHT (LES)	FIXED ON-CREIT 396.2	INITIAL SPARES & EXP 94.6	SUPICIAL 495.9	RESUPPLY SPARES & EXP 61.9 Retury to Earth 230.3		(P8/PAY)	MATERIALS PRODUCED	PCTAPLF ¥A→ER= 62.853 CC2= 5.228 NITHCG54= 0.396	
GCI-85 09:45	SYSTER 66 F20 PECOVEFY - S.C.M.C	MISSICN DATASTATA	MODULFS 11 MODULFS SIZE 4010.0 F CREMPERSONS 8 INITIAL SUBFLY PERICO 90.0 D	SUESYSTEM DATA FER UNIT - 1 PEQUIRED	FDWER (WATIE)				HEAT ICAD - SENSIBLE (ATU'S)			PAYLGAD					SUBSYSITM DESIGN CRIIFRIA	SUBSYSTEM MASS PALANCE DATA PER UNIT (I	MATERIALS REGUIRED	×≒STE wÀIER= 64.7∩3 CXYGER= 5.215 S.215	

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TABLE 5.2-11 SUPERCRITICAL WATER OXIDATION SUBSTSTEM SUMMARY

17-CCT-85 C9:45

RCEING ENGINEERING TRADES SINDY - (HEIS)

SCAU SPACE STATICH ECLSS'CCHFIGURAFION AC. I SURWAR' SUEFI - PAGE 3 8 wan crem i wodule – Initial Supriy Pekion = 90.° days, resupply period = 90.0 days

				TCTAL WE	GHT (LB)	1		TCTAL VOL	UME (FT3)	
ITEW		UNITS	FIXED	INITIAL	RESUPPLY	RETURN	FIXED	INITAL	PESJEPLY	PETURN
NO.	SUBSYSTEM OF COMPUNENT	REO T	LIAGO-NO	SPC+EXF	SPR+EXP	TC EAPTH	0%-CPBIT	SPR+EX5	SPR+EYP	TJ ERFIE
	HX & FANS - AIR CCCLING	-	60°9	0.0	0°0	0.6	2.0	0.0	0	
70	HX & FANS - DOR CONTRUL		80°	73.0	146.0	146.0	4.0	4	с (л. (2 0 2 0
2	HX - EQUIPMENT CCLUPLATES	- 22	261.R	0.0	с. с	د• 0	۰. د	0.3	0	0.0
1 11	HX & FANS - HUMIDITY CONTROL	-	207.F	0.0	0.1	0.1	75.7	0.0	с, с,	0.0
4	Cry Rrwgval - EDC	-	310.8	31.1	و. م	6 . 3	14.7	1.5	₹ • ·	4.0
-	CC2 BEFUCTION - BCSCH+++++++++	 !	522.6	360.7	372.5	961.5	53.5	55.5	a. • •	59.8
• •	TRACE CONTANINANT CONTROL		176.3	F8.5	85 . 3	69 ° 8	138.1	а. 4	4 . R	4.3
• •	ATMOSP KONITOR - NASS SPECTANT ¹		77.0	7.7	2.1	2.3	3°2	0.3	. .	0.1
	ny SUPPLY - STATIC FEEL ELFCTR.		271.7	166.1	166.1	160.1	6.0	2.j	2.6	2.6
	TO STOPACE - HI PRESS FRERG+	-	1411.4	0.0	42.3	42.3	94.4	0,0	2° b	2.8
1 C 1 4	NO SUEPLY - N244 DECOMPOSITION		0.0	0.0	0°0	C • 0	0.0	Ū• Ū	د. د	ۍ ٥
, n , v	20 STOPACE - HI PRESS FAFRGe-	-	143.7	0.0	€ * 7	4°3	10.5	0°0	- -	6 • 0
36	CARIN PRESSURE CONTROL		142.6	0°0	2.9	2.5	2.5	3°0	1.0	0.1
. C	PCT. HOC STORAGE - CLOSED LOCP		663.7	F6.4	19.9	19.9	24.f	2.5	C•0	0.7
	PCT HOD STORAGE - EMERGENCY	15	3187.5	0.0	υ. Ο	0.0	101.3	0.0	0.0	0.0
- 14 - 14	REVERSE COMOSIS - FOTAPLE HOF-		260.2	2.5	2.6	2.6	6.2	23.4	25.1	25.1
ה ני הי	PROFESSEE HOO POST-TREETMENT PU	1 1	0°2	0.0	0,0	0°0	0.0	0.0	د. د	0.0
	WASTE HOC STORAGE & PRE-TREAT-		211.0	16.7	91.5	101.0	25.5	1.0	15.0	13.5
	WASH HOD STORAGE		0*65	9°6	. ۳	о • е	13,5	1.4	4.0	*
4 6	HYGIFNE HOD STORAGE		148.5	14.9	5°7	4. Ú	26.3	2.5	0.6	0.6
- F-	REVERSE CSMOSIS - HYGIEVE 42C-	یں . •	1644.6	16.2	16.7	16.2	84.7	720.9	778 8	779.6
999	HOC RECOVERY - S.C.N.O	-	395.2	R9.5	61.9	230.3	11.9	1.5	9° E	2.7
) - 	PRCESSEL HOD PCST-IREATWENT H	۲G 1		0.3	6°0	0.6	د • ن	0.0	с . с	0.0
e	H20 GUALITY MONITCEING	-	6 0 .0	22.5	1.4	1.4	C •		0.0	
37	HEALTH & HYGTENE - HANT KASH		25.0	2.5	0 ° 8	8 ° 0	5. m			•••
38	HEALTH & HYGIENE - HOT H2C SPL	۲- ۲-	22.8	1.3	0	0.9	8 9 C	, .		
39	HEALTH & HYGIENE - COLT H2C SP	LY 1	20°ú	1.3	9°0	9 0 0				
40	HEALTH & HYGIENE - BOCY SHCWER		105.0	10.5	3°5	3.2	47 3		C	t r -
41	HEALTH & HYGIENE - DISPARGHER-		78.0	7.5	2.3	2.3				
42	HEALTH & HYGIENE - CLTP WASHID	F Y 1	78.1	7.8	E.C	2.3	4 - 0	P 0		n 0 5 0
44	HEALTH & BYGIEVE - EMER WATE C	сг Э	45 . 0	0.0	0°0	0.0		0.0		
46	HEALTH & HYGIENE - CVEN		40°U	4.0	1.2	1.2	2*2	. .		
47	HEALTH & HYGTENE - FOOT REFRID	GE 1	141.9	14.2	4°3	4.3	24.3	2.4		
48	HEALTH & HYGIENE - FOOT FREEZE	н- н	385.3	38.5	11.5	11.5	64.1	J.	C • 7	c • 7
				1 1 1 1 1 1 1 1 1						
	TCIALS		11279.0	1054.3	1063.5	1630.1	864.9	841.7	E.COP	90A

TABLE 5.2-12 SUPERCRITICAL WATER OXIDATION ECLSS LOGISTICS SUMMARY

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				101	AL ELECTPIC.	AL EQWER (N	A [75]	
1108	:	1 1 1 1			8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	1 1 1 1 1 1 1 1 1 6 6 7 7	50	8 9 9 9 9 9 9 9 9
	SUBSYSTEN CR CCMPONENT R	10.00 10.00	1.5	ំ ខេត្ត ខេត្ ខេត្ត ទេត ទេត ទេត ទេត ទេ ទេ ទា ទា ទា ទា ទា ទា ទា ទា ទា ទា ទា ទា ទា				191
	HX & FAUS - AIR CONLING	-	67286	822.4	0	0.0	0.0	0.0
10	HX & FANS - ODCR CONTRCL	•1	0 ° 0	0.0	J 0	0.0	0.0	
6	HX - EGUIPMENT CCLOPIATES	22	0°0	0.0	0.0	0.0	0	0.0
m	HX & FANS - HUMICITY CONTROL	•	17.6.0	176.0	ر . د	0.0	0.0	0.0
4	CO2 REVOVAL - EDC	٠	265.9	265.9	ر ن	c c	с С	0.0
11	CO2 REFUCTION - PCSCP		194.1	196.1	ບ ູ ບ	130.9	130.8	1307.5
13	TRACE CONTANINANI CONTROL	•*	260.4	260.4	0	304.5	304.5	0.0
+	ATMOSP MONITOR - MASS SPECTRWTF-	۰	с•с	0.0	ر • ر	0.0	0.0	115.0
61	C2 SUPTLY - STATIC FEED ELFCTH	•	156 . 6	156.5	J.C	5370.5	5326.6	0.0
22	02 STOFAGE - HI PRESS EMERG	-	с•°	0°0	ن• ت	0.0	υ°υ 6	15.0
24	NZ SUPPLY - N2H4 DFCCMPCSITICN	•••	ι°υ	0.0	с. С	0.0	د " 0	0.0
25	N2 STORAGE - HI FRESS ENERG	•••	u • 0	0.0	ເ ເ	0.0	0.0	15.0
26	CAPIN PRESSURE CONTREL	•••	0.0	0.0	ر• ي	30.0	30.0	0.0
28	POT. H20 STURAGE - CLOSED LOCP	•-•	0 ° 4	0.10	ບ ໍ ບ	0.0	с ° с	0.0
29	PUT. H20 STORAGE - EVERGENCY	15	c " 0	0.0	1001	0.0	с ° с	0.0
63	REVERSE OSMOSIS - POTARLE P20	•	36.4	36.4	ິ. ເ	0.0	0°0	0.0
35	PRCCESSED H20 POST-IREAIMENT PUT	•:	0.0	0.0	0.0	0.5	0.5	0.0
30	WASTE H20 STORAGE & FRE-TREAT	••	0°0	0.0	30°C	0.0	о • 0	0.0
11	WASH HZO STORAGE	•	u " 0	C•0	3°°C	0 0	0.0	350.7
74	HYGIENE HZO STCRAGE	٠.	0.0	0.0	30°L	0.0	0.0	399.8
75	REVERSE OSMOSIS - HYCIENE F2C	ŝ	230.1	230.1	."ບ	0.0	c c	0.0
66	H2C RECOVERY = S.C.W.C	•	549.5	549.5	936.7	0-0	с ° г	0-0
76	PRICESSED 420 POST-TREATVENT HYG	•	د د د	υ·0	ບ ໍ ບ	3.1	3.1	0.0
36	H2C CUALITY MONITCRING	-	0°0	0.0	ບ ໍ ບ	40.0	40.0	0.0
37	HEALTH & HYGIERE - HAND WASH		0.0	0.0	102.0	0.0	0.0	15.0
80 - M	HEALTH & HYGIENE - HCT H20 SPLY-	-	c c	0°0	200°C	15.0	15°C	0.0
6 E	HEALTH & HYGIENE - COLD H2D SPLY	. .,	د . 0	0.0	ι. Ο	ú•0	0.0	0.0
40	HEALTH & HYGIERE - BCDY SHCWER++	-	υ • υ	ن• ن	250°C	0.0	0°0	15.0
41	HEALTH & HYGTENE - DISPURSHER	•-	0°0	0.0	246.6	6.0	0.0	15.0
42	HEALTH & HYGIERE - CITH WASH/CPY	••	0°0	0.0	340.0	0.0	0.0	15.0
44	HEALTH & HYGIENE - EVER WSTE CCL	er.	د . 0	0.0	ວ ° ບ	0.0	0.0	0°0
-D 47	HEALTH & HYGIEVE - CVEN		ن• ن ن	0°0	45 ° C	0.0	0.0	370.0
47	HEALTH & HYGIENE - FCCT REFRIDGE	• •'	د • د	0.0	J.0	15.3	15.0	476.0
48	HEALTH & HYGTENE - FOOL FRFEZEF-	-1	ت• ت	c•0	ບ ໍ ດ	15.0	15.9	1360.0
	TCTALS		2753.9	2753.9	2191.4	58×0.4	5880.4	4474.0

PORTUG ENCINEEFING TAADES STUGM - TEFIS) SCVC SPACE STATION ECLESS CONFIGURE. I SUMMARY SHEET -

SCVE STATION ECLES.CCHTEUPATION IN I SUMMARY SPEET - PAGE 1 F MAM CREW I VEEULE INTIAL SUPPLY PEATER = 90.C DAYS, FESTPELY PERTED = 90.0 DAYS

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TABLE 5.2-13 SUPERCRITICAL WATER OXIDATION ECLSS ELECTRICAL POWER SUMMARY

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17-00T-85

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POFING ENGINEERING TAADES SIUCY - (BEIS)

54:60

17-001-85

SCAG SPACE STATION ECLOS-CONFIGURATION NC. I SUMMARY SPEET - PAGE 2 8 Man Crew 1 Mctule - Initial Supply Ferica = 90,0 pays, resupply perica = 90,0 pays

TCTAL SENSIBLE HEAT LOAD (ETU/HR)

