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18 January 1985

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FAIRCHILD REPUBLIC COMPANY

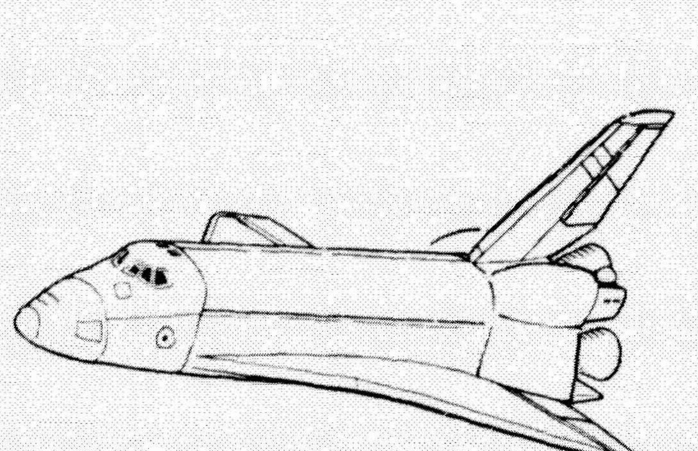
WASTE COLLECTION SYSTEM CONCEPTUAL STUDY

FINAL REPORT

NASA

LYNDON B. JOHNSON SPACE CENTER

CONTRACT NUMBER NAS9-17223



FAIRCHILD
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SPACE SHUTTLE ORBITER

WASTE COLLECTION SYSTEM

CONCEPTUAL STUDY

FINAL REPORT
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PREPARED FOR NASA
LYNDON B. JOHNSON SPACE CENTER
CONTRACT NUMBER NAS 9-17223

FAIRCHILD

Fairchild Republic Company Farmingdale, L.I. New York 11735

Fairchild Republic Company has prepared this Final Report in accordance with the Data Requirements List T-1837 and NASA Statement of Work Exhibit A to RFP 9-BC72-72-4-31P entitled Space Shuttle Orbiter Waste Collection System (WCS) Study. The report completes the contractual requirements per NASA Contract NAS 9-17223 dated 31 August 1984.

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WCS

TABLE OF CONTENTS

Executive Summary

This document summarizes the analyses and studies conducted to develop a recommended design concept for a new Fecal Collection System that can be retrofited into the Space Shuttle vehicle to replace the existing troublesome system which has had limited success in use. The concept selected is a Cartridge Compactor Fecal Collection Subsystem which utilizes an airflow collection mode combined with a mechanical compaction and vacuum drying mode that will satisfy the Shuttle requirements with respect to size, weight, interfaces and crew comments.

A follow-on development program has been recommended which will result in flight test hardware retrofitable on a Shuttle vehicle. This will permit the NASA to evaluate the system which has Space Station applicability before committing production funds for the Shuttle fleet and Space Station development.

1.0 INTRODUCTION

Fairchild Republic Company (FRC) has completed the three month study in response to the NASA Statement of Work, Exhibit A to RFP9-13C72-72-4-31P entitled Space Shuttle Orbiter Waste Collection System (WCS) Study per NASA Contract NAS 9-17223 dated 31 August 1984. The study was conducted in accordance with the Program Plan, Figure 1-1 and FRC Proposal AE006P2100 dated 13 August 1984. This final report has been prepared per the Data Requirements List Number T-1837 of Exhibit A to the aforementioned RFQ and completes the contractual requirements for the NASA Contract NAS 9-17223.

This report summarizes the verbal report MS254V1002 as outlined in Figure 1-2, presented to the NASA on 11 December 1984 at Johnson Space Center and approved by NASA letter dated 12 December 1984. The report will also address the technical direction requested in the aforementioned letter with respect to including a ROM (rough order of magnitude) estimate of Non Recurring and Recurring Costs for each system evaluated for the Shuttle which is shown in Appendix B. Also the Trade Study criteria and evaluation will be based on 60 man-days of WCS use rather than 210 which was the original baseline for the study.

2.0 SCOPE

The study objective was to develop a design concept for improved waste collection that resolves the inflight usage problems encountered with the present Space Shuttle Orbiter waste collection subsystem (WCS) and which could be a precursor for the Space Station WCS. The effort completed has resulted in a recommended optimum waste collection subsystem design concept which could be developed as an Orbiter flight test article for concept verification and subsequent production of new flight hardware. Appendix A of this document contains a systems requirements definition of the recommended approach for an optimum fecal collection subsystem which will provide the basis for follow-on effort to develop test hardware for concept verification on the Shuttle Orbiter vehicle.

3.0 TASK

Develop a design concept for improved waste collection that resolves the in-flight usage problems encountered with the present Space Shuttle Orbiter waste collection subsystem. Inflight use of the existing subsystem had only limited success. Generally, the urine collection function has been satisfactory. However, problems have been experienced with feces collection.

3.1 Orbiter Waste Collection System (WCS) Review

The existing Space Shuttle Orbiter WCS is designed to accommodate both male and female crew members. Air flow is used to separate and collect the metabolic wastes, urine and feces. Once collected, the urine is transferred to a waste storage tank. The feces collection assembly contains a high speed motor which directs the collected feces against the side of the container where the feces are vacuum dried.

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WASTE MANAGEMENT SYSTEM

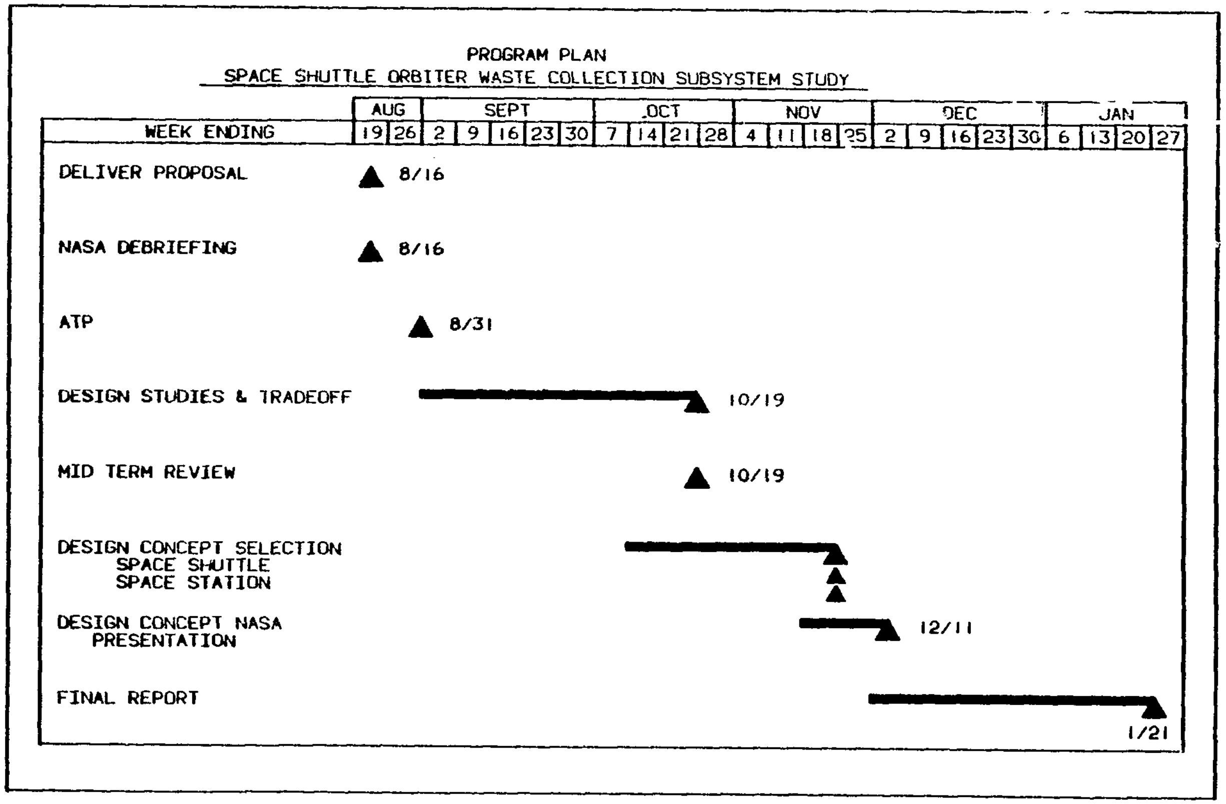


Figure 1-1.

AGENDA

- INTRODUCTION
- PROGRAM PLAN
- SHUTTLE ORBITER WASTE COLLECTION SUBSYSTEM
- STUDY CRITERIA
- DESIGN CONCEPTS
    - SYSTEM DESCRIPTIONS, SKETCHES, SCHEMATICS
- TRADE STUDY
    - DISCUSSION WITH RESPECT TO CRITERIA
- OPTIMUM DESIGN CONCEPTS
    - SHUTTLE
    - SPACE STATION
- SUMMARY

Figure 1-2

3.1.1 Orbiter WCS Functions

The WCS is an integrated multifunctional system primarily utilized to collect and process biowastes from male and female crew members in a zero gravity environment. The system is used as a standard earth one g facility, and performs the following general functions:

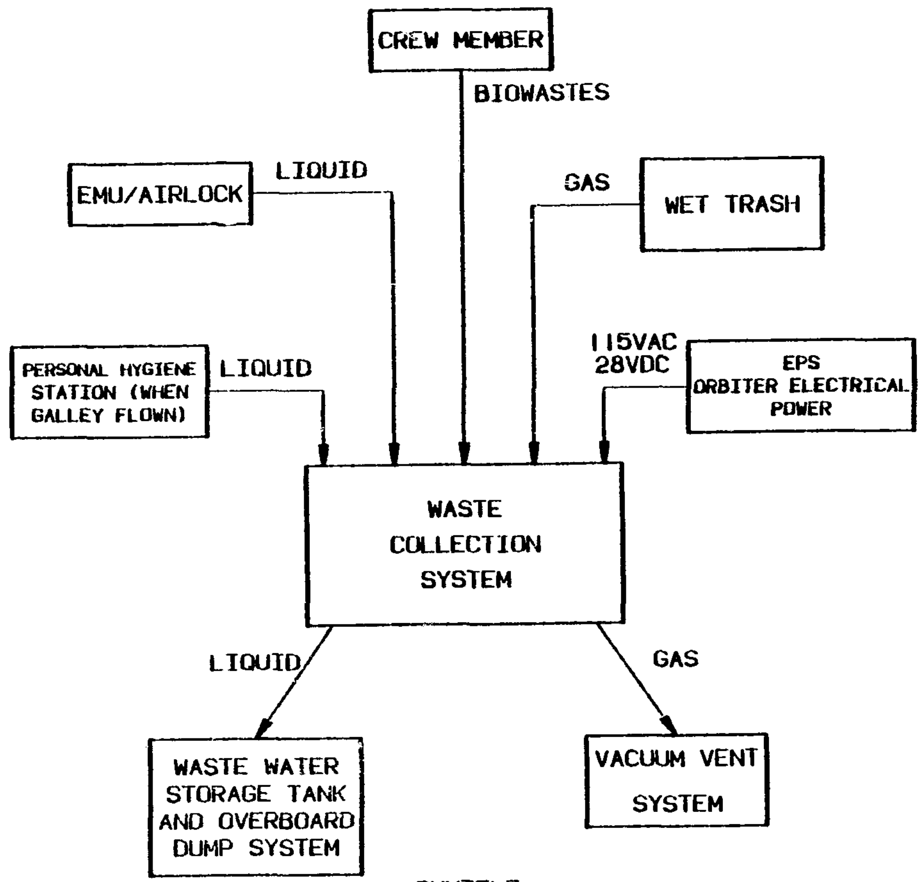
- o Collects, stores and dries fecal wastes and associated tissues.
- o Processes urine, and transfers it to the waste water tank.
- o Processes Extravehicular Mobility Unit (EMU) condensate water from the airlock, and transfers it to the waste water tank.
- o Provides an interface for venting trash container gases overboard.
- o Provides an interface for dumping Air Revitalization System (ARS) waste water overboard in a contingency situation.
- o For flights when galley is flown, processes wash water from the Personal Hygiene Station (PHS) and transfers it to the waste water tank.

The primary WCS Interfaces are shown in Figure 3-1 and the system schematic is shown in Figure 3-2.

3.1.2 Orbiter WCS Major Components are:

- o Commode - The commode is the storage container for solid waste. When in use, the commode is pressurized and transport airflow is provided by the fan separator. When not in use, the commode is depressurized for solid waste drying and deactivation.
- *o Slinger - The slinger, which is inside the commode, is a circular plate. It rotates at a high RPM to propel incoming solid wastes, and deposits them on the inner walls of the commode.
- o Urinal - The urinal, essentially a funnel attached to a hose, provides the capability to collect and transport liquid waste to the waste water tank. The fan separator provides transport airflow for the liquid.
- o Fan separators - The separators provide transport airflow through the commode and urinal, and separate the waste liquid from the airflow. The liquid is drawn off to the waste water tank, and the air returns to the cabin through the odor/bacteria filter.
- o Vacuum vent QD - The QD is used to vent liquid directly overboard from equipment connected to the OD, through the vacuum vent line.
- o WCS controls - The WCS has several valves and switches which are used to configure the commode for the different operational modes. Figure 3-3.

*During later missions the Slinger and Motors were removed and are replaced by a large liner bag with liquid/solid fitters.



SHUTTLE
WCS INTERFACES
(VACUUM PROCESSING)

Figure 3-1

FAIRCHILD REPUBLIC COMPANY

WASTE MANAGEMENT SYSTEM

MS254V1002
11 DECEMBER 1984

SPACE SHUTTLE WCS

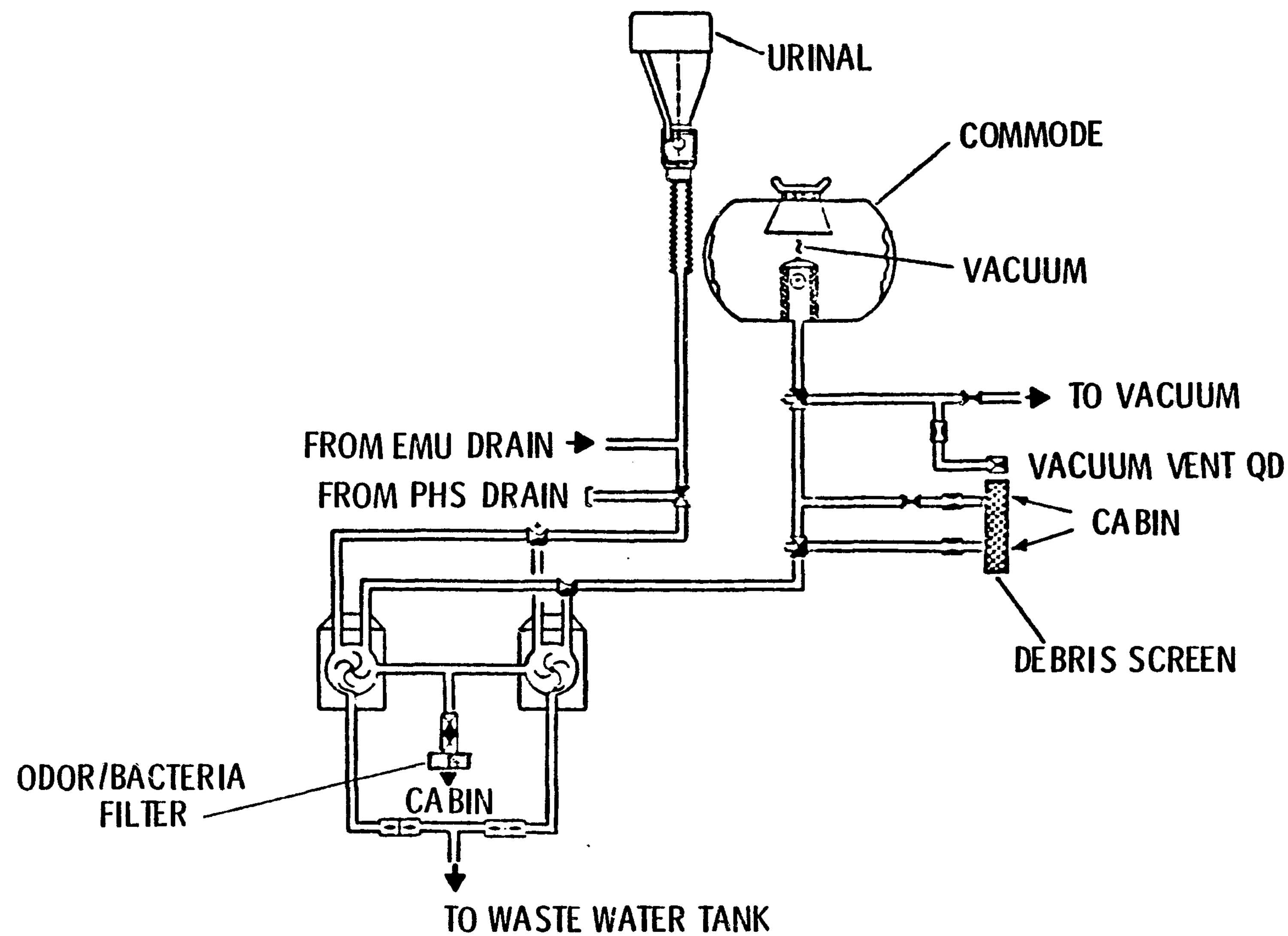


Figure 3-2

WASTE COLLECTION SYSTEM CONTROLS

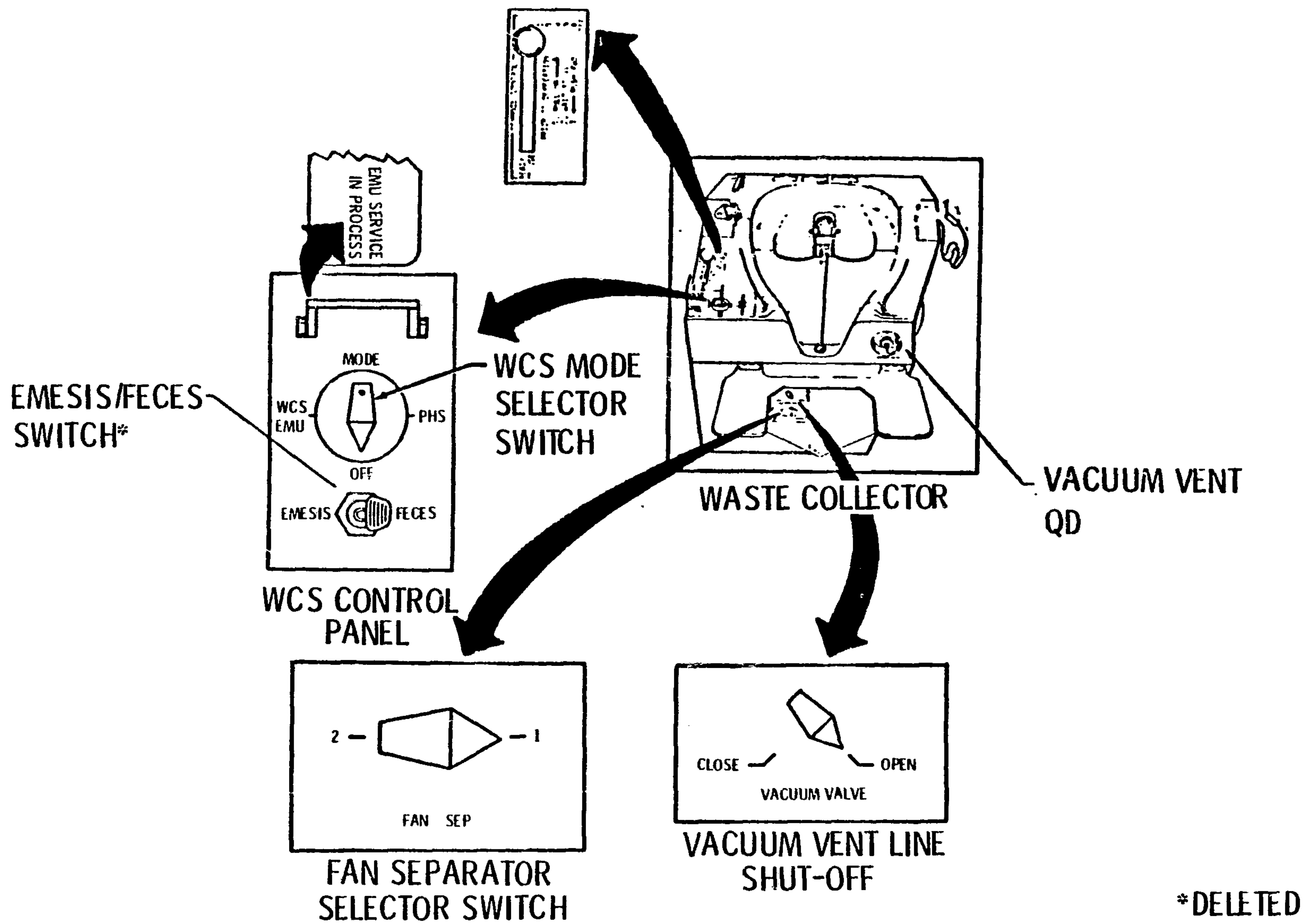


Figure 3-3

3.1.3 WCS Operational Modes

The WCS has three primary operational modes and four back-up failure type modes as follows:

- o Urine Collection
- o Urine/Feces Collection
- o EMU/Airlock Water Collection
- o Backup Feces Collection - Failed Slinger
- o Backup Feces Collection - Failed Fan Separator (Backup Fan Separator Activities)
- o Backup Feces Collection - Failed Fan Separators
- o Backup Urine Collection - Failed Close Pinch Valve

When the galley is installed in the Orbiter, the WCS will process the waste water from the Personal Hygiene Station (PHS) which is an integral part of the galley.

3.1.4 WCS Inflight Cleaning Maintenance

WCS cleaning is scheduled as a daily inflight activity. Biocidal cleanser, disposable gloves, general purpose dry wipes, small wet wipes and Contingency Slinger Scraper Tool (CSST) are provided for cleaning the WCS. A urinal screen located at the base of the urinal funnel captures air entrained debris and should be replaced at least twice per day. The odor/bacteria filter can be removed and replaced with a spare filter if excessive odors are present. In addition, the PHS water hose should be used:

- o At least once per day to clean or flush areas of the urinal with water.
- o To remove debris from transport tube below the commode gate valve (use water sparingly) as required.

3.2 Orbiter WCS Inflight Problems and Corrective Actions

Tables 3-1 are a listing of the inflight problems and associated corrective measures implemented by STS mission. In general the Urine Collection System, Odor Control System and improvements made in the body stabilization (restraint) designs are working well with minimal problems and corrective measures required. Based on crew surveys, waste collection is subject to many personal performances and usage performance varies among crew members. The flight problems listings cover flights STS-1 through STS-13 inclusive.

TABLE 3.1

SPACE SHUTTLE ORBITER
WASTE COLLECTION SYSTEM FLIGHT PROBLEMS

STS-1 FLIGHT PROBLEMS	CORRECTIVE ACTION FOR STS-2 AND SUBS
o DEGRADATION OF AIR FLOW, DUE TO FLOODING OF FAN SEPARATOR AND ODOR/BACTERIA FILTER PRIOR TO FLIGHT	o STOWED SPARE ODOR/BACTERIA FILTER, CHANGED SERVICING PROCEDURES TO PREVENT FLOODING
o URINE HOSE SCREEN BLOCKED WITH LINT AND OTHER DEBRIS	o DEVELOPED AND INSTALLED URINE PREFILTER WHICH CAN BE CLEANED OR REPLACED
STS-2 FLIGHT PROBLEMS	**CORRECTIVE ACTION FOR STS-3 AND SUBS**
NONE REPORTED	o NONE

TABLE 3.2

SPACE SHUTTLE ORBITER
WASTE COLLECTION SYSTEM FLIGHT PROBLEMS

STS-3 FLIGHT PROBLEMS	CORRECTIVE ACTION FOR STS-4 AND SUBS
o SLINGER STALLED DUE TO EMESIS BAG	o STS-4 & SUBS - EMESIS BAGS WERE STOWED IN WET TRASH BAGS - REVISED SLINGER START UP SEQUENCE, SLINGER SPINS BEFORE AIR FLOW BEGINS o STS-5 & SUBS - LOWER TINES WERE SWEPT BACK HIGHER TORQUE SLINGER MOTOR
o FECAL WASTES WEREN'T TRANSPORTED PROPERLY TO SLINGER DUE TO CREW MISALIGNMENT	o STS-4 - WCS ALIGNMENT TRAINER DEVELOPED - CREW HAD ACUTAL USE TRAINING LONG TERM FLIGHT SIMULATION - TRANSPORT TUBE TEFLON-COATED
o "LAST DROP" URINE COLLECTION INADEQUATE	o STS-5 & SUBS - IMPROVED URINAL DEVELOPED TO COLLECT URINE "LAST DROP"
o WIPES UNSATISFACTORY, TOO SMALL, TOO "SLICK" CREW USED LARGE WIPES	o STS-4 & SUBS - NEW TISSUE WIPES PROVIDED SIZE INCREASED FROM 4" x 5" TO 5" x 8½". BETTER TEXTURE.
o VACUUM VALVE KNOB CAME OFF OF SHAFT	o STS-4 & SUBS - SET SCREWS WITH ROLL PINS INSTALLED.
o WCS MODE SELECT VALVE DIFFICULT TO ROTATE DUE TO URINE SOLIDS BUILDUP I VALVE	o STS-4 & SUBS - VALVE MODIFIED TO PREVENT SOLIDS BUILDUP
o URINE LEAK AT URINAL CONNECTION AFTER PREFILTER REPLACEMENT DUE TO IMPROPER SIZE GASKET	o STS-4 & SUBS - PROPER GASKETS PROVIDED

TABLE 3.3

SPACE SHUTTLE ORBITER

WASTE COLLECTION SYSTEM FLIGHT PROBLEMS

STS-4 FLIGHT PROBLEMS	CORRECTIVE ACTION FOR STS-5 AND SUBS
o CREW NOT PROPERLY RESTRAINED, "NOT ENOUGH HANDS TO DO EVERYTHING"	o 3 BODY RESTRAINT DEVICES PROVIDED, CREW EVALUATED IN FLIGHT
	o ADJUSTABLE FOOT REST WITH FOOT RESTRAINTS DEVELOPED
o CREW NOT PROPERLY RESTRAINED DURING STANDUP URINATION	o TOE BAR AND LEG STRAPS DEVELOPED FOR STANDING URINATION
o URINE LEAKED FROM UNDER URINAL CAP	o URINAL CAP (FOR MALES) PROVIDED WITH SEAL TO PREVENT LEAKAGE AND PAINT COATING REMOVED TO PREVENT WETTING.
o SLINGER SLOWED DOWN OVER COURSE OF MISSION MOTOR, 4 TIMES AS MUCH TORQUE	o SLINGER MOTOR REPLACED WITH DIRECT DRIVE
o "LAST DROP" URINE COLLECTION INADEQUATE	o URINAL DESIGN IMPROVED, HAS "LAST DROP" MODE
o URINAL AIR FLOW WAS LOW AT TIMES, DUE TO PREFILTER CLOGGING	o PREFILTER PADS WERE DEVELOPED. URINAL WAS REDESIGNED TO ALLOW EASY CHANGEOUT OF THE THE NEW PREFILTER PADS. MORE PREFILTER PADS PROVIDED TO ALLOW DAILY REPLACEMENT
o CREW COMMENT: "TRAINING PRIOR TO FLIGHT IS ESSENTIAL"	

TABLE 3.4

SPACE SHUTTLE ORBITER

WASTE COLLECTION SYSTEM FLIGHT PROBLEMS

STS-5 FLIGHT PROBLEMS	CORRECTIVE ACTION FOR STS-6 AND SUBS
o IN GENERAL, WCS WORKED WELL, CREW DESCRIBED SYSTEM AS "OPERATIONAL	
o CREW EVALUATED 3 BODY RESTRAINTS, SELECTED THIGH BARS AS OPTIMUM	o WAIST BELT RESTRAINT REMOVED FROM FLIGHTS. THIGH STRAPS RETAINED TO HOLD STOWAGE BAG AND SERVE AS BACKUP TO THIGH BARS
o PROBLEMS	
- ON A FEW OCCASIONS, SMALL BITS OF FECAL MATTER CAME OUT OF COMMODE	- CREW TOLD DURING TRAINING TO MINIMIZE TIME THAT SLIDE VALVE IS OPEN. PROBLEM STUDIED.
- SLINGER LABORED AND CYCLED IN SPEED DURING LATTER MISSION DAYS	- FOR STS-8, UPPER TINES WERE RETAINED IN DOWN POSITION

TABLE 3.5

SPACE SHUTTLE ORBITER
WASTE COLLECTION SYSTEM FLIGHT PROBLEMS

STS-6 FLIGHT EXPERIENCE	CORRECTIVE ACTION FOR STS-7 AND SUBS
o IN GENERAL, WCS WORKED WELL	
o CREW DID NOT NOTICE FECAL MATERIAL COMING FROM COMMODE	
o PROBLEMS	
- FAN SEPARATOR #1 MADE UNUSUAL NOISE AND VARIED IN SPEED, BUT DID NOT STOP WORKING. FAN SEPARATOR #2 WAS NOT USED	- FAN SEPARATOR FAILURE ANALYSIS REVEALED BEARING WAS WORN. FAN SEPARATOR WAS REPLACED
- SLINGER LABORED AND CYCLED IN SPEED DURING LATTER MISSION DAYS	- PROBLEM UNDER STUDY

STS-7 FLIGHT EXPERIENCE	CORRECTIVE ACTION FOR STS-8 AND SUBS
o PROBLEMS	
- CREW REPORTED DEGRADATION OF URINAL AIR FLOW AND URINE BACKUP IN URINAL	- LOW AIR FLOW POSSIBLY DUE TO ODOR/BACTERIA FILTER FLOODING PRIOR TO LAUNCH. INVESTIGATIONS DID NOT CONFIRM THAT THIS HAPPENED. ADDITIONAL PROCEDURE IMPLEMENTED AT PAD TO RUN WCS AND CHECK FOR WATER IN DUCT PRIOR TO ODOR/BACTERIA FILTER INSTALLATION. NUMBER OF PREFILTER PADS STOWED WAS DOUBLED.
- SLINGER QUIT OPERATING ON FIFTH DAY OF MISSION, CREW CONTINUED TO USE WCS IN "OUT HOUSE" MODE WITH NO SIGNIFICANT DIFFICULTIES.	- SLINGER MICROSWITCH FAILURE CONFIRMED; SWITCH WAS REPLACED. PROCEDURE DEVELOPED FOR CREW TO JUMPER MICROSWITCH CONNECTORS IF PROBLEM OCCURS AGAIN.

TABLE 3.6

SPACE SHUTTLE ORBITER
WASTE COLLECTION SYSTEM FLIGHT PROBLEMS

STS-7 FLIGHT EXPERIENCE	CORRECTIVE ACTION FOR STS-8 AND SUBS
- DUST PARTICLES FLOATED FROM COMMODE POST-FLIGHT COMMODE WAS FULL OF PAPER AND SLINGER FILTER WAS CLOGGED DUE TO FECAL AND PAPER DUST	- PROBLEM UNDER EVALUATION. UPPER TINES WERE RETAINED IN DOWN POSITION TO PREVENT DUST GENERATION AND REDUCE REVERSE AIR FLOW AND PARTICLE IMPACTS. - CREW CAUTIONED TO MINIMIZE NUMBER OF TISSUES DEPOSITED IN COMMODE. USE WET WIPES AND DEPOSIT IN WET TRASH COMPARTMENT
- DURING POST-FLIGHT INVESTIGATION, DEBRIS SEAL WAS FOUND LEAKING. THIS ALLOWED FECAL MATERIAL INTO FAN SEPARATORS AIR DUCTS, BUT ODOR/BACTERIA FILTER PREVENTED IT FROM GETTING OUT OF SYSTEM INTO CABIN	- DESIGN CHANGE BEING EVALUATED. FILTER SILICONE COMPOUND WAS USED TO SEAL FILTER UNTIL IMPROVED FILTERS ARE AVAILABLE.

STS-8 FLIGHT EXPERIENCE	CORRECTIVE ACTION FOR STS-9
o IN GENERAL, WCS WORKED - URINE COLLECTION WAS SATISFACTORY, AIR FLOW WAS ADEQUATE - FECES COLLECTION WAS SATISFACTORY	
o PROBLEMS - SEVERAL TIMES, FECAL MATERIAL WAS EJECTED FROM COMMODE WITH SLIDE VALVE OPEN	o UPPER SLINGER TINES WERE REMOVED

TABLE 3.7

SPACE SHUTTLE ORBITER
WASTE COLLECTION SYSTEM FLIGHT PROBLEMS

STS-8 FLIGHT EXPERIENCE	CORRECTIVE ACTION FOR STS-9 AND SUBS
o PROBLEMS (cont'd)	
- SLINGER MADE IMPACT NOISES AND CYCLED IN SPEED IN LAST 24-36 HOURS OF MISSION	o CREW WAS PROVIDED WITH ALTERNATIVE PROCEDURE TO USE LATE IN MISSION ACCORDING TO THEIR OPTION: - USE COMMODE WITHOUT SLINGER TURNING - AFTER USE, CLOSE SLIDE VALVE AND OPERATE SLINGER
- COMMODE OUTLET VACUUM VALVE LEAKED, LOSING SOME CABIN AIR TO SPACE. CREW CLOSED MANUAL VACUUM VALVE AT NIGHT. ODORS DID NOT DEVELOP.	o VALVE LEAK DUE TO FAULTY LINKAGE. LINKAGE AND ALIGNMENT VERIFIED PRIOR TO STS-9. REDESIGN IS UNDERWAY.
- WCS NOISE LEVEL WAS DISTURBING - CREW AVOIDED USE DURING SLEEP PERIODS TO KEEP FROM WAKING OTHERS.	o NOISE ATTENUATION WAS INSTALLED ON COVER OF COVER OF WCS. SLEEP COMPARTMENTS WERE SEALED SEALED TO PROVIDE BETTER ACOUSTIC ISOLATION.
STS-9 FLIGHT EXPERIENCE	**CORRECTIVE ACTION FOR STS-11 (41-B)**
o URINE COLLECTION WAS SATISFACTORY THROUGHOUT THE MISSION	
o EVEN WITH THE TWO-SHIFT OPERATION, THE WCS DID NOT DISTURB SLEEP. SLEEPING COMPARTMENTS PROVIDED GOOD SOUND ISOLATION.	
o STARTING ON DAY 6, FECAL MATERIAL WAS EJECTED FROM THE WCS. THIS WAS DUE TO FINE DUST GENERATED BY THE LOWER TINES BLOCKING THE SLINGER DEBRIS FILTER AND STOPPING AIR FLOW.	o LOWER SLINGER TINES WERE REMOVED

TABLE 3.8

SPACE SHUTTLE ORBITER
WASTE COLLECTION SYSTEM FLIGHT PROBLEMS

STS-11 (41B) FLIGHT EXPERIENCE	CORRECTIVE ACTION FOR STS- (41-CB)
o COMMODE AIR FLOW WAS GOOD FOR ENTIRE MISSION. THERE WAS NOT WASTE MATERIAL EJECTION.	
o ON 1ST FLIGHT DAY, FAN SEP #1 FLOODED AND WOULD NOT RUN AT NORMAL SPEED. CREW USED FAN SEP #2 FOR THE REST OF THE MISSION. DATA INDICATED MOMENTARY, INTERMITTENT LOSS OF POWER TO FAN SEP #1.	o FLOODED FAN SEP CLEARING PROCEDURE DEVELOPED FOR CONTINGENCY USE ON ON SUBSEQUENT FLIGHTS. o WCS MODE SWITCH WAS CHECKED IN-VEHICLE VERIFIED TO HAVE PROPER OVER-TRAVEL.
o LATE IN MISSION, SLINGER CIRCUIT BREAKER OPENED DUE TO FECAL MATERIAL FREEZING FROM SLINGER TO TRANSPORT TUBE. CREW USED PRY BAR TO FIX THE PROBEM.	o TRANSPORT TUBE WAS SHORTENED
o CREW HAD NO PROBLEMS WITH SLINGER STOPPAGE HOWEVER, STARTING ON THE FOURTH DAY, CREW HAD TO USE SCRAPER TOOL TO PREVENT WASTE MATERIAL BUILDUP ON SLINGER HEAD.	o WCS WITH BAG LINER DEVELOPED AND AND WILL BE PROVIDED FOR FLIGHT 41-D.
o ON SECOND DAY, FAN SEP #1 EXHIBITED LOW AIR FLOW. CREW SWITCHED TO FAN SEP #2. AIRFLOW DID NOT IMPROVE. SEVERAL HOURS LATER FAN SEP #2 FAILED TO RUN. CREW SWITCHED BACK TO FAN SEP #1 AND REPLACED ODOR/BACTERIA FILTER. AIR FLOW DID NOT IMPROVE. LATER IN MISSION, CREW CYCLED DC BREAKER AND FAN SEP #2 RAN, BUT ONLY FOR SHORT PERIOD. CREW USED FAN SEP #1 FOR THE REST OF THE MISSION.	o POST-FLIGHT, THE URINAL IN-LINE HOSE SCREEN WAS FOUND TO BE CLOGGED WITH DEBRIS. CHANGE WAS MADE TO WCS CUE CARD AND TRAINING FOR CREW TO INSPECT/CLEAN SCREEN EACH TIME THEY REPLACE PREFILTER. o FAN SEP #2 PROBLEM WAS DUPLICATED AND WAS DUE TO AN INTERMITTENTLY FAILING LIMIT SWITCH. MANUAL SWITCHES WERE INSTALLED ON FRONT PANEL TO BYPASS BOTH MODE SELECTOR AND FAN SEP SELECTOR SWITCHES TO BE USED FOR BACKUP. REDESIGN OF SWITCHING CONTROLS ARE UNDER STUDY.

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TABLE 3.9

SPACE SHUTTLE ORBITER
WASTE COLLECTION SYSTEM FLIGHT PROBLEMS

<u>STS-11 (41B) FLIGHT EXPERIENCE</u>

- CREW HAD NO PROBLEMS WITH SLINGER STOPPAGE HOWEVER, STARTING ON THE FOURTH DAY, CREW HAD TO USE SCRAPER TOOL TO PREVENT WASTE MATERIAL BUILDUP ON SLINGER HEAD.
- ON SECOND DAY, FAN SEP #1 EXHIBITED LOW AIR FLOW. CREW SWITCHED TO FAN SEP #2. AIR FLOW DID NOT IMPROVE. SEVERAL HOURS LATER, FAN SEP #2 FAILE DTO RUN. CREW SWITCHED BACK TO FAN SEP #1 AND REPLACED ODOR/BACTERIA FILTER. AIR FLOW DID NOT IMPROVE. LATER IN MISSION, CREW CYCLED DC BREAKER AND FAN SEP #2 RAN, BUT ONLY FOR SHORT PERIOD. CREW USED FAN SEPT #1 FOR THE REST OF THE MISSION.

<u>CORRECTIVE ACTION FOR STS- (41-CB)</u>

- WCS WITH BAG LINER DEVELOPED AND WILL BE PROVIDED FOR FLIGHT 41-D.
- POST-FLIGHT, THE URINAL IN-LINE HOSE SCREEN WAS FOUND TO BE CLOGGED WITH DEBRIS. CHANGE CHANGE WAS MADE TO WCS CUE CARD AND TRAINING FOR CREW TO INSPECT/CLEAN SCREEN EACH TIME THEY REPLACE PREFILTER.
- FAN SEP #2 PROBLEM WAS DUPLICATED AND WAS DUE TO AN INTERMITTENTLY FAILING LIMIT SWITCH. MANUAL SWITCHES WERE INSTALLED ON FRONT PANEL TO BYPASS BOTH MODE SELECTOR AND FAN SEP SELECTOR SWITCHES TO BE USED FOR BACKUP. REDESIGN OF SWITCHING CONTROLS ARE UNDER STUDY.

3.2.1 Orbiter Improved Filter Bag System STS-41D (14)

A simplified redesigned system was flown on STS-14 which consisted of a large filter bag in the existing housing assembly. This system, provides the following improvements at minimal cost and redesign:

- o Eliminates Slinger/Motor Assembly
- o Eliminates Fecal Dust Generation
- o Eliminates Material Ejection
- o Reduces Noise
- o Reduces Energy Use
- o Enhances Turnaround
- o Minimum Design Impact to Prove Concept in Flight

Post evaluation comments of the system by crew members were material accumulated at the entry port under the seat and had to be cleaved away prior to each use. Waste material did not seem to adhere to bag but float in Zero-G. Satisfactory for short minimal usage missions but would not meet the 210 man-day requirement with respect to capacity.

3.3 Improved WCS Primary Concerns and Design Critiera

The information contained was obtained from a document entitled "Waste Collection System" (WCS) Review questions provided by NASA, and the Rockwell International (Space Division) Specification entitled "Collector Subsystem Waste." In addition, FRC has a wealth of experience with the Skylab project which contributed significantly to the proposed concepts.

3.3.1 Primary Concerns

Some of the primary concerns per figure 3-4, lead to design criteria. FRC was to be able to propose concepts that would eliminate certain problems, yet maintain the requirements established for the shuttle. These requirements included Storage restrictions; material compatibility; noise; and shuttle interfaces. In an attempt to be somewhat creative with the concepts yet to be able to meet user concerns and environmental considerations, a set of design criteria was established.

3.3.2 Design Criteria

The study crew was apprised of these concerns and criteria and were instructed to propose systems that would be in concert with the design criteria established and shown in Figure 3-5. Emphasis was placed on the criteria which dealt with the physical characteristics of the existing system. Some of the Design Criteria dealt specifically with the user requirements. These include such items as being Unisex; as close to normal use as possible; minimal crew training; and no crew contact with the waste material.

SHUTTLE WCS
PRIMARY CONCERNS & DESIGN CRITERIA

<u>CONCERNS</u>

- o COLLECTION AND RETENTION OF FECAL WASTES
  - PROBLEM: SOLIDS AND DUST MIGRATING
- o WASTE STORAGE CAPACITY
  - PAPER AND FECES
  - COMPACTION
- o MATERIAL COMPATIBILITY
  - CORROSION
  - URINE SOLIDS
- o USER PROBLEMS
  - CREW TRAINING
  - POSITIONING
  - CLEANUP
- o NOISE
- o TURNAROUND REDUCED
  - GROUND REFURBISHMENT
- o SHUTTLE INTERFACES

Figure 3-4

SHUTTLE WCS
PRIMARY CONCERNS & DESIGN CRITERIA

DESIGN CRITERIA

- WASTE STORAGE ISOLATION
- SAFE ODORLESS STORAGE OF WASTE
- MALE/FEMALE
- INDIVIDUAL URINE COLLECTION INTERFACE
- NORMAL TO USE/WITHIN MINIMAL TIME
- WIPE/FECAL CAPACITY
- MINIMAL CREW TRAINING
- NO CREW CONTACT WITH WASTE
- CREW FECAL SEPARATION
- CREW STABILIZATION
- COLLECT/STORE 210 MAN DAYS OF WASTE (FECES/WIPES)
- BACTERIA/ODOR CONTROL
- MINIMIZE OPERATING NOISE
- MINIMIZE WEIGHT, POWER & VOLUME
- RELIABILITY/REDUNDANCY (ELECTRICAL/SEALS)
- ORBITER RETROFITABLE

Figure 3-5

In conjunction with the design requirements, the contractor has used the Rockwell Waste Collection Subsystem Procurement Specification (Appendix C) as a guide. Consideration of candidate design concepts are not limited to the specified Orbiter subsystem weight, power and volume.

*The study has used 60 man-days in lieu of 210 man-days of WCS use per the redirection at the 11 December 1984 Oral Report meeting.

3.3.3 Design Criteria Space Station Applicability

The concerns and design criteria were originally applicable to the shuttle. In the process of the study, the team members were also asked to provide information concerning modifications and/or changes required to allow the shuttle proposed system to be applicable for space station use.

Prior to suggesting which proposed shuttle system had applicability to the Space Station, the study team reviewed and initiated certain assumptions per Figure 3-6. The assumptions were essentially based on information received from NASA. In addition, FRC information and experience with Skylab played a significant role in both understanding directed assumptions and the initiation of others which resulted in design criteria shown in Figure 3-7. These assumptions included such considerations as: Support 6 crewmen for 90 days; minimize waste volume storage; and no liquid/solid/gas overboard dump.

3.4 WCS Trade Study Criteria and Weighting Factors

In an attempt to evaluate the concepts proposed by the study team a list of criteria was established which was essentially based on the primary concerns and design criteria. To each criterion was arbitrarily assigned a weighting factor. The numbers were judged on importance to the study team and not necessarily established for other evaluators. However, based on this procedure we were able to quantitatively evaluate each concept per Figure 3-15.

The trade study criteria were assigned to six (6) general categories. The study team agreed to the assignments of the criteria based on a "best fit" philosophy. It is well to understand that the criteria may fit other categories or more than one or not be accepted by the reader. In any case, we proceeded with a basis for a quantitative analysis of the concepts. The general categories are shown in Figure 3-8.

The weighting guides were developed as shown in Figures 3-9 through 3-14 inclusive for each of the categories. Each team member rated each system and the several iterations of the ratings were discussed during team meetings. In addition, non-team members knowledgeable in the areas of engineering and waste management were asked to objectively rate the concepts. The reasons for several iterations were due in part to the bias on the part of the designer to rate his system. The iterations resulted in minimum bias and maximum objectivity and were tabulated for selection per Figure 3-15.

3.4.1 Safety

Crew contamination is of paramount importance. Exposure to untreated waste or contamination excluded the concept from consideration. Reliability required that the system continue to operate even in a degraded mode. It would be considered totally unreliable if the system became inoperable and a backup system were required. (Figure 3-9)

WCS SPACE STATION ASSUMPTIONS

- o SUPPORT 6 CREWMEN FOR 90 DAYS (540 MAN DAYS)
- o ON ORBIT MAINTENANCE
- o ON ORBIT RESUPPLY (90 DAY CYCLES)
- o MINIMIZE WASTE VOLUME STORAGE
- o SELECTIVE BIO-MEDICAL SAMPLING
- o RECYCLING SYSTEMS (LIQUID/SOLIDS)
- o NO LIQUID/SOLID/GAS OVERBOARD DUMP
- o SHUTTLE FLIGHT TESTABLE

Figure 3-6

FAIRCHILD REPUBLIC COMPANY	WASTE MANAGEMENT SYSTEM	MS254V1002 11 DECEMBER 1984

SPACE STATION WCS
PRIMARY CONCERNS & DESIGN CRITERIA

DESIGN CRITERIA

- o WASTE STORAGE ISOLATION
- o SAFE ODORLESS STORAGE OF WASTE
- o MALE/FEMALE
- o INDIVIDUAL URINE COLLECTION INTERFACE
- o NORMAL TO USE/WITHIN MINIMAL TIME
- o WIPE/FECAL CAPACITY
- o MINIMAL CREW TRAINING
- o NO CREW CONTACT WITH WASTE
- o CREW FECAL SEPARATION
- o CREW STABILIZATION
- *o COLLECT/STORE (6 MAN CREW X 90 DAY RESUPPLY) 540 MAN DAYS
- o BACTERIA/ODOR CONTROL
- o MINIMIZE OPERATING NOISE
- o MINIMIZE WEIGHT, POWER & VOLUME
- o RELIABILITY/REDUNDANCY (ELECTRICAL/SEALS)
- *o ON ORBIT MAINTENANCE/RESUPPLY
- *o NO LIQUID/SOLID/GAS OVERBOARD PUMP
- *o SELECTIVE BIO-MEDICAL SAMPLING

*SPACE STATION PECULIAR

Figure 3-7

WCS
TRADE STUDY CRITERIA

A. SAFETY

B. DISCOMFORT

C. ANNOYANCE

D. VERSATILITY

E. NON-FUNCTIONAL

F. SPACE STATION

SOURCE OF CRITERIA

RFQ SHUTTLE ORBITER WCS STUDY CONTRACT
NASA SUPPLIED DATA
FRC EXPERIENCE WITH PREVIOUS NASA HABITABILITY CONTRACTS
FRC EXPERIENCE WITH NASA SKYLAB WMS CONTRACT

Figure 3-8

Figure 3-9

WCS
TRADE STUDY
CRITERIA WEIGHTING FACTORS

	WEIGHT	WEIGHTING GUIDE
A. SAFETY		
1. CREW CONTAMINATION FROM STORED WASTE	10	10 NO EXPOSURE TO WASTE ON NEXT USE
		7 EXPOSURE TO TREATED WASTE ON NEXT USE
		0 EXPOSURE TO UNTREATED WASTE ON NEXT USE
2. CREW CONTAMINATION DURING USE	10	10 NONE
		5 CLEAN-UP MAY BE REQUIRED
		0 CONTAMINATION

WCS
TRADE STUDY
CRITERIA WEIGHTING FACTORS

	WEIGHT	WEIGHTING GUIDE
A. SAFETY		
3. RELIABILITY	10	10 SIMPLE DESIGN - FAIL SAFE OPERATION
		7 OPERATE IN DEGRADED MODE - MECHANICAL FAILURES
		5 COMPLEX DESIGN - FAIL SAFE OPERATION WITH MECHANICAL FAILURE
		3 COMPLEX DESIGN - MARGINAL PERFORMANCE WITH MECHANICAL FAILURE
		0 SYSTEM INOPERABLE - BACK-UP REQUIRED
4. DEVELOPMENT RISK	10	10 MINIMAL RISK (SPACE QUALIFIED)
		6 MODERATE RISK (SIMILARITY ANALYSIS)
		2 HIGH RISK (TEST AND ANALYSIS)

Figure 3-9.1

3.4.2 Discomfort

If crew waste separation required assistance it was considered unacceptable. During the degraded modes of operation, if a back-up system were required it was not considered acceptable. The system would be designed to meet the minimum requirements for 60 man-days. If it exceeded this requirement, it was a plus. All systems must meet the minimum requirement for use if it were to be acceptable. (Figure 3-10)

3.4.3 Annoyance

Male/female common use was a primary consideration. If a system required a replacement of some portion of the system so as to be used by any crewmember, the system received a lesser rating. It was however, acceptable. The time required for use included prep and clean-up time. A time-line was prepared and established a 12 minute requirement for use of the system including disrobing and rerobing. This time was found to be satisfactory by the users and served as a practical time for evaluating this criterion. Noise was an environmental criterion that received significant consideration. The study team established an acceptable evaluation of the concept if the noise generated did not exceed the noise level generated by the current system. In addition, the air flow requirements which are essential for the functional operation of any of these systems be maintained, and do not require air flows in excess of the existing requirements established. Finally, the system, if possible should be a "hands-off" operation. The closer we satisfied this requirement, the more acceptable the system. Any handling of an unsealed container would revert to the safety criteria to be satisfied and be eliminated from consideration. (Figure 3-11)

3.4.4 Versatility

The training required for use during zero g must be kept to a minimum. This time factor was the criterion that had to be satisfied for a proposed system to be acceptable for consideration. Material compatibility was based on space allocation and shelf life. Certain materials which were not tested would be scrutinized based on outgassing considerations. (Figure 3-12)

3.4.5 Non-Functional (Interface)

This category concerns itself with the physical environment and cost. The vehicle has been designed, a system has been designed to function within the confines of this design. Electric power, weight, volume and cost have already been allocated to a significant degree. The purpose of this category for evaluation was to consider any proposed concept within the design limitations of the current system. If a system were accepted from those proposed it would be retrofitable. These criteria and the ratings thereof are of extreme importance. (Figure 3-13)

3.4.6 Space Station

The system proposed must meet the man-day requirements to be acceptable. There is to be no overboard dump (based on a NASA input) and requires minimal on board servicing. Station interfaces and versatility are of secondary importance, once the system is considered conditionally acceptable for space station use. (Figure 3-14)

WCS
TRADE STUDY
CRITERIA WEIGHTING FACTORS

	WEIGHT	WEIGHTING GUIDE
B. DISCOMFORT		
1. CREW WASTE SEPARATION	8	8 APPROACHES 1G
		0 ASSISTED 0G
2. DEGRADED MODES/BACK-UP REQUIRED	8	8 USABLE IN DEGRADED MODE
		4 MARGINAL NO AIRFLOW
		0 NOT USABLE/BACK-UP SYSTEM REQUIRED
3. 210 MAN DAYS	8	8 EXCEEDS REQUIREMENT
		4 MEETS REQUIREMENT
		0 < REQUIREMENT
4. ODOR CONTROL	8	8 < THAN EXISTING
		4 SAME AS EXISTING
		2 > MORE THAN EXISTING

Figure 3-10

WCS
TRADE STUDY
CRITERIA WEIGHTING FACTORS

	WEIGHT	WEIGHTING GUIDE
C. ANNOYANCE		
1. MALE/FEMALE	6	6 INTERCHANGEABLE 3 REPLACEABLE
2. URINE COLLECTION	6	6 INTERFACES WITH EXISTING SYSTEM 3 MOD TO EXISTING SYSTEM
3. TIME REQUIRED FOR USE		
PREP	6	PREP < 1 MIN = 6; < 3 MIN = 3; < 5 MIN = 0
CLEAN UP	6	CLEAN UP < 3 MIN = 6; < 5 MIN = 3; < 10 MIN = 0

Figure 3-11

WCS
TRADE STUDY
CRITERIA WEIGHTING FACTORS

	WEIGHT	WEIGHTING GUIDE
C. ANNOYANCE		
4. ONBOARD SERVICING	6	6 SYSTEM SERVICABLE WITH EXTERNAL CHANGES
		3 OPERABLE WITH UNPLANNED MAINTENANCE
		0 NON-OPERABLE SERVICING NOT POSSIBLE
5. NOISE	2	2 NO ADDITIONAL NOISE
6. AIRFLOW	2	MEETS EXISTING REQUIREMENTS
7. MANUAL OPERATIONS	6	6 - 100% AUTOMATED (INCLUDES UP TO 4 CONTROL OPERATIONS)
		4 - > 4 BUT LESS THAN 6
		2 > 6 BUT LESS THAN 10
		0 HANDLING UNSEALED USED CONTAINER

Figure 3-11.1

WCS
TRADE STUDY
CRITERIA WEIGHTING FACTORS

	WEIGHT	WEIGHTING GUIDE
D. VERSATILITY		
1. TRAINING	3	3 < 1 HR 2 < 1 DAY 0 > 2 DAYS
2. WIPE LIMITED	4	4 UNLIMITED WET/DRY, 2 LIMITED DRY
3. MISSION REFURBISHMENT (TURNAROUND TIME)	6	6 ON ORBITER WITHIN 2.5 HOURS 4 ON ORBITER > 2.5 HOURS 2 REPLACE ON ORBITER
4. MATERIAL COMPATIBILITY	6	6 SPACE COMPATIBLE 3 SHELF LIFE LIMITED

Figure 3-12

WCS
TRADE STUDY
CRITERIA WEIGHTING FACTORS

		WEIGHT	WEIGHTING GUIDE
E.	NON-FUNCTIONAL (INTERFACE)		
1.	ELECTRICAL POWER	5	5 REDUCING 3 NO ADDITIONAL 1 ADDITIONAL
2.	WEIGHT	5	5 100 LBS. OR LESS 3 100-150 LBS. 1 OVER 150
3.	COST	5	5 STATE OF ART - MINIMAL TESTING 3 GROUND TESTING 1 DEVELOPMENT
4.	ONBOARD VOLUME	5	5 NO INCREASE 2 ADDITIONAL STORAGE AREA
5.	RETROFITABLE	5	5 MEETS EXISTING INTERFACES 3 MINOR CHANGES 0 MAJOR REDESIGN AFFECTING STRUCTURE

Figure 3-13

MS254V1003
18 January 1985

WCS
TRADE STUDY
CRITERIA WEIGHTING FACTORS

	WEIGHT	WEIGHTING GUIDE
F. SPACE STATION		
1. 540 MAN DAYS	5	5 EXCEEDS 4 MEETS 3 EXCEEDS WITH MAINTENANCE 2 MEETS WITH MAINTENANCE
2. NO OVERBOARD DUMP (LIQUID - SOLIDS - GAS)	5	5 MEETS 3 GAS VENT ON BOARD 0 LIQUID/GAS VENT ONBOARD
3. ON BOARD SERVICING MAINTENANCE - RESUPPLY	5	5 NORMAL 90 DAY RESUPPLY 3 NORMAL 30 DAY MAINTENANCE 1 < 30 DAY MAINTENANCE

Figure 3-14

WCS
TRADE STUDY
CRITERIA WEIGHTING FACTORS

		WEIGHT	WEIGHTING GUIDE
F.	SPACE STATION		
4.	BIO-MEDICAL SAMPLING	5	5 CAPABLE
			3 CAPABLE WITH ADDITIONAL HDW
			0 NOT CAPABLE
5.	STATION INTERFACES	5	5 ELECTRICAL POWER
			4 ECLSS THERMAL/COOLING SYSTEM
			3 ELECTRIC POWER AND ECLSS THERMAL/ COOLING
6.	VERSATILITY	5	5 USABLE FOR OTHER FUNCTIONS

Figure 3.14.1

FAIRCHILD
REPUBLIC COMPANY

WASTE MANAGEMENT SYSTEM

CONCEPTS	TOTAL SCORE	CREW CONTAMINATION FROM STORED WASTE	CREW CONTAMINATION DURING USE	RELIABILITY	DEVELOPMENT RISK	CREW WASTE SEPARATION	DEGRADED COLLECTION MODE (BACKUP)	210 MAN DAYS	ODOR CONTROL	MALE/FEMALE	URINE COLLECTION	TIME REQ'D FOR USE	ON BOARD SERVICING	NOISE	AIRFLOW	MANUAL OPERATION (SYSTEM USE)	TRAINING	WIPE LIMITED	MISSION REFURBISHMENT	MATERIAL COMPATABILITY	ELECT POWER	WEIGHT	COST	ONBD VOLUME	RETROFITTABLE	540 MAN DAYS	NO OVERBOARD DUMP (LIQUID-SOLID-GAS)	ON BOARD SERVICING MAINTAINANCE-RESUPPLY	BIO-MEDICAL SAMPLING	STATION INTERFACES	VERSATILITY	
		0-10				0-8				0-6							0-6				0-5					0-5						
		SAFETY				DISCOMFORT				ANNOYANCE							VERSATILITY				NONFUNCTIONAL					SPACE STATION						

HIGHEST SCORE RECOMMENDED

Figure 3-15

MS254V1003
18 January 1984

4.0 IMPROVED WASTE COLLECTION SYSTEM (WCS) DESIGN CONCEPTS

The following design concepts have been developed to eliminate problems and improve performance of the original WCS slinger design and modifications installed on STS missions shown in paragraph 3.2. Based on these problems FRC developed the design criteria and weighting factors shown in paragraph 3.4 for evaluating and selecting the recommended optimum concept for potential follow-on development and testing on future Shuttle Orbiter missions.

4.1 Shuttle WCS Design Concepts

The conceptual studies were accomplished in two phases, Phase one was to establish design concepts that are usable on and satisfy Shuttle requirements, Figure 4-1, and are adaptable to the Space Station. The second phase was to adapt the Shuttle design concepts with respect to meeting Space Station requirements.

4.1.1 Fecal Collection Bag Vacuum/Heat Drying Processes

The Fecal collection bag Vacuum/Heat Drying concept shown schematically in Figure 4-2 incorporates four processes; collection, containment, deactivation and storage. The concept is based on the waste collection system that was designed for and flown on Skylab (Fig. 4-3). The new system will automate closing and sealing of the Fecal collection bag.

4.1.1.1 Bag Collection System

The system features are summarized in Figure 4-4 and its interfaces for shuttle waste collection functions are shown in Figure 4-5. The system is designed to utilize and interface with the existing Shuttle urinal system, fan separators for airflow and odor control system.

The fecal bag collection design utilizes directional airflow as a gravity substitute as shown in Figure 4-6 to accomplish separation and entrainment of feces. The seat of the collector unit contains airflow jets which direct the air from the fan separator causing a directional force to separate and carry the bolus into the bag.

4.1.1.2 Collection Bag

The bag is the primary control device for waste containment as shown in Figure 4-7. Prior to each use, a bag will be placed in the collection unit. The bag is designed to be held in the collector at its hinges by hinge pins. The hinge pins will hold the bag in the open position, and upon release close the bag. The open and closed shape of the bag is assisted by a fiberglass spring cuff. During use, the bag is maintained in the plenum by the hinge pins and airflow being drawn into the bag.

After defecation and wiping, and inserting the wipes in the bag, the user will actuate (by opening the seat door) the closing and heat sealing of the bag for waste containment as shown in Figure 4-8. To heat seal, the system uses impulse heat sealing which heats and cools the heat jaws quickly, precluding any temperature/heat problems.

SHUTTLE
WCS
DESIGN CONCEPTS

- FECAL COLLECTION BAG VACUUM/HEAT DRYING
- FECAL COLLECTION BAG MICRO-WAVE STERILIZATION
- CARTRIDGE ARCHIMEDEAN SCREW FECAL COLLECTION VACUUM DRYING
- BLADDER DISPLACEMENT FECAL COLLECTION VACUUM DRYING
- CARTRIDGE COMPACTOR FECAL COLLECTION VACUUM DRYING

Figure 4-1

FAIRCHILD

WASTE MANAGEMENT SYSTEM

MS254V1002
11 DECEMBER 1984

SPACE SHUTTLE WCS
(BAG VACUUM/HEAT DRYING)

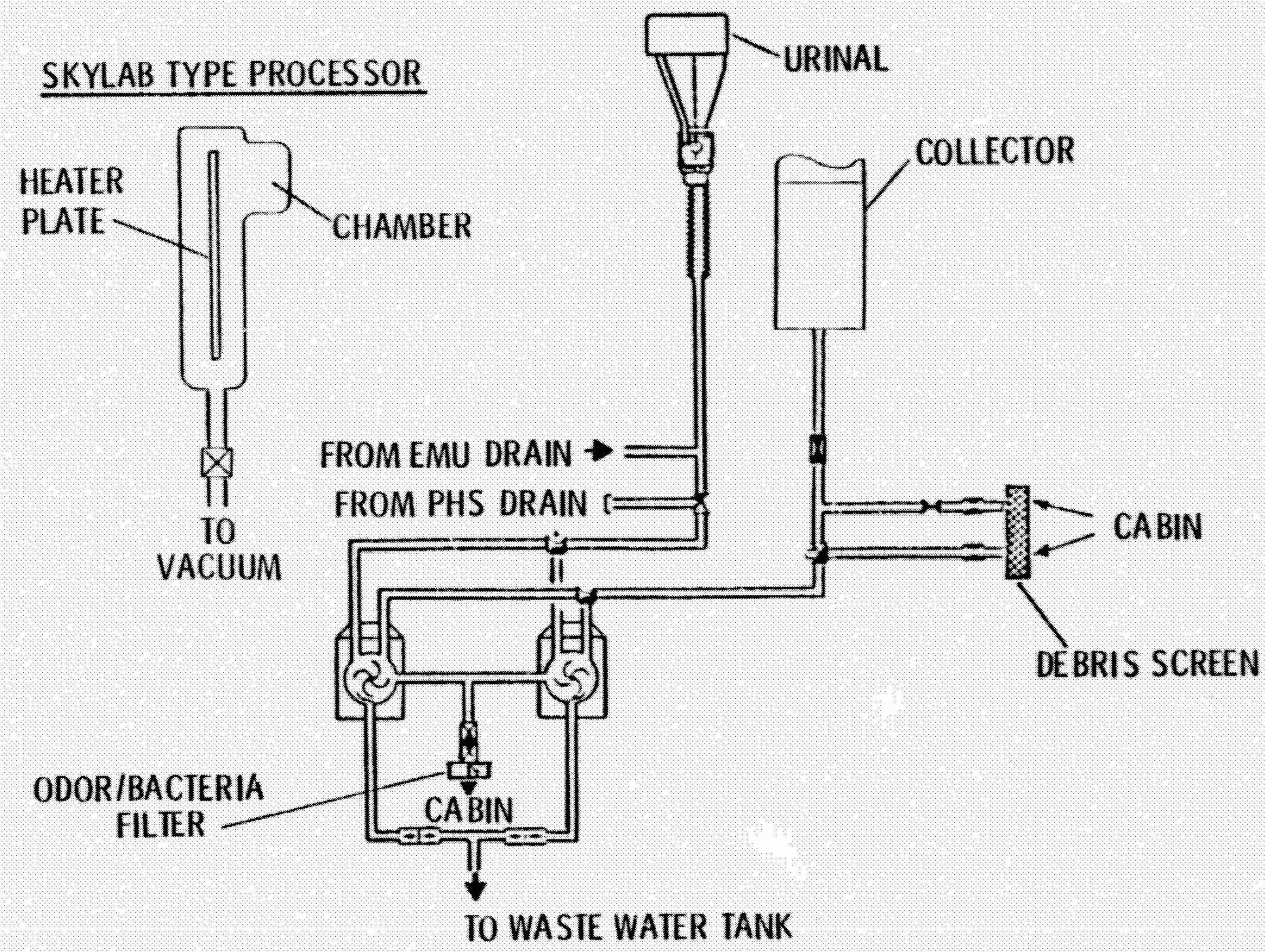
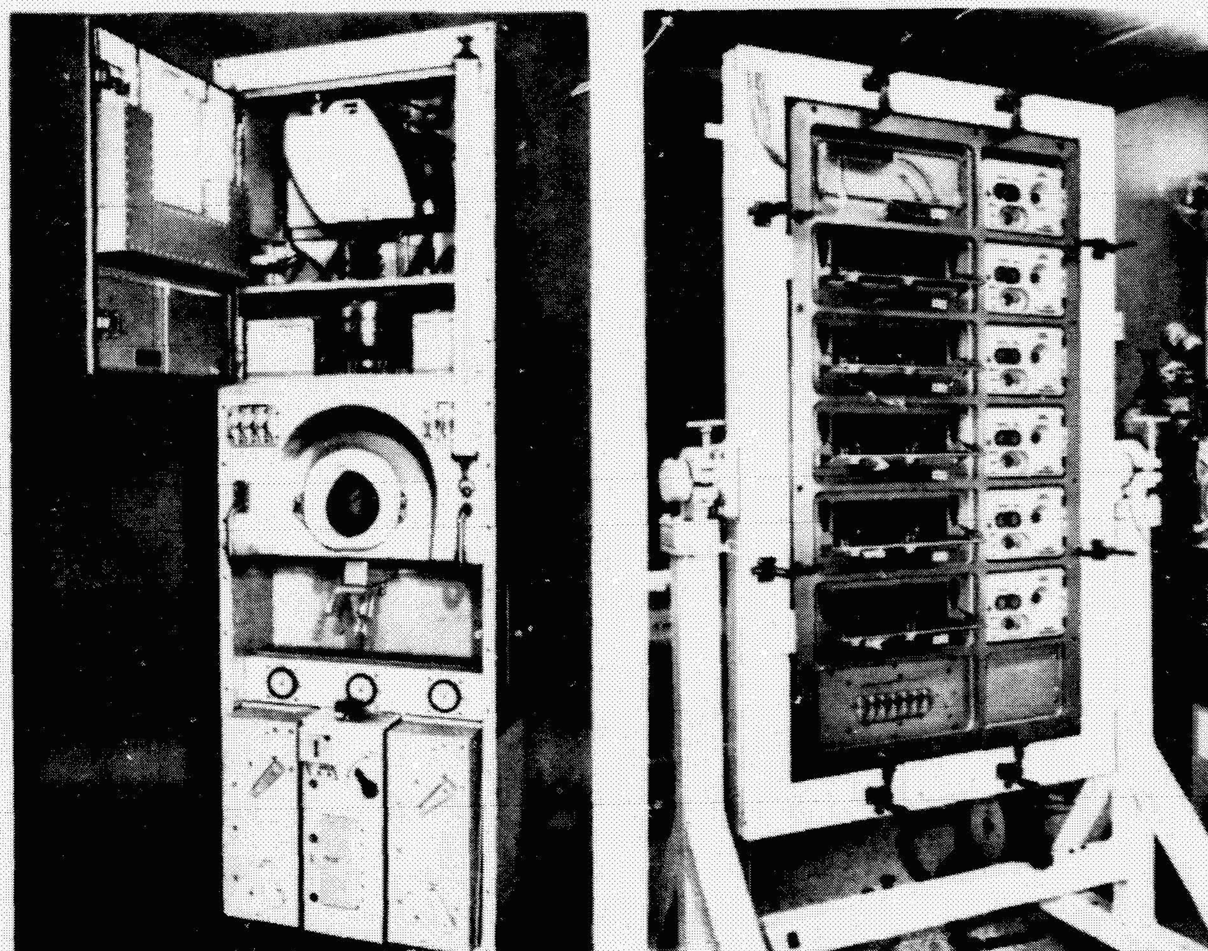


Figure 4-2

SKYLAB WCS

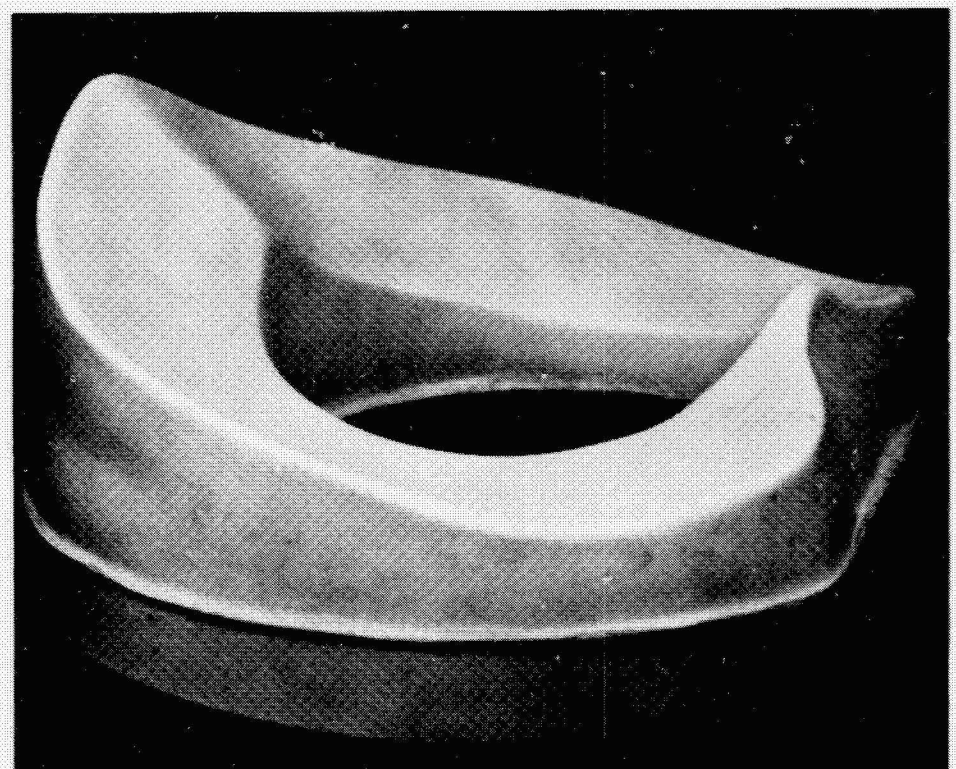


WASTE COLLECTION AND PROCESSOR MODULE

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

Figure 4-8

FECAL COLLECTION SEAT



ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

SEAT ASSEMBLY

Figure 4-2.1

SHUTTLE
SKYLAB TYPE FECAL COLLECTION BAG SYSTEM
(VACUUM/HEAT DRYING)