				AIR	,		diacij	8 6 8 7 8 8 8
TEP		UNTIS						
×C.	SUBSYSTEM CR COMPONENT	0.03	LS	LS	TNT	L.S	DS	LVI
	HX & FANS - AIF COULING	•••	301345	3013.5	ວ ໍ ບ	13709.4	13700.4	7414.5
70	HX & FANS - ODCR CONTRCL	-	0.0	0.0	ບ ໍ ດ	0.0	0.0	0 0
ы	HX - ECUIPMENT CLUDPLATES	22	0.0	0.0	ບ ໍ ບ	0.0	с• с	0.0
e	HX & FANS - HUMICITY CONTROL	-1	-824 °	-624.0	ບືບ	8578.5	8574.5	0.0
4	CG2 REMOVAL - EDC	Ļ	509.8	509.8	ι. -	1013.4	1613.4	0°0
11	CO2 RECUCTION - ROSCH	-	1232.0	1232.0	4462 . 7	691.1	591.1	0.0
13	TRACE COMTAMINALT CONTROL	-	2261.1	2201.1	υ·,	0.0	0.0	0.0
14	ATMCSP MONITOR - MASS SPECTRMIG-	-	۰° 0	0.0	392.5	0.0	د• د	0.0
61	C2 SUPPLY - STAIIC FEED ELECTR	•	607.9	607.8	د • دا	11548.1	1154R.1	0.0
22	C2 STOFAGE - HI FRESS EFERG		с ° 0	0.0	51.2	0.0	0°0	0.0
24	N2 SUPPLY - N2H4 DECCMPCSITICH	**1	0°0	0.0	C . 1	0.0	ι°υ	0.0
25	N2 STGRAGE - HT FRESS EFERG	-	ບ ໍ ່	0.0	51.2	0.0	0°0	0.0
26	CARIN PRESSURE CONTROL	•	102.4	102.4	ن• ن	0.0	0°0	0.0
28	POT. H20 STORAGE - CLOSEC LCCF	-	ن" ن	0.0	ບີບ	0.0	0°0	0.0
29	PUT. H2D STORAGE - EMERGENCY	15	ن• ن	0.0	341.3	0.0	0.0	د . ٥
63	REVERSE OSMOSIS - POTABLE P20	-	124.3	124.3	υ°0	0.0	u •0	0°0
ŝ	PRCCESSED H20 PCSI-IREAIMENT PCI	•	1.7	1.7	ບ • ຕ	0.0	0°0	0°)
30	WASTE H20 STCRAGE & PRE-IRFAT	4 4	υ°0	0.0	102.4	0.0	u*0	0.0
11	WASH H20 STORAGE	+1	ر• ب ر	0.0	1295.6	0.0	с", с	0.0
14 4	HYGIENE HZO SJCRAGE	-	0.0	0.0	1457.5	ΰ°0	0°0	0.0
75	REVERSE OSMOSIS - HYCIEKE F2C	ur,	785.3	785.3	ر. • د	0°0	u*0	0.0
66	HZC FECOVEPY - S.C.W.G	•-1	2370.1	2370.1	ວ ໍ ດ	539.5	539.5	0.0
76	PRCCESSED H20 POST-IREATWENT HYG	t	10.4	10.4	J * 0	0.0	0.0	0.0
36	H2C CUALITY MONITCPING	-	136.5	136.5	υ°υ	0.0	0.0	0.0
37	HEALTH & HYGIENE - HANC WASH	1	د• ر	0.0	392.5	0.0	0.0	0°0
38	HEALTH & HYGTENE - HCT H20 SPLY-	-	51.2	51.2	632.6	0.0	0°0	0.0
9 0	HEALTH & HYGIEVE - CCLC H2C SPLY	-1	с•• С	0.0	ن" ن	0.0	u"0	600.0
40	HEALTH & HYGIENE - BCDY SHCKER		د • ر	0.0	904.5	0.0	u".	0°0
41	HEALTH & HYGIENE - DISPAASHER	-	0°0	с . Э	2077.3	0.0	0.0	0.0
42	HEALTH & HYGIENE - CITH WASH/DRY	••	د• د	0.0	1211.5	0.0	0°0	0.0
44	HEALTH & HYGTENE - EMER WSTE CCL	~1	c •0	0.0	ບ ໍ ດ	0.0	u"0	0.0
40	HEALTH & HYGIENE - OVEN	-1	0°.	0.0	1416.4	0.0	0.0	0.0
47	HEALTH & HYGIENE - FOCT REFRIDCE	-1	ບັບ	0.0	ບໍ່	51.2	51.2	1624.6
48	HEALTH & HYGIENE - FÜCT FREEZED-	-	с. С	0.0	ວ * ດ	51.2	51.2	4541.7
					0 5 5 6 1 6			* * * * * *
	TOTALS -		10322.1	10322.1	14829.9	36773.5	36773.5	1429G.7

TABILE 5.2-14 SUPERCRITICAL WATER OXIDATION ECLSS HEAT REJECTION SUMMARY

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POELEG ENGIGEEPING TEADES STUDY - (BEIS)

SCHO SFACE STATICH ECLYS'CONFIGURATION NO. I SHAWARY SHEET - PAGE 4 E MAN CREM I WODULE INITIAL SURPLY PERION = 90.0 DAYS, RESUPPLY PERIOD = 90.0 DAYS

			ALANCE FO	8 2455555 111111111	(LE/DY)		S BALANC	E FOF YAT	11797) 33.	-
ITEX NC.	UNITS SUBSYSTEM OF COMFONENT REG'D	OXYGEN	NITACGEN	CAPBCN DTOXIDE	HYTROGEN	CCNDENSATE	PCTALL	* ASH	WASIF	HYGIERE
	BASIC CREW AND MODULE	-14.833	-0.387	17.600	N / D	41.200	-54.080	323.440	38.160	-340.600
-	HX & FANS - AIR COCLING++-+-1	0.0.0	000.0	0.000	000.0	0.050	000"0	0000	000"0	00000
0	HX & FANS - DOOR CONTRCL 1	0.000	00000	0.000	0.000	0.000	0.000	0.000	000°0	0.000
2	HX - EQUIP*ENT CCLCFLATES 22	00000	000.0	0.000	0.000	0.00.0	0.000	0000	000000	0,000
m	HX & FANS - HUMIDITY CONTROL 1	0000	00000	0.000	0.000	-51.400	0.000	0.00	00000	0.000
4	CC2 FEMOVAL - EDC1	-9.067	00000	0.000	-1.360	10.201	000°u	0.0.0	00000	0.000
11	CC2 REDUCTION - BOSCH 1	0.000	000*0	-72.809	-2.074	0-0-0	18.662	0000	0,000	0.000
13	TRACE CONTANINAUT CONTROL 1	0.000	000 0	00000	0.000	0.00	0,000	5-0-0	0,000	000.0
14	ALMOSP MONITOR - MASS SPECTRWIF- 1	0.000	000 0	0.000	0.000	00.0	0.000	0,000	00000	0.050
61	C2 SUPPLY - STATIC FEET ELECTR 1	29.115	00000	0.00	з, 635	0.00	-32,755	0.000	0.000	00000
22	02 STORAGE - HI PRESS EMERG 1	0.000	000-0	0.000	0.000	0.600	0,000	0000	505.0	0.000
24	N2 SUPPLY - N2H4 DECOMPOSITICH-+ 1	0.000	0.006	0.00.0	10.00	0,000	0.000	0.000	000 0	0.000
20	N2 STURAGE - HI PRESS EMERG]	00000	C.000	0.000	00000	0000	000.0	00000	00000	0.000
26	CARIN PRESSURE CONTROL 1	0-0-0	C.00C	0.0.0	00000	0.000	00000	00000	00000	0.000
28	PCT. H20 STORAGE - CLOSET LOCP 1	0.000	000*0	00000	0.000	0.000	C00.0	0000	00000	0.000
29	PCT. H20 STORAGE - EMERGENCY 15	00000	0.000	00000	000-0	0.000	000°0	00000	000"0	0.000
9 9	REVEFSE CSMOSIS - FCTAELE H2C 1	0000	000.0	0.000	000 0	0.000	48,315	0.010	3.584	000000
ŝ	PROCESSEE H20 POST+IREAIMENT PCT 1	00000	000-0	0,006	0,00,0	0.000	000.0	0.000	000°0	0000
30	WASTE H2C STORAGE & PRE-TREAT 1	0.0.0	0.00.0	0.000	00000	0-000	00000	0.000	00000	00000
11	WASH H2C STURAGE	0.000	0.000	0.000	50005	0.000	0.000	000000	000.0	0.000
4	HYGIENE F20 STORAGE 1	0.000	000.0	0000	000-0	0.000	0.1.0	00000	0.000	0.00.0
75	REVERSE CSMOSIS - HYGIENE HZC 5	00000	0.000	00000	ບໍ່ເບີ	0.0.0	000-0	-323.440	1°.406	374.034
50	H2G RECOVERY - S.C.N.C 1	-5.215	n . 396	5.228	ວາວ*ບ	0.000	62 . 53	0.000	ـەں"وين	0.000
16	PROCESSEE P20 POST-TREATMENT HYG 1	0.00	000.0	0.000	000°0	0.00.0	0000"0	040.0	000°0	0.000
36	H20 CUALITY MOWITCRING 1	0.000	000.0	000.0	000°0	00000	0.00	000.0	0.000	0.000
15	HEALTH & HYGIENE - HANT WASH 1	00000	000.0	0.000	000 0	00000	00000	0.000	000.0	0.090
20 (M (HEALTH & HYGIENE - HOT HIC SPLY- 1	0000	000-0	0.000	000.0	00000	00000	000.0	0.00.0	0.010
5	HEALTH & HYGIEVE - COLF F2C SFLY 1	0.00	300° J	0000	000.0	00000	00000	0000	000.0	0.010
4 C	HEALTH & HYGTENE - BOCY SHOKER 1	0.0.0	0,000	0.000	00,00	0.000	0.000	000.0	00000	0.000
4	"EALTH & HYGIENE - JISHWASHER 1	000-0	0.000	000000	000°0	0.000	0.00	0000	600.0	0.000
42	HEALTH & HYGIE'SE - CLTF FASH/DFY 1	0.0.0	, COC	0.0.0	000.0	00000	000.0	0.000	0.00	0.000
4	HEALTH & HYGTENE - EMER NSTE COL 3	00000	c.noo	0.000	000.0	0.000	000.0	010.0	c.00n	00000
40	HEALTH & HYGTENE - CVEN 1	0000	000 0	0.00.0	000 0	0000	000.0	0.000	000.0	0.000
47	HEALTH & HYGIENE - FOCT REFRIDGE 1	0.0.0	000.0	000.0	202 2	000*0	000.0	0.000	0000	000.0
48	HEALTH & HYGIENE - FOOT FREEZER- 1	0.00.0	000000	0.000	0,00,0	0.0.0	0.000	0.000	00010	0.000
	SUESYSTER ULLAGE (CUMULATIVE)	C 0 0 0	-0.015	-0.019	-0.002	0.00.0	u, ni n	050.0	00000	0.000
		1								****
	ICIALS	0.000	000000	0.000	0.205	0.00	42.997	0000	000 0	-36.766

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TABLE 5.2-15 SUPERCRITICAL WATER OXIDATION ECLSS MASS BALANCE SUMMARY

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PORENTER PLATE FROM ON ONE CONTRACTOR FROM THE FROM ON ONE CONTRACTOR FROM THE FROM ONE CONTRACTOR FROM THE FROM ONE CONSTRATE FROM ONE CONSTRATE FROM ONE CONSTRATE FROM ONE CONSTRATE TO THE FROM ONE	MISSICN	рата	SPACE STAT	1 C.N		ECISS CLOSE	UILONNA GUIC		
SUBSYSTER DATA FED TWIT - 1 REDURED FOR STATICK POWER (WATES) FOWER (FOWER (FOWER) FOWER (FOWER (FOWER) FOWER (FOWER (FOWER) FOWER (FOWER (FOWER) FOWER (FOWER (FOWER (FOWER) FOWER (FOWER (HODULFS HODULFS CREWPEASONS CREWPEASONS Luitia	1 1010.0 FT3 4010.0 FT3 ERICD 90.0 LAYS	RESUFELY PEDIOD CRBTY CRBTY CRBTY CRBTY CRBTY CRBTOE	90.0 DAYS 56.0 ATA 36.0 ATA			50 ar 1 >> 1+5 1+5 1-5 1 - 2* 2* 1-1	
PMER (WATES) PMER (WATES) LIGHTSTEE (574'5) HEAT ICAD - SFASIBLE (574'5) LIGHTSTEE 31:5 LIGHTSTEE 45:5 LIGHTSTEE	SUPSYSTE	- TIN'I SEA M	1 REPUTRED FOR ST	AT ICK					
LIGWISTE DARKSID TATEWITTEN 0.0 HEAT ICAD - SFNSIBLE (BTU'S) HEAT ICAD - SFNSIBLE (BTU'S) LICUTSITE DARKSID DARKSID TICUTSITE PAYLOAD PAYLOAD HEAT ICAD - SFNSIBLE (BTU'S) LICUTSITE PAYLOAD PAYLOAD HEAT ICAD - SFNSIBLE (BTU'S) LICUTSITE DARKSID		POWER (VATIS)			50		25		
HEAT ICAD - SFNSIELE (BTU'S) HEAT ICAD - SFNSIELE (TOS) HEAT ICAD - SFNSIELE					:				
HEAT ICAC - SFASTBLE (BTU'S) 1.5 0.0 0.0 HEAT ICAC - SFASTBLE (BTU'S) INTERMITTENT 0.0 0.0 HEAT ICAC - SFASTBLE (BTU'S) INTERMITTENT 0.0 0.0 HALCAC STASTBLE (BTU'S) INTERMITTENT 0.0 0.0 PAYLCAC Stastster 36.6 CANIW AIP 0.0 PAYLCAC Stastster 36.6 CANIW AIP 0.0 PAYLCAC VALCAC VELICAT 0.0 0.045 F PAYLCAC VALCAC VELICAC 0.0 0.045 F PAYLCAC VALCAC VALCAC 0.0 0.045 F PAYLCAC VALCAC VALCAC VALCAC 0.0 PAYLCAC VALCAC VALCAC VALCAC <td< td=""><td></td><td></td><td>1911</td><td>JUL STOR</td><td></td><td></td><td>0.0 •••</td><td></td><td></td></td<>			1911	JUL STOR			0.0 •••		
HEAT ICAD - SFASIBLE (BTU'S) HEAT ICAD - SFASIBLE (BTU'S) LIGHTSTFE DARKSTDE DARKS				SIDF Smittfut	51•0 0•0		, c , c , c		
LIGUTSTE DARKIDE DARKIDE DARKIDE DARKIDE DARKIDE DARKIDE DARKIDE DARKIDE DARKIDE DARKIDE DARKIDE DARKIDE FIXED DARCHTE BARKIDE FIXED DARCHTERIA SUBSYSTEM DESIGN CHIERIA ASS DALATE DARCHTERIA ASS DALATERIA ASS DALATE DARCHTERIA ASS DALATERIA ASS DALATE DARCHTERIA ASS DALATERIA ASS DALATE DARCHTERIA ASS DALATERIA ASS DALATE		0577 1087 - SENS	1015 (00,100)		ATC	110 TEVO	1111111	arga nitoti	
LIGUTSIFE 38.5 CAPLA MP 0.0 0.0 0.0 PAYLCAD INTENTIFAT 0.0 0.0 0.0 0.0 PAYLCAD VEICHT (185) VEICHT (185) VCLUME (FT3) 0.0 FIXFD DWCEDIT 10.5 110.5 10.5 0.0 FIXFD DWCFIEL 50.6 CAPLA MID 0.0 0.045 F FIXFD DWCFIEL 10.5 10.5 0.0 0.045 F FIXFD DWCFIEL 10.5 10.5 0.0 0.045 F SUBSYSTEM DESIGN CHITERIA 122.8 455.9 0.4 0.7 SUBSYSTEM DESIGN CHITERIA 10.5 2.3 0.4 0.7 SUBSYSTEM DESIGN CHITERIA 172.8 2.5 0.4 0.7 SUBSYSTEM DESIGN CHITERIA 10.7 122.8 0.4 0.7 SUBSYSTEM DESIGN CHITERIA 10.7 122.8 0.4 0.7 SUBSYSTEM DESIGN CHITERIA 10.7 122.8 0.4 0.4 SUBSYSTEM DESIGN CHITERIA 10.7 0.7 0.4 0.4 SUBSYSTEM DESIGN CHITERIA 0.12.9 0.4 0.4 <td></td> <td></td> <td></td> <td></td> <td>r </td> <td></td> <td></td> <td></td> <td></td>					r				
PAYLGAD			1.164	ITSIFE	2	ala wlaw	c"c	10-45 F	
PAYLGAD IMTERVITTENT 0.0 0.0 0.0 PAYLGAD FIXED DN-CREIT VELGMT (185) VCLUME (F73) FIXED DN-CREIT 170.5 FIXED DN-CREIT VCLUME (F73) FIXED DN-CREIT 170.5 FIXED DN-CREIT VCLUME (F73) SUBSYSTEM DESIGN CRITERIA 172.8 FESUPERT 45.5 0.7 SUBSYSTEM DESIGN CRITERIA 172.8 CRITERIA 0.0 SUBSYSTEM DESIGN CRITERIA 10.52.8 2.3 0.4 SUBSYSTEM DESIGN CRITERIA 10.74V)				STDF		alv widt	c	4.)-45 F	
PAYLGAD VEIGAT (183) VCLUME (FT3) FIXED DW-CREIT 110.5 VCLUME (FT3) FIXED DW-CREIT 110.5 6.5 FIXED DW-CREIT 17.3 0.7 SUBSYSTEM PESIGN CMITERIA 17.3 7.3 SUBSYSTEM PESIGN CMITERIA 17.2.8 6.5 SUBSYSTEM PESIGN CMITERIA 17.2.8 7.3 SUBSYSTEM PESIGN CMITERIA 455.5 2.3 SUBSYSTEM PESIGN CMITERIA 455.5 2.3 SUBSYSTEM PESIGN CMITERIA 455.5 2.3 SUBSYSTEM PESIGN CHITERIAL 455.5 2.3 SUBSYSTEM PESIGN CMITERIAL 2.5.5 2.3 SUBSYSTEM PESIGN CMITERIAL 455.5 2.3 SUBSYSTEM PESIGN CMITERIAL 2.5.5 3.4 SUBJAN 2.5.5 <td></td> <td></td> <td>LWI</td> <td>TEATTAR</td> <td>0.0</td> <td></td> <td></td> <td></td> <td></td>			LWI	TEATTAR	0.0				
FIXED DW-CRBIT INITIAL SPARES & EXP 12.3 SUPTCTAL 122.8 AESUPELY SPARES & EXP 12.3 AESUPELY SPARES & EXP 13.3 AESUPELY SPARES & EXP 13.3		PAYLCAD			(SEI) 180		VCLUME (FT3)		
SUBSYGTEM PESIGN FER ATT 12.3 SUBTCTAL 172.8 RESUPELY SPARES & EXP 12.3 RESUPELY SPARES & EXP 22.5 RETURN TU EARTH 455.9 RETURN TU EARTH 455.9 SUBSYSTEM PASS PALAMCE TATA PER JUNIT (LA/LAY)									
SUBSYGTEM DESIGN CRITERIA SUBSYGTEM DESIGN CRITERIA SUBSYGTEM PASS PALANCE CATA PER UNIT (LA/LAY) SUBSYGTEM PASS PALANCE CATA PER UNIT (LA/LAY) MATERIALS PRODUCED MATERIALS PRODUCED			F 1 X F	TIAT CLARES L TVD	110°5		(F - 		
SUBSYSTEM DESIGN CRITERIA 1/2.8 7.3 RESUPPLY SPARES & EXP 22.5 2.3 RETURM TU EARTH 455.5 2.3 SUBSYSTEM DESIGN CRITERIA 455.5 2.3 SUBSYSTEM PASS PALANCE CATA PER JWIT (LAJITAY) 455.5 2.3 SUBSYSTEM PASS PALANCE CATA PER JWIT (LAJITAY) 455.5 2.3 SUBSYSTEM PASS PALANCE CATA PER JWIT (LAJITAY) 455.5 2.3 InPUT ATER = 62.963 MATERIALS PRODUCED MATERIALS LOSS									
RESUPELY SPARES & EXP 22.5 2.3 RETURN TU EARTH 465.5 9.4 SUBSYSTEM DESIGN CRITERIA				SUPTCIAL	172.8		7.3		
SUBSYSTEM DESIGN CRITERIA			REST	IPFLY SPARES & EXP	22.5		2.3		
SUBSYSTEM DESIGN CRITERIA			11. JAN	RN TU EARTH	455.5		0 · 7		
SUBSYSTEM MASS PALANCE CATA PER UNIT (LA/LAY)	3 I SY SBUS	EM DESIGN CRITERIA-	F 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	, , , , , , , , , , , , , , , , , , ,		4 F L P F F F F F F			
HATEHIALS REGUIRED HATERIALS PRODUCED AATERIALS LOST 	SUBEYETE	EM MASS PALANCE DAT	A PER UNIT (LR/FAY				L 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	
INPUT #AIER = 62.963 PRICESED WATER = 58.037 VCF PRICE - 4.928		WATERIALS REGULE	Ē	MATERIALS PRODU	JCE J	4 F.	TERIALS LOST		
	O	INPUT ATER E	2.963	PRICESSED NATES	2 = 58.037 4.92b	8			

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TABLE 5.2-16 VAPOR COMPRESSION DISTILLATION SUBSYSTEM SUMMARY

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			TCTAL WEI	GậT (15)			15TAL VCL		
	ITS F	IXED	INTTAL	DESUPPLY	PETURI	L B X E J	INTTAL	PESUPPLY	RETURN
I HX 6. FENS 1 FLA COCLETCIAL	- 20 0 5	CREIT 49.3	SFR+EXE 0.0	528+535 0.5	TC EARTH 0.5	ON-CRETT 1.6	566+510 0-0	6.53 + 6 × 5	15 EAFTS 0.0
70 HX & FAMS - NDOR CONTRIL		80°0	73.0	146.0	145.0	6 4	4.7	с. р.	- 0
2 HX - EQUIPMENT COURPLATES 2	2 2	261 . 8 ^{.3}	0.0	د. ت	0.0		0.0	ι. 0	0.0
3 MX & FANS - HUMIDITY CONTRCL	•	19P.4	0.0	۔ ن	0.1	17.3	0.0	с . с	0.0
4 CG2 REMOVAL - EDC	-	25.45	25.1	7.5	7.5	12.2	1.2	∿ • د	0.4
11 CC2 REPUCTION - POSCH	•·	522.K	360.7	372.5	961.5	53.5	55.5	59°e	59.5
13 TRACE CONTAMINANT CONTROL	Ŧ	176.3	8.°85	a • a 8	в ж. 8	13°,0	£• ;	۲ ۰ ۲	с. 4
14 AIMOSP MENITOR - MAGS SPECIRVIP-	•	77.0	7.7	2.3	2.3	5°*	0.3	-	0.1
61 C2 SUPPLY - STATIC FEER ELECTR	•	23°0	174.5	124.5	124.5	5.02	1.9		1.9
22 02 STORAGE - HI PRESS EMERG	1	J68.4	0.0	37.1	32.1	71.3	0.0	2.1	2.1
24 N2 SUPPLY - N244 DECOMPOSITION	Ŧ	0.2	0.0	с ° С	υ • 0	د. ت	0.0	0°0	0.0
25 NZ STORAGE - HI PRESS FRERG	ţ	161.9	0.0	4°0	4 3	11.9	0.0	F ° 0	0.4
26 CABIN PRESSURE CONTROL	-	1.42.6	0.0	5°2	2.9	· ۵° ک	0.0	۰ .	0.1
28 PCT. H2C STOPAGE - CLOSET LOFP	Ŧ	563.7	66.4	10.0	19.3	24.5	2.5	0.7	0.7
29 PCT. H20 STURAGE - EMERGEACY 1	14 29	175.0	0.0	J°0	0.0	94.5	0.0	с ° с	0.0
63 REVERSE CSMOSIS - ECTARLE E26	-	249.4	2.5	2.5	2.5	۴.1	22.3	24.0	24.0
35 PROCESSED H20 POST-TREDTMENT PCT	•	د م د	0.0	0.0	0.0	د • ک	0.0	د د	0.0
30 WASTE F2C STORAGE & PRE-TREAT	•	0.115	16.7	91.5	101.0	25.5	1.0	15.0	13.5
71 WASH H20 STORAGE	•	0 ° 0	6°6	3.1	3.0	12.5	1.4	0.4	0°+
74 HYGIENE F20 STORAGE	-	1.0.0	14.9	4.5	4.5	20.3	2.0	5°2	0.6
75 REVERSE CSMOSIS - HIGIENE F2C	5 16	544.6	16.2	16.2	16.2	8°.7	720.9	8°011	778.3
34 H2G RECOVERY - VCD	•	110.5	12.3	22.5	465.8	£*\$	0.7	2.3	9 . 4
76 PROCESSED M20 POST-IREATMENT HYG	Ŧ	1.5	0.3	0°3	0.0	د. د	0.0	ن • ت	0.0
36 H2C CUALITY MONITORIMG	۴	°.'9	22.5	1.4	1.4	ت • ت	1.5	• •	0.1
37 HEALTH & HYGIENE - HAND WASH		25.0	2.5	ь - 0	6 °9	ы:• г	0.3	0.1	0.1
38 HEALTH & HYGIENE - HÖT HZO SPLY-	1	22.8	1.3	0.9	6.0	в°0	0.9	• • ¢	0.1
39 HEALTH & HYGTENE - COLT 42C SPLY	-	20.0	1.3	υ - κ	0.6	9. C	0.1	0 . 1	0.1
40 HEALTH & HYGTENE - BOLY SHOWER	1	105.0	10.5	3.2	3.2	47.3	4.7	1.4	1.4
41 HEALTH & HYGIENE - LISPWASPER	•	74.O	7.8	2 . 3	2.3	5.4	8°0	6 .0	0.3
42 PEALTH & HYGTENE - CLTE WASH/DPY	*1	79.0	7.8	2.3	2.3	τ.	9.6	6 0	0•3
43 HEALTH & NYGTENE - COMMONE/URING	4	591 . F	0.0	591 . 5	853 . 2	74.0	0.0	74.0	74.0
44 HEALTH & HYGIERE - EMER WSTE COL	m	45.0	0.0	с с	0.0	с•м	0.0	0°0	0.0
45 HEALTH & HYGIENE - JPASH COMPACT	ł	40.0	4.0	1.2	750.0	۰ °۲	C.4	۳ . ۲	6°°6
46 HEALTH & HYGIE ^N E - CVEN	•	ひ * ひ *	4.0	1.2	1.2	2.5	0°.3	0.1	0.1
47 HEALTH & HYGTENE - FOOT REFRIDGE	-	141.0	14.2	د . ۲	4.3	24.3	2.4	۲ • 0	C.7
48 PEALTH & HYGIENE - FOOT FREEZER-	•	385.3	36.5	11°5	11.6	₽4 . †	ເ ຕັ	2.5	2.5
	:]	9 5 3 1 1	
TCIALS	110	147 . 0	933.3	1563.5	3655,5	925° n	339.4	c 10° 1	1078.5