- o USE OF EXISTING SUBSYSTEMS
  - URINAL
  - BLOWER
  - ODOR CONTROL
  - FAN/SEPARATORS
- o MANUAL INSERTION OF INDIVIDUAL BAG
  - INDIVIDUAL BAG PREVENTS AIRFLOW DEGRADATION
- o AIRFLOW FOR SEPARATION
- o BAG HEAT SEALED
- o MANUAL INSERTION OF SEALED BAG IN PROCESSOR
  - CAPABILITY TO PROCESS/DRY OTHER WASTE
  - VOMITUS
  - DESICCANTS
  - WET WIPES
- o VACUUM PROCESSING
  - INDIVIDUAL BAG PROCESSING CHAMBERS
  - ELECTRICAL HEATER TO ACCELERATE DRYING
- o VOLUME
  - CLEAN BAGS
  - PROCESSED BAGS
- o SHUTTLE REFURBISHMENT
  - REMOVE PROCESSED BAGS
  - RESUPPLY FRESH BAGS
  - NO VEHICLE INTERFACE DISCONNECTS

Figure 4-4

FAIRCHILD
REPUBLIC COMPANY

WASTE MANAGEMENT SYSTEM

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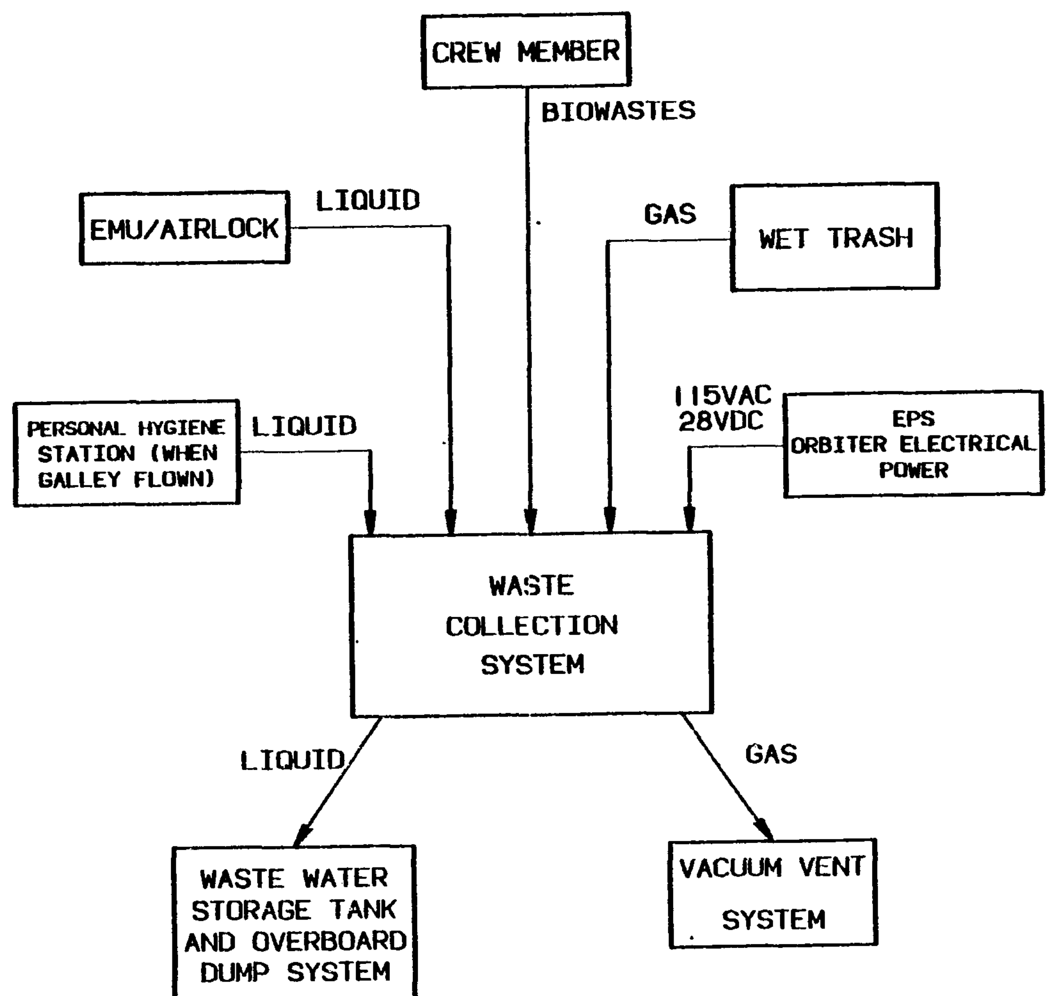
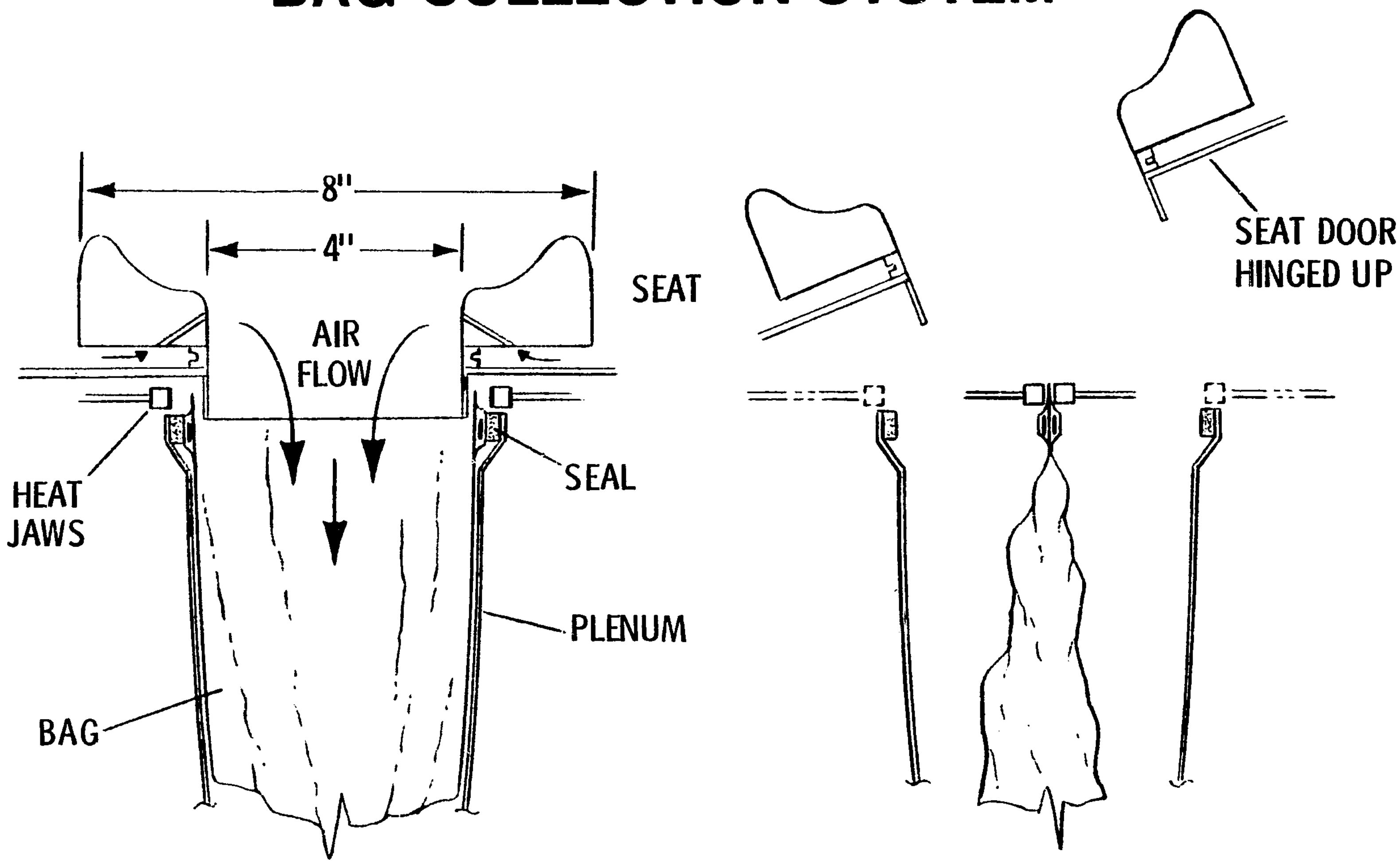


SHUTTLE
WCS INTERFACES
(VACUUM PROCESSING)

Figure 4-5

BAG COLLECTION SYSTEM



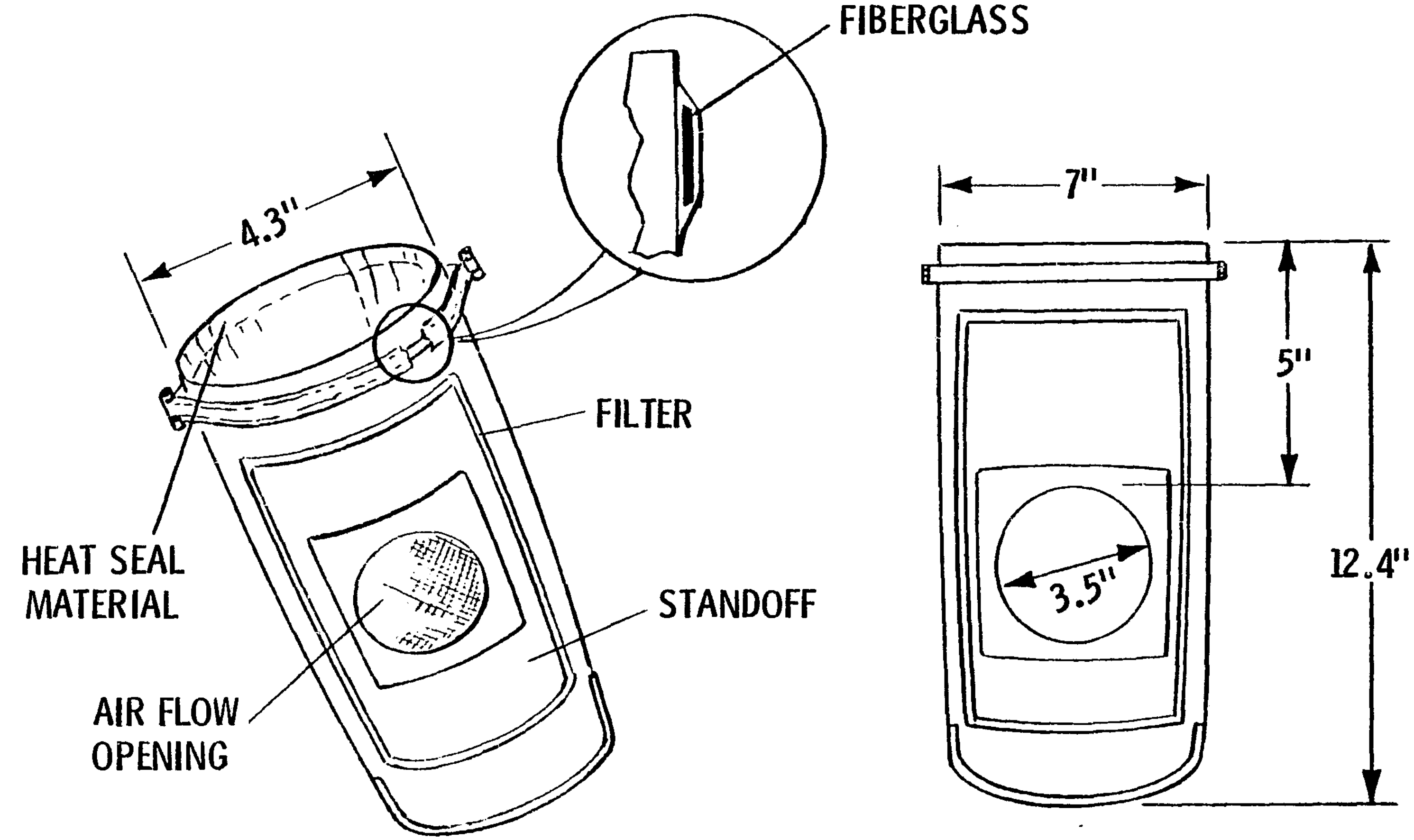
COLLECTION MODE

SEAL POSITION

SECTION CUT LOOKING AFT

Figure 4-6

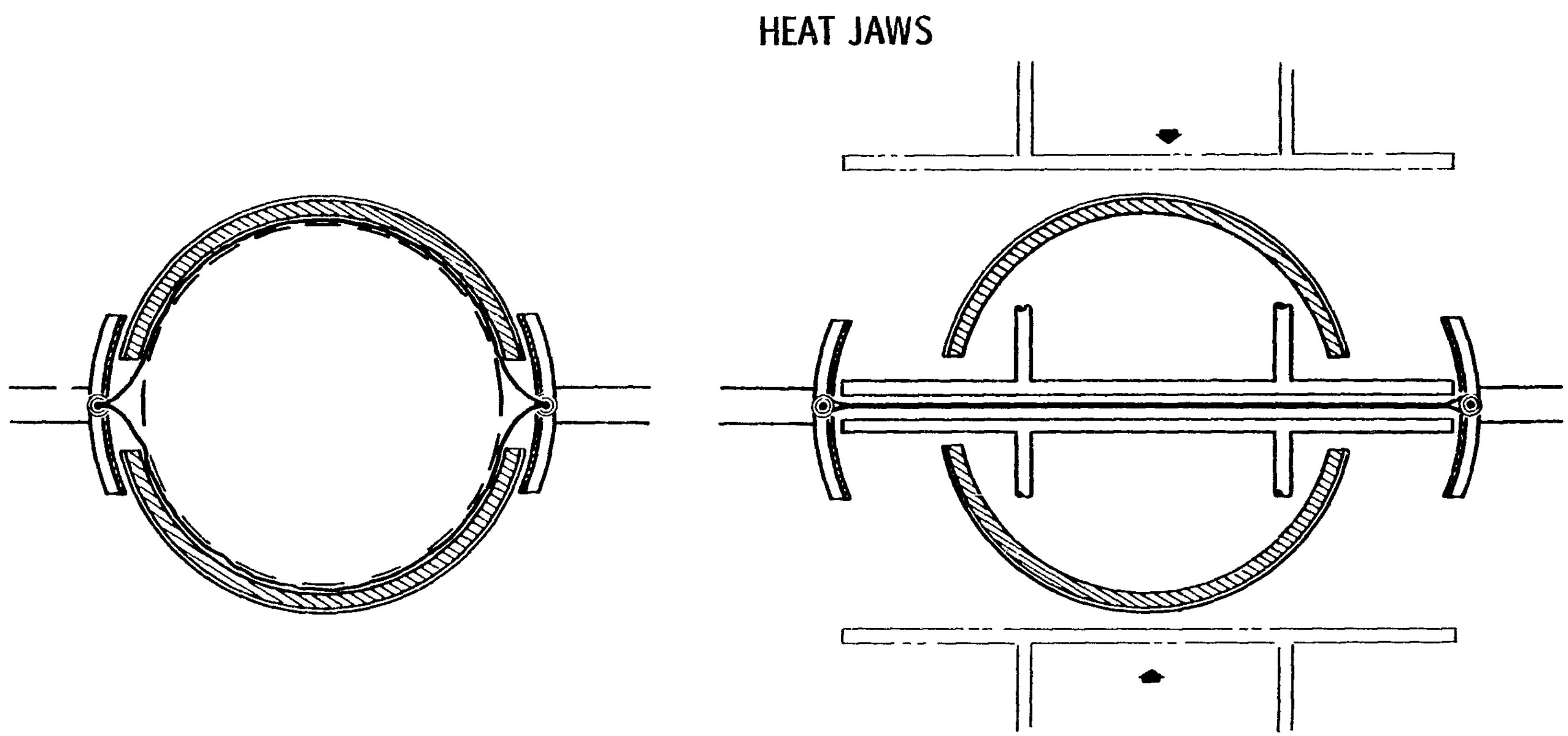
COLLECTION BAG



OPEN POSITION   FLAT POSITION

Figure 4-7

COLLECTION BAG HEAT SEAL



COLLECTION MODE

SEAL POSITION

TOP VIEW
PLENUM AND BAG MECHANISM

Figure 4-8

4.1.1.3 Vacuum Drying
Once sealing is completed, the bag can be manually taken from the collection unit and placed in the vacuum/heat drying chamber (Figure 4-9) for deactivation. The chamber is vented to vacuum for freeze drying and heated to increase the capability to process or dry other materials such as vomitus, wet wipes, desicants, etc.

The heat is applied by a hot plate. It dries the waste by evaporation of the moisture and vents the vapors through the bag into a discharge line and out into space. The total processing time required depends upon the drying temperature used as plotted in Figure 4-10. At each temperature, the drying time is based upon the input power required which accounts for the heat loss through the chamber walls to a 70°F cabin and the latent heat of vaporization of the moisture. The power levels range from 70 to 180 watts and drying temperatures from 100 to 160°F. With adequate insulation on the chamber exterior, no touch temperature problems would result during processing. However, if the processing temperature is higher than the human burn threshold of 113°F, the bag must be allowed to cool before removal from the chamber after processing. From Figure 4-10, the optimal power/temperature/drying time combination can be determined to best satisfy the requirements of the system.

Once the material is deactivated it is safe to handle and store in a passive container for long periods of time.

Shuttle refurbishment will consist of emptying the used bags, supplying unused bags and cleaning the unit with a biocide. No vehicle interface disconnects are necessary.

4.1.1.4 System Use

Figure 4-11 depicts an average time line for crewman defecation. The following are the steps for a cylce:

- Prepare System for Usage
- Prepare Self for Usage
- Switch on system blower
- Defecate, micturate
- Dismount
- Open seat door - Actuates closing bag, blower shut down and bag sealing.
- Remove bag and place in processor.
- Switch processor on.
- Place clean bag in collector.
- Close seat door
- Later, remove processed bag from processor and place in passive storage.

Each mechanism will have a separate override switch. The switches will only be used for test and in case of failure.

SKYLAB TYPE FECAL COLLECTION BAG SYSTEM

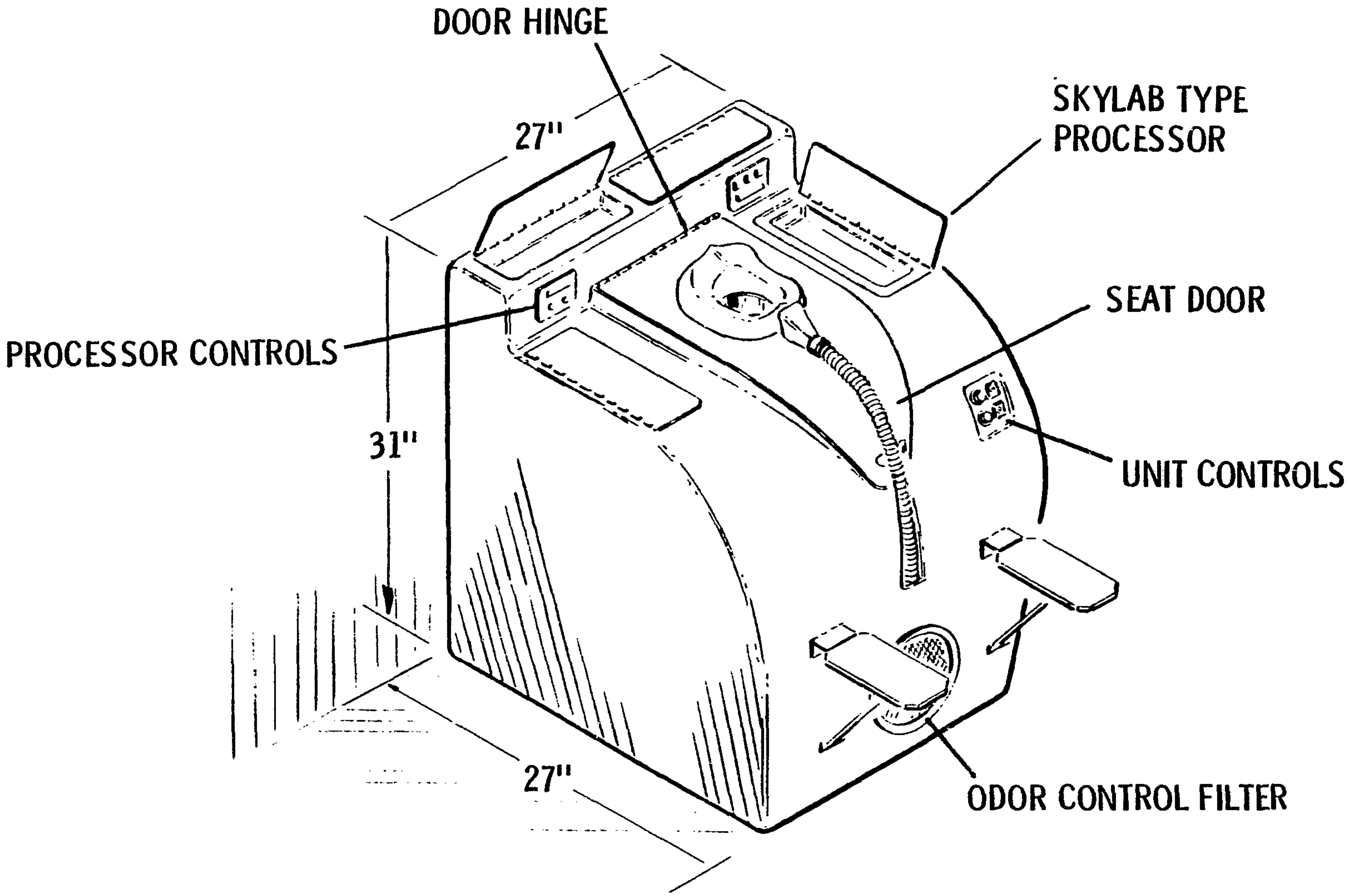


Figure 4-9

FECAL COLLECTION BAG-VACUUM/HEAT DRYING TEMPERATURE AND POWER vs. DRYING TIME

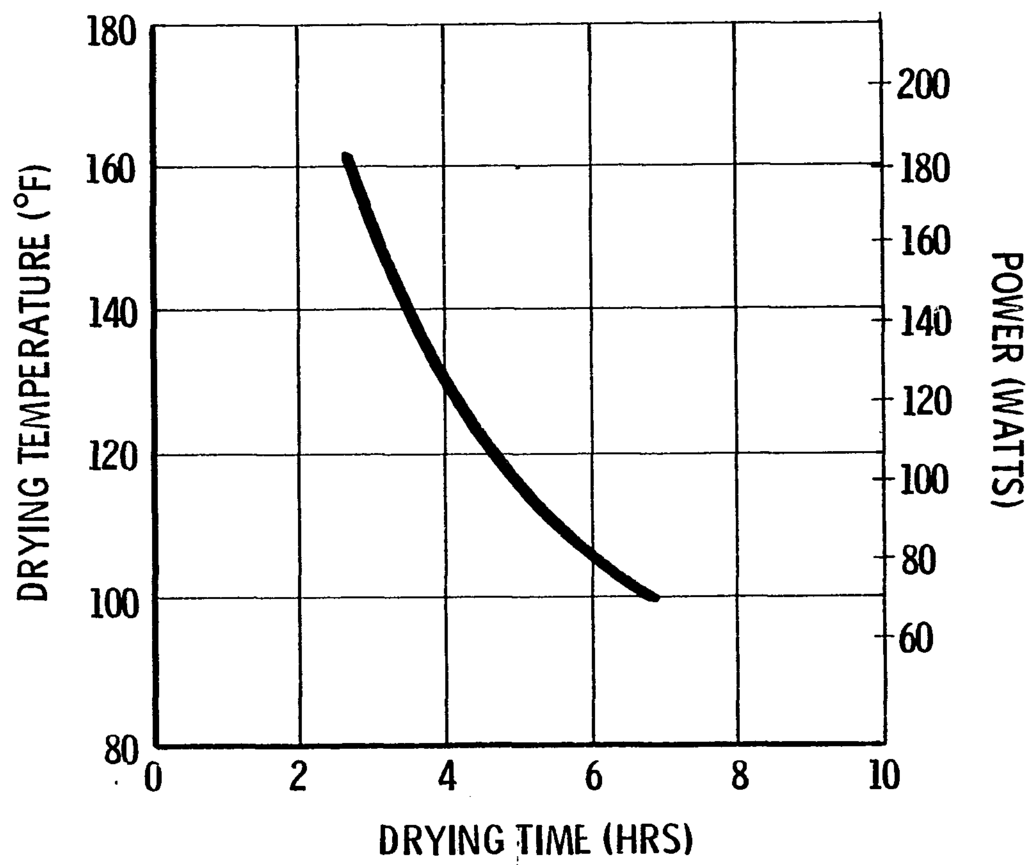


Figure 4-10

FAIRCHILD

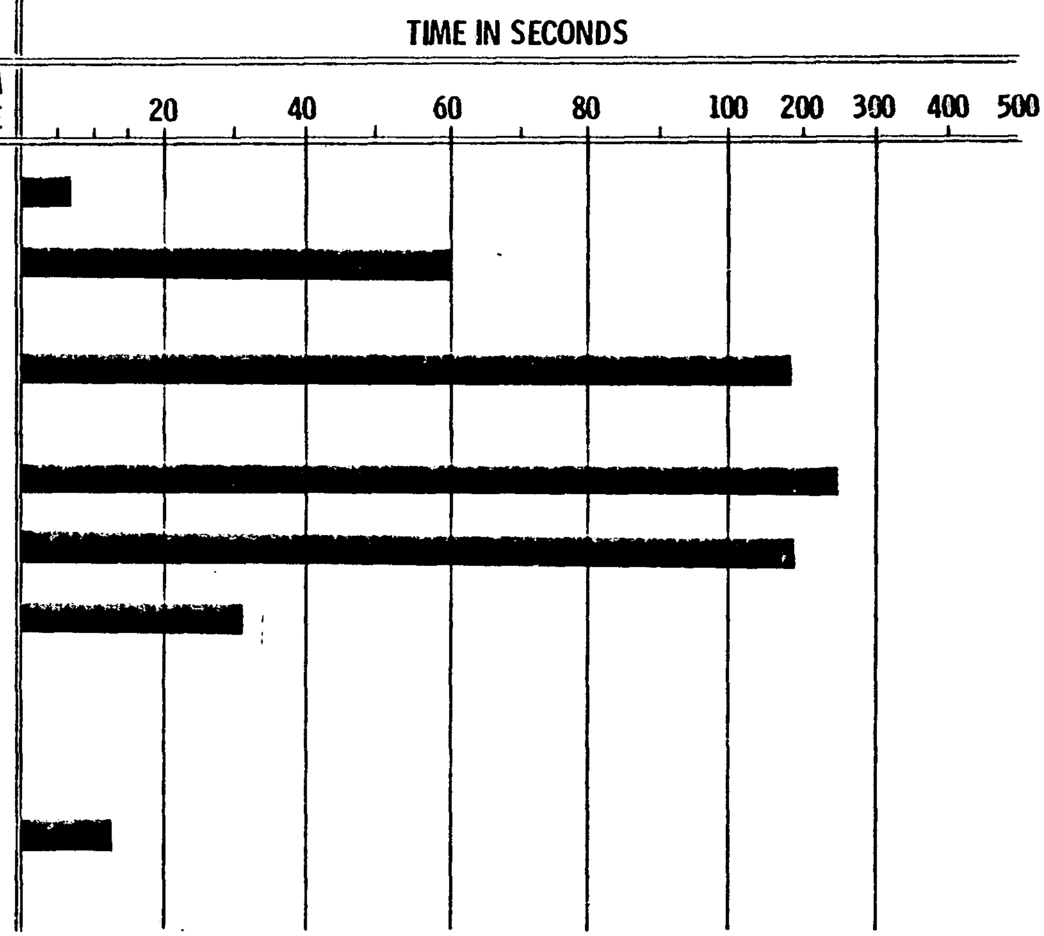
WASTE MANAGEMENT SYSTEM

MS254V1002
11 DECEMBER 1984

WCS CREWMAN TIME LINE - PREP THRU CLEANUP

CREWMAN TIME-LINE FOR WASTE COLLECTION SYSTEM USE

TASK SEQUENCE	TASK TIME	CUM TIME
1. ENTER WCS AREA	5	5
2. PREPARE WCS FOR USAGE	60	65
3. PREPARE SELF (DISROBE)	180	245
4. USE WCS	240	485
5. REROBE	180	665
6. COMPLETE WCS TASK REQUIRED WHEN USE COMPLETE (REMOVAL)	30	695
7. STORE REMOVED PORTION (MICRO-WAVE OR FREEZER)	10	705



SUMMARY: LAPSE TIME 12 TO 15 MINUTES

Figure 4-11

MS254V1003
18 January 1984

During processing, the microwave heating evaporates the moisture in the bag which then vents through the bag into a discharge line and out into space. The bag must be positioned and secured properly inside the chamber for effective usage of DWP in zero gravity. No touch temperature problems would be encountered on the exterior of the chamber during processing. An insulated glove or a wait-until-cool approach must be used for bag removal after processing.

4.1.3 Cartridge Archimedean Screw Fecal Collection, Vacuum Drying

In this concept, Figure 4-14 the well known principle of the Archimedean screw is applied to transport air entrained fecal waste to a specific storage region of the collector, compressing it to some extent, and inhibiting its back migration. A motor driven screw is located below the seat opening with the axis of the screw aligned with the opening. A perforated cylindrical shell surrounds the screw, and the bottom of the screw is open to a storage region. As the screw rotates, wastes are either squeezed through the shell perforations or are forced to the bottom storage region. An outer cylindrical filter permits low pressure-drop air flow for collection. The components inside the pressure shell, including the screw, perforated cylinder, and filter assembly, form a removal cartridge for servicing. The features of the system are shown in Figure 4-15 and the design concept is shown in Figure 4-16.

4.1.3.1 Screw

A view of the isolated screw is shown in Figure 4-17. A single screw is shown, but it could be designed to have a double screw with the second screw offset by 180 degrees. The screw is modified by having the central portion hollowed-out at the top. This opening is equal to the seat opening at the receiving end and tapers to a solid screw toward the bottom. This opening provides additional pathways for less obstructed air flow, and also creates a longer unobstructed region for the entering fecal bolus without bottoming. The screw is made of a resilient hydrophobic platic that can tolerate some deformation and resist wetting. Rotation of the screw propels the waste downward and outward. During collection the screw could rotate slowly, (20-30 rpm). Inasmuch as the central opening is large enough to hold a normal collection, the screw could remain motionless during collection if the rotating screw could in any way be considered threatening. Following collection, and after the slide valve at the seat is closed, a high speed rotation safely clears the screw of waste. The screw is connected to the driving motor by a slip-fit spline connection which allows the cartridge to be removed leaving the motor behind.

4.1.3.2 Storage Region

The storage region consists of the space between the perforated shell and the filter assembly, and the space below the screw. The screw and shell form a barrier against migration of wastes from this region. Some waste will contact the filter, but the large filter area will prevent degradation of air flow.

SHUTTLE
SKYLAB-TYPE FECAL COLLECTION BAG SYSTEM
(MICROWAVE STERILIZATION)

- o INTERFACE WITH SUBSYSTEMS
  - URINAL
  - BLOWER
  - ODOR CONTROL
  - FAN/SEPARATORS
- o MANUAL INSERTION OF INDIVIDUAL BAG
  - INDIVIDUAL BAG PREVENTS AIRFLOW DEGRADATION
- o AIRFLOW FOR SEPARATION
- o BIO MEDICAL SAMPLING
- o BAG HEAT SEALED
- o MANUAL INSERTION OF SEALED BAG IN PROCESSOR
  - CAPABILITY TO PROCESS/DRY OTHER WASTE
  - VOMITUS
  - DESICCANTS
  - WET WIPES
- o VENTED BAG
  - CABIN AIR
  - DEHUMIDIFIER/CONDENSER
  - ODOR CONTROL
- o NON-VENTED
  - INCREASED STORAGE
  - NO VAPOR/ODOR CONTROL
- o ELECTRIC POWER
  - 1100 WATTS
  - EMI SHIELDED
- o STORAGE/RESUPPLY
  - CLEAN BAGS
  - PROCESSED BAGS
  - ODOR CONTROL FILTERS
- o MAINTENANCE
  - NORMAL DAILY
  - MINIMAL RESUPPLY

Figure 4-12

MICROWAVE PROCESSOR

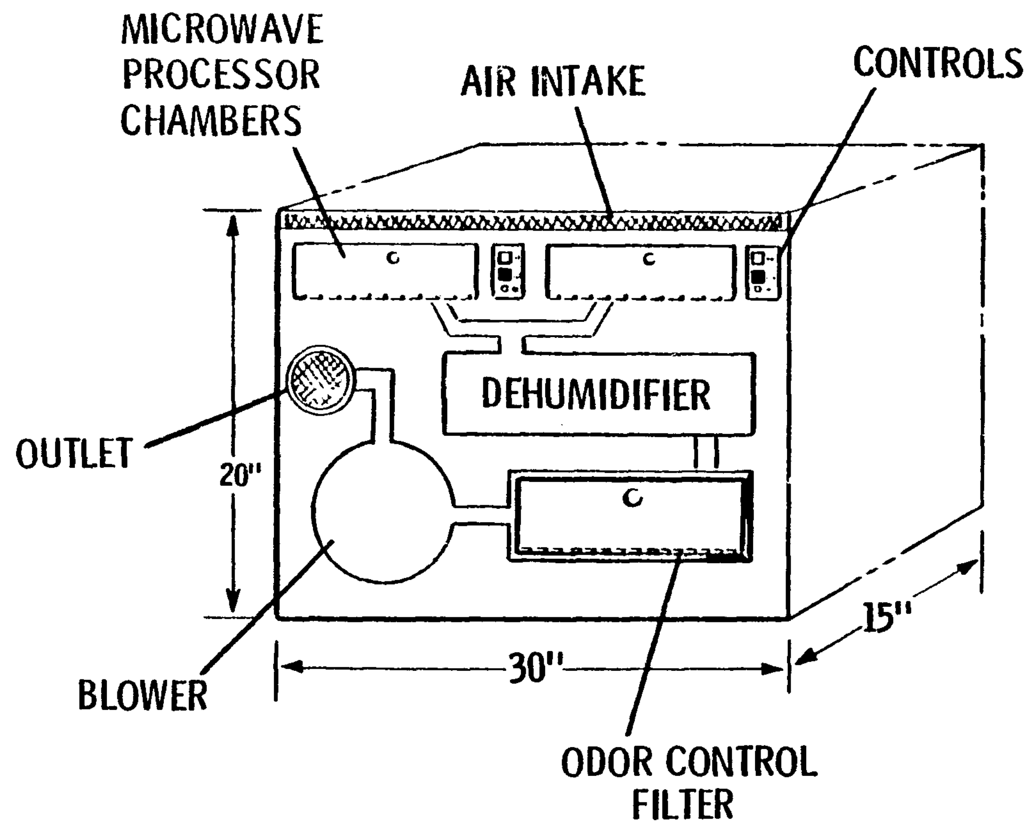


Figure 4-12.1

FAIRCHILD REPUBLIC COMPANY	**WASTE MANAGEMENT SYSTEM**	MS254V1002 11 DECEMBER 1984

MICROWAVE UNIT

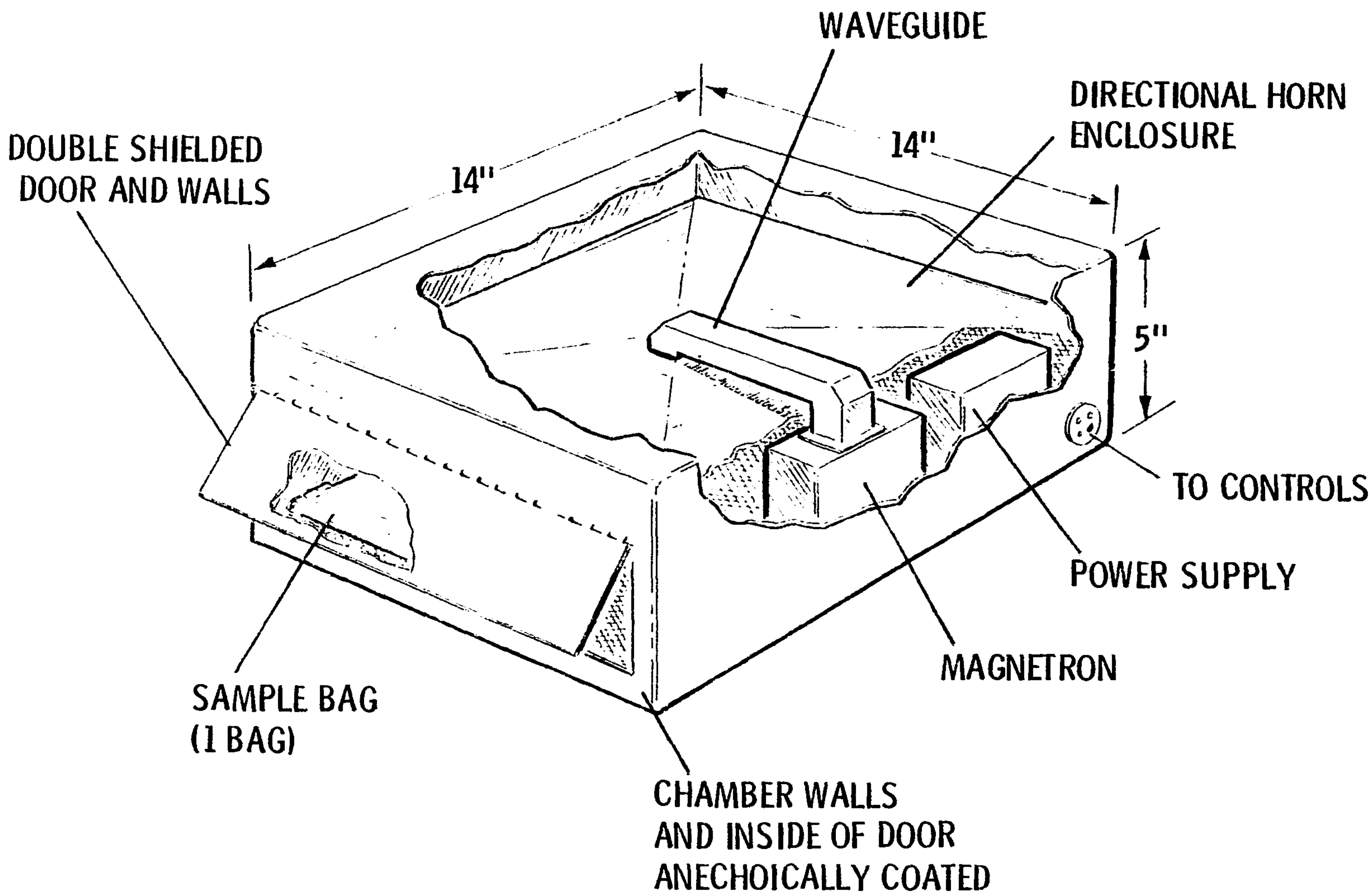


Figure 4-13

MS254V1003
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FAIRCHILD REPUBLIC COMPANY	**WASTE MANAGEMENT SYSTEM**	MS254V1002 11 DECEMBER 1984

ARCHIMEDEAN SCREW COLLECTION SYSTEM

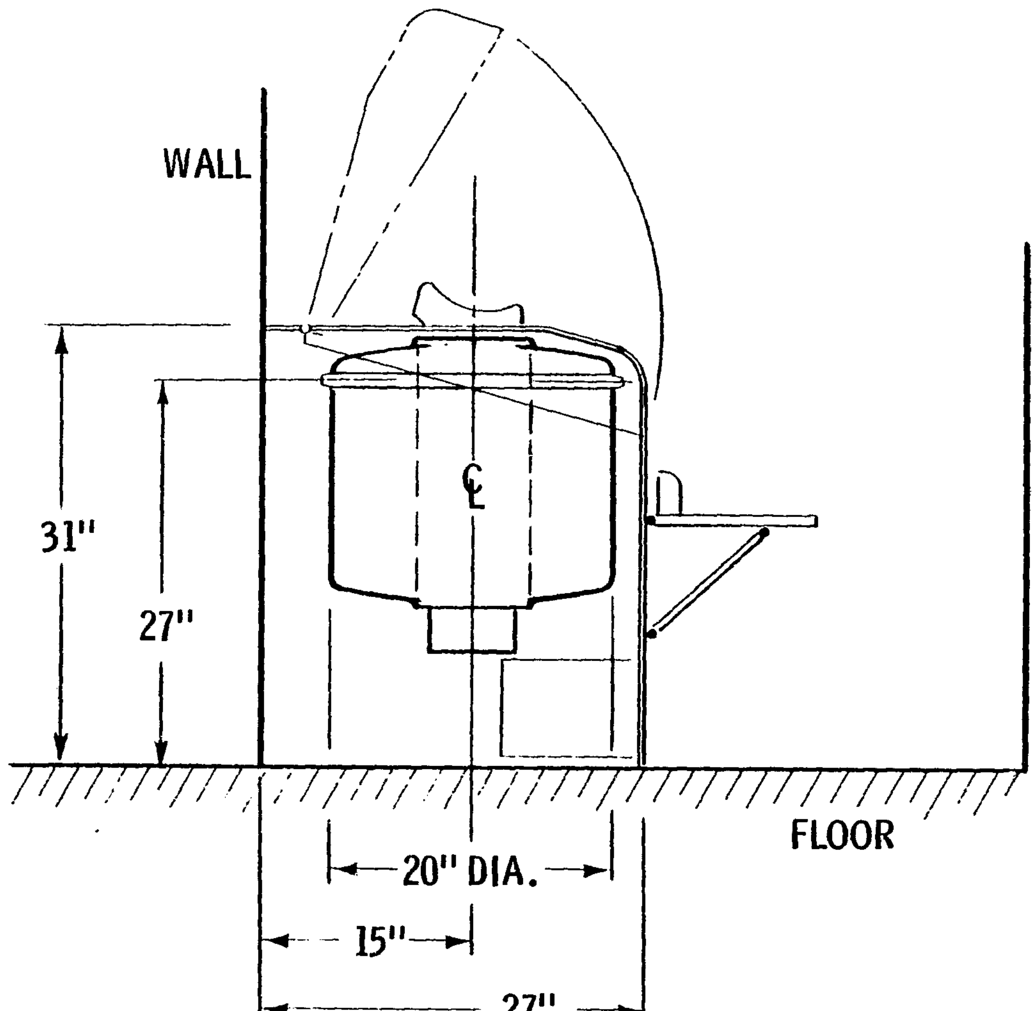


Figure 4-14

SHUTTLE
CARTRIDGE ARCHIMEDEAN SCREW FECAL COLLECTION SYSTEM
VACUUM DRYING

- USE OF EXISTING SYSTEMS
  - URINAL
  - SEPARATORS
  - BLOWER
  - ODOR CONTROL
- AIR ENTRAINMENT OF WASTE
- TRANSPORT AND COMPACTION EFFECTED BY ROTATING SCREW INSIDE OF PERFORATED CYLINDER
- ELECTRICAL POWER SCREW DRIVE MECHANISM
- NOT WIPE LIMITED
- SMALL COLLECTOR ENVELOPE
- VACUUM DRYING/STORAGE
- SHUTTLE REFURBISHMENT
  - CARTRIDGE REPLACEMENT

Figure 4-15

ARCHIMEDEAN SCREW

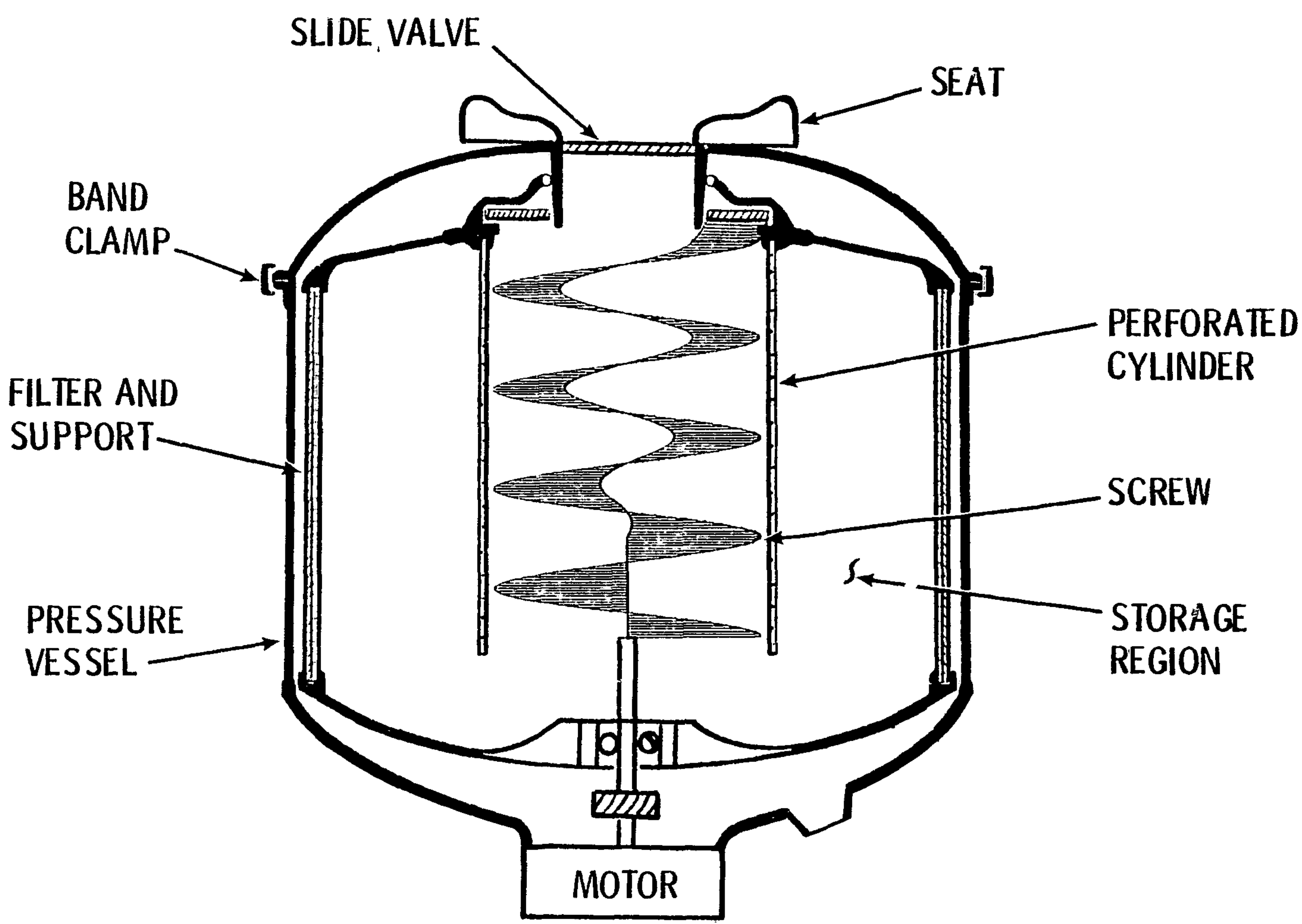


Figure 4-16

ISOLATED ARCHIMEDEAN SCREW

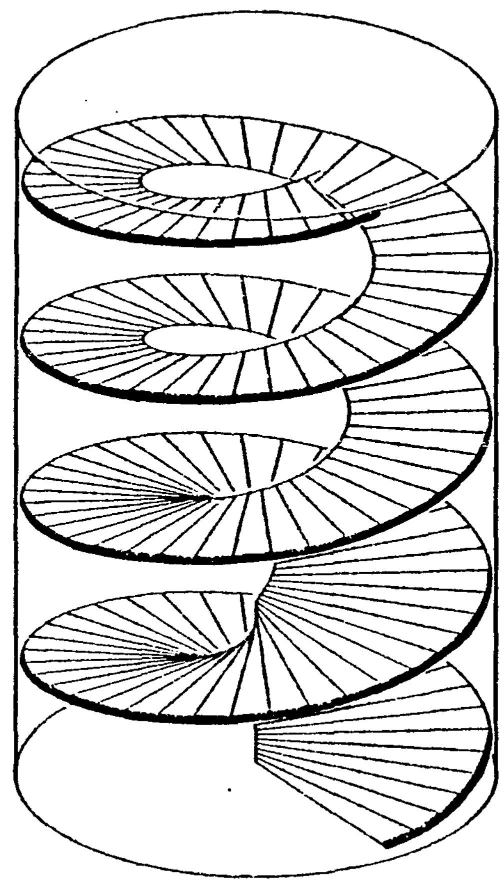


Figure 4-17

4.1.3.3 Filter Assembly

The filter assembly consists of a cylindrical bacteria filter suported by a porous foam backing, and structural supports. The filter assembly is the only expendable item in the collector. There is a space between the collector pressure shell and the filter forming a plenum for flow to the air line.

4.1.3.4 Cartridge

The cartridge comprises the screw, perforated shell, the filter assembly, and support structure as shown in Figure 4-17.1. It is intended that refurbishment between missions consists of an exchange of cartridges, general clean-up, and test. When removed from the collector and capped at the entrance opening, the wastes are sealed and vented through the bacteria filter. The cartridge is the only component removed from the Shuttle. After clean-up and filter assembly replacement, it is ready for re-use.

4.1.3.5 Operation

Collector operation, starting from the collector in the vacuum processing mode is as follows. User controls close the air line to vacuum and pressurize the collector. After the blower is started and the slide valve at the seat is opened, the collector is ready for use. After use, the slide valve is closed and the blower is shut down. The screw is now rotated at high speed to clear the central collection region and transfer the wastes to the storage region. The collector is then reconnected to vacuum.

4.1.3.6 Refurbishment

Refurbishment is accomplished without major disassembly and without breaking any lines. Servicing consists of loosening the band clamp holding the upper portion of the collector the fixed lower portion and replacing the cartridge. No other on-Shuttle tasks are required other than tests to assure proper reassembly of the collector upper portion. Clean-up and refurbishment of the cartridge are accomplished off-Shuttle.

4.1.4 Bladder Displacement Fecal Collection, Vacuum Drying

The concept of the bladder displacement fecal collector Figure 4-18 was proposed for the original Shuttle procurement and is presented now because it is an approach for dealing with the problem of waste volume now evident in Shuttle. The features of the system are shown in Figure 4-19. The major component is a elastomeric bladder which, with differential air pressure, positively displaces and compresses wastes in the collector to a storage region. One-G tests with prototype hardware (Figure 4-20) verified the concept.

During collection, air entrained wastes enter the collector with the bladder in its naturally retracted state. After collection, the storage area is open to vacuum for drying of feces, and the bladder, which has one atmosphere pressure on the other side expands into the collector displacing all waste matter against a course screen. (Figure 4-21) The pressure is sufficient to force the feces through the wipes and screen into a storage region. Wipes remain primarily on the screen. On activation of the system, the collector is brought up to cabin pressure and the bladder retracts. These steps are illustrated in Figure 4-22.

REPLACEABLE CARTRIDGE

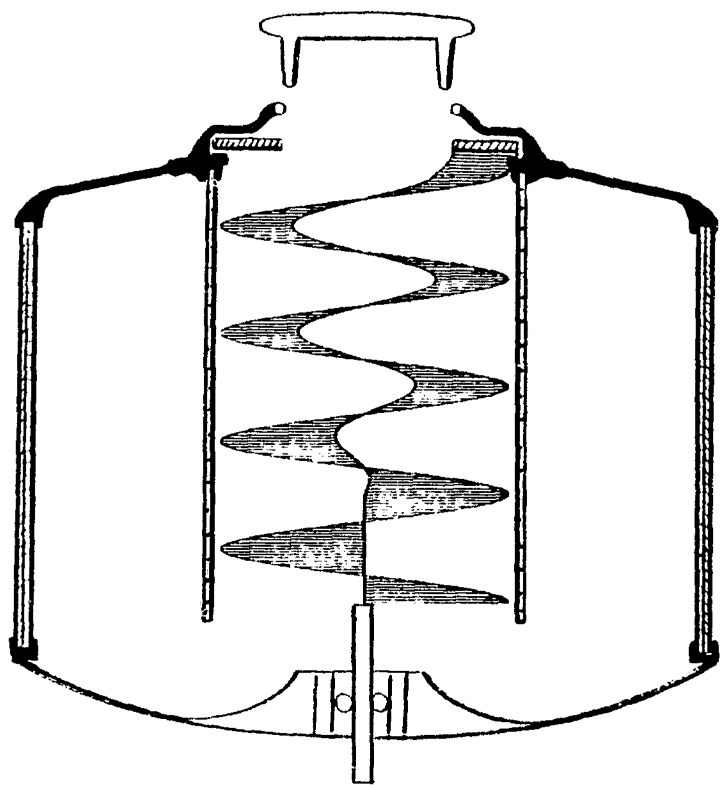


Figure 4-17.1

SPACE SHUTTLE BLADDER WCS

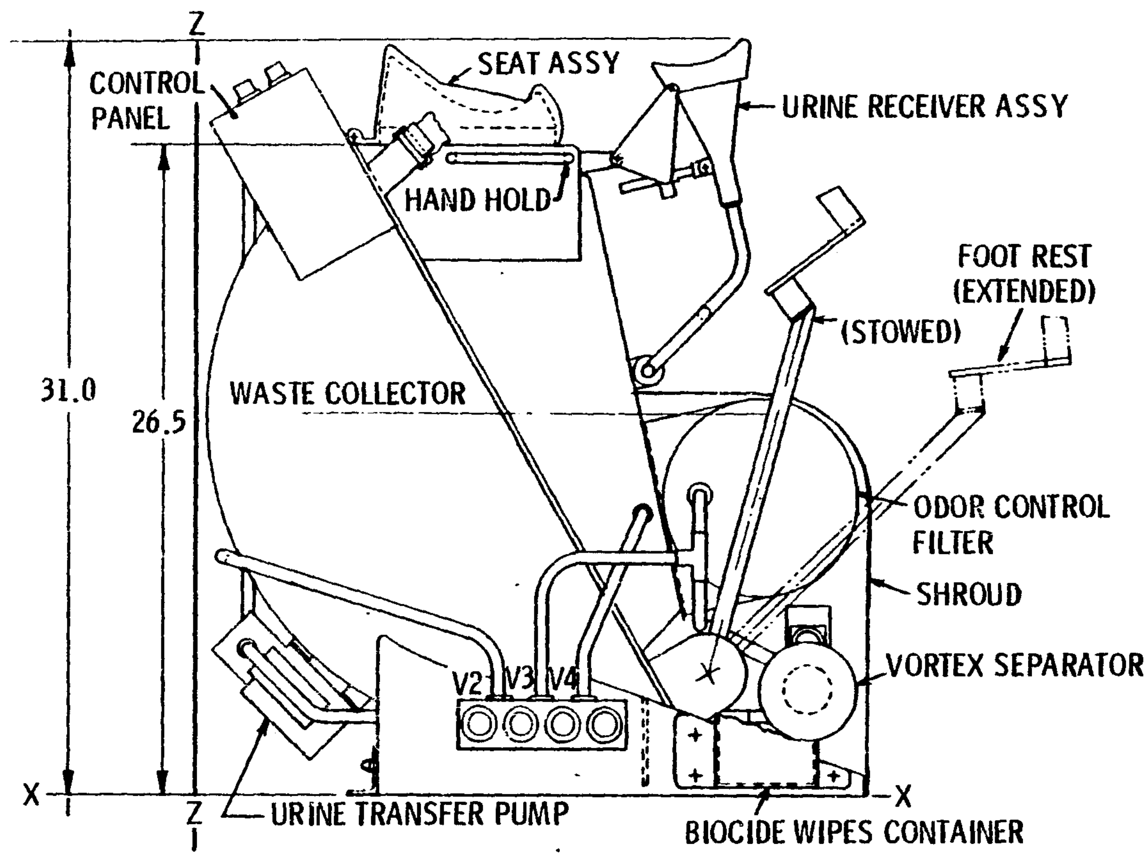


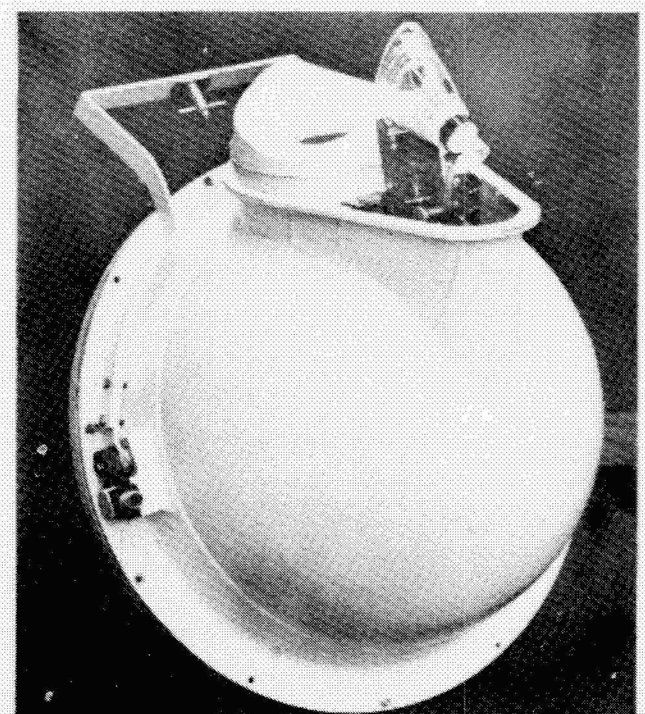
Figure 4-18

SHUTTLE
BLADDER DISPLACEMENT FECAL COLLECTION
VACUUM DRYING

- USE OF EXISTING SUBSYSTEMS
  - URINAL
  - FAN/SEPARATORS
  - BLOWER
  - ODOR CONTROL
- AIRFLOW FOR SEPARATION AND TRANSPORT
- LARGE FILTER AREA
- BLADDER COMPACTION OF WASTES
- BLADDER ACTUATION - DIFFERENTIAL PRESSURE
- POSITIVE RETENTION OF FECES
- VACUUM DRYING/STORAGE
- SHUTTLE REFURBISHMENT
  - SEALED MODULE REPLACEMENT

Figure 4-19

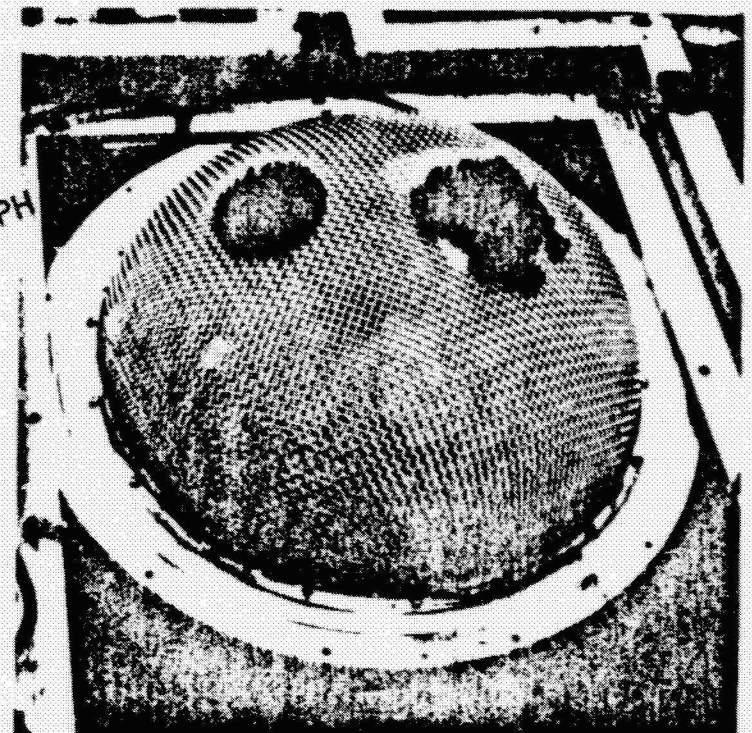
EXPANDABLE BLADDER FECAL COLLECTOR



COLLECTOR UPPER SHELL

Figure 4-20

EXPANDABLE BLADDER FECAL COLLECTOR



SCREEN

Figure 4-21

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BLADDER COLLECTOR

OPERATING MODES

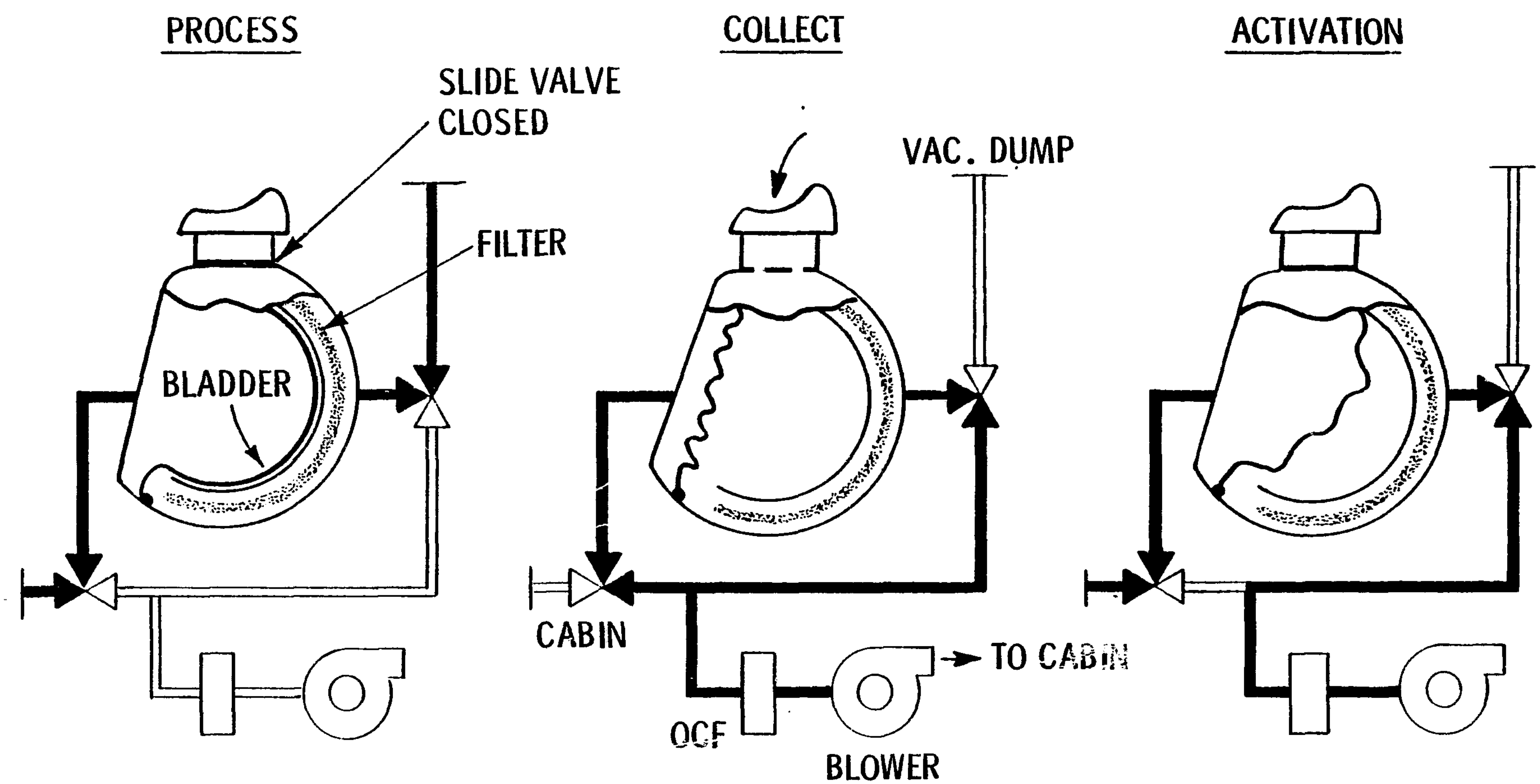

Figure 4-22

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4.1.4.1 Bladder and Screen

The bladder shape is hemispherical Figure 4-23 when expanded against the hemispherical screen. It is heavy enough to resist deformation at the screen pores while accommodating irregularly shaped wastes throughout the collector. Retraction from the vacuum-frozen waste has not been a problem. The bladder is initially expanded by the small differential pressure created by the fan-separator when the seat valve is closed. Thus when the system is opened to vacuum, the only air lost is that between the screen and outer pressure shell.

4.1.4.2 Filter Assembly

The filter assembly is also hemispherical. It is located just inside the pressure shell forming a shallow air plenum between the shell and filter, and a deeper waste storage region between the filter and the screen. The filter area is large enough to tolerate large areas of obstruction.

4.1.4.3 Refurbishment

At mission end the WCS is removed from Shuttle and replaced by a clean unit. The WCS is refurbished by flushing and cleaning the components other than the filter assembly, which is replaced.

4.1.5 Cartridge Compactor Fecal Collection, Vacuum Drying

The cartridge compactor fecal collector Figure 4-24 addresses two limitations of the bladder system: it replaces the bladder, which might be a source of failure, with a metal-bellows sealed piston; and it provides a removable cartridge containing the sealed wastes and all contaminated parts so that System refurbishment can be performed rapidly on-Shuttle. The features of the system are shown in Figure 4-25.

Figure 4-26 depicts the system design concept. Wastes are transported by air flow into the collector. After use the seat opening is valved off, and the collector is open to vacuum. The piston which is open on one side to cabin air is forced by differential pressure into the cylindrical collector basket. The wastes are forced either down or through the perforated sides of the basket. Most wipes would collect in the bottom of the basket. The feces would collect in the basket bottom or in the toroidal storage region between the basket and the filter assembly. The piston assembly, collector basket, air filter and support shell together form the replaceable cartridge Figure 4-27 and 4-28. This system will accommodate a large variety of wastes without difficulty.

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WASTE MANAGEMENT SYSTEM

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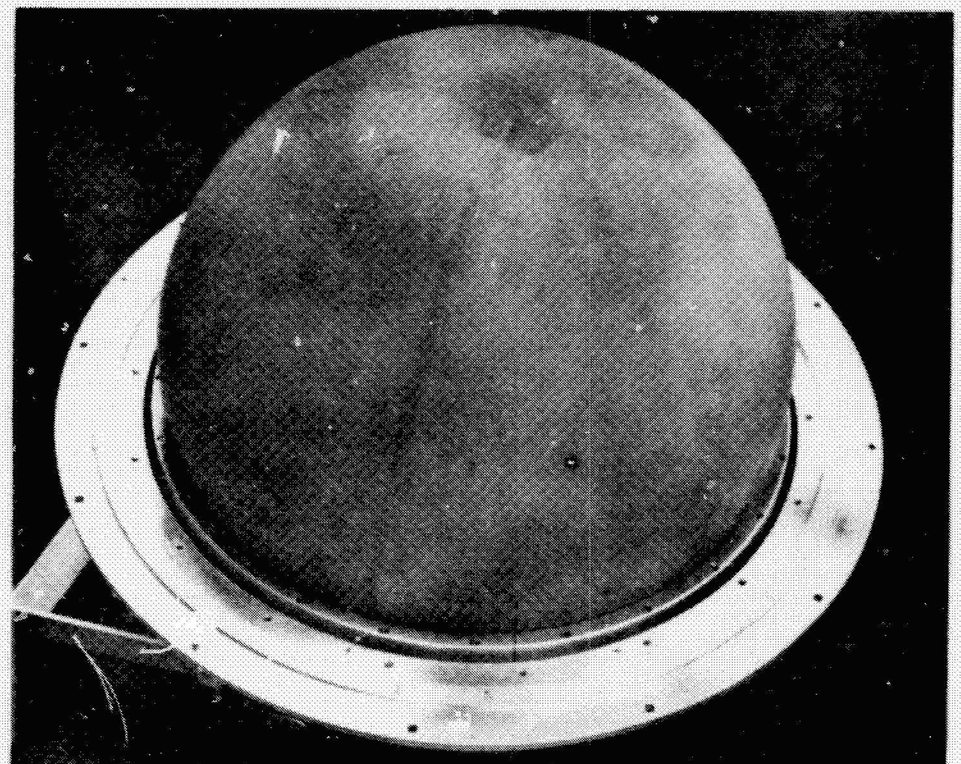
EXPANDABLE BLADDER FECAL COLLECTOR



ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

BLADDER

Figure 4-23

CARTRIDGE COMPACTOR

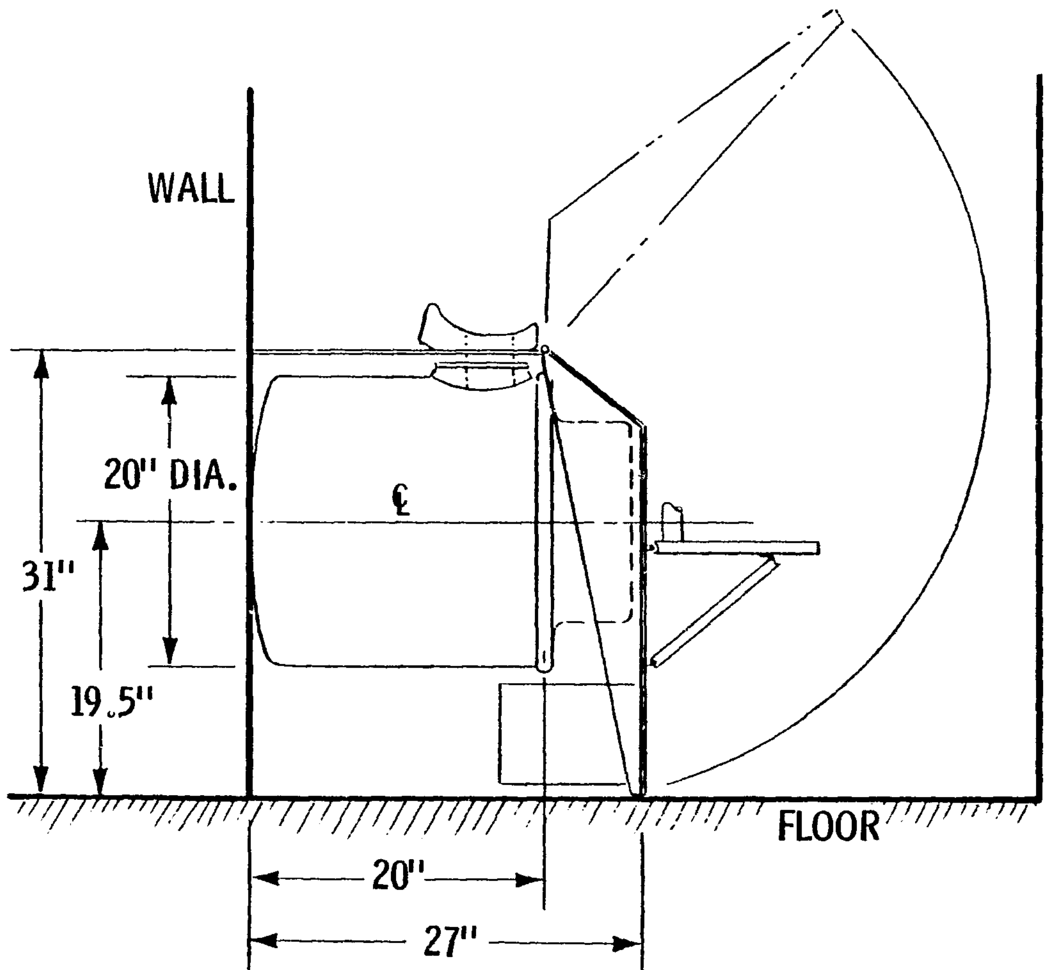


Figure 4-24

SHUTTLE
CARTRIDGE COMPACTOR FECAL COLLECTION SYSTEM
VACUUM DRYING

- USE OF EXISTING SUBSYSTEMS
  - URINAL
  - FAN/SEPARATORS
  - BLOWER
  - ODOR CONTROL
- AIRFLOW FOR SEPARATION AND TRANSPORT
- LARGE FILTER AREA
- PISTON COMPACTION
- ACCEPTS VARIETY OF WASTES
  - WET WIPES
- SPACE EFFICIENT
- SHUTTLE REFURBISHMENT
  - SEALED CARTRIDGE REPLACEMENT
  - CARTRIDGE REFURBISHABLE