POSITG STREEPING TRADES SILLY - (LETS)

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SFACE STATION ECLSS CONFIGURATION WILL - 2 SUMMARY SUBER - PAGE 3 TATTAL SUBDLY DESTON ± 30.0 PAYS, SEATONEY FROID -VCr 1 VDrULE

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TABLE 5.2-17 VAPOR COMPRESSION DISTILIATION ECLSS LOGISTICS SUMMARY

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ROEING ENGINEERING TRADES STUDY - (LETS)

96.0 DAYS STATICA ECLSS COMPICURATION 40. 2 544 VAPY SVEFT - PAGE 1 INITIAL SURPLY PERION = 90.0 CAVS, RESUPPLY PERIOU = SPACE VCC 1 MCCULE MAN CREW

TABLE 5.2-18 VAPOR COMPRESSION DISTILLATION ECLSS ELECTRICAL POWER SUMMARY

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CEING EVALUEERING TEADES SINDY - (PUTS)

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SPACE STATION ECLSS CONFIGURATION NG. 2 SUNMAPY SHEET - PAGE 2 Imilial Supply Perton = 90.° Cave, pesupply period = 90.0 Days VCC F MAN CREW 1 WOLUTE

ITIAL SENSIOLE HEAT LEAD (ETU/HP)

	:			AJR			GINDIT	
	SUBSYSTEM OR COMPUNENT P	50,03						
1	HX & FANS - AIR COLING	-	2391.1	7351.1	0.0	10870.9	16570.9	8579.3
70	HX & FANS - ODOR CONTROL	F	0:0	0.0	с с	0.0		0 0
2	HX - ECUIPMENT CCLEPLATES	22	0°0	0.0	0.0	0.0	0.0	0 0
m	HX & FANS - HUMIDITY CONTROL	-1	-798.1	-798.1	ມູ ້ ເ	F158.9	6180.9	0.0
4	CO2 RE#OVAL - EDC	7	424.3	424.3	ر• د	1275.4	1275.4	0.0
11	CO2 REDUCTION - POSCH	-	1232.0	1232."	4462.7	691.1	£91.1	0 0
13	TRACE CONTAMINANT CONTREL	-	2701.1	2201.1	ر. د	0.0	د • د	0.3
14	AT*CSP MONITOR - MASS SPECTRWIR-	-	6 0	0.0	392 . 5	0.0	с . с	0.0
61	C2 SUPPLY - STAIIC FEET ELFCTR	•	447.0	447.9	с` * с	P510.7	5510.7	0.0
22	C2 STCFAGE - HI FRESS FRERG	•	0.0	0.0	51.7	C•0	د • د	0.0
24	M2 SUPPLY - M244 DECCMPOSITION	1	~. -	1.3	49.2	0.0	ú°c	0.0
25	N2 STORAGE - HI FRESS FRERGE	-	د د	0.0	51.7	0.0	c° c	0.0
26	CAPIN PRESSURE CONTRILETER	-	102.4	102.4	0°C	0.0	0°0	0.0
28	POT. H20 STORAGE - CLOSED LOOP	•-1	د •	0.0	0°C	0.0	0°0	0.0
29	POT. H20 STORAGE - EVERGENCY	14	c•0	0.0	319.5	0°0	د• ن	0.0
63	PEVERSE OSMOSIS - POTARLE W2G	••1	119.6	118.6	5°0	0.0	0°0	0°0
35	PRCCESSED H20 FOST-TREATWENT PCT	-	1.F	1.5	ວ ° ເ	ú•o	c°c	0.0
0	WASTE H20 STORAGE & FRE-TREAT	4	د ، د	0.0	107.4	0.0	0.0	0.0
11	WASH H20 STORAGE	1	c•0	0.0	1285.£	0.0	ù°0	0.0
74	HYGIENE 420 STORAGE	•1	د د	0.0	1463.5	0.0	د د	0.0
75	REVERSE DSMOSIS - HYCIENE #20	ŝ	765.3	785.3	с " С	0.0	υ°υ 0	0.0
9 F	H2C RECOVERY - VCD	-	366.2	396.8	ບ ໍ ດ	0.0	c° c	0.0
76	PRCCESSED H2D FOST-IREATMENT HYG	-	10.4	10.4	J * 0	0.0	د • د	0.0
36	H2C OUALITY MONITCRING	-	136.5	136.5	ن • د	0.0	с. с	0.0
37	HEALTH & HYGIENE - HANT WASH	-	0°0	0.0	392.5	0.0	ς ° υ	0,0
9 6	HEALTH & HYGIENE - HUT H20 SPLY-	-	51.2	51.2	682 . F	0.0	с ° 0	0.0
6)	HEALTH & HYGTENE - CCLC H2C SPLY	-	с- с	0.0	о • с	0°0	0°0	0°0u9
40	HEALTH & HYGTENE - BRDY SHCHER		u•5	e.o	904 . 5	C•0	¢.	0°C
41	HEALTH & HYGIENE - DISH#ASHER	-	د • ن	0.0	2070.3	с° О	د. د	0°0
42	PEALTH & HYGIEVE - CLTH MASH/DPY	-	د•ی	· • 0	1711.6	0.0	د. د	0
43	HEALTH & HYGIENE - CCMMCPE/URINL	۳	· • 0	0.0	1943 . 7	0°0	0°0	0°0
4	HEALTH & MYGIERE - EVER WSTE CCL	m	υ°υ	0.0	5.6	0.0	د. د	0.0
45	HEALTH & HYGIEVE - TCASH CCHPACT	•••	0.0	0.0	460.8	0.0	د • 0	0°0
4 6	PEALTH & HVGT2ME - OVEN	-1	ن• ن	0.0	1416.4	G • O	0°0	0°0
47	HEALTH & HYGIEVE - FCOT REFRIDGE	-	د د	0.0	J. * 0	51.2	51.2	1024.5
8 ₽	HEALTH & HYGIENE - FOOD FREEZER-	- I	د د	0°0	ວ ໍ ວ	51.2	51.2	4041.7
	TDTALS		7492.6	7392.6	17158.6	29639.4	29633.4	15445.6

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TABLE 5.2-19 VAPOR COMPRESSION DISTILLATION ECLSS HEAT REJECTION SUMMARY

17-CCI-85 r9:49

PUELVG EVULVEELVG TAADES SINCY - (AFIS)

VCT SPACE STATION ECLES CONFIGURATION DD. - 2 SUMPARY SUEET - PAGE A E van Crei 1 moeule – Iutital Supply Peaton = 90,0 tang, resupply peaton = 90,0 days

			MASS BI	ALANCE FOR	A GASSES	[[B/DY]	2 V W	SS PATANC	5 POR WAT	EF (LF/F))
ITE"		TS	UXYGEN	L'EDGELI		HYERCGEN	CENTENSATE	PrTALLE	HZH	KAS15	HYGIEVE
P.O.4	SUBSYSTEM OF COMPONENT RE	0,0			DIAXIDE						
	BASIC CREW AND MCUTLE		-14.833	-0.387	1.600	N / A	41.200	-54°C80	373.410	39,160	-349.800
-1	HX & FANS - AIR COCLING	•	0.000	000-0	0-0-0	c.00r	0.00.0	0,000	0.000	000.0	0000
70	PX & FANS - DDDR CCNTRCL	•-1	Guố *0	0.000	0.00.0	0.000	000.0	u00°u	0.0.0	0,000	0000
N	HX - EQUIPMENT COLIPLATES	~	0000	000.0	0,00,0	500°u	0.000	000°u	0.000	ບົບ ບົບ	000*0
m	"X & FANS - HUMIDITY CONTROL	1	00000	100°	0.00.0	5.00	-19.065	0,00	0.000	J00°-J	0.000
4	CC2 PEWOVAL - EDC	•	-6.991	ບົບບີ້ບ	0.000	-1.049	7.865	0°0°u	000.0	000°u	0.00.0
11	CC2 PERUCIIO4 - BOSCH		0.000	30°°°	-17.582	⊷1.59¤	0.00	14,335	0.000	600.0	0.00.0
13	TRACE CONTANIMANI CONTROL	1	0.000	060°0	0.000	0,000	0,000	000.0	046 0	000°J	0,000
14	AJMOSP MCNITOR - MASS SPECTRATE-	•	0 0 0	000°0	0,000	100-1	0.00.0	100° ° C	00000	000.0	0,000
61	C2 SUPPLY - STATIC FEET ELECTR	• ••	21.925	ບິບີບີບ	0.0.0	2.729	0,000	-24,553	0.000	000°0	0.000
22	C2 SICPACE - HI PRESS FWERG	•1	000000	JÜC'J	0.00.0	C.000	0.00.0	000.0	0-0-0	ບໍ່ກີບໍ່ ບ	0.250
24	N2 SUPPLY - V2H4 DECOMPOSITICM	•	0.000	0.400	0.000	0. 952	0.00	v0u"u	0000.0	0.000	00000
25	N2 STGRAGE - HI PRESS EMERG		0,000	000"0	0.000	000°0	000.0	0°0°0	0,010	Unu".	00000
26	CABIN PRESSURE CONTROL	•	0000	00000	0.000	0.000	0.00	00 υ °ύ	0.000	00010	0,000
28	PCI. H20 STORAGE - CLOSED LUCP	•	0000	560° J	0.000	100°0	0,000	000.0	0,0,0	· 66° ·	0.000
29	PCT. H20 STORAGE - EMERGENCY	4	0.000	0.00	0.0.0	000° J	0,000	u00°0	0.000	600.0	0.00.0
63	REVERSE ČSMOSIS = FOTAPLE H2C	FI	00000	000.0	0.000	000°0	000 0	46.121	0.000	2.944	000000
ы С	PROCESSED H2D POST-IPEATVENT POT	F	0.000	00000	0.000	000000	000	00000	0.0.0	000000	000.0
30	WASTE P2C STORAGE & PRF-TREAT	-	0.000	r.00r	0000	000°0	0,00	000° 0	000	000"0	0.000
71	WASH H20 STORAGE	1	0.000	000°0	0000	3,900	0.0.0	00000	0.000	00000	0°0'0
74	PIGIENE F20 STOFAGF	Ŧ	0.000	000°6	0.000	100°J	0.00	0°0°0	0.0.0	000"0	00000
75	REVERSE CSMOSIS - HYGIFHE H2C	S	0000	000 0	0.0.0	00000	0,000	· ucu • o	-323.440	19.405	304.034
ы 4	ндо кесоvечу - VCD		000.0	r.000	0.000	C.00r	0.00	59°037	00000	-60.510	00000
76	PACCESSED HZO POST-IPEALVERT HYG	•••	0.000	000000	0.000	ບົດບີ	0.000	000.0	0000	000 0	0.000
Зó	P2C CUALITY MONITOFING	*1	0000	JŪŪ°J	0.000	ບົບບໍ່	0.000	000.0	0.000	00000	126 0
37	HEALTH & HYGTENE - HAND WASH	Ŧ	0000	000.0	0.000	000°0	0.00	000.0	0.000	0.000	0 000
38 9	HEALTH & HYGTENE - HOT H2C SFLY-	1	0,000	000.0	0.000	0°0°0	0.000	00.°0	000 0	00 0° 0	0.000
6 E	HEALTH & HYGIENE - COLD F2C SPLY	•	0.000	000-0	0.000	500.5	0.00	u0u°u	0.000	000.0	0.000
40	HEALTH & HYGTENE - BODY SHCKER	F	0-0-0	.00°.	0.000	ບຽວ"ບ	0.000	, , , , ,	000.0	005.0	0.000
41	HEALTH & HYGIERE - DISPWASHED	•	0.000	v ° v 0 v	0.000	ບ່ວວ້.	0.000	000°ů	0.0.0	000 ° 0	0.000
42	HEALTH & HYGTEVE - CLT ^U WASH/DRY	•••	0000	00000	000	000.0	0.000	000°u	00000	000°0	0.000
43	PEALTH & HYGTENE - COMPOTE/UFINL	T	0.000	u00"u	0.000	0.000	0,010	00000	000 0	000°u	ີ່ດີ
44	PEALTH & HYGTENE - EVER WSTE COL	m	0.000	000.0	0.000	JO4 J	0.000	u0u*5	0.0.0	000.0	0000
4 5	HEALTH & HYGIENE - IRASH CCAPACT	1	ÚUQ 0	000.0	0000-0	0.000	0.00	000.0	000"0	0000	0.000
4 Ú	HEALTH & HYGIENE - OVEN	•	0.010	000"0	00000	0000	0 0 000	unu"u	000 000	00000	0.350
Lÿ	HEALTH & HYGTEVE - FOOD REFRIDGE	ŗ	0.000	660.0	0000	ເດເຈັ	0.00	000°0	0.000	0.00	0-0-0
4 3	HEALTH & HYGTENE - FOCT FREEZER-	-1	0.000	366°3	000°ú	000"0	0.0.0	ເດີດ "ບ	0.020	100° J	00000
	SURSYSTE* ULLAGE (CUMULATIVE)		0.000	÷[0"0-	-0°013	-C.DCR	000000	000.0	0.000	i,000	00000
	TĈTALS	;	0000	u00"u	00000	0.125	0000	3°.c11	0.000	000 °u	-36.766