Figure 4-25

CARTRIDGE COMPACTOR

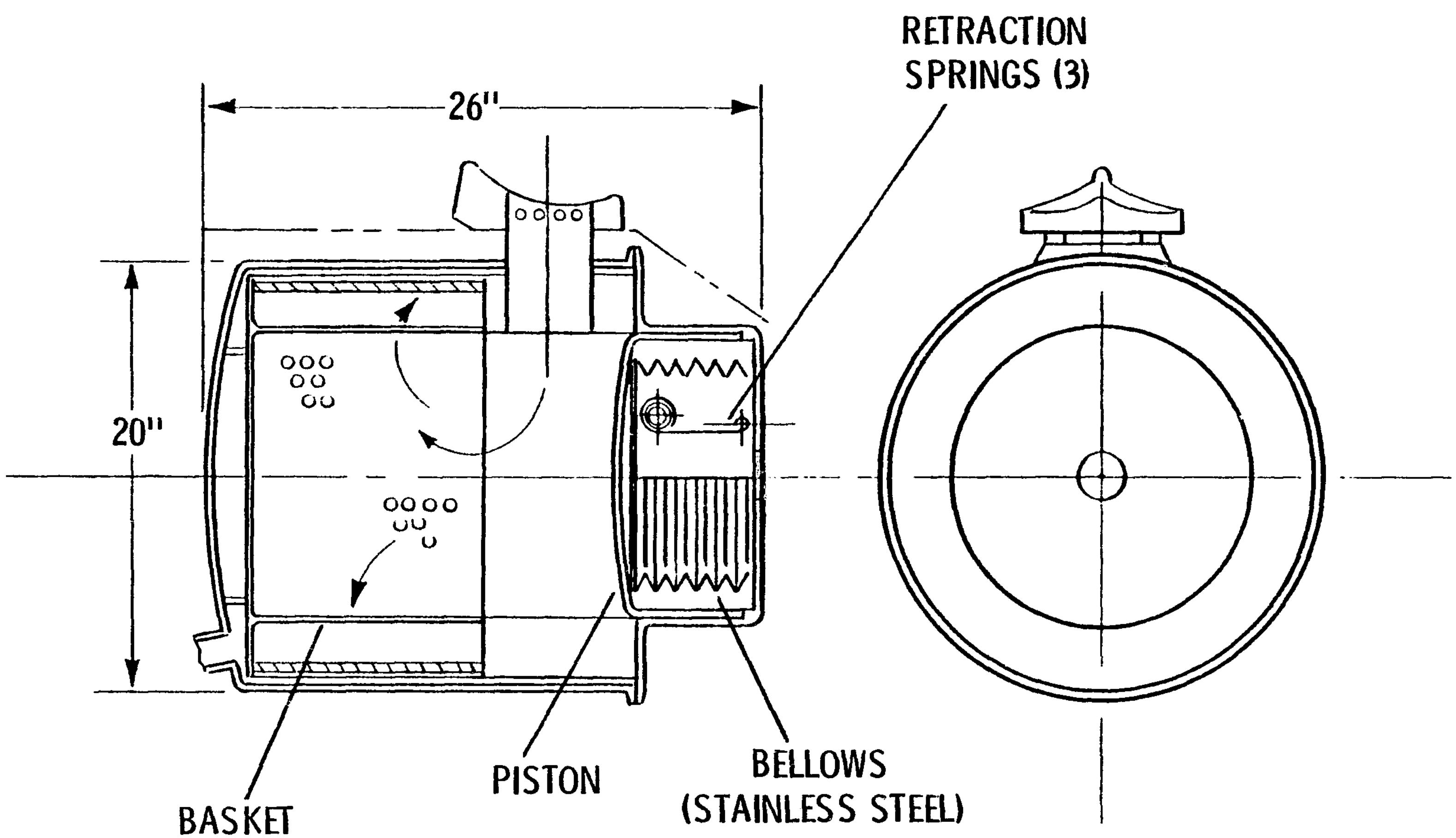


Figure 4-26

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WASTE MANAGEMENT SYSTEM

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CARTRIDGE COMPACTOR

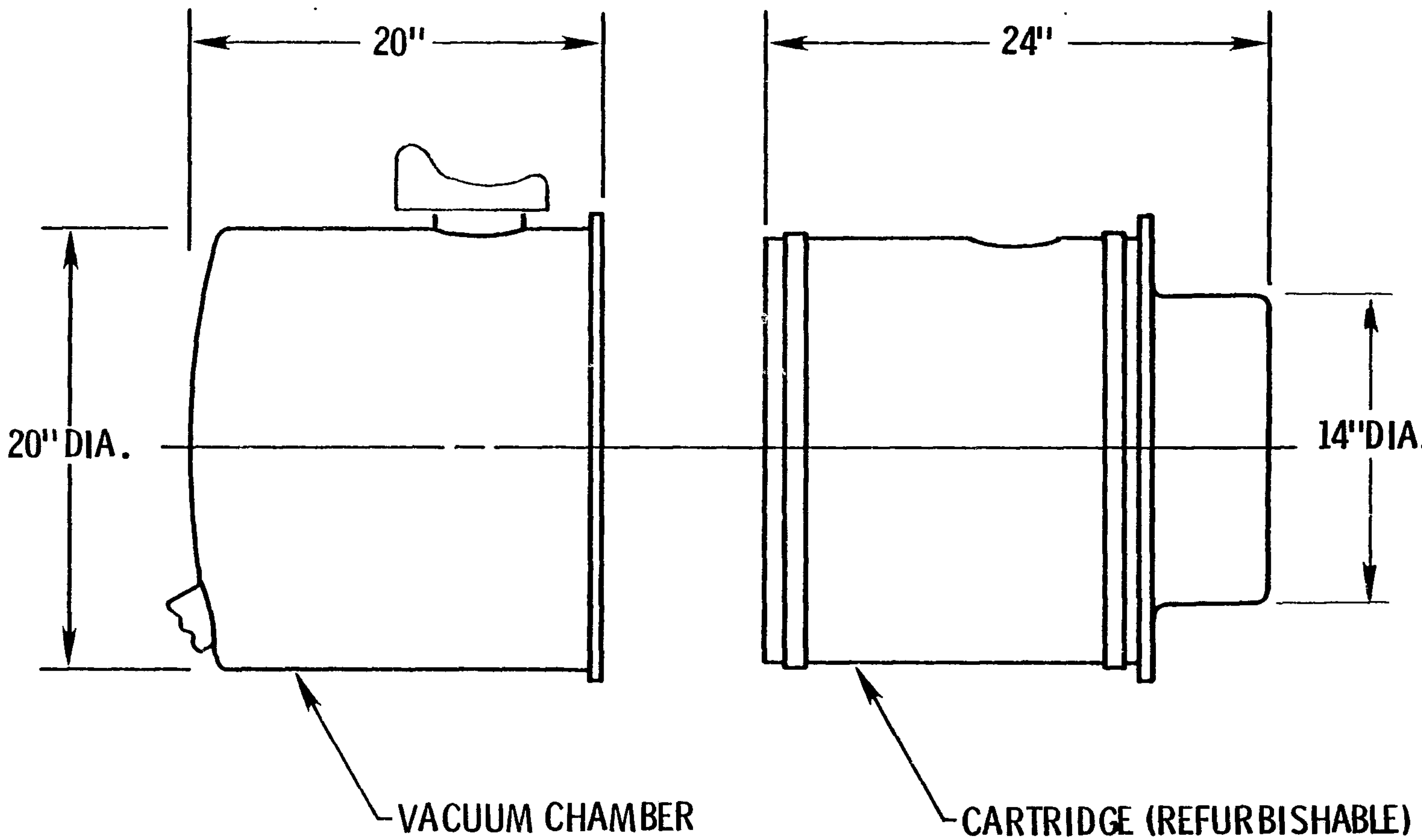

Figure 4-27

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FAIRCHILD REPUBLIC COMPANY

WASTE MANAGEMENT SYSTEM

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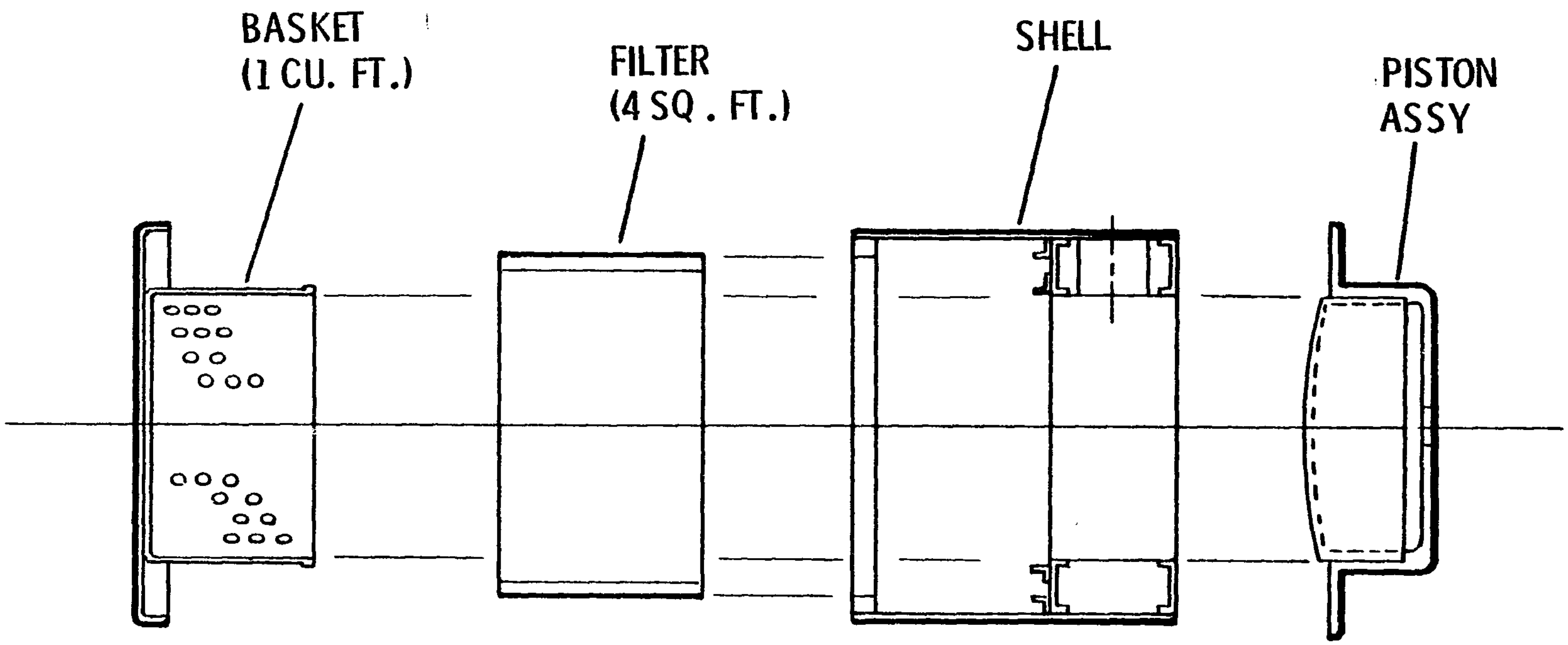
CARTRIDGE COMPACTOR



CARTRIDGE
EXPLODED VIEW

Figure 4-28

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4.1.5.1 Bellows/Piston Assembly

The steel bellows is a standard off-the-shelf item which is attached to the rear face of the piston. The piston has a face area of 90 square inches which, when the collector is evacuated, exerts a net force of over 1000 pounds as the piston is driven into the basket. The face of the piston is teflon coated to minimize problems of freezing in the extended position. If tests show that freeze-up may occur, placement of a heating element on the back face of the piston will melt the ice at the interface of the waste and piston. The heater would require a low power level and would not have to be on continuously. The heater would automatically turn on when the collector is re-pressurized for the next use. The piston face shape is slightly convex to direct wastes radially as the piston is activated. Three retraction springs attached to the bellows face return the bellows and piston with a force of 300 pounds when the collector is pressurized. In the retracted position, a large open volume is created for waste collection. As wastes build up in the basket, the piston stroke decreases.

4.1.5.2 Collector Basket

The collector basket Figure 4-29 forms the bottom of the cartridge and has a solid bottom. The thin perforated sides will deform to accommodate the moving piston. The available collection volume in the basket is about one cubic foot. This is equivalent to the undried compressed volume of a 210 man-day mission. An equivalent volume is available in the storage region between the basket and air filter. If the storage requirement were decreased, say to 60 man-days, the collector basket and cartridge could be decreased in length and diameter. Note that the volume reduction would be proportionally less than the capacity reduction because of the nearly constant non-storage volume. On the other hand the capacity could be scaled upwards with smaller proportional change in volume.

4.1.5.3 Filter Assembly

The cylindrical filter is supported by a porous plastic foam and a rigid perforated shell and forms the outer wall of the toroidal storage region. The filter area is four square feet, and so can tolerate large quantities of waste in contact with it without significant air flow degradation. The space between the filter and cartridge shell forms an air plenum and air flows out through openings in the bottom cartridge plate. The filter is the only expendable part of the cartridge. After clean-up off-shuttle, the cartridge is refurbished with a new filter.

CARTRIDGE COMPACTOR

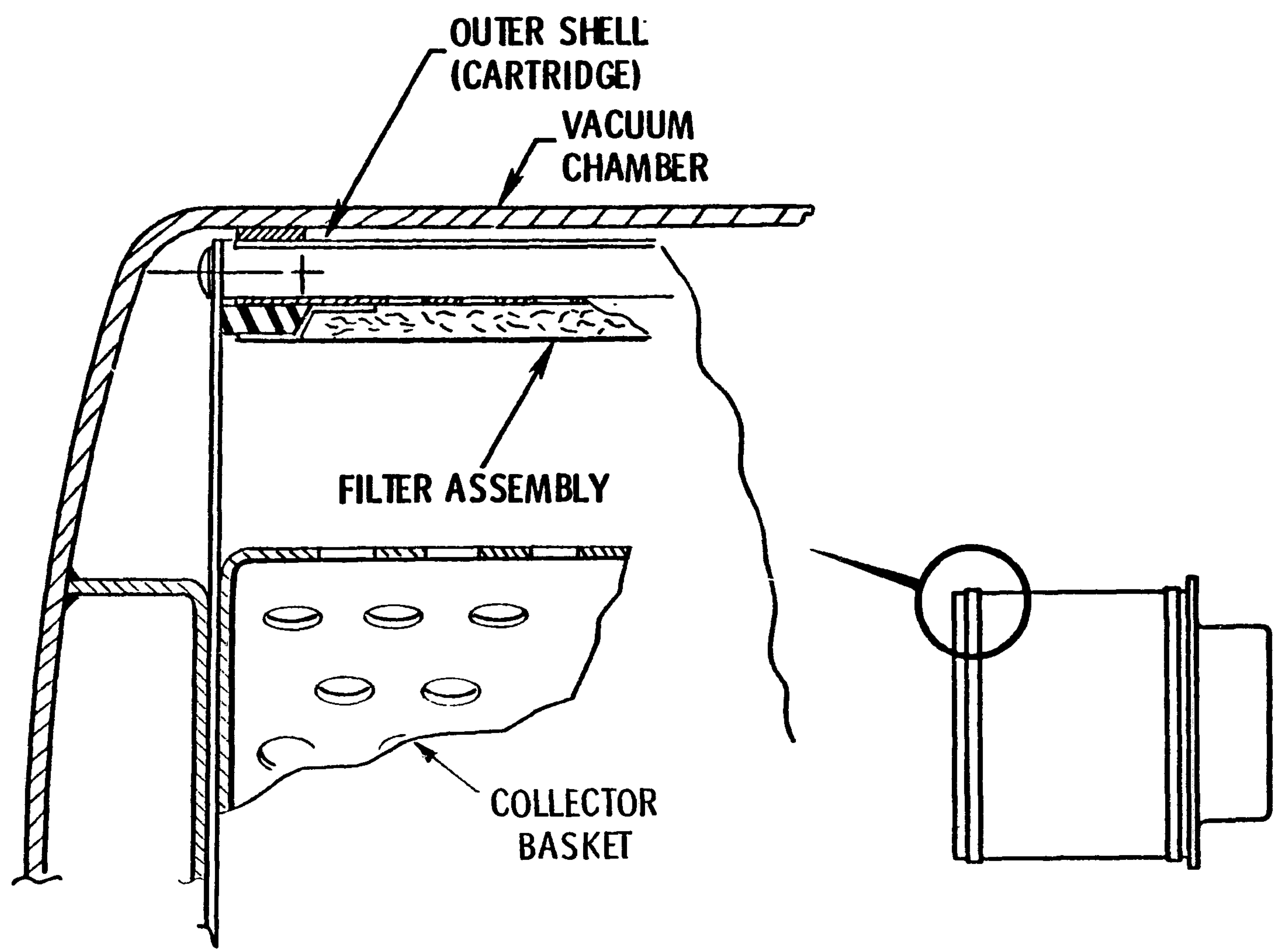


Figure 4-29

4.1.5.4 Operation

With the system in the vacuum processing mode, user operated controls switch the collector exhaust line from vacuum to cabin air and the collector is repressurized. The piston, which was in the extended position, now returns to its compressed position by the action on the retractor springs. The blower is started and the seat slide valve opened and the collector is ready for use. After use, operator controls close the seat opening valve, shut off the blower, and connect the collector to vacuum. The piston now extends and compacts waste in the storage region, where it remains during the processing. A manually operated screw attached to the back of the piston face and passing through the interior of the bellows to the front of the collector could be used to retract or extend the piston in the event of an obstruction.

4.1.5.5 Refurbishment

Refurbishment is accomplished quickly on-shuttle without major disassembly or breaking of lines. It is only necessary to replace the used cartridge with a clean one, conduct a superficial clean-up, and test the system. All waste and contaminated surfaces are contained and sealed (by the bacteria filter) in the cartridge.

The cartridge change procedure is as follows:

Loosen the band clamp holding the cartridge in the collector vacuum shell.

The transport tube connecting the seat to the collector fits into an opening in the cartridge. Raise the seat and remove the transport tube from the opening freeing the cartridge. Insert a snap-on cap in the cartridge opening to complete the sealing of the cartridge.

Replace the cartridge.
Close band clamp.

4.2 Space Station WCS Design Concepts

This second phase of the studies was to adapt the Shuttle design concepts to Space Station Design Concepts, by addressing requirements which would not be the same. Figure 4-30 is a list of design concepts developed during the study which would satisfy preliminary space station requirements shown and discussed in paragraph 3.4.6. Figure 4-31 depicts the WCS interfaces for Space Station waste collection.

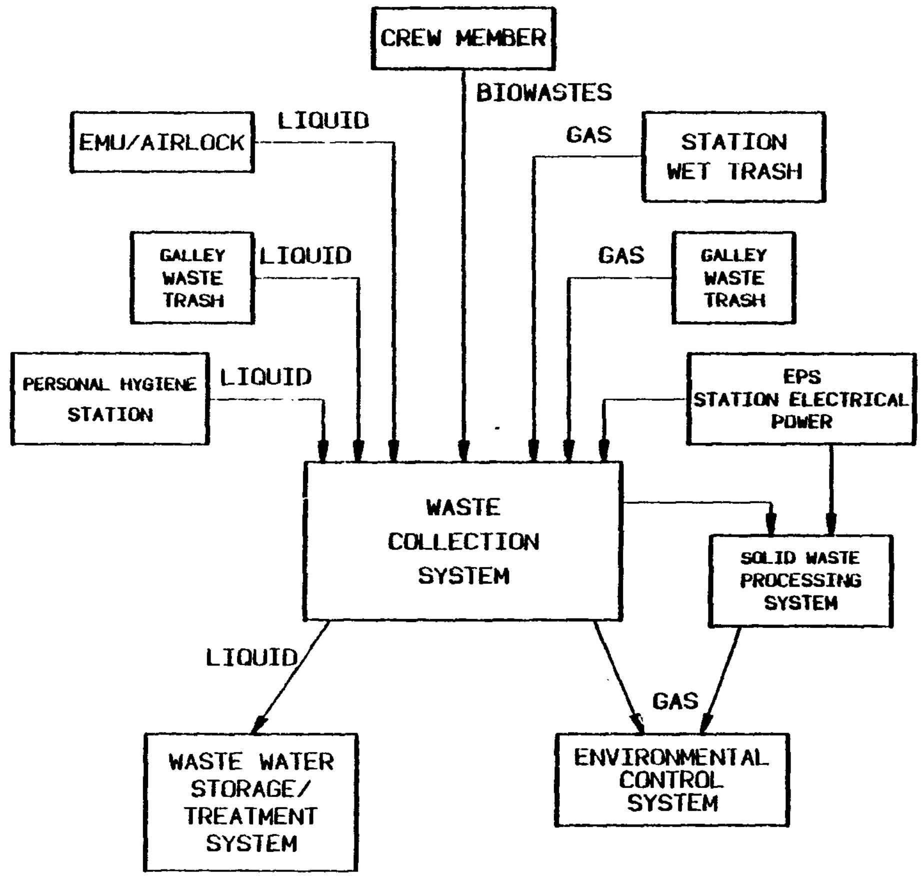
4.2.1 Fecal Collection Bag/Microwave Sterilization

The Microwave Sterilization System is similar to the Microwave Sterilization/Drying System described in paragraph 4.1.2 except inactivation is accomplished by sterilization with microwave heating in lieu of vacuum drying utilizing microwave heating and venting overboard. The system features are summarized in Figure 4-32 and a system schematic is shown in Figure 4-32.1.

SPACE STATION
WCS
DESIGN CONCEPTS

- o FECAL COLLECTION BAG MICROWAVE OVEN STERILIZATION
- o FECAL COLLECTION BAG CONVECTION OVEN STERILIZATION
- o FECAL COLLECTION BAG FREEZER STORAGE
- o CARTRIDGE ARCHIMEDEAN SCREW FECAL COLLECTION REFRIGERATOR/FREEZER STORAGE
- o CARTRIDGE COMPACTOR FECAL COLLECTION REFRIGERATION/FREEZER STORAGE
- o FECAL COLLECTION BIOLOGICAL INACTIVATION AND STORAGE

Figure 4-30



SPACE STATION
WCS INTERFACES
(STERILIZATION PROCESSING)

Figure 4-31

SPACE STATION
SKYLAB-TYPE FECAL COLLECTION BAG SYSTEM
(MICROWAVE STERILIZATION)

- o INTERFACE WITH SUBSYSTEMS
  - URINAL
  - BLOWER
  - ODOR CONTROL
  - FAN/SEPARATORS
- o MANUAL INSERTION OF INDIVIDUAL BAG
  - INDIVIDUAL BAG PREVENTS AIRFLOW DEGRADATION
- o AIRFLOW FOR SEPARATION
- o BIO MEDICAL SAMPLING
- o BAG HEAT SEALED
- o MANUAL INSERTION OF SEALED BAG IN PROCESSOR
  - CAPABILITY TO PROCESS OTHER WASTE
  - VOMITUS
  - DESICCANTS
  - WET WIPES
- o QUICK OPERATION
  - 1 UNIT REQUIRED
  - 1 BACK-UP
- o VENTED BAG
  - CABIN AIR
  - DEHUMIDIFIER/CONDENSER
  - ODOR CONTROL
- o NON-VENTED BAG
  - INCREASED STORAGE REQUIREMENTS
  - NO VAPOR/ODOR CONTROL
- o ELECTRICAL POWER
  - 1100 WATTS
  - EMI SHIELDED
- o STORAGE/RESUPPLY
  - CLEAN BAGS
  - PROCESSED BAGS
  - ODOR CONTROL FILTERS
- o STATION MAINTENANCE
  - NORMAL DAILY
  - MINIMAL RESUPPLY

Figure 4-32

SPACE STATION WCS (MICROWAVE STERILIZATION)

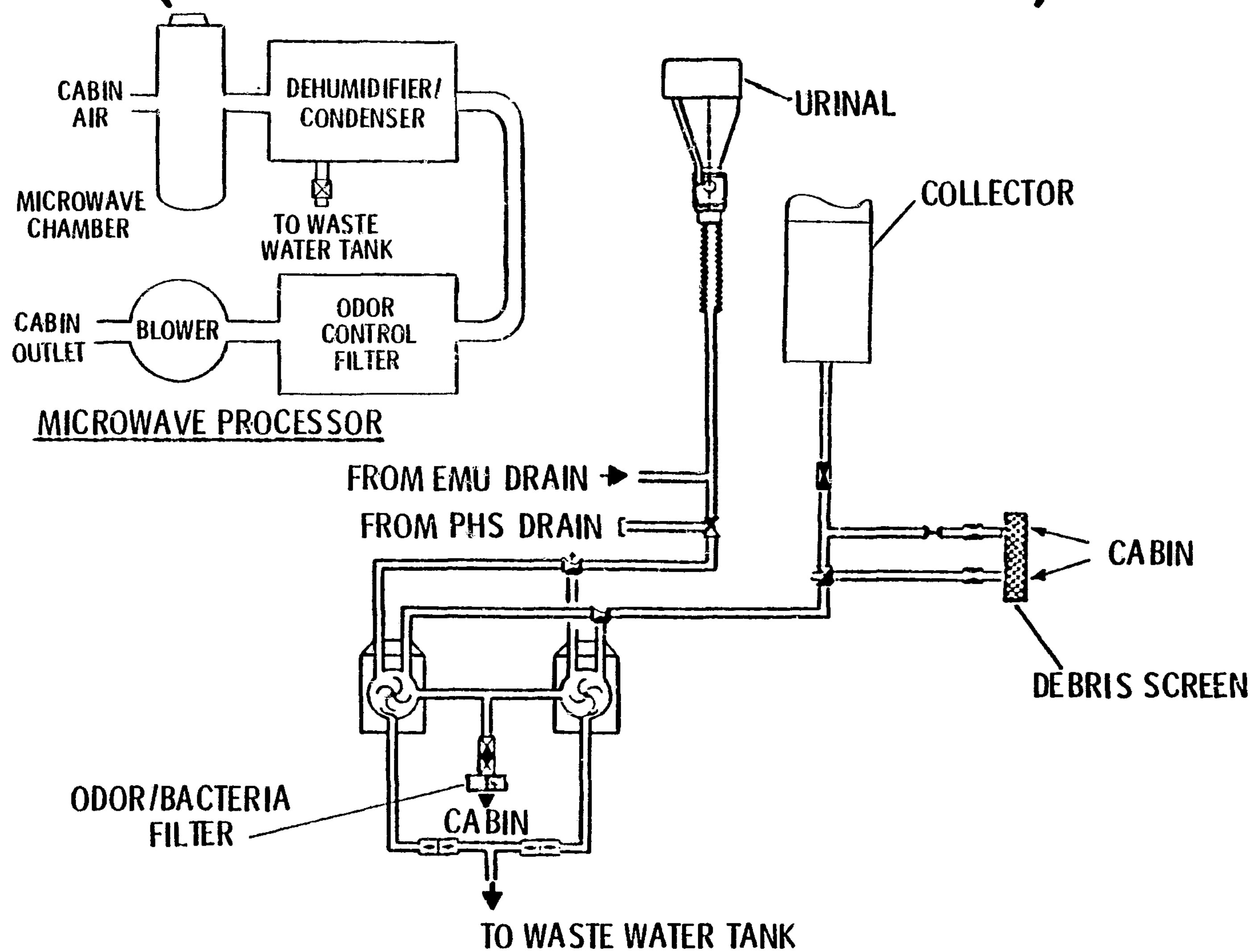


Figure 4-32.1

4.2.1.1 Microwave Sterilization/Collection Bag

The microwave system concept for the space shuttle is applicable to a space station with the exception that the vapors produced during processing cannot be discharged overboard. The gases and vapors must be retained either in the bag or in the cabin air. Using a vented bag as in the shuttle concept, the gases released during processing must be deodorized and all vapors removed before being vented into the cabin air. This requires the addition of an odor filter and a dehumidifier/condenser to the system as shown in Figure 4-33. Another approach would be to use a non-vented bag whereby all the gases produced during sterilization are held in the bag. The bag must then be designed to allow for expansion and the processing chamber and storage area must be sized to allow for the increased-size bags. During sterilization, the non-vented bag will increase in volume as the vapors and gases are produced. As the bag cools after processing, the vapors will reach their dew point and recondense, decreasing the volume somewhat, but not back to its original volume at pre-processing. No vapor/odor controls is needed during processing with a non-vented bag. Power requirements for the microwave processing system do not change for the space station system and remain at 1100 watts.

4.2.2 Fecal Collection Bag/Convection Oven Sterilization System

The Convection Oven Sterilization System is similar to the Microwave System described in paragraph 4.2.1 except for utilization of a convection oven in lieu of a Microwave oven for sterilization. The system features are shown in Figure 4-34 and a system schematic is shown in Figure 4-35.

4.2.2.1 Convection Oven Sterilization/Collection Bag

Convection ovens use a blower to circulate hot air in the chamber and to apply uniform heat distribution. The forced convective heat transfer is a desirable feature for heating in zero gravity operation. Commercial airlines as well as the space shuttle at present use convection ovens for food preparation. For space station application with no overboard dump, the circulated air in the oven and gases vented from the bag must be deodorized and dehumidified before circulating into the cabin as shown in Figure 4-36..

Desired temperatures for sterilization are 250°F and above with a holding time of ten minutes (ref 1). Power requirements and holding time can be traded off as shown in Figure 4-37 for a temperature of 250°F. The power demand accounts for the heat absorbed by the evaporating moisture in the bag plus the heat loss to a 70°F cabin through the oven walls. Pre-heat time to obtain 250°F will be 5 to 10 minutes depending upon the power level. This ranges from 500 to 1200 watts for holding times of 20 to 5 minutes, respectively. The optimal temperature/power/time combination should be selected to best satisfy the requirements of the system.

MICROWAVE PROCESSOR

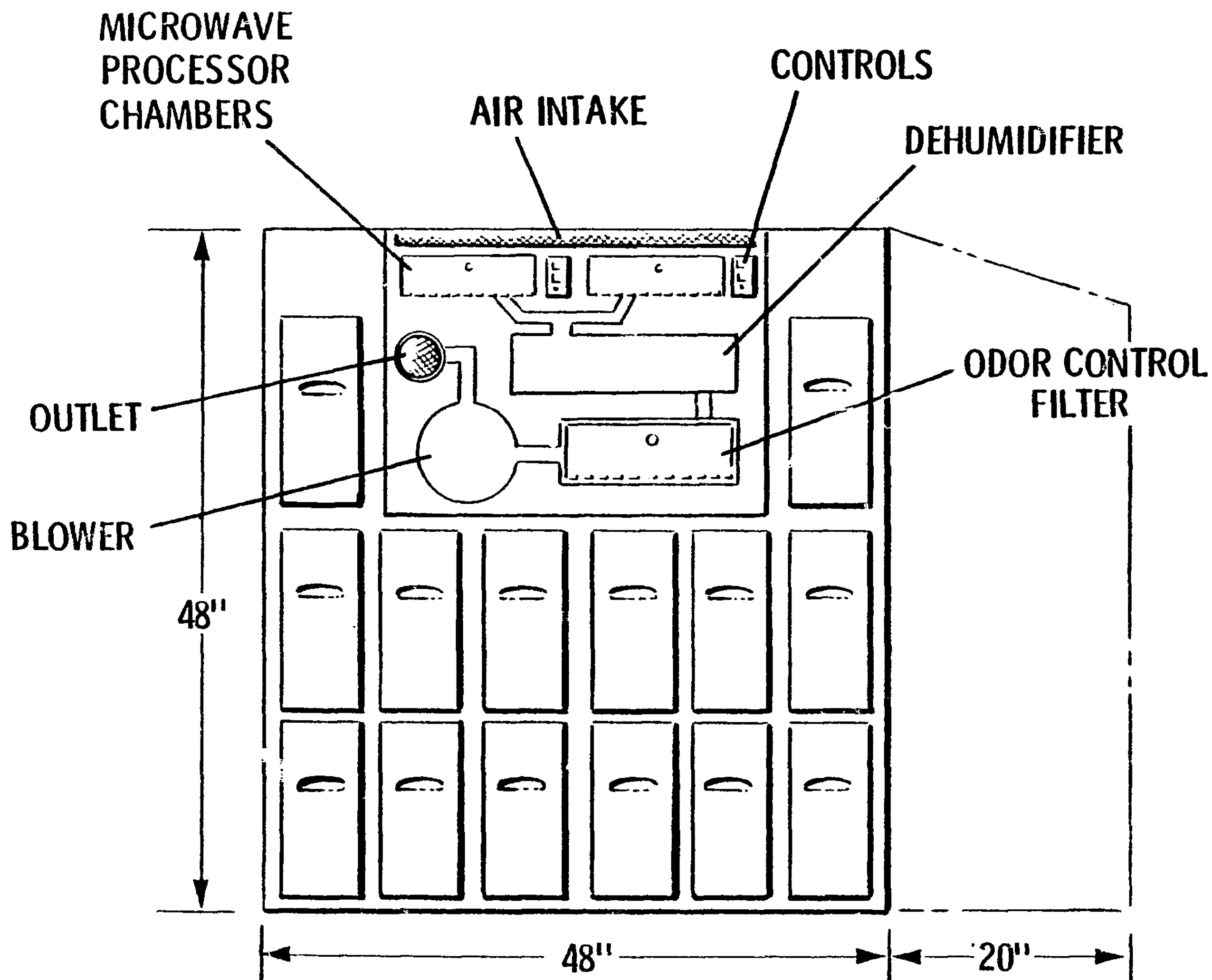


Figure 4-33

SPACE STATION
SKYLAB-TYPE FECAL COLLECTION BAG SYSTEM
(CONVECTION HEAT STERILIZATION)

- USE OF EXISTING SUBSYSTEMS
  - URINAL
  - BLOWER
  - ODOR CONTROL
  - SEPARATORS
- MANUAL INSERTION OF INDIVIDUAL BAG
  - INDIVIDUAL BAG RESISTS DEGRADATION OF AIRFLOW
- AIRFLOW FOR SEPARATION
- BIO MEDICAL SAMPLING
- BAG HEAT SEALED
- MANUAL INSERTION OF SEALED BAG IN PROCESSOR
  - CAPABILITY TO PROCESS OTHER WASTE
  - VOMITUS
  - DESICCANTS
  - WET WIPES
- 6 UNITS REQUIRED
- VENTED BAG
  - CABIN AIR
  - DEHUMIDIFIER/CONDENSER
  - ODOR CONTROL
- ELECTRICAL POWER
  - SEE POWER CURVE
- STORAGE/RESUPPLY
  - CLEAN BAGS
  - PROCESSED BAGS
  - ODOR CONTROL FILTERS
- STATION MAINTENANCE
  - NORMAL DAILY
  - MINIMAL RESUPPLY

Figure 4-34

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SPACE STATION WCS (CONVECTION OVEN STERILIZATION)