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TABLE 5.2-20 VAPOR COMPRESSION DISTILLATION ECLSS MASS BALANCE SUMMARY

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24-001-85 r7:34	.) a	Cheat of the track for the sub-) - 1115 -	. ۹ ۲۰۰۶ ا		
SUPSYSTEM 33 420 8	Erculty - Threshow	ω .	ULSS CLAFIG	เ •ียะ กอโมะส		TIT IL TIT
AU NICOLA		8 T 9 4 6 7 4 8 9 4 9 4				
	3045 8047 8047 8047 8047 8047 8047 8047 8047	STATICH		בכופי כונפין	ט דנום בותכבוטיי	υ,
	MPRULES Rocule Size Arcule Size CPE*Persons Initial Syfely Peric 90.0 5A		115 115 115 115 115 115 115 115 115 115	C12 - 2504CT	102 102 102 102 102 102 102 102 102 102	9 CC
SUBSISERS	DATA FEP PHIT + 1 REGULARD F	CR STATIÓR		; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ;	T 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
	POWER (WATTS)		しゃ		Da	
		LTGHTSICE DafkStde Intervittert	12.5 12.5 0.0		ट्ट्ट् इ इ 	
	HEAT LUAD - SEASIBLE (BTU'S)		dI:	LET STA	u E II D'I T	drg1 dift]
		LIGUTEIDE Darveide Inteamittens	55 114 114 114 114 114 114 114 114 114 1	ala vlavo ala vlavo	င်င်င် ကြင်င် 	1 4 4 5 5 7 1 7 1 7 1 7 7 1 7 7 7 7 7 7 7 7 7
	Paylo a C	ш [5	(sel) Japi.		เธริส) ออกไวง	
		FIXED OM-CREIT Initial Spapes & FxD	42.1 0.0		ας. 19ς	
		SUPTERL	92.1		= = = =	
		RTSUPELY SPARES & 2YP RETURN TO EERTA	33.3 5 55.2		1 . F 1 0 . F	
SUBSYSTEM	DESIGN CRITERIA			***	****	
	COUTIVUOUS ČPERATICY GULY.					
SURSYSTER	MASS BALAYCE DATA PFR UPIT (L	"				
	⊬ATERIALS REQUIREN 111111111111111111111111111111111111	00107 00107 00107 00107 00107 00107 00107 00107 000000	псты 		2581416 1085 	2,253

TABLE 5.2-21 THERMOELECTRIC INTEGRATED MEMBRANE EVAP. SUBSYSTEM SUMMARY

24-861-85 F7:35

 $(c_1c_2) = \lambda_1(c_2)$ and $c_2(c_1c_2) = (c_2c_2)$

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F MAN THER I MOTULE STATION BOLES CONFICUDIATION NO. 2 SNARAPY SPERT - PAGE 3 F MAN THER I MOTULE INITIAL SUBFIT FERTION = 90.0 DAYS, PESUPILY FERICE = 90.0 DAYS

						-				
				TCTAL PU	(P1) 109.			TCTAL VCI	(FT3) 340,	
ITEV NC	FULSCU GU MUBUADONO	Derts.	FIVER	Terrar	DESUPPLY	PETURN	FIXET	TRTIAL	¥€s∪aFLΥ	RETURA
		ت بر ۲		エメリナドコン	2 K 4 K 4 K 4 K	TC EAPTS	11997-00	SPPHEXT	578+EXP	TT EAPTE
10	THEFT IS A CONTRACT OF A CONTR	- •				5	1.7	0.0	5°0	C ° 0
		- (C • C ·	146.0	146.0	v • ₽	4.0	ບ ໍ ່ 4	8.0
N P	コン ニ ロクローワ ひごう しつせいせいせいせいせいしょう コンコン ちゅうかい しょうかんかい ひしょうかい		H [07	ເ ເ	c .	0°)	0.1	0 • U	ູ	0.0
n •	「たん」を「ちゃらい」「「ねしゃ」「」」」「「この四字にします」」(この) ひょうひょう	-	4 4 4 5 1	0°0	0.1	6.1	72.3	0.0	с ° 0	0.0
4	(UZ MERUVAL = FDC++=+++===============================	•	250.6	75.1	7.5	7.5	12.2	1.2	4.0	
	CC2 REPUCTION - BOSCH	•	522.5	360.7	372.5	5£1,5	53.53	55.5	55.2	с С
m -	TRACE CONTRAINT CONTROL	•	174.3	19 - 9 19 - 9	5°68	86.8	1.05	7 4	α. τ	α. 1
4	ATPOSE MENITOR - PASS SPECTRATE-	•	77.0	7.7	5.3	2.3	- 1 			° -
61	C2 SPPPLY - STAILC FEEL FLECTR	•	223.ņ	124.5	124.5	124.5				• •
22	C2 STOPAGE - MJ PRESS SKERG	÷	1006.4	() • v	32.1	32,1	71.3	0		, - - -
42	V2 SUPPLY - P2H4 DECOMPUSITION	-	0.2	(·•)	ت • ن	0.0	5.0	0 - D	, c	• •
25	NZ STORAGE - HI PRESS EMERG	•	161.0	0.0	۵. ۵	ं क	11.9		• • •	
9 0 1 7	CABIN PRESSURE CONTROL	-	142.6	ن• 0	2.4	2.9	2.5	0.0	c	
8 0 7 8	PCT. H20 STOPAGE - CLUSET LOCP	-	£63.7	£ 0 • 4	10.0	19.5	20.6	2.5		• •
51	PCT. HZC STOPAGE - EMERGENCY	11	2¢75°0	0°0	ບ ໍ ບ	υ Ū	20	0.0	c.	
nni i Gui	REVERSE CSMOSIS - FOTAFLE F2C-+-	.	242.4	2°5	2.5	2.5		22.3	24.0	
ი. ო	PROCESSET HON POST-IPERTVENT POT	-	2. ℃	0.0	ີ່ເ	0.0	د د	0.0		
0 - M 1	WASTE H2C STORAGE & PRE-TREAT	- .	211.0	16.7	91.5	1010	25.5			
11	WASH H20 STOPAGE	•:	0.99	5°6	с 	0.6				
4 I 1 1	HYGIENE H20 STORAGF	•	148.5	14.9	5°7	4.5	20.3	2 0	. u . c	• .c
22	REVERSE CSMOSIS - FIGITAE P2C	v	1644.6	10.2	16.2	16.2	1.08	720.4	778 0	
	H2C RECOVEPY - TIMES	- .	97.1	0°J	33.3	5 85.2	a •	0	•	
3.	PRECESSEE 420 POST-IPEATVERT HVG	•r'	1.5	e.o	ٿ ٿ	0.0	ت	0		
ן נ יי יי	HZU CUPLIT MONITCHING	•	ود"،	72.5	1.4	4.1	0 .5	1.5		
100	PEALTH & PYGIEVE - HART WASH	•	2°*'2	2.5	50	3 0	3.5		, ,	
ם היו	HEADTH & HIGIEVE - HOT HIC Selv-	•	22.5	1.3	ປະ • ເລີ	6 ° 0	۰ ب	6 0	- - -	
ר כ אין ד	HEADTH & HYGIEYE - COLT H2C SPLY Nemetry : "Mercine" (2000 - 2000)	⊷,	26° U	1.3	ين. د	9°0	α c	0.1	0.1	0.1
 	TEADURE & HEGOLEVE I HOLY SHOWER IN		105.0	10°2	3.2	3.2	47.3	4.7	1.4	
, ⊢ , t	TEALT & TIGIETE - CINERANFERTA-	•	16.0	7.8	5.3	2.3	в. 4	ເ. 8 ເ	0°9	0
4 M		-	15.0	7.3	2.3	2.3	₽°3	0 • é	6°3	0
n 4 1 4	TEADYS & MIGIENE = COMPOSE/VEINE TTATES : SATTANE = COMPOSE/VEINE	9	F91.F	0.0	491 . F	6°3 . 2	14°U	0.0	74.0	74.0
1 T		~ 1	C • 1	0 •6	•	0.0	с. Г	0.0	0.0	0.0
י ז ל	「ロチリーローターコーの「白」と「コースの二」(「光クタハー	-1	ر • ر ،	5.5	.	750.0	с . г	G.4	• • 0	63.9
0 F F 7	A CONTRACT A CONTRACTACT A CONTRACT A CONTRACTACT A CONTRACTACT A CONTRACTACTACT A CONTRACTACTACT	•		ې •		1.2	2.5	E.)	0.1	0.1
- c F =	TERPER & TUGUERE I FOUR FREEDOR	-1	1:1.0	14.2	6 ° •	۳. ۲	24.3	2.4	0.7	0.7
0 t	tterere e bigiewe a fuch esteriera	•	36 7.	38.5	11.6	11.6	54.1	6 . 4	2.5	2.5
					* * * *	8 1 E E E F F	1			*****
	EF 8.337.04		11025.4	0.172	1674.5	6°741E	923.2	834 . 7	10° a 1° 0'	1079.5

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

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E MAN CREN I NOTULE SPACE STATION ECLOSECONTRION AG. 2 SUMMARPY SUBET - PAUE I I VITAL SUPPLY PERION A VOLUE IVERTON A VOLU EXIS, PESUPULY SEPTCE = 50,0 CAYS ! •

(STIA: 1	
FOFCP	
ELECTRICAL	
TELL	

ITEN		114579		μĊ		1 6 7 7 7 7 7 7 7	DQ	E J J J J J J J L Z
• 22	SLASYSTEM OR COMPOLENT	950°n	57	54			V ~ . V ~ .	
-	HX & FANS - AIR CCCLING		712.8	712.3	د. د		200	
01	אַר אַנאיצ - טמעא כניאנאנר		0°0	0°0	ن. د	0 0	c	
7	HX - ECUIPHERT CCLCPIATES	53	5.4	0.0	υ . .	с с		
m.	HX & FANS - HUMITIY CONTROL	-	164.7	164.7	်း င	0 0	с С	
4	CO2 FE'OVAL - FUC	-	205.0	205.0		0		
-4 (1	CO2 PERUCTION - RESCRAMENTER	•	196.1	196.1		130.8	130.6	1307.5
- - -	TRACE CONTRALIANTS CONTROL	•-	200.4	260.4	ເ ື ເ	3.4°5	202	
d' •	ATWCSP REALIZER - RANG SPECTARTER	-	0°0		ر. د	0	c	115.0
	G2 SUPPLY → STAIIC PPEL FLPCTR.→	-	120-5	125.0	ر • ر	3-53-5	3053.5	
2 1	LZ STUTAGE - BI FRESS FRESGETERE	-	د• د	0.10	د. د	0°0	0 U	15.7
* u V C	THE STATE IN THE STATE OF THE STATE STATES AND	-		0.1	14.1	0.1	c	0
n (7 6	AND CONTRACT AND THE CONTRACTOR OF A CONTRACT OF A CONTRAC	. .	د د	0.0	ر. د	0.0	0.0	15.0
2 C	CATE FRESSURE CONTROL		۲	0.1	ر • ر	30.05	0.05	
D 0 V (PUL - FIC STUPAGE - CTUSED LOUP		د د	0 • 0	د، د	0°U	c°C	
۲, (PUD. BZU STURAGE - EMERGERCY	; 1	د د	0.0	0°00	° • 0	2°0	C. U
ים הים	ALTEROR USHON A ROTATLE FZTATE	-	34.2	94 ° U	د " ن	ú•0	6° 0	0
ი ი ო ი	FRECERSED BZC FRETTERTVERT PCT	-	د. د	0.0	ບ ໍ ່	0°2	0°2	0.0
) . 1 I	PACTE FZC STERAGE 5 FRE-TREAT		د ت	0.0	ີ 1 ເ	0.0	0 °	0.0
	***** TVO 570556844444444444444444444444444444444444	•	د • ن	0.1	3°°C	0.0	с с	356.7
3" L - F		•	ິ . ເ	0.5	ي • ت	0°0	с с	108.2
n 1	PEVERSE USHCGIS - HYGIFWE H2C	u.	231.1	230.3	ر• د	0.0	, , , ,	0.0
יי) ו יי) ו	HZC RECOVERY - TIMES-AFA		12.5	12.5	ي • ر	144	C . 4 4	
0 v	PRICESSED HZO POSI-ISESINENI HYS	•	ر • ن		ر. • د	3.1		0-0
0 r 5 r	EZC CERTITY WONITCHING	. .	с. С	0.0	د د	40.0	ι.	0 - 0
2	FEALTH & HYGIENE - HAND WASH	-	د ن	· · · ·	100.0	0 0	c	15.0
20 C 70 C	REPLIE & HYGIENE - HOT HOC SPLV-	• 1	د •ی	`. C	500° L	15.0	15.0	
ה כ יק י	HEALTH & HYGIENE - COLU P2C SPLI		6°0	0. ·	ر • ز ز	֥0	с с с	0
	TERET & HYGLERE - ECCY GHERER-		د د •	0. 0	25°.C	0.0	د د	15.0
r s	The set of	-	د ت	; • ;	545	ن• د	с . с	
	TRACTOR & HIGIERE + CTTE YASSAUPY	• ·	ະ ເ	ः • •	し。してで	0.0	د د	15.0
n . 1 .	TERL'E & SYGLERE = CTRWCTE/URINE Number :	¢ ,	د د	ن• ر. ت	1°097	0°0	с с	f0.)
# 4 * <	TERLIK & HIGIERE + EVEN + STE CTU	(m	د •	ເ	ر د	0.0	د د	0.0
1	TERUTO ANALE ANDERS A TURNER TORNER	-	د د	 •	120.5	0.0	с. С	15.0
0 r 7 5		•	د د	5 • 6		0.0	0°.	370.0
	TRALES R 3401418 - FICT REFRICT	·	د ر	0. 0	、 • ت	15.0	ς . Γ	476.0
0 7	HERETS STREND - BUCC EXERCE	•	د. ر	.•.u	ر * د	15.0	15.7	1360.0
			8 5 5 8 8 8 8 8	1 				
	TUTALS		1936.4	1936.4	1667.7	4651.3	4651.3	4550.1