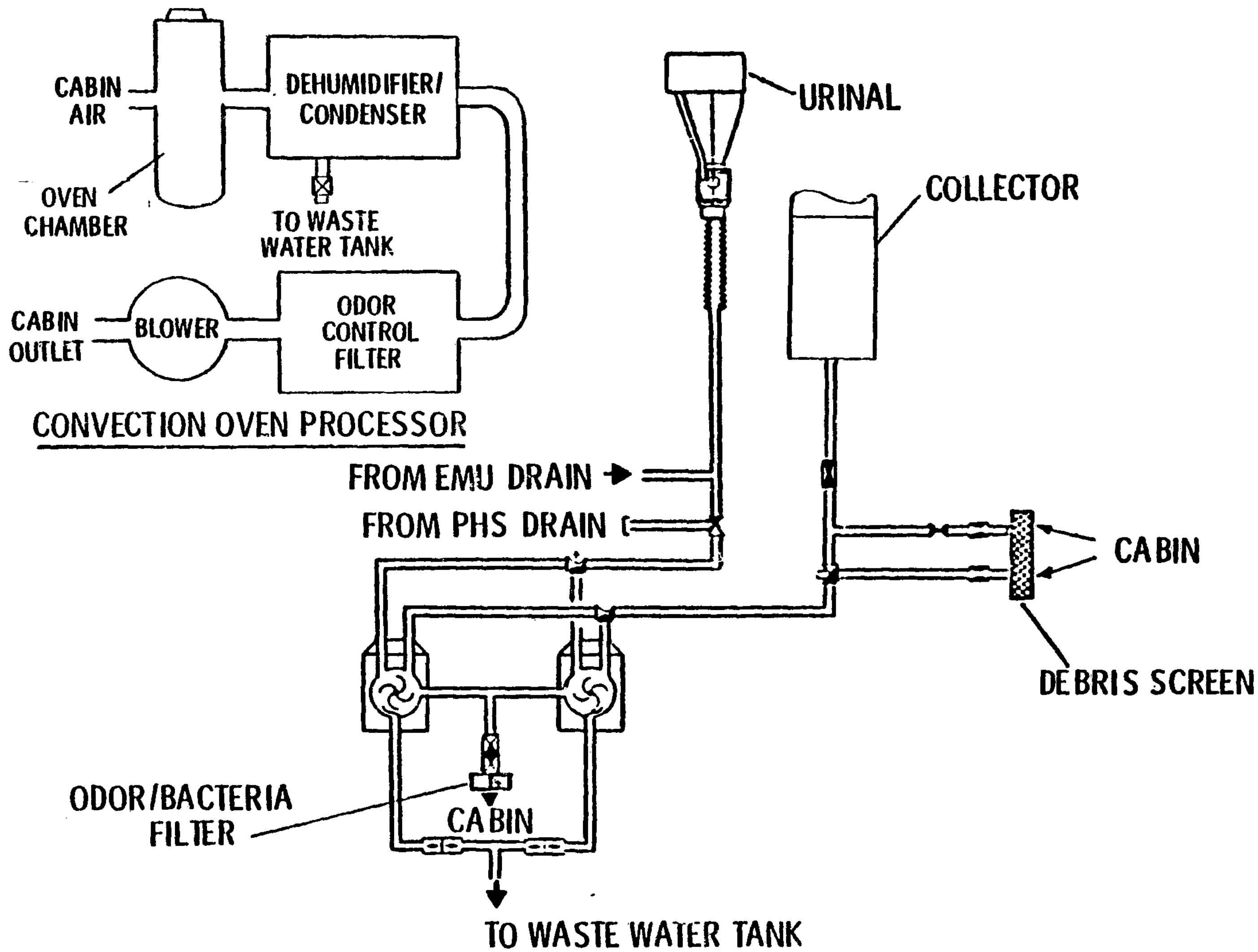

Figure 4-35

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WASTE MANAGEMENT SYSTEM

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CONVECTION OVEN PROCESSORS

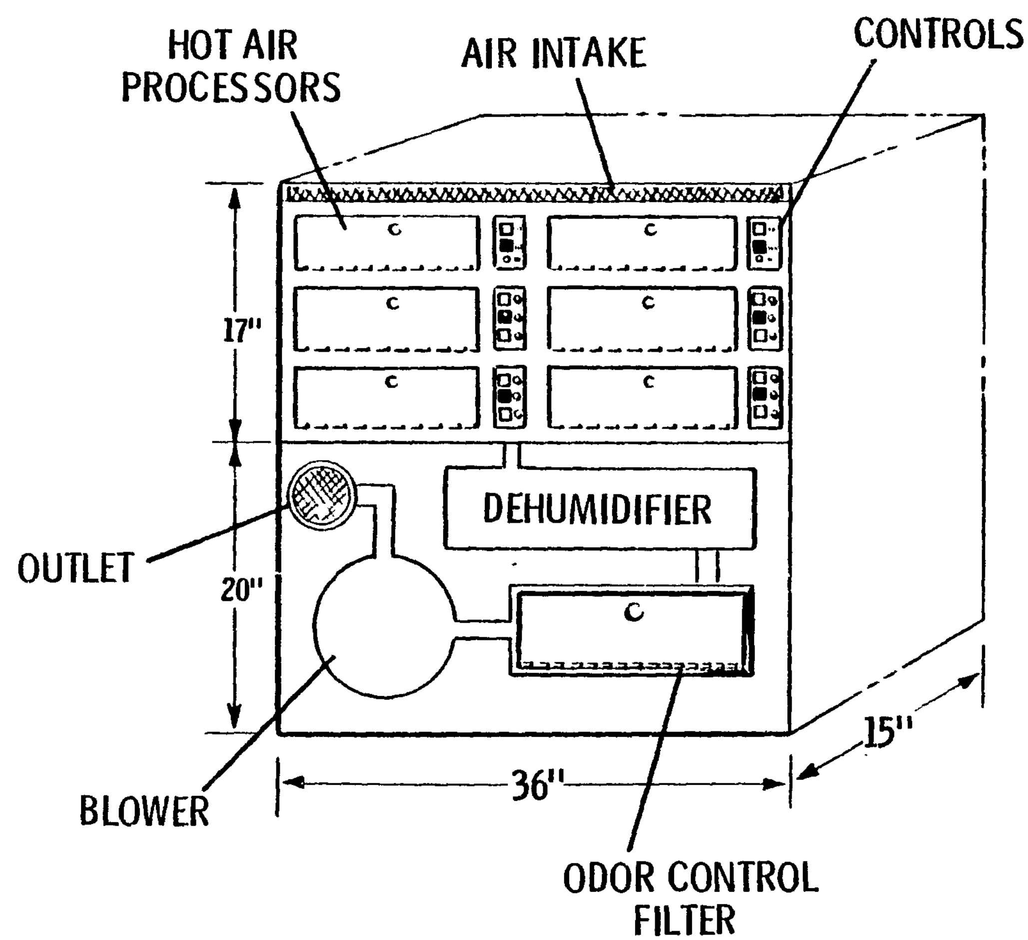

Figure 4-36

MS254V1003
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CONVECTION STERILIZATION - POWER vs. TIME

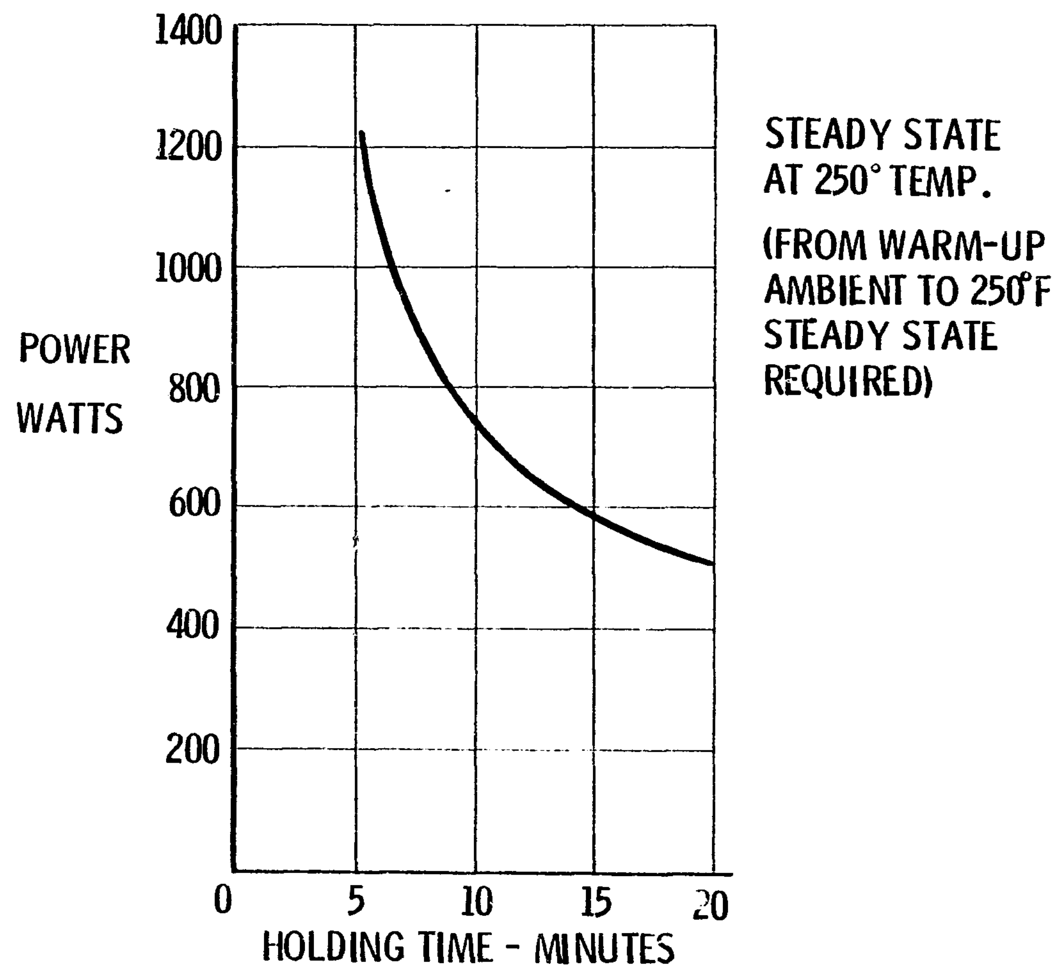


Figure 4-37

4.2.3 Freezer Processing/Collection Bag System

The Freezer Processing System for collection bags is similar to the Fecal Collection Bag Vaccum/Heat Drying Process System described in paragraph 4.1.1 except it utilizes freezing for bacterial/odor deactivation in lieu of vacuum/heat drying. The collection bag and airflow collection system are identical as described in paragraph 4.1.1.1. Figure 4-38 summarizes the features of the system, Figure 4-39 depicts the system interfaces for Space Station Waste collection and a system schematic is shown in Figure 4-40.

4.2.3.1 Freezer Processor/Collection Bag

Power requirements for a collection bag/freezer processor vary according to the man-day sizing requirement for freezer storage. Figure 4-41 shows the electrical power for a cryogenic refrigeration cycle for various man-day requirements. The 50 to 540 man-day requirements show an 80 to 150 watts power demand, respectively. These are based on a freezer temperature of $0^{o}F$ at which the retardation of the biological activity is maximum (Ref 1). The power requirements are based on the continual rejection of the heat transferred through the freezer walls from a $70^{o}F$ cabin and a transient heat load to cool and freeze one bag from each of 6 crew members per day from $98.6^{o}F$. As the freezer must operate continuously, the dominating factor in the power demand is the heat transferred from the cabin through the chamber walls. Options to reduce the cabin heat load, such as evacuated super-insulator panels, should be investigated to reduce the power demand.

References

1) SAE Aerospace Applied Thermodynamics Manual, 2nd ed., Society of Automotive Engineers, pub., NY, 1969.

4.2.4 Cartridge Archimedean Screw Fecal Collection, Refrigeration/Freezer Storage

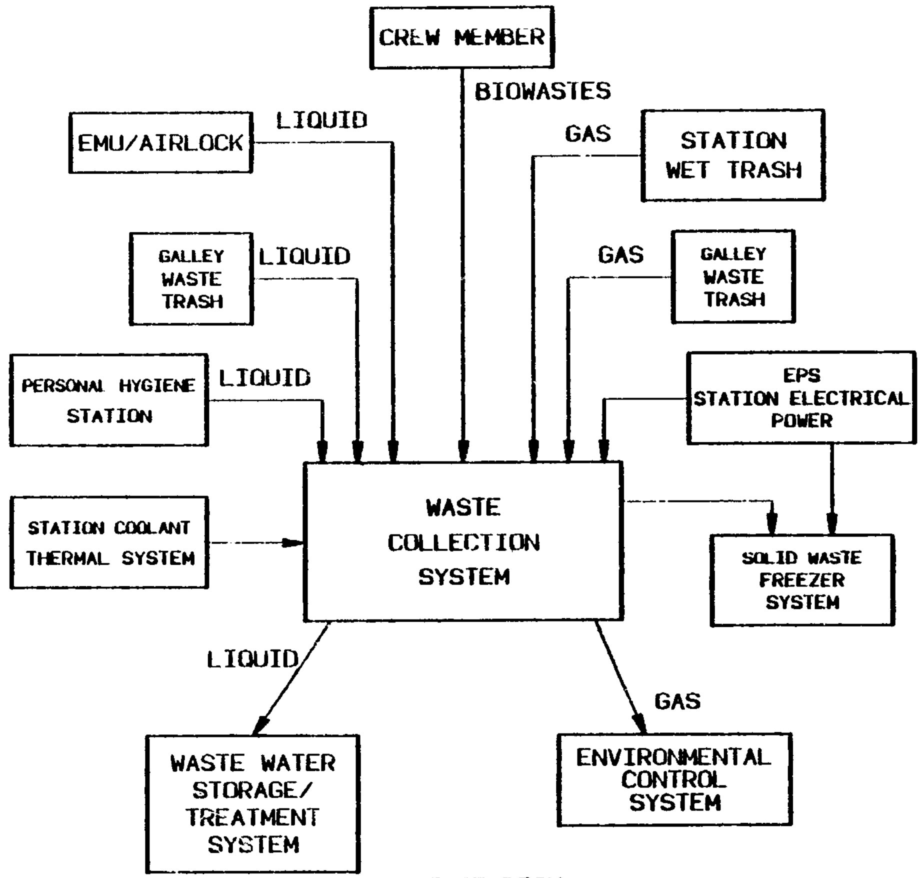
Single collection systems such as bag collectors do not, in general, have temporary holding requirements before permanent treatment. With multiple collection systems such as this, the waste must be stabilized in some way to prevent undesirable bacterial growth and odor generation which may overload the odor control filter. It may be that if the moisture content were not great that bacterial growth will be self-limiting. However, it seems prudent to provide some inhibition. Low collector temperature seems the most practical approach.

Temperature reduction below freezing without drying was deemed inadvisable because of the possibility of a screw freeze-up. Holding the temperature above freezing however may provide only a limited holding time. An estimated safe holding time of one week at 35-40 degrees F was made by a microbiological consultant. At the end of this time the cartridge would be removed and placed in a freezer for storage until returned to Earth by a re-supply ship. Clearly the safe holding time must be investigated because of the impact on servicing times and cartridge inventory. In the discussion which follows, one week replacement of the cartridge was assumed. If one week holding proves too conservative, multiple collection units become more attractive.

SPACE STATION
SKYLAB-TYPE FECAL COLLECTION BAG SYSTEM
(FREEZER STORAGE)

- o INTERFACE WITH SUBSYSTEMS
  - URINAL
  - BLOWER
  - ODOR CONTROL
  - FAN/SEPARATORS
- o MANUAL INSERTION OF INDIVIDUAL BAG
  - INDIVIDUAL BAG PREVENTS AIRFLOW DEGRADATION
- o AIRFLOW FOR SEPARATION
  - BIO MEDICAL SAMPLING
- o MANUAL INSERTION OF SEALED BAG IN STORAGE
  - CAPABILITY TO STORE OTHER WASTE
  - VOMITUS
  - WET WIPES
- o FREEZER STORAGE
  - ELECTRICAL POWER
- o STORAGE/RESUPPLY
  - CLEAN BAGS
  - FROZEN BAGS
- o STATION MAINTENANCE
  - NORMAL DAILY
  - MINIMAL RESUPPLY

Figure 4-38



SPACE STATION
WCS INTERFACES
(REFRIGERATION/FREEZER STORAGE)

Figure 4-39

SPACE STATION WCS (FREEZER STORAGE)

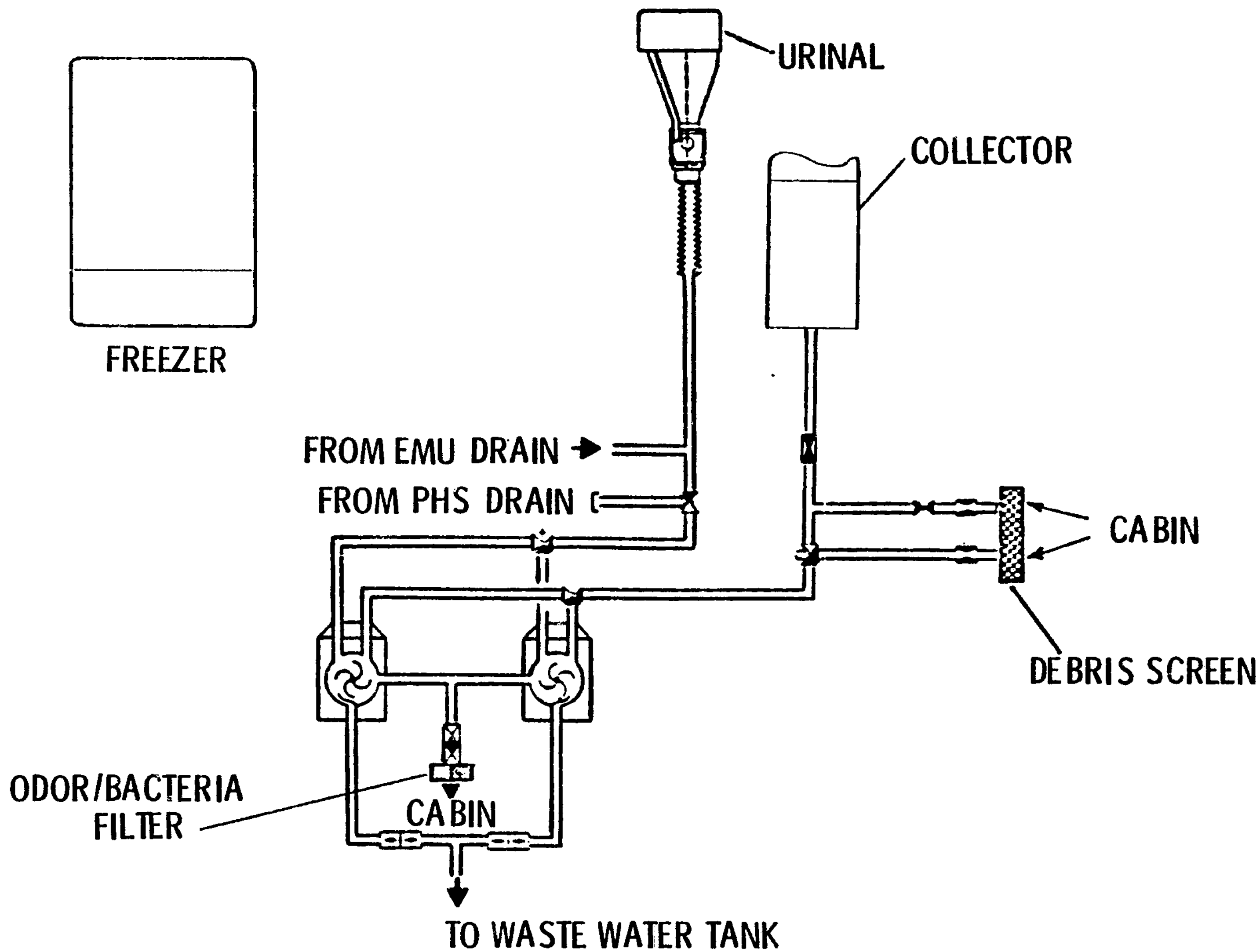
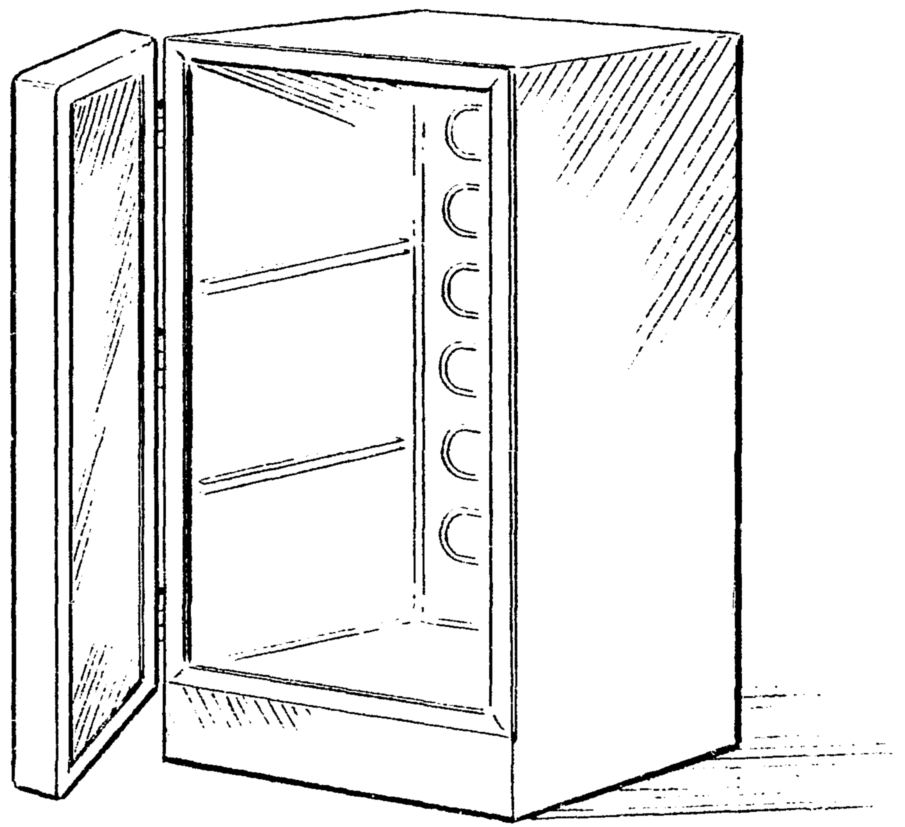


Figure 4-40

SPACE STATION WCS BAG FREEZER UNIT



FREEZER @ 0° F		
MAN DAYS	INTERNAL VOLUME (CU.FT.)	POWER (WATTS)
50	2	80
210	7	100
540	17	150

Figure 4-41

MS254V1003
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The collector system is basically the same as that described previously in section 4.1.3 with the exception of the cooling provision and re-sizing. Only these differences are discussed here. Figure 4-42 summarizes the features of this system.

Power requirements for use on a space station design are for,

1) Refrigerating the collector to 40°F to hold the current collection cartridge up to one week when a empty cartridge is inserted. The chilling effect slows down bacterial growth.

2) Freezing the used cartridge in a 0°F freezer for final processing.

4.2.4.1 Cooling requirements

Cooling can be provided either by the Space Station cooling loop or a dedicated refrigeration system and requires approximately 50 watts power. The cooling coils would in either case be wrapped around the outside surface of the fixed part of the collector vessel. Insulation around the coils would be provided. Heat transfer from the waste to the collector wall would occur by radiation and conduction.

Refrigeration power requirements for the collector are on the order of 50 watts based on a cryogenic refrigeration cycle to hold the collector cartridge at 40°F. However, due to the low cooling requirements to maintain 40°F the collector may be tied into the space vehicle cooling load and eliminate the need for a separate cooling system. The peak cooling load on the collector occurs during collection when warm 70°F cabin air passes through the unit to aid in collection and fresh waste material is added at body temperature (98.6°F). A dehumidifier is required for the cabin air entering collector so that no water condenses in the cool collector. A dehumidifier and odor control are required for air being recirculated from the collector back to the cabin for water picked up in the collector and odorous gases, respectively.

4.2.4.2 Cartridge Size

Based on a six man crew and a one week replacement cycle, the cartridge was sized for 50 man-days. This results in a reduction of the cartridge diameter from 18 inches to 13 inches.

4.2.4.3 Freezer Storage

The freezer Figure 4-43, processor which is sized to hold a maximum of 12 cartridges, requires 300 watts peak power to maintain a 0°F processing temperature. Due to higher cooling requirements than the refrigerator system, a separate cryogenic system must be used for cooling. The peak power is based on the rejection of heat obtained through the freezer walls from a 70°F cabin and the transient heat load to cool and freeze a filled cartridge (with 60 man-days of waste) from 40°F to 0°F. Inasmuch as the cartridge seals the waste contents, it may be feasible to consider sharing a freezer with expendable supplies which are consumed at a rate equal to or greater than the cartridge accumulation.

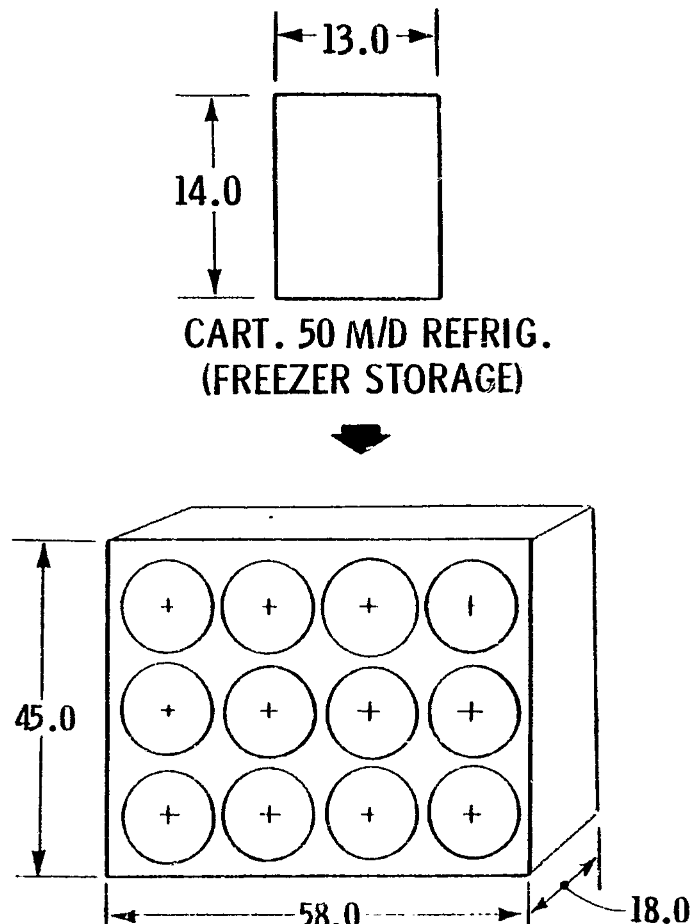
SPACE STATION
CARTRIDGE ARCHIMEDEAN SCREW FECAL COLLECTION SYSTEM
REFRIGERATION/FREEZER STORAGE

- INTERFACE WITH SUBSYSTEMS
  - URINAL
  - FAN/SEPARATORS
  - BLOWER
  - ODOR CONTROL
- AIR ENTRAINMENT OF WASTE
- TRANSPORT AND COMPACTION EFFECTED BY ROTATING SCREW INSIDE OF PERFORATE
- ELECTRICAL POWER SCREW DRIVE MECHANISM
  - REFRIGERATION POWER 50 WATTS @ 40^oF
  - FREEZER 300 WATTS @ 0^oF
- NOT WIPE LIMITED
- SMALL COLLECTOR ENVELOPE
- FREEZER LONG TERM STORAGE
- STATION SERVICING
  - CARTRIDGE REPLACEMENT
  - SHUTTLE RESUPPLY/DISPOSAL

Figure 4-42

FAIRCHILD REPUBLIC COMPANY | WASTE MANAGEMENT SYSTEM | MS254V1002 11 DECEMBER 1984

SPACE STATION
CARTRIDGE ARCHIMEDEAN SCREW FECAL COLLECTION SYSTEM
FREEZER STORAGE REQUIREMENTS



540 M/D FREEZER STORAGE

Figure 4-43

4.2.4.4 Electrical Power

According to refs 2) and 3), the present operational power level of the space station as projected for design is 65KW but future requirements may push that to 100-300 KW. Thus for the present forecast, the WMS systems as proposed for the space station (with power demand ranging from 80 to 1200 watts) would tap under 2 percent of the total power to operate. If station power increase, this could drop to under 1 percent. Therefore, the power levels as proposed are within reasonable limits of acceptability.

Reference:

2) Carlisle, Richard F., "Space station: tehnology development", Aerospace America (September 1984), pp 60-66.

3) Baer, Tony "Space Station Thermal Control" Mechanical Engineering (December 1984) pp. 22-33.

4.2.5 Cartridge Compactor Fecal Collection, Refrigeration/Freezer Storage

The cartridge compactor collector proposed for Shuttle use in section 4.1.5 can be modified for Space Station in an analogous way to the Archimedean screw modification in section 4.2.4, with the same cooling power requirements. There is, however, the additional requirement to supply a driving force for the piston since the differential pressure created by venting the collector to space is not now available. This can be done either by a small mechanical pump evacuating the collector to the cabin through the odor control filter and creating almost an equivalent differential pressure, or by the addition of an electric motor screw drive. Figure 4-44 summarizes the feature of the system.

The resized compactor cartridge is reduced from 21.5 inches in diameter to 13.5 inches. The storage freezer, Figure 4-45 has a 29 cubic foot capacity for the resupply cycle storage.

4.2.6 Fecal Collection, Biological Inactivation and Storage

There are existing commercially available toilet systems for special circumstances such as recreational vehicles, where, because either water is scarce or dumping is not feasible, the systems are self contained and a small water supply is recirculated. These systems operate for extended periods without problems. This is accomplished by the inactivation and digestion of the wastes in a water medium by added bacteria and enzymes. The aerobic digestion converts most of the wastes to water and carbon dioxide without great odor generation and without a significant pathogen population. There is a very small solid residue. Such a system can operate almost indefinitely with periodic removal of excess fluid.

C-2

The adaptation of the biological toilet to Space Station is attractive for the following reasons:

Few expendable resources are required.

It accepts other organic wastes which might create odors.

Air flow cannot be degraded by filter loading.

Large storage volumes are not required.

Waste storage does not require power.

It has the potential for recycling.

To adapt the biological toilet for zero-G Space Station use, it is necessary to handle the two-phase system to permit air flow through the system, and to provide for venting. If Space Station were to operate at artificial gravity, such a system would be a leading candidate. Figure 4-46 summarizes the features of the system and Figure 4-47 depicts the WCS interfaces.

The separation of the waste slurry from air is done centrifugally. Figure 4-48 shows a system schematic in which a set of paddles in the collector shell are slowly rotated and sweep the collector volume forcing the fluid to the collector wall. When fluid flow is established, valves at the seat opening and at the air exit line are opened and air for feces collection can flow through the central air space of the collector. After collection, the valves are closed, the rotation of the paddles is stopped, and the liquid is free to migrate throughout the collector presenting a large surface area for aerobic digestion.

4.2.6.1 System Description

The WCS seat is mounted on-axis over a cylindrical collector shell. A slide valve just below the seat, and a valve near the center of the bottom face at the exhaust pipe isolate the contents of the collector. Initially the collector contains a small charge of water. During collections a slurry of feces wipes, and other organic wastes is formed. Weekly additions of a packet of freeze-dried mixture of bacteria and enzymes are made by the crew. The paddle assembly is driven by a motor mounted below the collector bottom face. The exhaust air goes to the urine fan-separator, through an odor-control filter, and back to the cabin. Excess fluid can be bled off through a line at the center of the collector cylinder while the paddles are operating.

4.2.6.2 Paddle Assembly

The paddle assembly in Figure 4-48 is shown with three blades. This might in fact be four or more blades. Each blade extends radially close to the cylinder wall. The lower portion is continuous to the central axis and wipes the bottom face clear so that no material remains near the exhaust valve. The upper portion of the blades is hollowed at the center to create an unobstructed collection region.

Air entrained waste flows through the central region of the paddle assembly. A baffle is required to prevent anything but air passing through the exit. Conical baffles are shown. The baffle would either direct waste to the collector wall or hold it during collection. Subsequent random fluid interaction when paddling ceases will fluidize the waste which then eventually joins the fluid volume. To guarantee liquid-solid and air separation, small radius continuous cones can alternate with cones which extend to the water layer but have a central opening.

4.2.6.3 Operation

To prepare the collector use, the paddles are slowly rotated to impart sufficient momentum to the fluid in their path to maintain a circular flow around the walls without breaking up the fluid mass. A hollow core is soon formed and the valves may be opened for air flow and collector use. Following collection, the collector is valved off and the air flow stopped.

During the digestion process gas is generated and the pressure buildup must be relieved. Again it is necessary to separate the slurry by use of the paddles so that excess gas can be bled off from the central region. In this case it is not necessary to activate the fan. This venting will be performed automatically as required.

The concept of a liquid WCS will require experimental verification to demonstrate that two phase systems can be adequately handled. Such experience however would probably prove of value to other systems that may be proposed for Space Station.