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

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	2.61.1		AIR	,		17601 T	
Strester of Corfordation	DEC.SI	LS.					
HX & FARS - ALF CCCLING	-	2432.E	7432.6	ر د	11059.0	11059.6	P591_1
PX & FANS - ODCF, CONTRUL	-	0°0	0.0	ι" c	C.0	ບ ໍ ບ	0
PX - ECUIPMENT CCLDFLATES	. 22	5	¢•¢	ن • ن	C.O	с . с	0 0
PX & FANS - PUMITITY CONTROL	-	1-397-	-755.1	ر• ن	é°∃s[g	6143.5	(°)
CO2 PE*CVAL = EDC		424.3	424.3	ي • د	1275.4	1275.4	0.0
CO2 PERUCTION + PCSCF	-	1232.0	1232.0	4262.7	501.1	6.5	0.0
TRACE CONTRAINART CONTROL	•	22U1.1	2201.1	ι -	0		
PILESE PONITOR - PASS SPECTERITE	•••	0.0	6.0	3.52	с Э	د د	0.0
C2 SUFFLY - SIATIC FFEU FUFCTR	-	C.747	6-202	ບ ໍ ບ	P510.7	8510.7	0.0
C2 STCPAGE - HI FRESS EMERG	-	د د	0.0	51.7	3°0	С ° с	0.0
№2 SUPELY = N2H4 DECCAFCSITICA	•••	۲ ۰ ۶	1.3	· • 0 7	0.0	с с	0
N2 STOFAGE - HI FRESS ERERG		с ° 0	0.1	51.3	0.0	נ כ	0.0
CAPIN PRESSURE CCNTRFL		102.4	1,2.1	ر•ر	J • 0	с с	0.0
POT. H20 STCRAGE - CICSED ICCP	•	ເ ເ	0°0	ر د	0.0		0.0
POT. H20 STGRAGE - EMERGENCY	- 14	ເ ເ	(•)	u. a Tr:	0 0	د د	0 0
PEVERSE DSMCSIS - PCTAPLE P20	•-	119.6	118.5	c	0 n	c c	0.0
PRECESSED H20 POST-IFERTVENT PCT	•••	1.6	1.5	د • •	0.0	c c	0
WASTE F20 STORAGE & FRE-TREAT		c°υ υ	0.0	107.4	0.0	0	0
WASH H20 STORAGE		ت•ن ن	u•0	1235.6	0.0	د د	0.0
HYGIERE H20 STORAGE		с с	0.0	1453.5	0.0	с с	0.0
USA ANGINE - AICIEFA ASU	۲	185°.	795.3	υ. υ.	0.0	د د	0.0
H2C RECOVERY - TIMFS	-:	534.0	534.0	Э ° Е	0.0	с .	0.0
PRCCESSED U20 PCET-TEEATMENT HYG	-	10.4	10.1	ر•ر	0.0	C u	0.0
H2C CUALITY MONITCRING	~	136.5	136.5	ن• ن	0°0	ר י	0.0
HEALTH & HYGIENE - HART WASH		د• ی	0.1	392.5	0.0	с. С	0.0
HEALTH & HYGIEVE - HCT H2C SPLY-	-	51.2	51.2	652.5	0.0	C C	0 ° 0
HEALTH & HYGIENE - CCLC H2C SPLY	**	U • 0	0.0	0.5	ς. Ο	c •c	6-0-9
FEALTH & HYGTENE - BILY SHINER	-	с с	0.0	9°7°5	0°0	د •	0 J
PEALTH & HYGIENE - DISFAASHER		с• с	0°0	2079.3	0.0	د • ت	0.0
PEALTH & HYGIERE - CITE FASH/DFY	•••	ن• د	с•о	1211.6	0.0		0.0
NEVLTH & HVGIERE - CCRNCCE/UPI'L	4	ن• ن	6°0	1843.5	0.0	د • :	с . о
HEALTH & HYGIENE - ENER VSTE COL	en L'I	د د	0.0	ι. Ο	с•0	د د	0.0
HEALTH & HVGTEVE - TFASH CTMPACT	+	د • د	0°0	4 ° J 5 7	0.0	د. د	· • • •
PEALTH & HYGIENE - CVEN	-	د. د	ن ا	; 1 1 6 4	0°0	с. с.	0°0
BEALTH & HVGTERE - FILL REFERENCE	•+ 1.1	د . د	0.0	ر د	51.2	51.7	1=24.6
PEALTE & RYGIEME - FACT FREEZER-	•	د. ۲	5°0	ι.	51.2	5.5	4041.7
					* * * *	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
TCTALS -		7681.3	7681.J	17167.7	296278.1	7 C P 7 F . 1	15427.4

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

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ò TIVE STATE STATE STATES ETESS CHETCLEPTED AG. 2 SUPALY SHETD + FAGE S B MAN (SFR. 1 MCDULE - Initial Superty Firits" = of.0 Davis, Firstory Devic, =

		TATTAL S ASS F	GEFLT FER FERTER		.C CAYS, 1	rslerly brai		.0 5815 5 5815 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5		
1.1.1										
	SUPER CONTRACT OF ARTER SUPERIOR	CXYGEN	PITECCE		FICALGE:	CCALENSNEL	Prideli	4 S F	LINT 1	HYGTENE
,	PASIC CREW AND PCDULETTTTTTTTTT	552.41-			K / S	100 10	000 000			
-1	HX & FANS - FIR COCLING }	0.000	000 0	0000						
0	HX & FANS - PDCR_CCUTRCL 9	100-0	000-0	00000		0.00	000 0	0.000		
Ni i	HX - ECUIPMENT COURFLATES 22	0.000	1°00'	0.00.0	101-1	0.0.0	u nu " u	0.00	0.000	0.000
ጣ	PX & FERS - ROWIFITY CONTROL 1	000-4	ن-دەر	0-040	000°0	-49.045	000°0	0.000	00000	0.000
d'	CC2 REMOVAL - EDC1	-6.9a1	0.4 0.0	440°ú	1°i45	7.865	0 U U U	0.000	r.001	0.000
-	CC2 REFUTION - ECSCH	0.00.0	ປີບີບັ	-37,552	15211	0.000	14.365	0.000	00000	0.000
m :	TRACE CONTANINALY CONTROL	0000	د ∙ر ∷) د	0.000	160°u	0.00	0°00	0.000	0000	0.000
₹ ••	PURCES FUELTING SEASON SPECTRALE	0 J J J J	100° J	0.00.0	J) J J J J J J J J J J J J J J J J J J	0.000	r.run	0.00	C (1) L	0.0.0
61	C2 SUPPLY - STATIC FFET ELECTR 1	21.625	ວກວ້ານ	0.000	2.729	0.00	-21.551	0-0-0	v00" u	0.000
22	02 STORAGE - HI PRESS EMERG 1	0v0°3	ن"رەر	0 0 0 0 C	1000	6 J Q * 0	U . C . U	000	00016	0.000
4	V2 SUPPLY - W2H4 DECCHECSITIC: 1	00000	5.40r	0.010	C. 752	0.0.0	1000	0.0.0	000	0.0.0
52	V2 STCRAGE - HT PRESS FRENG 1	0-0-0	ر ئردر	0.00.0	0000-0	0.000	ບິນ ບິ	0.0.0	000 0	0.000
90	CAPIN PRESSUPE CONTROLOGICATION	0°000	1000	000100	00000	0.00	000° u	000 0	000 U	0.000
3	PCT. H2C STOPAGE - CLOSEF LUCP 1	0-0-0	ر ٹر ن	000000	100°	0,000	000.0	0.00	00000	0.000
5	PCT. H2C STUPAGE - EMERGENCY 14	000)	JU10 - J	0.00.0	ບິດກູ້	9.000	00000	0.000	0000	0.0.0
ng i	REVERSE COMONIS - FOTAFLE PIC 1	000	000-0	ວ່ວຍ "ບ	ບົບບີ	0.0.0	46.121	0-0-0	2.944	0.000
	PROCESSET H20 PCST-IMENIMENT PCT	0.0.0	.0.°.	0.00.0	0,000	0.000	00000	0.000	v 0 v [°] 0	0.000
رت ۱۳۰	WASTE HZC STOKAGE & PRE-TREAT	0.000	ບດີບໍ່ນີ້	0.000	006-0	0.0.0	ບົບບໍ່ປ	00000	000-0	00000
	WASH HZC STUPAGE	0000	ບົດບໍ່ບິ	0.000	0°0°0	0.0.0	00000	0.0.0	0.00	0.00.0
4	PIGIENE P20 STORAGE	0 - 0-0	500.5	0.0.0	0,000	0.000	00000	0-0-0	000 0	000.0
25	REVERSE CSMOSIS - FIGIFLE F2C F	0.0.0	000 0	0.000	00000	000°0	ບົບຄົບ	-323.440	19.405	304.034
33	P2C SECOVERY - TIMES1	0.00	ر•زەر	0-0-0	0000	0.0	54,539	0.0.0		0000
76	PROCESSED H20 POST+IREATMENT HYG 1	0.0.0	000 0	0.00.0	000°0	0.000	0,00,0	0.000	10 J	0.00
36	H2C CUALTY MONITCRING 1	00000	ر ن 0 ن • ر	000.0	ΰΟυ "ϊ	0.00	ປີວີບີ້ວ	0.000	000 0	0.00.0
-	НЕАЦТА & НУСТЕМЕ + ЗАМГ КАСИ 1	0.000	ປິບປີ ບ	0.010	1001	1 U O O O	r.o.o.	0.0.0	ບິບີບີ້ບ	0000
i m	PEALTH & HYGIEVE - HOT HIC SELY- 1	00000	JOJ",	0,000	c.,cc	0.000	uðu°u	00000	000 0	0.00.0
n n	HEALTH & HYGIENE - COLD HIC SPLY)	0,000	003"4	600.0	000.0	0.00	600"0	00000	0.00	0.000
4	HEALLE & SYGIEVE - BODY SHOFFR 4	0-00	00.00	0.0.0	0001	000000	ບົບບໍ່	0.000	00000	0000
4. i	HEADTH & HYGIEME - DISTWASHER +	0-0-0	0000 0	ບັນນີ້ບ	000.0	0-0-0	ن•ن ٥ ت	0.00.0	00000	0.000
47	HEALTH & HYGTENE - CUTH VASH/DRY 1	0000	000°0	010.0	C D u C D	0.000	600.0	0.0.0	000"0	00000
1 1 1 1	HEALTH & HYGTEVE - COMMORE/UPIRL A	6 u 0 u 0	ر ° ژ 0ر	100°C	000°i	0,000	ن • زن ن	0.0.0	00000	00000
7 I 7	HEALTH & HYGIEVE - EMER 45TE CPL 3	0000	00000	0.00 • 14	000.0	0° C U I	ບົບ ບໍ່	0.000	000 0	010.0
4	HEALTH & HYGIEME - IRASH COMPACT 1	0.00.0	1000	0.0.0	000"0	0.000	unu"ü	0.000	00000	0.0.0
4	PEALTH & HVGIENE - CVEN	0.000	ن•ن•ن	000.0	、 05°	0°¢;0	v0v*u	0-000	υΟ ΰ [°] ΰ	0.000
4	REALTE & HYGIENE - FOOT REFRIDGE 1	000.00	, ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	000.0	100°	0.000	ເດຍ " ບ	0.000	ເດີ້.	0.0.0
4	PEADLE & FYGERER - FOOT FREEZER.	0.00.0	0.000	600.0	ຜິດປີ ບ	0,000	0°0°°	00000	v00°0	0.000
	SUBSYSTEM VERAGE (COMULATIVE)	0000	\$IJ.0-	510.015	-0°0CE	0,00,0	504°S	0.00	202 0	0.000
						262698				
	TTTTT STATUT	010.0	50.50	000*0	c.125	000000	36.617	0-000	ن°0ن" ر	- 36.766

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

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POFING ENGTREERING TOAPES SINDY - (BETS)