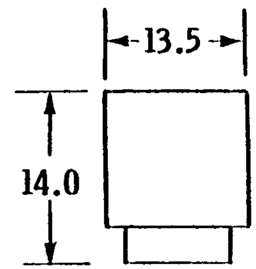
WASTE MANAGEMENT SYSTEM

SPACE STATION
CARTRIDGE COMPACTOR FECAL COLLECTION SYSTEM
REFRIGERATION/FREEZER STORAGE

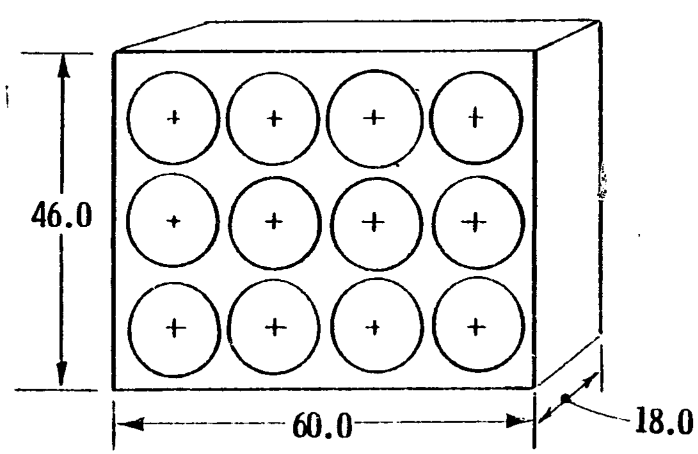
- o INTERFACE WITH SUBSYSTEMS
  - URINAL
  - FAN/SEPARATORS
  - BLOWER
  - ODOR CONTROL
- o AIRFLOW FOR SEPARATION AND TRANSPORT
- o LARGE FILTER AREA
- o PISTON COMPACTION
- o ACCEPTS VARIETY OF WASTES
  - WET WIPES
- o SPACE EFFICIENT
- o SHORT TERM REFRIGERATION HOLDING
  - ELECTRICAL POWER 50 WATTS @ $40^{\circ}F$
- o FREEZER LONG TERM STORAGE
  - ELECTRICAL POWER 300 WATTS @ $0^{\circ}F$
- o STATION SERVICABLE
  - CARTRIDGE REPLACEMENT
  - SHUTTLE RESUPPLY/DISPOSAL

Figure 4-44

SPACE STATION
CARTRIDGE COMPACTOR FECAL COLLECTION SYSTEM
FREEZER STORAGE REQUIREMENTS



CART. 50 M/D REFRIG.
(FREEZER STORAGE)



540 M/D FREEZER STORAGE

Figure 4-45

SPACE STATION
BIOLOGICAL TREATMENT AND STORAGE SYSTEM

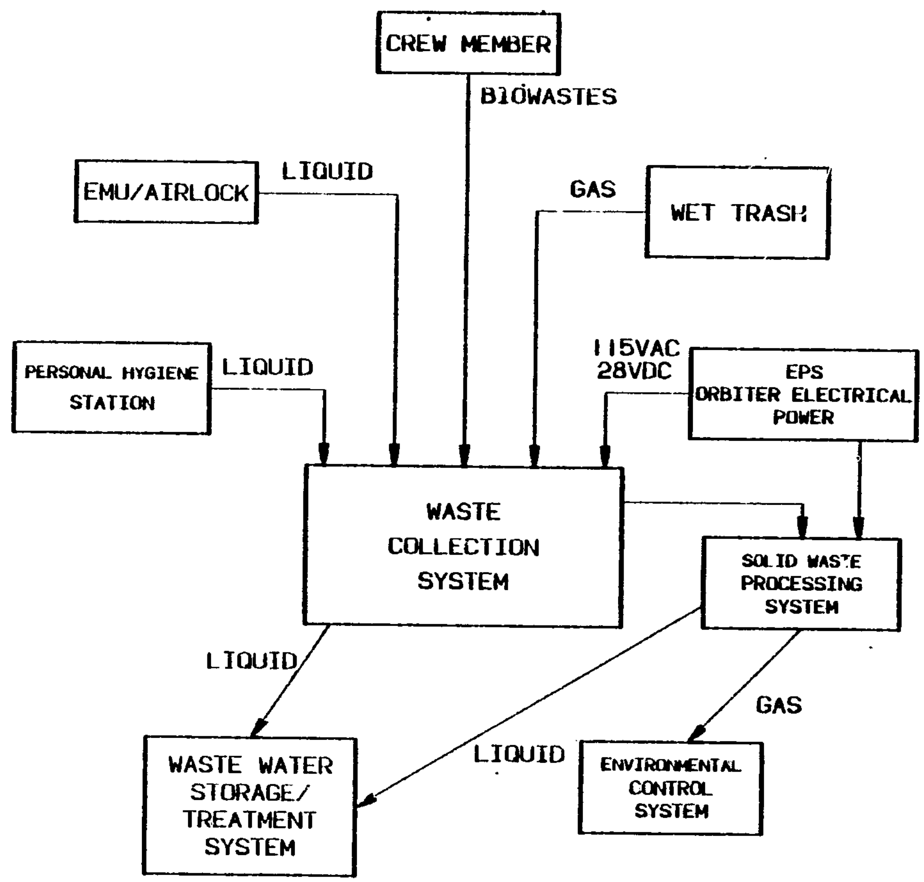
- INTERFACE WITH SUBSYSTEMS
  - URINAL
  - FAN/SEPARATOR
  - ODOR CONTROL
- AIRFLOW SEPARATION AND TRANSPORT
- ACCEPTS WIPES AND OTHER ORGANIC WASTE
- WASTE DIGESTION IN A LIQUID SYSTEM
- WASTE CONVERTED TO WATER AND GAS
- PERIODIC ADDITION OF ENZYMES AND BACTERIA
- CONTINUOUS INDEFINITE OPERATION
- CENTRIFUGAL LIQUID-AIR SEPARATION
- STATION SERVICING
  - PUMPING EXCESS FLUID TO HOLDING TANKS
  - GAS ABSORBER INTERFACE WITH ECLSS

Figure 4-46

FAIRCHILD REPUBLIC COMPANY

WASTE MANAGEMENT SYSTEM

MS254V1002
11 DECEMBER 1984



SHUTTLE
WCS INTERFACES
(BIOLOGICAL PROCESSING)

Figure 4-47

SPACE STATION
WCS LIQUID BIOLOGICAL SYSTEM

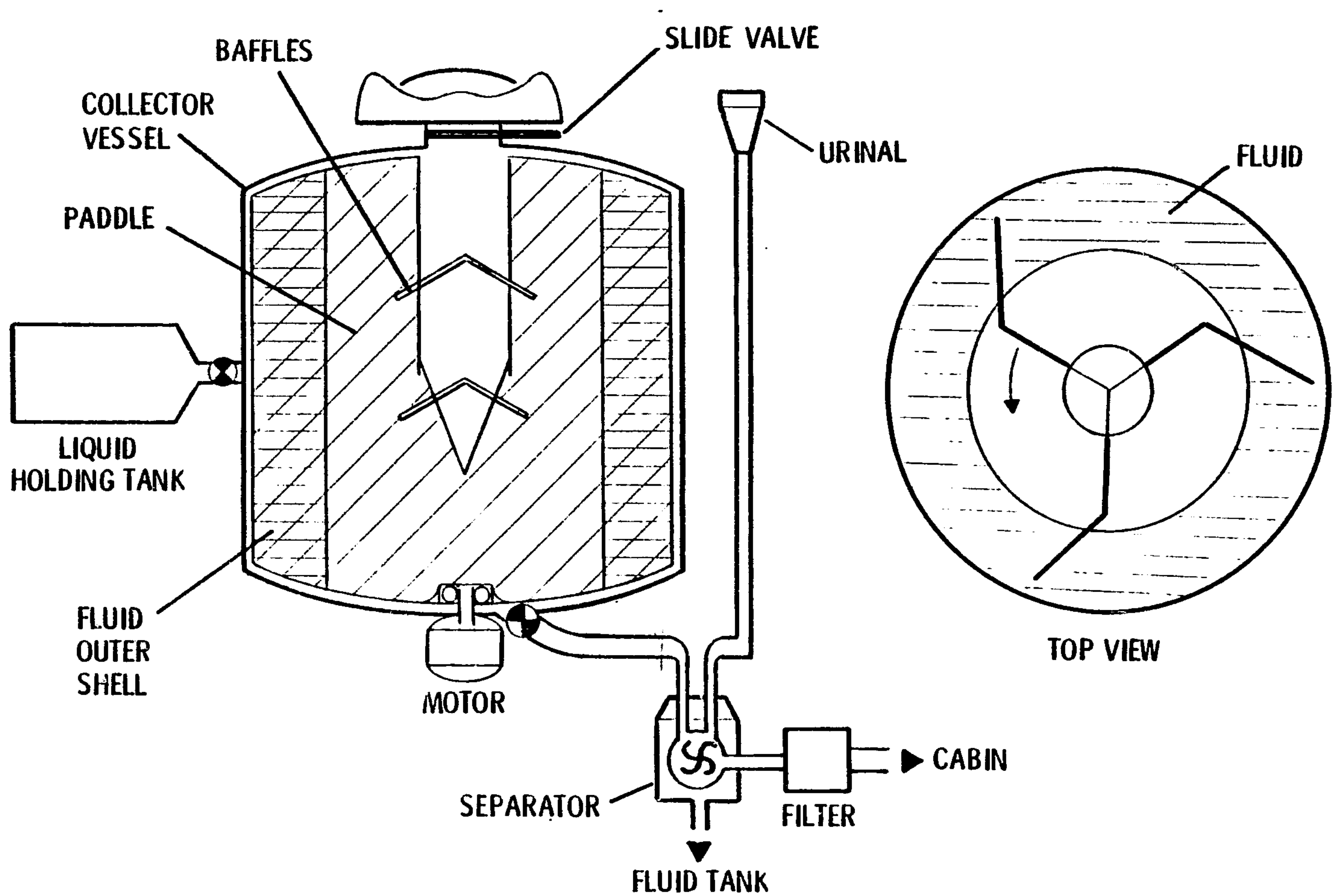


Figure 4-48

5.0 WCS DESIGN CONCEPTS SUMMARY

Ten (10) systems were carried through the evaluation matrix, and are summarized in Figure 5-1. It was determined that only one concept, Microwave Oven Sterilization, had potential application to both Shuttle and Space Station. The Station requirement for no overboard venting of gas, liquids and/or solids imposes severe system penalties of weight, power and complexity, as represented by the need for waste processing by heat or cold sterilization rather than vacuum drying. All the Station-oriented systems incorporate one of these methods while the simpler Shuttle concepts utilize vacuum drying as a baseline. Incorporation of an on-board freezer or sterilization oven would impose undue penalties on the Shuttle. It was felt however that a relatively small one-chamber microwave oven that could sterilize feces within a 10 minute time-line, was a possibility to be considered during the Shuttle systems evaluation.

An advanced concept for potential long term future Space Station use was also developed, based on biological inactivation and storage. This type of system is not envisaged for initial Station application, but would more appropriately be considered if urine/feces water reclamation requirements were necessary for a long duration mission.

5.1 WCS Trade Study

5.1.1 Space Shuttle

Results of the trade study evaluation for the Space Shuttle design concepts are shown in the Matrix Summary, Table 5-2. Numerical ratings are based on the weights guide shown in Figures 3-9 through 3-14 inclusive.

5.1.1.1 Safety

5.1.1.1.1 Crew Contamination from Stored Waste. Each of the five (5) systems were evaluated on how well they met the specific overriding characteristic within each of the categories assessed. For example, the first category -Crew Contamination from Stored Waste - is concerned with the degree of exposure to unprocessed/processed waste a crewmember is subjected to on a sequential use of the system. Systems 1 and 2, which are based on use of a new, clean bag for each use, would have no exposure to the previous defecation, which would have been collected in its own bag and placed in a separate processing unit apart from the collector. These systems therefore have zero exposure and score maximum (10).

System 3 provides a limited volume opening within the Archimedean Screw for collection and subsequent transport through the system. Although rotation of the Screw will move feces into the storage area, it is likely that an immediate next use will result in unprocessed feces being "in-transit" and possible close contact with the crewmember. Although the bulk of the previous uses will have been transported and processed, some mix of unprocessed and processed feces may be captured within the screw, therefore this system scored a three (3) rating.

Systems 4 and 5 provide a long clear opening for defecation with waste material directed by airflow to the filter surfaces within the collectors. Although a sequential use would result in unprocessed feces within the collector, the feces should be directed away from the opening, minimizing

SUMMARY
WCS
DESIGN CONCEPTS

CONCEPTS	SHUTTLE	STATION
o FECAL COLLECTION BAG AND VACUUM/HEAT DRYING SYSTEM	X	
o FECAL COLLECTION BAG AND MICRO-WAVE OVEN STERILIZATION	X	X
o FECAL COLLECTION BAG AND CONVECTION OVEN STERILIZATION		X
o FECAL COLLECTION BAG AND FREEZER STORAGE SYSTEM		X
o CARTRIDGE ARCHIMEDEAN SCREW FECAL COLLECTION AND VACUUM DRYING SYSTEM	X	
o CARTRIDGE ARCHIMEDEAN SCREW FECAL COLLECTION AND REFRIGERATOR/FREEZER STORAGE SYSTEM		X
o BLADDER DISPLACEMENT FECAL COLLECTION AND VACUUM DRYING SYSTEM	X	
o CARTRIDGE COMPACTOR FECAL COLLECTION AND VACUUM DRYING SYSTEM	X	
o CARTRIDGE COMPACTOR FECAL COLLECTION REFRIGERATION/ FREEZER STORAGE SYSTEM		X
o FECAL COLLECTION BIOLOGICAL INACTIVATION AND STORAGE SYSTEM		X

Figure 5-1

FAIRCHILD
REPUBLIC COMPANY

WASTE MANAGEMENT SYSTEM

SPACE SHUTTLE

SYSTEM NO	CONCEPTS	TOTAL SCORE	SAFETY				DISCOMFORT				ANNOYANCE							VERSATILITY				NONFUNCTIONAL					SPACE STATION					
			CREW CONTAMINATION FROM STORED WASTE	CREW CONTAMINATION DURING USE	RELIABILITY	DEVELOPMENT RISK	CREW WASTE SEPARATION	DEGRADED COLLECTION MODE (BACKUP)	210 MAN DAYS	ODOR CONTROL	MALE/FEMALE	URINE COLLECTION	TIME REQ'D FOR USE	ON BOARD SERVICING	NOISE	AIRFLOW	MANUAL OPERATION (SYSTEM USE)	TRAINING	WIPE LIMITED	MISSION REFURBISHMENT	MATERIAL COMPATIBILITY	ELECT POWER	WEIGHT	COST	ORBD VOLUME	RETROFITABLE	540 MAN DAYS	NO OVERBOARD DUMP (LIQUID-SOLID-GAS)	ON BOARD SERVICING MAINTENANCE-RESUPPLY	BIO-MEDICAL SAMPLING	STATION INTERFACES	VERSATILITY
		156																														
1	COLLECTION BAG VACUUM/HEAT DRYING	114	10	5	8	8	8	6	4	8	6	6	6	6	2	2	2	2	2	6	3	1	3	5	2	3	-	-	-	-	-	-
2	COLLECTION BAG MICROWAVE STERLIZATION	96	10	5	5	6	8	6	4	3	6	6	6	3	1	2	2	2	2	6	3	1	3	1	2	3	-	-	-	-	-	-
3	ARCHIMEDEAN SCREW CARTRIDGE VACUUM DRYING	98	3	7	0	2	7	0	4	4	6	6	12	5	1	2	6	3	4	4	6	2	3	1	5	5	-	-	-	-	-	-
4	BLADDER COLLECTION SYSTEM VACUUM DRYING	108	6	8	5	4	7	4	4	4	6	6	12	2	2	2	6	3	4	2	3	3	3	3	4	5	-	-	-	-	-	-
5	COMPACTOR CARTRIDGE VACUUM DRYING	120	6	8	7	5	7	4	4	4	6	6	12	3	2	2	6	3	4	4	6	3	5	3	5	5	-		-	-	-	-

Table 5-2

MS254V1003
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contact potential. These systems scored six (6) rather than seven (7), due to this potential for unprocessed waste in the collector but not in contact with the crewmember.

5.1.1.1.2 Crew Contamination During Use

The primary consideration within this category is the degree that the system limits the fecal collection path, thereby creating obstacles during the collection process. Systems 1 and 2 are based on the use of finite shaped conical bags for fecal collection. There is a potential for fecal bolus impact on the bag sides and/or bottom during use, which could result in both system and crewmember contact with the feces, requiring cleanup. These systems therefore scored five (5).

Systems 3, 4 and 5 provide larger openings during use, minimizing need for potential cleanup. System 3 however, provides a finite opening that is larger than the bags of Systems 1 and 2, but smaller than Systems 4 and 5, and consequently was scored as a seven (7), while Systems 4 and 5 scored eight (8). Neither of these systems could be scored for no cleanup potential (10), since the short transport collar under the seat could be impacted.

5.1.1.1.3 Reliability

The degree of complexity of each of the systems and possible failure modes are assessed in this category.

The highest scored system (8) was the simplest Skylab proven concept, System 1, modified however to incorporate an automatic heat sealing bag closure mechanism. Although the heat sealing system will require development, it was not considered a high risk item. Also, in the event of a mechanism failure, the bag will be capable of manual sealing thereby permitting the system to operate in a degraded mode.

System 3 received the lowest ranking (0) due to the inoperability of the system in the event of a motor failure which would inactivate the screw mechanism. A back-up system would be required to support this concept.

Systems 2 and 4 were considered more complex designs but would meet the criteria for fail safe operation in the event of a system component failure. Bladder System No. 4, is designed so that the bladder fails to an open or collect position. The Microwave Oven however, would require a back-up in the event the magnetron failed or more likely bags would simply be stored in wet trash.

The Compactor Cartridge System 5, incorporates a mechanical override to drive and retract the piston in the event of a freeze-up of the compactor during operation. The system would be capable of operating in a degraded mode utilizing mechanical compaction rather than differential pressure.

5.1.1.1.4 Development Risk

The degree, amount and complexity of testing required to prove the concept are assessed in this category.

The highest ranked system is the Skylab proven system utilizing similar airflow collection and vacuum/heat drying for fecal bag processing. Two areas of test are required however to demonstrate the system - development of the heat sealing device and utilization of a double vacuum chamber with a common heating plate. Since these tests can be performed in a 1-g environment to verify the design, development risk is minimized.

System 3 is scored the lowest (highest risk) due primarily for the need of extensive 0-g testing to verify the basic concept.

System 4 requires extensive cycling tests to prove integrity of the bladder instruction and random displacement of the feces and wipes throughout the screen. This may require 0-g testing if questions exist after 1-g tests at various collector positions to simulate a random collection pattern.

Systems 2 and 5 are considered moderate risk concepts in that the microwave oven is an adaptation of a conventional 1-g proven design and the compactor cartridge system is basically an all mechanical system using a standard stainless steel bellows and negator-type retraction spring. Mechanical cycling can be demonstrated in 1-g and questions concerning potential system freeze-up can be tested in a cold chamber. It is not anticipated that 0-g testing would be mandatory to prove these concepts.

5.1.1.2 Discomfort

5.1.1.2.1 CrewWaste Separation

This category considers the effectiveness of the airflow to separate the fecal bolus from the crewmember.

The two bag concepts, Systems 1 and 2, utilize a new collector bag for each defecation thereby providing a predictable, known airflow through the filter area with each collection. These systems are basically load independent as compared to all the other systems where it is possible to have airflow degradation as the collector load builds up with time.

Systems 1 and 2 were ranked highest with separation approaching 1-g, whereas all the other systems were ranked slightly lower due to the possibility of slightly reduced airflow with time.

5.1.1.2.2 Degraded Collection Mode

Systems are rated in this category as to how well they perform in the event of a failure of the airflow system to produce full volume of collection air.

The bag collection systems 1 and 2, employ individual, new bags with every use. A reduction in airflow would permit collection in a degraded mode since the full filter area is unblocked from a previous use as in non-bag systems. In the event of a total airflow failure, collection would be similar to the Apollo back-up concept of direct defecation into an individual bag.

Systems 4 and 5 have large internal volumes and would operate as a "honey bucket" in the event airflow degrades.

5.1.1.2.3 210 Man-Days Operation

All systems were sized to accommodate the maximize potential mission of 7 men for 30 days. With the requirement changed to 60 man-days based on discussions at NASA/JSC during the final oral presentation, it is anticipated that all concepts will be satisfactory as is. It is also possible that some down-sizing would improve ratings in the area of volume, weight, power and cost.

5.1.1.2.4 Odor Control

The criteria for measurement in this category is how well the concept performs versus the existing Shuttle system.

System 1, utilizing relatively small individual collector bags imposes the least load on an odor control filter and over the mission length should produce less total load than the existing system.

Systems 3, 4 and 5 should be comparable to the existing system. System 2 adds a small load to the existing odor control filter due to a possible gas vent requirement from the microwave oven.

5.1.1.3 Annoyance

5.1.1.3.1 Male/Female Use

All systems are fully compatible for both male and female use. There are no interfaces peculiar to one sex.

5.1.1.3.2 Urine Collection

All systems are fully compatible with the existing Shuttle urine collection system. There are no interfaces peculiar to one system.

5.1.1.3.3 Time Required For Use

This category is divided into preparation time and clean up time to reflect the importance attributed to crewmember time and involvement with the waste collection system.

Systems 1 and 2 require manual insertion and subsequent removal after heat sealing, of each collector bag. These systems are estimated to require between 4 to 8 minutes of crew time, resulting in total scores of 6 each.

Systems 3, 4, and 5 are fully automated and require only setting of the operational controls equivalent to the current Shuttle system. Total preparation and cleanup time is estimated at under 4 minutes, resulting in maximum scores of 12 each.

5.1.1.3.4 On Board Servicing

Scoring in this category is dependent on the on-board capability for system servicing or repair to keep the WCS operational.

System 1, utilizes an automated heat sealing mechanism to close and seal the fecal collector bag. Actuators for driving the heat sealer and accessible for replacement in the event of failure. The bags are designed so that closure and sealing can be performed manually as an additional override feature. All other parts of this system are mechanical and are not likely to be subject to on-board servicing needs.

System 3 utilizes a single motor to drive the Archimedean screw, and is located external to the collector shell to facilitate replacement on-orbit. There are no additional components requiring servicing.

The lowest scored system is the Bladder Collection design (System 4) which has the internal expandable bladder mechanism to compact feces. This design precludes on-orbit servicing of the bladder, but in the event of a bladder failure, the system would be operable in a "honey-bucket" mode.

System 2 would require a backup mode for processing feces in the event of a magnetron failure, which would not be serviceable on-orbit. The system would be operable in this condition, but in a degraded mode.

System 5 provides a manual backup for expanding and retracting the bellows. The system would be operable however no on-board servicing is likely.

5.1.1.3.5 Noise

All systems are rated against the existing Shuttle WCS noise level.

Systems 2 and 3 require one additional motor to operate over and above the current Shuttle system, and are penalized for adding noise.

Systems 1, 4 and 5 do not add or subtract any additional noise producing components and are assumed to be equivalent to the current system.

5.1.1.3.6 Airflow

All systems will successfully collect feces utilizing the existing Shuttle airflow requirements, and are rated equal in this category.

5.1.1.3.7 Manual Operations

This category assesses the degree of complexity in operating the system, other than the normal control operations to set the basic system.

Systems 1 and 2 received the lowest scores due to the requirement for manually handling a collector bag. Each bag must be retrieved from clean storage, inserted into the collector unit, and after defecation and automated sealing, manually removed from the collector and placed into the vacuum processor chamber or microwave oven. The fecal bag must then be manually removed from the processing device and placed into the storage receptacle.

Systems 3, 4 and 5 are basically automated systems with respect to control operations. No special handling or additional control setting is required over and above the existing system. These systems all received maximum scores.

5.1.1.4 Versatility

5.1.1.4.1 Training

Systems 1 and 2 are penalized for the additional time required to familiarize the crewmembers with the bag handling procedures currently not part of the existing system routine.

Systems 3, 4 and 5 should not require any more training time than the existing Shuttle system and all scored equally as well.

5.1.1.4.2 Wipe Limited

Systems 1 and 2 are limited in wipe capacity due to the controlled size of the collector bag.

Systems, 3, 4 and 5 are all variations of a compaction design approach and have more tolerance to the number and types of wipes collected. These systems therefore score higher in this category.

5.1.1.4.3 Mission Refurbishment

This category assesses turnaround time as a function of system refurbishment requirements either on the Orbiter within a given time period, or whether the system must be removed and replaced as with the current WCS system.

Systems 1 and 2 score the highest in this category since only stored used bags must be removed from the Orbiter and new clean bags installed for the next mission. The basic system does not require any refurbishment or servicing between missions other than normal planned maintenance.

Systems 3 and 5 require refurbishment of the cartridges in the system. Filled cartridges are removed from storage and replaced with fresh cartridges. These are larger in size than the bags in Systems 1 and 2, and will require more care in handling and consequently slightly more time, resulting in a lower score. However, the basic system does not require servicing other than normal planned maintenance.

System 4 received the lowest score due to the need for separating the collector shell on the Orbiter with tools and handling a larger, heavier replacement shell.

5.1.1.4.4 Material Compatibility

Systems 1, 2 and 4 have shelf life limitations due to the use of bags, filters and the rubberized, coated bladder. Each of these materials will require establishment of useful life data and potential cost impact of "per lot" procurement, consequently were low rated.

Systems 3 and 5 have no shelf life limited materials in their construction and received maximum scores.

5.1.1.5 Non Functional

5.1.1.5.1 Electrical Power

The criteria for measurement in this category is based on the proposed concept requirement with respect to the existing system power.

Systems 1 and 2 require additional power over the current design due to the need for heat sealing of the bags.

Systems 4 and 5 are mechanical systems requiring no additional power and System 3 requires the use of a motor to drive the screw mechanism.

5.1.1.5.2 Weight

Preliminary weight analysis indicates System 5 can be designed and fabricated to weigh under 100 pounds, and consequently scores the highest.

All other systems are estimated to be comparable to the current Shuttle design, in the 100-150 pound range.

5.1.1.5.3 Cost

This category only considers the cost of development (non-recurring) rather than the recurring costs per system which are addressed separately in this report.

System 1 will require the least amount of development testing since it is based on the Skylab proven design for collection and processing. The requirement for heat sealing the collector bag can be demonstrated through 1-g tests rather than more costly 0-g testing on the Shuttle.

Systems 2 and 3 receive minimum scores due to the developmental nature of these concepts. Both will require 1-g and 0-g demonstration tests to verify the concept.

Systems 4 and 5 can be demonstrated through random positioning of the collector in 1-g to simulate 0-g operation. The critical technologies - bladder cycling in System 4 and possible freeze-up in System 5 - can be tested at 1-g in a temperature controlled environment. These systems could be downrated if excessive 1-g testing is required to demonstrate the concept.

5.1.1.5.4 Onboard Volume

Each system is measured against the current volume requirement on the Orbiter.

Systems 3, 4 and 5 would entail no increase in existing Orbiter volume with preliminary studies indicating a possible volume reduction for System 5. System 4 may require a slight increase in volume after the bladder chamber is finally sized.

Systems 1 and 2 require storage of bags, imposing additional volumetric penalties on the Orbiter.

5.1.1.5.5 Retrofitable

All systems are basically retrofitable within the Orbiter, however Systems 1 and 2 require a modification to the WCS compartment to accommodate storage for collector bags, and are penalized for this additional requirement.

5.1.2 Space Station

Results of the trade study evaluation for Space Station design concepts are shown in the Matrix Summary, Table 5-3. Numerical ratings are based on the weighting guide shown in Figures 3-9 through 3-14 inclusive.

System concepts developed for Space Station are primarily driven by the requirement for no overboard venting of gas, liquids and solids. This requirment precludes those systems that are based on vacuum venting of collected feces to process and inactivate the waste. Those concepts presented in Table 5-3 reflect modifications of the system concepts discussed for Space Shuttle to incorporate on-board waste inactivation techniques.

Systems 1, 2 and 3 are variations of the collector bag method used on Skylab, with three alternate sterilization methods - convection oven, microwave oven, and freezer - used for processing the collected feces.

Systems 4 and 5 are similar to their Shuttle counterparts with a new requirement for holding waste within the cartridge for a given cycle time at refrigeration temperature prior to replacement and subsequent used cartridge storage at freezing temperature.

System 6 is a new concept specifically considered for a long term Station mission where partial water recovery may be required for possible use as wash water rather than potable water.

Ratings of all systems within the first five categories of Safety, Discomfort, Annoyance, Versatility and Nonfunctional, are basically similar in rationale to the Shuttle scoring. The additional complexity of on-board waste treatment by either heat or freezing/refrigeration provides the primary impact on system scoring, generally resulting in penalties for weight, volume, reliability, complexity, development risk, power, etc., and consequently lower comparative scores than the Shuttle systems.

Table 5.1.2-1 adds an additional evaluated category specifically dedicated to Space Station, and this category will be discussed in more detail, as follows.

5.1.2.1 Space Station Category

5.1.2.1.1 540 Man-Days

All systems are sized to at least meet the basic requirement for a 540 man-day cycle prior to resupply. System 6 has the inherent capability to exceed this requirement with minor servicing involving drawing off excess fluid.

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WASTE MANAGEMENT SYSTEM

SPACE STATION

SYSTEM NO	CONCEPTS	TOTAL SCORE	SAFETY				DISCOMFORT				ANNOYANCE							VERSATILITY				NONFUNCTIONAL					SPACE STATION						
		167	CREW CONTAMINATION FROM STORED WASTE	CREW CONTAMINATION DURING USE	RELIABILITY	DEVELOPMENT RISK	CREW WASTE SEPARATION	DEGRADED COLLECTION MODE (BACKUP)	210 MAN DAYS	ODOR CONTROL	MALE/FEMALE	URINE COLLECTION	TIME REQ'D FOR USE	ON BOARD SERVICING	NOISE	AIRFLOW	MANUAL OPERATION (SYSTEM USE)	TRAINING	WIPE LIMITED	MISSION REFURBISHMENT	MATERIAL COMPATIBILITY	ELECT POWER	WEIGHT	COST	ONBD VOLUME	RETROFITABLE	840 MAN DAYS	NO OVERBOARD DUMP (LIQUID-SOLID-GAS)	ON BOARD SERVICING MAINTAINANCE-RESUPPLY	BIO-MEDICAL SAMPLING	STATION INTERFACES	VERSATILITY	
1	COLLECTION BAG CONVECTION STERILIZATION	106	10	5	4	6	8	6	-	3	6	6	6	6	1	2	2	2	2	-	3	1	3	1	2	-	4	3	5	5	5	5	
2	COLLECTION BAG MICROWAVE STERILIZATION	110	10	5	5	6	8	6	-	3	6	6	6	3	1	2	2	2	2	-	3	1	3	1	2	-	4	3	5	5	5	5	
3	COLLECTION BAG FREEZER STORAGE	127	10	5	8	8	8	6	-	8	6	6	9	3	2	2	4	2	2	-	3	2	1	3	2	-	4	5	5	5	5	3	
4	ARCHIMEDEAN SCREW CARTRIDGE FREEZER/REFRIGERATION STORAGE	90	3	7	0	2	7	0	-	4	6	6	12	5	1	2	6	1	4	-	6	1	1	1	2	-	4	5	1	0	3	0	
5	COMPACTOR CARTRIDGE FREEZER/REFRIGERATION STORAGE	114	6	8	6	5	7	4	-	4	6	6	12	3	2	2	6	1	4	-	6	1	1	3	2	-	4	5	1	3	3	3	
6	COLLECTION SYSTEM BIOLOGICAL INACTIVATION STORAGE	86	3	7	0	1	7	0	-	3	6	6	12	0	1	2	6	1	4	-	6	2	3	1	3	-	3	0	3	0	5	0	

Table 5-3

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5.1.2.1.2 No Overboard Dump

Systems 1 and 2 require an on-board gas vent of the sterilization chamber to accommodate the gas expansion within the collector bag during heat processing. The bags could be designed to expand and contain the gas build up, but a significant storage penalty accrues with this option.

Systems 3, 4 and 5 are based on placing the collector bag and cartridges into freezer storage. With these methods, no venting is required.

System 6 requires a liquid vent on-board to keep the system operational by pumping excess fluid to holding tanks.

5.1.2.1.3 On Board Servicing

Systems 1, 2 and 3 are sized to meet a normal 90 day resupply cycle by replacing used collector bags with a fresh supply of unused bags. No additional system servicing or maintenance is required to keep the system operational.

Systems 4 and 5 are designed with replaceable cartridge elements held at refrigeration temperature. Initial analysis indicates a one-week cycle is approximately optimum for sizing the system, thereby resulting in a lower score for this category.

System 6 requires removal of excess fluid and the addition of enzymes in approximately a 30 day cycle, consequently this system scores lower than the 90 day resupply mission requirement.

5.1.2.1.4 BioMedical Sampling

This is an anticipated requirement for Space Station to be part of the Health Maintenance Facility. Although it is not expected that this requirement will drive a WCS design, the capability of adapting a concept to meet this possible need is considered in this category.

The bag collection methods of Systems 1, 2 and 3 are inherently capable of providing a specific fecal collection and isolating it from the balance of feces.

Systems 4 and 6 are basically bulk collection methods not adaptable to individual isolation of a fecal collection. A separate collector utilizing a sample bag would be required with these concepts.

System 5 could accept insertion of a fecal collection sample bag within the colelctor utilizing the basic system airflow for actual collection, and therefore is adaptable to the sampling requirement.

5.1.2.1.5 Station Interfaces

Systems 1, 2, 3 and 6 have minimum interfaces with the Space Station, requiring only electrical power to drive the system.

Systems 4 and 5 also require an electrical interface with the Station but are penalized for the additional interface with the thermal/cooling loop for maintaining the cartridges at refrigeration temperature prior to freezer storage.

5.1.2.1.6 Versatility

This is "catch-all" category to provide benefit for a system that would inherently add features for other functions, such as accepting certain wastes from a medical facility or animal experiments.

Systems 1, 2, 3 and 5 basically can be used for processing and storage of wastes other than human feces, since the individual collector bags and compactor system are not feces limited. Systems 1 and 2 utilizing sterilization rather than freezing as in Systems 3 and 5, have slightly more versatility. Systems 4 and 6 are directly sensitive to the types of waste that can be handled and are not recommended for accepting miscellaneous materials.

5.2 Shuttle WCS Recommended Concept

Based on the scoring criteria and the analyses described, Fairchild recommends the highest scored system, the Compactor Cartridge/Vacuum Drying concept for potential Shuttle application.

The system ranks high in reliability, minimum development risk, minimum operational time to use, adaptability for manual override, ability to accept larger quantities of wipes, low weight and volume, and ease of retrofit in the Orbiter. The positive and simple compaction feature assures full mission use even to a maximum 210 man-day mission. The system is simple to refurbish on the ground requiring only a cartridge change rather than servicing a complete system. It is anticipated that the system can be proven in a 1-g environment with the most difficult technical concern of system freeze-up during vacuum processing demonstrated in a low temperature chamber.

5.3 Space Station WCS Recommended Concept

Based on the scoring criteria and the analyses described, Fairchild recommends the second highest scored system, the Compactor Cartridge Freezer/ /Refrigeration Storage concept for potential Space Station application.

Fairchild has discarded the highest scored system, the Collection Bag with Freezer Storage, primarily due to meetings with NASA personnel and a Shuttle flight crewmember where clear preferences were expressed for non-bag systems. Fairchild recognizes the strong aversion to handling fecal bags and concurs that for a long term Station mission a more earth-like system is desirable. This significant subjective input is sufficient to alter the ratings, and a system similar to that proposed for Space Shuttle which scored second in the evaluation, is the recommended system.

The primary technical problem is the optimum sizing of the system with respect to "filling" the cartridge with compacted waste. In the analyses performed by Fairchild, it appeared that approximately a 50 man-day requirement or about a one week cycle, would result in a "reasonable" servicing period and storage volume over the 540 man-day mission. The resulting system was approximately the same size as that generated for the Shuttle, and penalties were assessed accordingly.

This system differs from the Shuttle technique in that compacted waste is held at refrigeration temperature (40°F) for the one week cycle prior to cartridge removal and insertion into separate long term freezer storage at 0°F. The technical concern of freeze-up in the Shuttle system is therefore not a problem for the Station design, which does not see temperatures below 40°F. The addition of a freezer for used cartridge storage does not add technical risk but does result in penalties for cost, volume, power and on-board servicing for approximately weekly cartridge changes.

Overall, the automated collection features, simplicity of controls, safety, and the major advantages of a positive compaction design capable of handling a variety of wastes, results in an attractive system for Space Station application.

6.0 Recommended Follow-On Efforts

6.1 Cartridge Compactor Fecal Collection System Development

Fairchild recommends that a follow-on effort to this study be initiated by the NASA to develop the Cartridge Compactor fecal collection design for Shuttle and Space Station application.

A phased development effort could be implemented as follows:

Phase 1 - Preliminary specifications, design requirements, and compactor design.

Phase 2A - Implement Shuttle peculiar design requirements, sizing vacuum drying impact, prototype design and fabrication ground tests, and Shuttle flight tests.

Phase 2B - Implement Space Station peculiar design requirements, sizing, on-orbit servicing, refrigeration impact, prototype design and fabrication ground tests, and Shuttle flight tests.

The Phase 1 effort involves development of a basic design for the main elements of the cartridge compactor fecal collection system. This portion of the study would be concerned with the comfiguration of the structure, sizing internal mechanisms such as the bellows and return springs, override or mechanical operation, airflow requirements, collection seat configuration, and controls operation. Approximately a 5-6 month design study effort is anticipated.

If this design were to be considered for both Shuttle and Space Station, then Phase 2A and Phase 2B would be recommended for sequential implementation. If the intent were to utilize this concept for Station only then Phase 2B would follow Phase 1.

Phase 2A and/or Phase 2B involves development of the design generated in Phase 1 for specific application to Shuttle and/or Space Station. These efforts would be concerned with the specific processing method involved (vacuum drying and/or refrigeration), replacement and servicing, appropriate controls, design and fabrication of test hardware, 1-g ground tests, and flight test of a prototype unit. Approximately a 12-14 month effort is anticipated to implement either Phase 2A or Phase 2B. If both phases were to be implemented, total elapsed time would be approximately 18 months.

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APPENDIX A

SYSTEM REQUIREMENTS

Fecal Waste Collection Cartridge Compactor
Subsystem Requirements Specification

3. REQUIREMENTS

3.1 Fecal Waste Collector Subsystem (FCS) Definition. The FCS will be used for collecting, storing, and drying fecal wastes and associated toilet paper.

The FCS will accommodate both male and female occupants in zero gravity and in one g with vehicle in the horizontal position. Fecal waste will not be handled by the crew. Fecal waste will be dried by exposure to space ambient. Air flow will be used for directional control of the fecal waste. There will be no water flush in the fecal waste subsystem.

3.1.1 Item Diagram

Figure 1 and 2 is a schematic of the FCS.

3.1.2 Interface Definition

3.1.2.1 Electrical Power Characteristics. The electrical power characteristics at the FCS interface shall be in accordance with Rockwell Specification MF0004-002.

3.1.2.2 Instrumentation. Operational instrumentation (OI) and development flight instrumentation (DFI) interfaces shall be in accordance with Rockwell Specification MF0004-006.

3.1.2.3 Power Characteristics. The FCS shall perform as specified herein with input power meeting the requirements of Rockwell Specification MF0004-002 for main dc power (28 vdc) and for inverter ac power (400 Hz, 15 vac, 3 phase).

3.1.2.4 Electrical Connectors. The seller shall define the applicable connectors and submit to buyer for approval.

3.1.2.5 Urine Collection Subsystem. The fecal collection subsystem shall provide a mounting interface for the Urinal Receptacle.

3.1.2.6 Fan Separator Airflow. Directional control of fecal waste shall utilize the airflow provided by the Fan Separator.

3.1.2.7 Vacuum Port. The pressure chamber of the fecal collection unit shall utilize a Femal Dynatube Fitting, Part Number ME273-0126-1628 for interface with the vacuum vent system. The locations shall be coordinated with the buyer.