SUBSYSTEM 67 F20 RECOVEFY - V.F.C.A.K. -----

ECLAS CONFIGURATION Nº. 2

JOP IL VCAP

MISSICK DA	. 7 Å			[]]]]]]]]]]]]]]]]]]]	, , , , , , , , , , , , , , , , , , ,			
		SPACE STATI	ION		ECLSS CLUSED	LOCP FUNCTIC	И. 2 С	
	MODULES Module Size Crewpersoks Initial Supply Fer	4010.0 FT3 4010.0 FT3 100 90.0 RAYS ⁵	RESUPPLY PERIOU Orbit Lightside Darkside	ас. о Съук 196. о Кин 196. о Кин 196. о Кин	CC2 REDUCTI CC2 REDUCTI 02 CE4EFATI		571 151 151 151 151 151 151 151 151 151	
SUBSYSTEN	DATA FER UNIT - 1	REQUIRED FCR STA	NDIT4					
	POWER (WATTS)			AC		24		
		L1011 DA9K9 14115	ISIDE Stde Amittent	117.7 117.7 96.0		с., с с с о		
	HEAT LOAD - SENSIA	LE (BTU'S) LTGH7 DARK9 INTFF	ISITE Sidf Syltent	4 4 5 1 5 1 5 1 5 1 5 1 5 1 6 1 7 1 7 1 7 1 7 1 7 1 7 1 7 1 7 1 7	AIR TEMP Carly Air Carlw Air Carlw Air	21000 11000 21000 21000 21	1.12410 TEN 14141 - 1154 46445 F 40445 F	
	PAYLOBD	FIXE	¥E D ON⊷ČREIT IAL SPAFES 5 CXP Supirial	1641 (LBS) 524.0 192.4 192.4		111 111 111 111 111 111 111 111 111 11		
wəlsyseus	DFSIGK CRTIERIA	RESUL	PPLY SPARES & EXP RM TO EARTH	65.7 196.7		c • • •		8 9 8 8 8
SPBSYSTER	MASS FALANCE LATA	PFR UTIT (LE/DAY)						
	MATERIALS REGUIRET HASTE WAIFR = 63 VASTE WAIFR = 63 OXYGEN = 63 ANTIFCAM = 63 PH ADJUSTFR = 0 FILTER = 0 FILTER	000 005 005 005 005 005 005	MATEFIALS PROD 	HCFE 		1001 1001 1005 1005 1005 1005 1005 1005		

TABLE 5.2-26 VAPOR PEASE CATALYTIC AMMONIA REMOVAL SUBSTSTEM SUMMARY

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RCEIRG ENGIMEEFING TRADES STUDY - (BFIS)

VCAR SPACE STATIOU ECLSS CONFIGURATION NC. 2 SUMMAPY SHEET - PAGE 3 R Man Crew 1 Mccule Intilal Supply Pertug = 90.°C DAV3, RFGUPFLY PEPIDD = 90.0 JAYS

		TUTAL VEL	GuT (LB)			TCTAL VGI	UME (FT3)	
ITEM NG. SUBSYSTEM OR COMPONENT RED	TS FIXED "D CN-CRBIT	INTIAL Spr+exp	aESUPPLY SPR+EXP	TC EADTH	FIXED	JWIIIAL Sedifye	PESJPPLY Algelsjo	RETUPN TO TAPTU
1 HX 6 FANS - AIR COCLTNG 1	50.0	0.0	0.5		1.7	0.0	0.01	
70 HX & FANS - ODOR CONTREL 1	عن • د	73.0	146.0	146.0	C.4	4 D	с а	6
2 HX - EQUIPMENT COLUPLATES 22	261.9	0.0	0°0	0.0	0.1	0.0	0	
3 HX & FANS - HUMIDITY CONTROL 1	203.3	0°0	0.1	0.1	74.1	0.0	c "C	0.0
4 CC2 REMOVAL - EDC	293.0	28.3	יי מי	5°3	13.5	1.4	ч С	0
11 CC2 REDUCTION - BOSCH 1	522.6	360.7	372.5	9f1.5	53.5	55.5	a 60	
13 TRACE CONTANINANT CONTEOL 1	176.3	89.8	α•α÷	5°9	135.0	70 - T	4.8	1
14 ATMOSP MENITOR - MASS SPECTRWIP- 1	77.0	7.7	2.3	2.3	1073 1073 1073	0.0		0.1
61 C2 SUPPLY - STATIC FEEL ELECTR 1	24P.5	146.3	146.3	146.3	с. С	2.2	2.2	2 2
22 02 STORAGE - HI PRESS EMERG 1	1248.2	0.0	37.4	37.4	E3.4	0.0	2.5	
24 N2 SUPPLY - N294 DECOMPOSITICA- 1	0.1	0°0	u°u	0.0	с . с	0 0		0
25 N2 STORAGE - HI PRESS EMERG 1	149.2	0.0	v*v	4.4	10.9	0.0		
26 CARIN PRESSURE CONTROL 1	142.6	0.0	2°0	2.9	12.5	0.0	1.0	
28 PCT. H2G STOPAGE - CLOSET LUCP 1	663.7	66.4	10,0	6.61	24.5	2.5		
29 PCT. H20 STURAGE - EMERGENCY-+ 14	2675.0	0.0	с ° с	0.0	94.5	0.0		0 0
63 REVERSE CSMOSIS - FOTAFLE H2C 1	254.8	2.5	с. • л	2.5	5.2	22.9	24.6	24.6
35 PROCESSEE H20 POST-IREATVENT PCT 1	0.2	0.0	ີ່	0.0	с . с	0.0		
30 WASTE H2C STURAGE & PRE-TREAT 1	211.0	16.7	41.5	101.0	25.5	0.1	15.0	10.5
71 WASH H20 STORAGE	Ú⁰65	6°6	с• м	C. 8	13.5	1.4		
74 HYGIENE H20 STORAGE1	148.5	14.9	4°2	4.5	21.3	2.0	. v C	9.0
75 REVERSE CS"OSIS - HYGIENE H2C 5	1644 ° 6	16.2	16.7	16.2	6.6.8	720.9	778.5	778.3
67 420 RECOVERY - V.P.C.A.R 1	524.6	102.4	65.7	196.7	57.7	0.0	2.1	
76 PROCESSER H20 POST-TPENTWENT HYG 1	1.5	0.3	د• ،	c•0	ů°ů	0.0	c.0	0.0
36 H2C GUALITY WOWITOFING 1	وں• ب	22.5	1.4	1.1	6 4	1.5	-	1 0
37 HEALTH & HYGIENE - HANT HASH 1	25°0	2.5	0 . A	0°3	а. Г	0.1		1.0
38 HEALTH & HYGIENE - HOT H2C SPLY- 1	22.R	1.3	ۍ د	6*0	0 . 8	6.0	0.1	0.1
39 HEALTH & HYGIENE - COLD F2C SPLY 1	20.0	1.3	ч°-с	0.6	9°9	0.1		0.1
40 HEALTH & HYGIENE - BODY SHCHER- 1	105.0	10.5	3.2	3.2	47.3	4.7	1.4	1.4
41 HEALTH & MYGTEME - DISPWASHER 1	78.0	7.8	2.2	2.3	8.4	6°0	0.3	
42 HEALTH & HYGIENE - CLTP WASH/DRY 1	75.0	7.8	2. - 3	2.3	8.4	9.6		
43 HEALTH & HYGTEWE - CONNODE/URINL 4	691 . F	0.0	691.6	893 . 2	u" 0 L	0 .0	74.0	74.0
44 HEALTH & HYGIEVE - EVER WSTE COL 3	45.0	0.0	د. د	0.0	د . ۳	0 ° 0	0°0	0-0
45 HEALTH & HYGIENE - IRACH CCMPACT 1	U T	4.0	1.2	750.0	7.0	0.4	E.0	93.9
46 HEALTH & HYGTENE - OVEN 1	4 u C	4.0	1.2	1.2	2.5	6.0	- - -	0.1
47 HEALTH & HYGIENE - FOCT REFRIDGE 1	141.0	14.2	٤.4	4.3	24.3	2.4	5.0	
49 HEALTH & HYGIERE - FOUT FREEZER- 1	385.3	38.5	1.5	11.0	84.1	יין אין אין מיין	5	2.5
	1 6 1 1 7 7			7 8 1 F E E				
ICIALS	11696.3	1045.5	1734.5	3414.2	8°066	8.258	E°055	1073.9

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

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PCFIMG EMGINEERIMG TRANES SIVEY - (yrir)

VCAR SPACE STATTER EPLES CONFIGUPANION NC. 2 SUMMER SHEET - PAGE 1 F Man CRFM 1 McPule - Injiin Supply PFRium = 90°C CAYE, resipply fering = 40°C JAYS

				TOT	AL ELECTFIC	AL POWER (51	17S)	
1758	Ξ	0 f F 7		AC	• • • • • • • • • • • • • • • • • • •		DC	3 5 8 8 8 8 8 8 8
NC.	SUBSYSTEM CP COMPONENT	E0,03	Ľ,	LS				1
	HX'& FANS - AIF COOLING	÷	711.5	711.5	ບ ໍ ບ	0.0	с . с	0.0
70	HX & FANS - DDCR CONTRCL		0.‡0	0.0	ເ " ເ	0.0	с. с	0.0
7	HX - EGUIPMENT CCLDPLATES	22	0.0	0.0	0.0	0.0	0.0	0.0
m	FX & FANS - HUMICITY CONTROL	*1	170.7	170.7	ວ°ບ	0.0	c	0.0
4	CO2 PEMOVAL - EDC		237.9	237.8	ر * ر	0.0	с. С	0.0
11	CO2 FERUCTION - PCSCH	•	196.1	196.1	ບ ໍ ບ	130.8	130.8	1307.5
13	TRACE CONTAMINAL CONTRCL	-	260.4	260.4	ن•ن ن	304 5	304.5	0
14	ATMOSP MONITOR - MASS SPECTRWITH	•1	د د	0.0	0° L	0.0	0.0	115.0
1 4	C2 SUPPLY - STATIC FEED FLECTR	-	139.7	139.2	ن. د	4673.0	4673.0	0 0
22	C2 STCPAGE - HI PRESS EMERG	-	ς • υ	0°C	ر • ت	0.0	د .0	15.0
74	N2 SUPPLY - N244 DECOMPOSITION	••	ບ ໍ ບ	ن • 0	L	0°0	с"с С	0.0
25	NZ STCRAGE - HI FRESS FYERG	-	0°0	0.0	ບ ໍ ບ	0.0	د • د	15,0
26	CAEIN FRESSURE CCNTRCL	-	0.0	0.0	0.0	30.0	30.0	0.0
28	POT. H2C STCRAGE - CLCSED LOOP	-	0°0	0.0	J.C	0.0	ບືບ ບ	0.0
29	POT. H20 STORAGE - EMERGENCY	14	د •0	0.0	£°26	0.0	د. د	0.0
63	REVERSE CSMOSIS - POTABLE H2C	÷.	35.6	35,6	υ°0	с•0	0.0	0.0
ы ПС	PRCCESSED 420 POST-IFEATMENT PCT	-	0.0	0.0	ບ ໍ ຍ	0.5	0.5	0.0
3 0	WASTE H20 STORAGE & PRE-IREAT	-	ن• ن 0	0,0	30°08	0.0	0.0	0.0
71	KASH HZC STURAGE		د• ن	0.0	20°C	0.0	0.0	356.7
74	HYGIENE H20 STOHAGE	•••	د• د	0.0	J°18	0 • ۲	0°0	398.8
75	REVERSE OSMOSIS - HYGIENE H20	ſ	230.1	230.1	ບີບ	0.0	0°C	0.0
67	H2C PECGVEPY - V.P.C.A.R	1	517.7	117.7	85°ر	0.0	0°0	0.0
76	PRCCESSED 420 POST-IFEATVENT 4YG	-	υ°υ	0.0	J.O	3.1		0.0
9 0	H2C QUALITY "GNITCPING	÷	ن• ن	0.0	U°0	40.0	40.0	0 0
37	HEALTH & HYGIENE - HANT WASH	•-1	ن• ن ن	0.0	100.0	0.0	0.0	15.0
(0) ()	HEALTH & HYGIEVE - HUT H20 SPLY-	7	0°ن	0.0	200.0	15.0	15.0	0.0
6 e	HEALTH & HYGIENE - CTLC H2C SPLY	÷	c•. c	0.0	J°0	0.0	0.0	0.0
40	HEALTH & HYGIENE - BIDY SHOWER	••	c ب	0.0	250.0	0.0	υ ・ υ	:5.0
41	HEALTH & HYGIEVE - DISFWASPER	-	د د	0.0	う。いたこ	0°°0	0°0	15.0
4 2	HEALTH & HYGIEVE - CLTF WASH/DRY	-	د • ن	0.0	j"u*8	0°0	0.0	15.0
£ 7	HEALTH & HYGIENE - CCMMCDE/URINL	4	ů°ů	0.0	ت9∪°ن	0.0	0.0	60.0
44	HEALTH & HYGTEVE - EVER WSTE COL	m	ر• ن	C•0	د " ث	0.0	0.0	0.0
4) 4)	HEALTH & HYGIENE - TPASH CCHPACT	-	с•°	с•0	120.0	0.0	ں ° ر	15.0
40	HEALTH & HYGTENE - GVEN	1	د • د	0.0	U • 5 🕈	0.0	J°C	370.0
47	PEALTH & HYGIENE - FFOT REFRIDGE	-	0°0	(•0	ن• ۲	15.0	15.0	470.0
4 8	9EALTH & 4YGTENE - FROT FREEZER-	1	0°0	0.0	ر. د	15.0	15.n	1360.0
							9 1 1 1 1 1 1	
	TOTALS	!	2°56J2	2069.2	2038.C	5225.8	5726 B	4519.0

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

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	00.U DAYS		
Z SHARAT SHEFT - FAGE Z	° CAYS, RESUPPLY PERIOD =		' PEAT LOAD (STU/HR)
SEACE STATING ECLSS CORFIGURATION NG.	INITIAL SUPPLY PERTON = 90°C		TCTAL SENSIBLE
Y C A K	1 VCCULE		
	A CREW	•	

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и 14 14 14 14 14 14 14 14 14 14 14 14 14	U SUBSYSTEM OR COMPONENT R	EO.D	L S		1638 638 61111	5.1	11111111111111111111111111111111111111	
-	HX & FANS - AIR COOLING	-	2428.5	2428.5	с• С	11040.8	11040.8	R561.0
70	HX & FANS - ODCR COUTRCL		0:0	0°C	υ°c	0.0	0.0	0 0
2	HX - ECUIPMENT CCLDPLATES	22	0.0	0.0	0.0	0.0	υ •υ	0.0
m	HX & FANS - HUMICITY CONTROL	-1	-812.3	-812.3	د • ن	9398 . 5	9°3588	0.0
4	CO2 REVOVAL - EDC	•	470.3	470.3	ະ•ີ ເ	1457.3	1457.3	0.0
11	CO2 REPUCTION - POSCH	•	1232.0	1232.0	4462.7	691.1	631.1	0.0
13	TRACE CONTANINALT CONTRCL	-	2201.1	2201.1	υ°υ	0.0	c°u	0.0
14	ATMCSP MONITOR - MASS SPECTRMIP-	-	0°0	0.0	392.5	0.0	υ ° ΰ	0.0
61	C2 SNPFLY - STATIC FFEC ELECTR	-	E31.7	531.7	ບີບ	10102.3	10102.3	0.0
22	C2 STURAGE - HI FRESS EMERG	-	υ ° υ	0.0	51.2	0.0	0.0	0.0
24	N2 SUPELY - N244 DECCMPCSITION	-	0 . 3	0.3	12.5	0.0	0°0	0.0
25	NZ STOPAGE - HI FRESS EMERG	-1	ں • ں	0 0	51.2	0.0	c.•0	0.0
26	CAPIN PRESSURE CONTROL	t	102.4	102.4	ມ ີ ເ	0.0	د•0	0.0
28	POT. H20 STORAGE - CLOSED LOCP	•-	υ°υ	0.0	ני כי	0.0	ن• د	0.0
29	POT. H2C STCRAGE - EVERGENCY	14	0°0	0.0	10 ° 0 ° 0 ° 0	0.0	с•с с	(: * 0
63	REVERSE OSMOSIS - POTABLE P20		121.7	121.7	0°ŭ	0.0	c •0	0.0
ទ	PRCCESSED H2D POST-TREATWENT PCT	••	1.6	1.6	J°0	0.0	0.0	0.0
0 E	WASTE P20 STORAGE & PRE-TREAT		د • د	0.0	102.4	0.0	c•0	0.0
11	KASH H20 STORAGE #144444	*1	د • ن ن	0.0	1285.6	0.0	د. 0	0.0
74	HYGIENE H20 STCRAGE++++++++++++++++++++++++++++++++++++	-1	د. د	0.0	1463.5	0.0	c.0	0.0
75	PEVERSE OSMOSIS - 4YCIENE H2G	ŝ	785.3	795.3	د • د	0.0	c. 6	9. 0.
67	H2C PECOVEPY - V.P.C.A.R	-1	401.7	401.7	ີ້	0.0	د . د	0.0
76	PRECESSED HZG POSI-IREATMENT HYG	•	10.4	10.4	ວ ະ ບ	Ú.9	υ ・ υ	C*0
36	H2C QUALITY MONITCRING	F	136.5	136.5	ບ ໍ ບ	0°0	с•с	0.0
37	HEALTH & HYGIENE - HAND WASH	-1	0°0	0.0	392.5	0.0	c.0	0 0
33	HEALTH & HYGIEVE - HCT H20 SPLY-	-1	51.2	51.2	682.6	0.0	0°0	0.0
6 e	HEALTH & HYGIENE - CCLC H2C SPLY	•-4	0°0	0.0	0.0	0.0	0.0	0°00°0
40	HEALTH & HYGIENE - BCDY SHCWER	-1	с•с	0.0	504°2	0.0	с. О	0.0
41	HEALTH & HYGIENE - DJSHMASHER	•	ເ ເ	0.0	2070.3	0.0	u" u	0.0
42	HEALTH & HYGTENE - CLTH WASH/DPY	-	с•о	0.0	1211.6	0.0	°°0	0°0
64	HEALTH & HYGIENE - CCMMCDE/UPINL	Ð.	د•د	c	1843 . 7	0°0	ύ°υ	0°0
44	PEALTH & HYGIENE - EVER KSTE CCL	m	с•с	0.0	0°C	0.0	0°0	0.0
45	HEALTH & HYGIENE - THASH COMPACT	-	υ - υ	0.0	460.5	0.0	0.0	0.0
46	PEALTH 5 HYGIENE - DVEN	•••	ن• ن	0.0	1416.1	0.0	c. 6	(·•0
47	HEALTH & HYGIEVE - FCOT REFRIDGE	-	с• с	C • 0	υ°c	51.2	51.2	1574.6
8 8	FEALTH & HYGIEVE - FOUT FREEZER-	•1	с С	0.0	ະ ເ	51.2	51.2	4641.7
				11111		***		1 7 1 5 1
	TOTALS		7662.4	7662.4	17122.5	31792.5	31792.5	15427.2

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

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VCAR SPACE STATION ECUES CONFICURATION AC. 2 SUGMADI SUEET - PAGE 4 E Mam Chem 1 Module - Tutitat Supply Perion = 90°C rays, Mischerly Freitur - 40°C Days

		2 V928	ALANCE FO	R RASSFS	(YCY)	¥ 5	SS PALANC	5 FOP % AT	taran) ag	~
ITEW	UNTES	DXVGEN	NITREGEN	1 ARBON	нускодем	CCADENSATE	PUTABLE	1004		HYGIENE
22	SUBSYSTEM OR COMPONENT REG'D			DICTOR		•)	•	
	BASIC CREW AND MODULE	-14.833	-0.387	17.600	4 / W	41.200	-54.080	373.440	38.160	-340.800
1	HX & FANS - AIF CECLING 1	00000	000 .	0.000	ບ່ານບໍ່ມ	0.000	00u°u	0.000	000.0	00000
70	HX & FANS - ODDR CONTROL 1	00000	000-0	0.00.0	100°	0000	0,00	0.0.0	000 0	0.000
14	4X - ECUIPMENT COLEPLATES 22	0000	000-0	0.000	101°0	0,000	000 °u	0.070	0,000	0.0.0
m	HX & FAMS - HUMIDITY CONTROL 1	00000	0.00	000.0	00000	-50.322	000000	0.000	000 .	0.000
4	CC2 REMOVAL - EDC1	-8.108	000-1	0,000	-1.21£	9.172	00000	0,0,0	000 0	0.000
11	CC2 FERUCTION - BOSCH 1	0.000	000°°		-1.854	0.000	16.587	0:0:0	00000	00000
13	TRACE CONTAMINANT CONTROL 1	0000	000° J	0.000	000-0	0.000	1.000	0000 • 0	0.000	00000
4	ATMOSP MENITOR - MASS SPECTRMTR- 1	0.010	0°00"	0.00.0	100°J	0,000	00000	0.010	00000	00000
÷:	P2 SPPPLY - STAILC FEEL ELECTR 1	25.645	r.000	0°00°0	3 . 206	0.000	-29,950	0.000	ບິ0ບື່ນ	0000
22	C2 STCPAGE - HI PRESS THERG 1	0.000	J(:)"	0.019	0 000°0	0°010	ບ0ບ ໍ ່ ນ	0.000	000.0	0.000
24	N2 SUPPLY - M2H4 DECOMPOSITICA 1	0.000	r.102	0.000	C°013	0.000	u^u^u	0.0.0	000	0000
25	N2 STORAGE - HI PRESS FMFRG 1	00000	c.000	0,0,0	000.0	0,000	000°u	0000	000°u	0.000
26	CABIN PRESSURE CONTROL 1	0.000	υ00°υ	0.00	000-0	(.uo*0	000°0	0.000	0.00	0.000
28	PCT. H20 STORAGE - CLOSET LOCP 1	0.000	000°0	0.000	C. AOP	0.000	0,000	0000	000.0	0.000
2 <i>à</i>	PCT. H2C STORAGE - EVEPGENCY 14	0.000	000.0	0.000	000°0	0000	000.0	0.000	001 0	0.000
63	PEVERSY CSMOSIS - FCTAPLE 426 1	000000	00000	0.000	0.00	0.000	47.307	0000	6TU°E	0.000
ЭS	PROCESSED H20 POST-IREATVENT PCT 1	0.000	000.0	0.000	00000	0.000	000 0	0.000	00000	0.000
30	WASTE H2C STORAGE & PRE-TREAT 1	0.000	r.cor	00000	00010	0,000	uño"u	0.000	0.000	0.000
71	WASH H20 STDRAGE	00000	000°0	0.000	000 0	0000	00000	0.000	00000	0.000
74	HYGIENE HZO STORAGE 1	0,000	, 00 °	0,000	000.0	0.000	000-0	00000	000000	0.000
75	REVERSE CSMOSIS - FYGIENE H2C+++ 5	0.000	r.ñon	0.000	2000	0,009	000°0	-323,440	19.406	304,034
67	HZO RECOVERY - V.P.C.A.R 1	-2.703	°,299	2.814	C.05C	0.000	61.723	0.000	-00.585	000*0
76	PPOCESSEE 420 POST-IPEATVENT HYG 1	0.00	J00 J	000.00	ບົບບີ	0.000	0,000	00000	000°0	0.000
36	P2C GUALITY MCNITOFING1	0.000	100°'	0.0.0	100° J	0.000	000° 0	0000	000°0	00000
37	HEALTH & HYGIENE - HANT WASH 1	00000	000-0	0,000	000.0	0000	000°0	0-0-0	600.0	0000"0
ж М	HEALTH & HYGIENE - HOT H2C SPLY- 1	00000	000.0	0.00	000.0	0,000	000°0	0000	60000	00000
6 6	HEALTH & HYGIEVE - COLF F2C SPLY 1	0.000	000°0	0.000	100°U	000.00	00000	0.000	0000 0	0000
0 v	HEVRLH & HACIENE - BOOA SHOMER 1	0.000	000.0	0,000	101°0	0000	000.0	0.000	600°0	00000
4	HEALTH & HYGIENE - UISPWASHER 1	0.000	000.0	0.000	ເດີນ ເ	0000	0°0°0	0.0000	00000	00000
42	HEALTH & HYGTENE - CLTU WASH/DFY 1	0.00	1,000	000.0	000.5	0.000	0.000	0,000	00000	0,000
43	PEALTH & HYGTEVE - COMMOLE/UPINL 4	0u0°ù	1.000	0-0-0	000°0	000-0	u0v°0	00000	000.0	0:000
44	HEALTH & HYGIENE - EVER WSTE COL 3	0000	000.0	000 * 0	ບາດເ	00000	000000	000.0	0000 0	0000
45	HEALTH & HYGIENE - IPASH CCMPACT 1	0.000	ບບິນ " ບ	Cu0*6	ເວິດ "ບ	0.000	u0u°e	0.000	00000	0'0'0
46	HEALTH & HYGISNE - CVEN+1	0.00.0	r.ruc	009.0	ປີບໍ່ບໍ່	0.000	0,00,0	0,000	1 00°0	00000
47	HEALTH & HYGIENE - FOOE PEFRIDGE 1	00000	000"0	000 .	ر * ن0 د	0.00.0	000°0	00000	u0u"0	00000
79 74 74	HEALTH & HYGIENE - FOOT FRERZER- 1	0,000	00000	0.00.0	ເຈັບ ເ	00000	100°	0.000	00000	0.000
	SUBSYSTEP ULLAGE (CUMULATIVE)	0000 0	-0.015	-0.019	-c.c3	0.000	000 0	0000	000.0	0.0.0
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	Trials	0000	000-0	0,000	0°145	(°U() • O	42.782	0000	0,000	-36,766

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

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Physiochemical Waste Ma	6. Performing Organization Code				
, , , , , , , , , , , , , , , , , , ,		SLX			
7. Author(s)	8. Performing Organization Report No.				
M. Oleson, T. Slavin, F. Liening, R.L. Olson		37 10. Work Unit No.			
9. Performing Organization Name and Address	m(02/				
Boeing Aerospace Company Seattle, Washington 98124 ·		11. Contract or Grant No. NAS2-11806			
					13. Type of Report and Period Covered
				12. Sponsoring Agency Name and Address	Contractor Report
National Aeronautics and Space Administration		14. Sponsoring Agency Code			
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15. Supplementary Notes					
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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.

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