SPACE SHUTTLE WCS

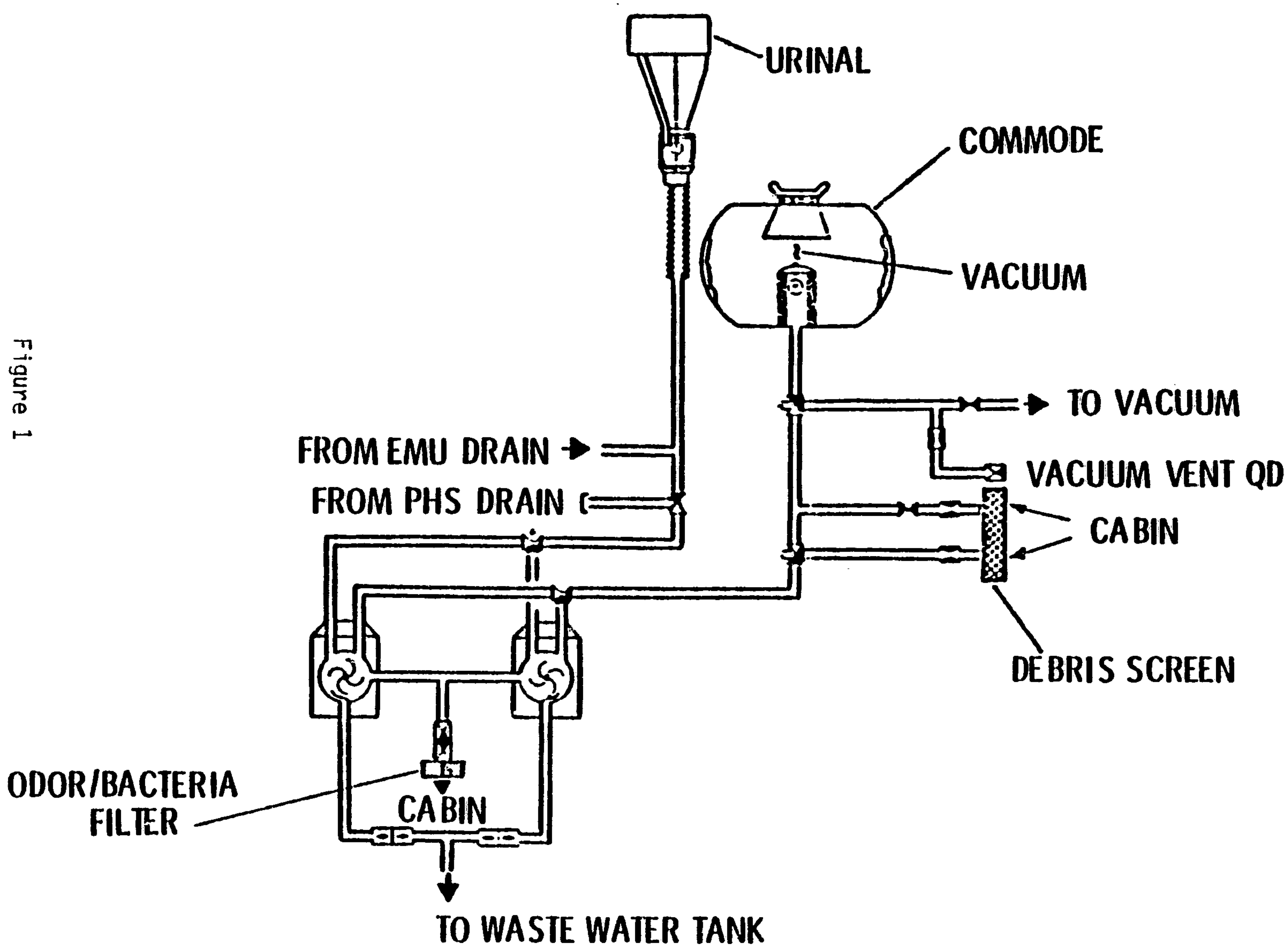

Figure 1

CARTRIDGE COMPACTOR

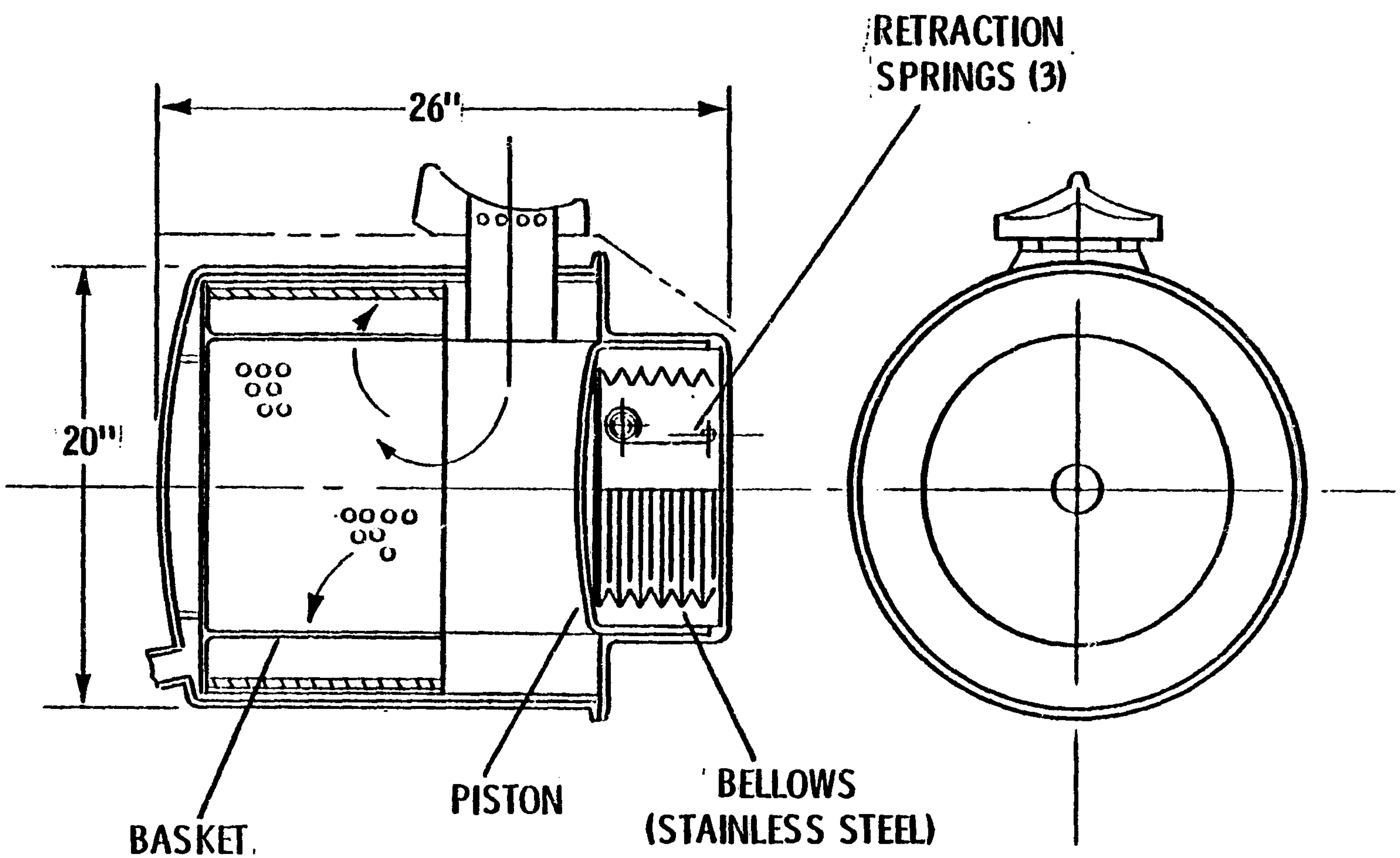

Figure 2

3.1.3 Item and Major Components Identification. The identification of the FCS items and its major components shall be TBD.

3.1.4 Buyer Furnished Property. The following items will be supplied by the buyer and shall be incorporated in the FCS. (TBD)

3.2 Characteristics.

3.2.1 Performance.

3.2.1.1 Life Performance. The FCS shall be designed to provide the most cost effective life capability, considering minimum maintenance and refurbishment as well as state-of-the-art hardware design. Upon completion of tradeoffs by the seller to establish the optimum relationship between hardware life capability, maintenance, and refurbishment, the following life objective will be changed to requirements.

3.2.1.2 Useful Life. As a design objective, the FCS shall have a minimum useful life of 20,000 hours, which are equivalent to 100 orbital missions in a 10 year period from date of delivery. The average orbital mission will be 7 days; however, the design shall not preclude the capability to extend the orbital staytime up to 30 days. Preventive maintenance, servicing, repair, and replacement of parts shall be consistent with the Seller's tradeoff results as agreed to by the buyer.

3.2.1.1.3 Shelf Life. As a design objective, the FCS shall be capable of operating in accordance with the requirements specified herein any time with a period of 10 years from date of delivery when exposed to the environment of 3.2.5.

3.2.1.2 Collector Assembly. The collector assembly shall accommodate both male and female crew and shall contain the fecal waste collector, control valving, instrumentation, interconnecting plumbing, and mounting framework. The waste collector shall have a storage capacity equivalent to 60 man-days of vacuum dried feces and toilet tissue. Each man-day usage results in 0.27 pounds of fecal and paper waste which includes 0.2 pounds of moisture. The assembly shall accommodate at least four usages per hour, and shall not require fecal waste handling. All portions of the assembly exposed to space vacuum shall withstand at least 16.0 psia cabin pressure without damage. Provisions shall be made to prevent particulate waste carry-over during vacuum drying. The assembly shall remove bacteria, and fecal odors, skin, hair and other body particles from the entrainment air through the existing filter system before returning it to the cabin.

3.2.1.4 Leakage/Venting. The average cabin air loss through an empty collector due to venting and leakage shall not exceed 1.3 lb per day. Nominal defecation frequency will be one defecation per man per day for six men. Pressure lines, valves and fittings leakage shall not exceed 10^{-4} sccs helium at 14.9 psid.

3.2.1.4 Collector Assembly Configuration. Foot and body restraints which facilitate usage of the assembly while the orbiter is performing space operations shall be provided. The foot support shall include foot restraints and shall be adjustable. Toe restraints shall be provided. The body restraint system shall retain the crew person in the proper location and position. The waste collector assembly shall include a piston compactor operated by differential air pressure to compact waste in a storage area of the collector. The transport tube inner surfaces shall be designed to minimize fecal retention. The ballast air flow and commode repressurization inlets shall be routed to the front cover of the collector assembly. Arrangement of manually controlled valves and devices and nomenclature shall facilitate operation of the assembly. Interlocks shall be provided which prevent vacuum venting (drying) prior to closure and sealing of the waste collector access.

3.2.1.5 Odor/Bacterial Filter. The collection airflow shall interface with the existing odor/bacterial filter which meets the following requirements:

a. The filter shall be capable of filtration of contaminated air from the FCS at a flow rate of 38 scfm.

b. The filter shall be capable of operating in a maximum pressure of 16 psia.

c. The filter shall be capable of operation at an air flow rate of 38 scfm.

d. The pressure drop across the filter shall not exceed 2.35 inches of water at a 38 scfm air flow rate.

e. The filter shall be capable of removing 99.999 percent of all particles 0.45 microns or larger.

f. The filter shall be capable of supporting a minimum differential pressure of 1.0 psi.

g. The total weight of the filter shall not exceed 7.5 pounds.

3.2.2 Physical Characteristics.

3.2.2.1 Envelope. The envelope of the WCS shall not exceed the dimensions shown in Figure 3.

3.2.2.2 Mounting. The seller shall determine the required mounting provisions and shall submit to buyer for approval.

3.2.2.3 Weight. The weight of the Fecal Collection Unit shall not exceed 76 pounds. This weight does not include expendables.

3.2.2.4 CG and Moments of Inertia. The center of gravity (CG) of the FCS shall be determined in three axes from a defined referenced datum.

FAIRCHILD REPUBLIC COMPANY	**WASTE MANAGEMENT SYSTEM**	MS254V1002 11 DECEMBER 1984

SHUTTLE WCS CARTRIDGE COMPACTOR SYSTEM

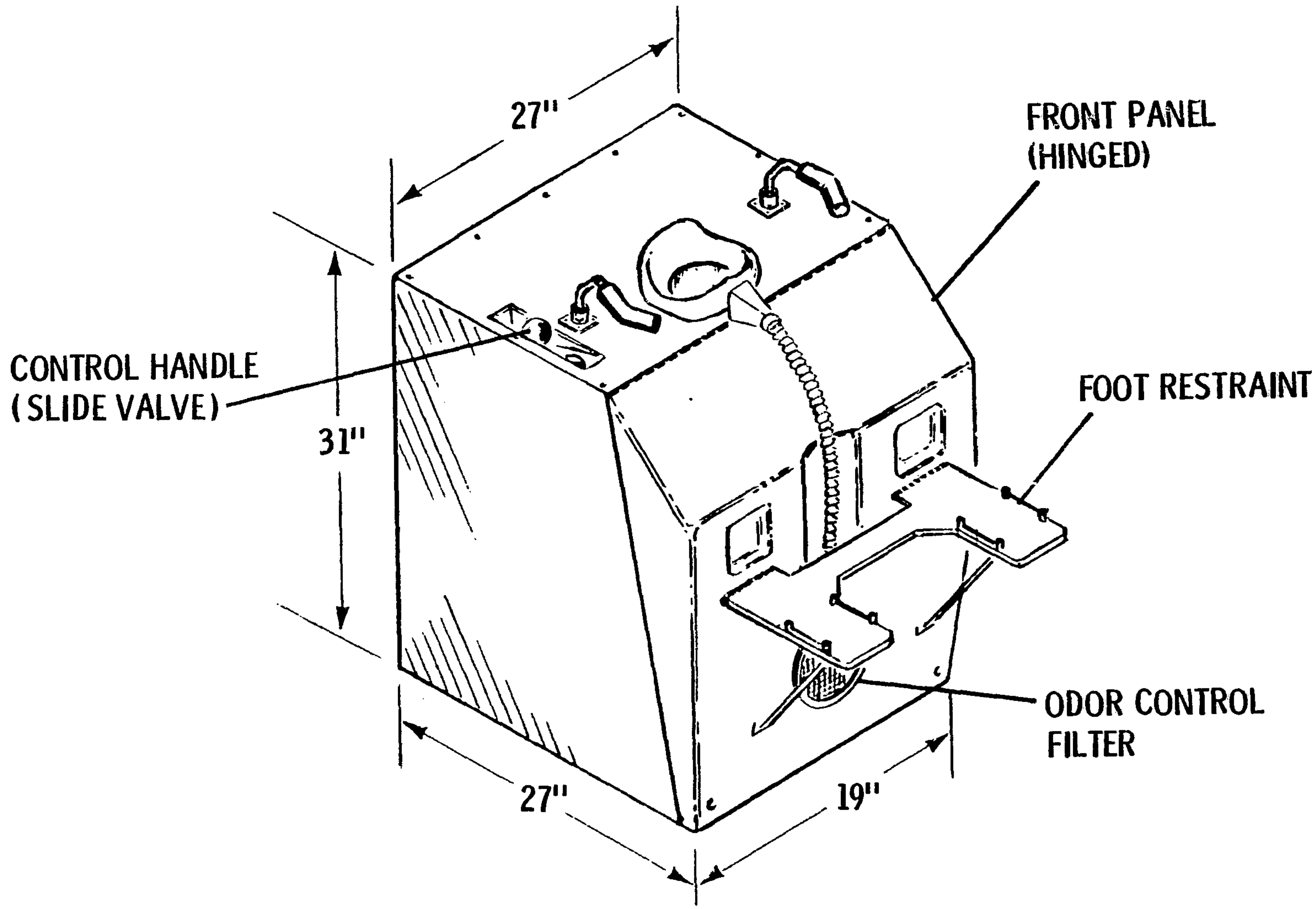

Figure 3

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3.2.2.5 Factors of Safety. The factors of safety specified below are minimum and shall be used for the FCS components.

Components	*Proof	*Burst
Tanks, Valves	1.5	2.0
Pressurized lines and fittings less than 1.5 inch diameter	2.0	4.0
1.5 inch diameter or greater	1.5	2.0

*Note: Factors times maximum operating pressure

3.2.2.6 Pressure Vessels. The use of pressure vessels is discouraged but if used, pressure vessel shall be designed to the requirements of MC999-0097.

3.2.2.7 Monitoring Devices. Analog and discrete signals provided to the buyer monitoring devices shall be in accordance with 3.1.2.2. The FCS shall have as a minimum the following monitoring devices:

Absolute Presure Transducer	0.0 to 2.0 psia; output to buyer shall be 0.0. to 5.0.volt analog.
Start Switch Event	28 vdc discrete
Redundant Switch Event	28 vdc discrete
Fan/Separator Motor Speed Indicators (2)	Tach Signals

3.2.2.8 Surface Finishes. All exterior surfaces of the FCS, except the seat, shall be light gray in color. The seat shall be a normal polyurethane color. All surfaces of the FCS that require paint shall receive a primer coat of Super Koropon R-515-700/R910-704 (DeSoto, Inc., Des Plaines, ILL) and a final cost of MIL-C-332186 polyurethane paint light gray in accordance with color No. 36622 of FED-STD-595.

3.2.2.9 Test Points. The seller shall define the test points necessary for checkout of the FCS and submit to buyer for approval.

3.2.2.10 Nomencalture and Markings. The FCS nomenclature and markings shall be in accordance with MF0004-019.

3.2.3 Reliability

3.2.3.1 Redundancy. The FCS shall be designed so that any single failure shall not result in:

a. Loss of the cabin atmosphere.

b. Contamination of the cabin atmosphere.

3.2.3.2 Failure Deterent and Detection. The FCS design shall incorporate the following:

a. Separation of Redundant Equipment. Redundant subsystems, and redundant major elements (if used) of subsystems, panels, power supplies, tanks, controls, shall be separated by the maximum practical distance, or otherwise protected, to insure that an unexpected event that damages one is not likely to prevent the other from performing the function.

b. Protection of Redundant Components. To the extent practicable redundant components susceptible to similar contamination or environmental failure causes such as shock, vibration, acceleration or heat loads shall be physically oriented or separate to reduce the change of multiple failure from the same cause(s).

c. Redundant Electrical Circuits. Redundant electrical control circuits shall not be routed through the same connector. Redundant connectors and electrical wire bundles shall be located such that an event which damages one is not likely to damage another. Redundant components shall not be powered from the same power bus.

d. Redundancy Verification. Each path or redundant subsystem shall be capable of verification of operational status during flight. During ground turnaround, operability of all redundancies shall be capable of being verified.

e. Leak Protection - External Ports. External ports used for ground servicing shall incorporate provisions to preclude leakage in flight where such leakage could result in subsystem performance degradation. A disconnect and associated sealing cap may be considered as redundant components.

f. Checkout Point Connection. Electrical and fluid ground checkout test points will permit normal planned subsystem checkout to be made without disconnecting tubing or electrical connectors normally connected in flight.

g. Joining Techniques. Tubing and fittings shall be jointed by brazing, welding or some other equivalent permanent joining technique, except where mechanical disconnects are required for replacement and servicing, or where components would be adversely affected by the joining technique.

h. Transient Caused Failures. Subsystems shall be designed such that transient out of tolerance conditions or component failures will not cause other component/subsystem failures.

i. Inadvertent Electrical Shorting due to Debris. Malfunction or inadvertent operation of electrical or electronic equipment caused by exposure to conducting or non-conducting debris or foreign material floating in a gravity free state shall be prevented by design.

j. Gravity Sensitivie Components. Gravity sensitive components (i.e., lightingly spring-loaded check valves, scavaging type water separators, etc.) which are required to function in earth gravity, must be oriented to neutralize gravity effects in the vertical and horizontal (vehicle) modes. If hardware packaging cannot satisfy the above orientation requirement, the gravity sensitive components will not be used.

k. Vibration Sensitive Components. Solid state switches and amplifiers shall be given preference over electromechanical relays and other vibration-sensitive electrical/electronic parts in baseline design configurations consistent with range safety requirements. Sealed-type terminal blocks shall not be used.

l. Fatigue Failures. Flexible line sections shall be designed to preclude possible fatigue failures resulting from induced vibrations.

m. Securing Threaded Parts. Threaded parts and fasteners shall be positively locked to prevent loosening during service.

3.2.4 Maintainability

3.2.4.1 Design Allocations. The design shall satisfy the following maintainability allocations:

a. On-orbiter fault isolation utilizing on-orbiter test capability or applicable GSE within 0.5 hours.

b. Odor/bacteria filters shall be replaceable in 15 minutes. (Assume/assure free access.)

c. On-orbiter cartridge replacement and functional checkout after within 0.5 hours.

d. LRU off-orbiter fault isolation, SRU removal/replacement and functional checkout of each LRU within 8.0 hours.

e. Scheduled maintenance required for equipment shall be limited to replacement of time/cycle sensitive equipment.

3.2.4.2 Design Features. The design shall incorporate the following maintainability features.

3.2.4.2.1 Maintenance.

a. The FCS shall be designed to preclude the use of special tools and equipment for site maintenance and repairs.

b. Special tools, if required, and approved by the buyer, shall be designed to withstand the intended use throughout the life of the equipment.

c. Intentional blank.

d. LRU's shall be designed so that routine corrective maintenance can be accomplished at the shop level of maintenance. Repair of LRU's shall be accomplished by the replacement of Shop Replaceable Units (SRU's).

e. SRU's shall be designed so that maintenance actions not requiring extensive refabrication, refurbishment can be accomplished at the shop level of maintenance. Corrective maintenance of SRU's shall be accomplished by the replacement of minor subassemblies of piece parts. SRU's shall be designed to preclude the loss or dropping of hardware which could cause internal damage or affect the LRU's serviceability or increase maintenance time.

f. The necessity for any maintenance servicing or checkout tasks, other than built-in test capability, to be accomplished during flight is prohibited.

g. Non on-vehicle adjustments or calibration shall be required except as identified elsewhere in this specification.

h. Suitable warnings shall be provided on instruction plates or service placards if hazardous conditions exist when maintenance is performed.

i. Intentional blank.

j. Capability for refurbishing the cartridge shall be provided. The cartridge assembly shall require the replacement of the filter subassembly only.

3.2.4.2.2 Installation

a. The equipment design shall physically prevent the incorrect installation of modules and sub-modules. Clearly visible color coding and labeling in close proximity to maintenance disconnect points shall be used to facilitate removal and replacement of any subassembly level of equipment.

b. Components shall be mounted in a manner to avoid blind adjustments.

c. Mechanical retention devices for equipment/components shall not require lockwiring, except that the ME273-0126 female Dynatube fittings at the vacuum vent.

d. Fluid and pneumatic interfaces to package installed LRU's shall incorporate disconnects operable without requiring special tools. Quick disconnects, when utilized, shall be self-sealing upon disconnect with no leakage while disconnected and self purging when reconnected to prevent fluid loss and system contamination.

e. If a component is mounted and secured by bolts where the component must be held in place until the bolts are engaged, pilot keyhold mounting or similar installation aid shall be provided.

f. Threaded fasteners used for securing a single component, where practical, shall be the same type, size, and tensile strength.

g. Assembly/subassembly installations shall be designed such that accessibility to threaded fasteners may be accomplished without the use of universal joints, angular extensions, handle extensions, or combinations thereof, in conjunction with torque tools.

h. Captive fasteners shall be utilized to fasten LRU's.

3.2.4.2.3 Accessibility

a. The subsystem installation shall provide adequate personnel access to, and tool clearance between LRU's. The removal of any LRU shall not require removal of any other functional hardware, plumbing or wiring. Tubing and wire run protection shall be incorporated in traffic areas and wire bundle accessibility shall be provided without invalidating other wiring circuits or their related equipments.

b. Electrical connectors shall be accessible without disassembly or removal of functional equipment or components.

c. Servicing and test points shall be clearly marked and shall be accessible without requiring removal of access plates or covers except service caps.

d. All fasteners on a single access cover shall be of the same length, diameter, and type.

3.2.4.2.4 Replacement

a. Mounting provisions shall permit SRU removal and replacement without disconnecting any equivalent level SRU in the line replaceable unit. If removal of a LRU structural element is required for access, such removal shall not affect electrical or mechanical alignment, nor shall the mechanical strength of the unit be impaired to the point that bending of the unit, its assemblies, electrical harnesses, or plumbing attachments, will occur during normal bench handling of the unit.

b. Interconnecting plumbing and wire runs shall be of suitable attachment, length, and mounting to facilitate LRU replacement. Attach fittings for components routinely removed after each mission shall be operable without hand tools and shall be accessible without requiring removal of access panels or covers.

3.2.4.2.5 Handling.

a. Handling provisions shall be provided on LRU's in accordance with MIL-STD-1472.

b. All wiring harnesses shall be protected from handling damage. The protective considerations shall not inhibit repair or replacement of the wire harness.

3.2.5 Environments.

3.2.5.1 Transportation (Packaged). The FCS shall be capable of meeting the operating performance requirements specified herein after exposure to the following transportation conditions when packaged.

a. Temperature	Minimum ambient of minus 65°F. Maximum ambient of plus 150°F. Maximum compartment temperature while on ground of plus 190°F for one hour and plus 150°F for six hours.
b. Pressure	Maximum of 15.23 pounds per square inch absolute (psia) (sea level), minimum of 3.28 psia (35,000 feet).
c. Humidity	0 to 100 percent relative humdity, including conditions wherein condensation takes place in the form of water or frost.
d. Shock	Refer to 5.2.3
e. Vibration	Refer to 5.2.3

3.2.5.2 Storage. The FCS shall be capable of meeting the operating performance requirements specified herein after exposure to the following storage conditions, when packaged.

a. Temperature	Minus 23°F to plus 150°F.
b. Humidity	0 to 100 percent relative humidity, including conditions wherein condensation takes place in the form of water or frost.
c. Pressure	Maximum of 15.23 psia (sea level), minimum of 9.76 psia (10,000 feet).

d. Ozone	Surface maximum 3 to 6 parts per hundred million (phm); 60 phm for 1 to 3 hours in any 24 hour period. 100 phm at 35,000 ft.
e. Fungus	As specified in MC999-0096.
f. Sand and Dust	Equivalent to 140 mesh silica flour with particle velocity up to 500 feet per minute and a particle density of 0.25 grams per cubic foot.
g. Hail and Snow	Hail (nominal) diameter equals 0.30 inches with a fall velocity of 66 feet/second. Snow of 10.2 pounds per square foot.
h. Salt Fog	Salt atmosphere as encountered in coastal areas, the effect of which is simulated by exposure to a 1.0 percent salt solution by weight.
i. Rain	Maximum of 19 inches in 24 hour period including short period extremes for one hour of four inches.
j. Solar Radiation	Solar radiation of 377.6 Btu/ft^2/hr for three hours in any 24 hour period.

3.2.5.5 Ground Handling Loads. The FCS shall be capable of meeting the operating performance requirements specified herein after exposure to the following ground handling loads when unpackaged.

a. Handling Shock	Bench handling shock as specified in MIL-STD-810, Method 516.1, Procedure V.
b. Design Shock	20 g terminal sawtooth shock pulse of a 11 millisecond duration in each of 6 axes.
c. Hoisting Loads	2 g vertical within a plus or minus cone angle of 20 degrees.

3.2.5.4 Flight Environments.

3.2.5.4.1 Operating. The FCS shall be capable of operating during and after being exposed to any feasible combination of environments specified in a, b, c and d, and shall be capable of operating after being exposed to any feasible combination of environments specified in e, f, g and i. The FCS is not required to operate after being exposed to crash safety environments.

a.	Temperature	
	Atmospheric	Minimum: 65°F Maximum: 90°F
	Structural	Minimum: 61°F Maximum: 120°F
b.	Pressure	
	Cabin	Maximum: 16.0 psia Minimum: 8.0 psia Rate of Chg: 1.0 psi/min Oxygen Partial Pressure Max: 3.45 psia
	Overboard Pressure	Minimum: Torr.
		Atmosphere DiLuent - Nitrogen
c.	Relative Humidity	Maximum: 85 percent relative humidity at 65°F dry bulb, 17 percent at 90°F dry bulb
d.	Salinity	One percent by weight
e.	Lightning	As specified in MF0004-002, Indirect
f.	Acceleration	Plus or minus 5.0 g
g.	Vibration	
	Mission Phase	
	Random vibration occurs at liftoff transomic, and Q_{max}.	Acceleration spectral density increasing at the rate of plus 6 dB/octave from 20 to 150 Hz; constant at .03 g^2/Hz from 150 to 1000 Hz; decreasing at the rate of minus 6 dB/octave from 1000 to 2000 Hz. The vibration occurs for a duration of 48 minutes per axis.
	Sinusoidal vibration results from wind gusts, engine start and shutdown, staging and landing.	Sweeps 5 to 35 Hz at one octave per minute at .25 g's peak.

h. Crash Safety

gx	gy + Right	gz + Up
+20	±3.3	+10.0 - 4.4

There shall be no failure of the mounting attachment, and the equipment shall remain in place and not create a hazard.

i. Shock

Landing

Rectangular pulses of the following peak accelerations, time durations, and numbers of applications in the vertical/up direction during landing:

Acceleration (g Peak)	Duration (Milliseconds)	Application
0.23	170	22
0.28	280	37
0.35	330	32
0.43	360	20
0.56	350	9
0.72	320	4
1.50	260	1

3.2.5.4.2 Ferry Flight. The FCS shall be capable of meeting the performance requirements specified herein after exposure in a drained condition to any one or combination of the following environments.

a. Pressure — Maximum: 15.23 psia; Minimum: 3.25 psia

b. Temperature — Maximum: Plus 120°F; Minimum: Minus 10°F

c. Humidity — Maximum: 100 percent relative; Minimum: 8 percent relative

3.2.5.5 Checkout Environment (FCS Installed). The FCS shall be capable of operating as specified herein after exposure to environments specified as follows:

a. Pressure

Operational Leak Check — Cabin pressure of 18.0 psia maximum at sea level.

Structural — 30 psia

b. Temperature

Cabin — 35°F minimum, 120°F maximum

c. Humidity — 8 to 100 percent relative humidity including conditions wherein condensation takes place in the form of water or frost.

d. Salt Fog — Salt atmosphere as encountered in coastal areas, the effect of which is simulated by exposure to a 1.0 percent salt solution by weight.

3.2.6 Transportability. The FCS shall be designed so as to be capable of being handled and transported to using facilities without damage or degradation, utilizing available methods of transport with the item prepared for shipment. The equipment design shall be compatible with the planned packaging and transportation system to the extent that loads induced in the equipment during transportation will not produce stresses, internal loads or deflections resulting in damage to the equipment.

3.2.6.1 Disassembly. Equipment requiring disassembly for shipment shall be designed to facilitate disassembly and reassembly.

3.2.6.2 Pressurization. Design shall not require pressurization of tanks or components to maintain structural integrity during shipment.

3.2.6.3 Integral Protective Capability The equipment design shall incorporate one or more of the following provisions for protection of components which are highly vulnerable to damage during transport and associated handling:

a. Provide attach points for installation of temporary protective device (covers, reinforcing structure, desiccant cartridge, air breather/filter heater, etc.).

b. Make provisions for removal of sensitive component(s) for separate shipment.

c. Provide "built-in" protective device (e.g., cover, caging of free-moving components, desiccant chamber, heater, etc.).

3.3 Design and Construction.

3.3.1 Materials, Processes, and Parts.

3.3.1.1 Material and Processes. Materials and processes for the FCS shall be in accordance with MC999-0096 to the extent specified in the requirements table of the purchase order.

3.3.1.2 Parts Standardization. Parts utilization shall be based upon: (1) selection of qualified parts, (2) proper derating and application, and (3) minimizing the number of part types. Parts used in design and fabrication shall be selected from MF0004-100, and MF0004-400.

3.3.1.3 Material Compatibility. Materials and processes used in fabrication of the FCS shall be compatible with the environmental conditions specified herein.

3.3.1.4 Threads and Fasteners. Screw threads shall be in accordance with MIL-S-7742 or MIL-S-8879 for fastener ultimate tensile strengths below 160,000 pounds per square inch (psi). MIL-S-8879 shall be used for fastener ultimate tensile strengths of 160,000 psi or greater. External threads in accordance with MIL-S-8879 for fastener tensile strengths of 160,000 psi and greater shall be produced by a single threadrolling process after final heat treat. (Exception to MIL-S-7742 and MIL-S-8879; the single element gaging procedures shall not be a requirement for acceptance, but will be used as a reference method when acceptability is questionable).

3.3.1.5 Purging. To prevent the entrapment of contamination, dead end passages shall be capable of being automatically purged whenever the assembly interfaces are subjected to purge conditions.

3.3.1.6 Filters and Strainers. The FCS shall incorporate filters, strainers, or equivalent means to preclude deterioration of performance or malfunction due to contaminants or particle generation, entering contamination sensitive components. Where flow reversal may occur in the unit, filters or strainers shall be included on both sides of the critical contamination-sensitive components. The replaceable urine pinch valve filter shall be located upstream of a line filter in the urinal hose assembly.

3.3.2 Selection of Specifications and Standards. Specifications and standards for use in the design and construction of the FCS, other than those specified herein, shall be selected in the order of precedence in accordance with MIL-STD-143, except that NASA documents, when suitable for the purpose shall take precedence.

3.3.3 Electromagnetic Compatibility and Electrical Design.

3.3.3.1 Electromagnetic Compatibility (EMC). The FCS shall meet the electromagnetic interference and compatibility requirements of MF0004-002 for Class 1D equipment.

3.3.3.2 Electrical Design Requirements. Electrical design requirements for the FCS shall be in accordance with MF0004-002 to the extent specified in the requirements table of the purchase order.

3.3.3.2.1 Input Power Source. The FCS instrumentation shall operate from a 28 vdc power source. Rotating motors shall operate from a 115 vac or a 28 vdc power source.

3.3.3.2.2 Power Consumption. The maximum power consumption of the FCS shall not exceed 220 watts ac and 50 watts dc.

3.3.3.2.2.1 Metal and Metal Couples, Restriction on Use. Metal joints which require electrical bonding shall be precise, dry, and conducting. Nonconducting corrosion inhibitors may be added after joint assembly. conducting metal joints shall be required for electrical circuit fault-current return, electrostatic corona prevention, and structural shielding from lightning-strike induction and avionic interference.

3.3.3.2.3 Electrical and Electronic Piece-Parts, Closure Construction. Electrical and electronic piece parts with all-welded closure construction shall be used.

3.3.4 Identification and Marking.

3.3.4.1 identification of Parts. Each part fabricated shall be identified with a part number. The same specification or part number shall be used to identify all like materials, processes, and parts. Seller shall assign a new part number to the part when authorized changes make the superseded part not interchangeable with respect to interface, reliability, safety, logistics, traceability or performance. For traceable items the part identification shall additionally include the manufacturer's identification code in accordance with DoD Handbook H 4-1, and be lot numbered or serial numbered when required.

3.3.4.2 Identification of Lines. Lines shall be identified in accordance with MIL-STD-1247.

3.3.4.3 Identification of All Development/Qualification Test Specimens. Test specimens shall be permanently and obviously identified prior to testing with the words " ENG. TEST ONLY" in addition to the identification required by the Drawing/Specification to preclude their use on production items. The letters shall be indelible and provide a distinctive and vivid contrast with the color of the specimen. The lettering size and identification location shall be clearly visible to casual observation. Materials used for the identification shall be compatible with the test specimen and its operating environment. When the size or configuration of the test specimen is such the identification cannot appear on the specimen, other suitable means such as attached metal tags shall be used.

3.3.4.4 Nameplates. Nameplates shall be marked in accordance with MIL-STD-130 and shall include (as applicable) item name; buyer's control number; Federal North Atlantic Treaty Organization Stock Number (FSN/NATO); manufacturer; date of manufacture; and manufacturer's serial number, part number, lot number, and code identification number. Abbreviations, in accordance with MIL-STD-12, may be used.

3.3.5 Traceability. Traceability shall be provided by assigning a traceability identification to items/major component as identified in 3.1.3. Such identification shall provide the means of correlating each of its historical records. Conversely the records shall be traceable to each item/major component.

3.3.5.1 Traceability Classification. For lower tier items, traceability classifications shall be established classifying raw materials, part, assembly, or end item for determining the marking and traceability records required (or excluded for exempt items) for that item. Seller subordinate supplier engineering documentation (e.g., drawings and specifications) shall specify traceability or exemption for items in accordance with the applicable classifications defined in 6.1. Electronic/Electrical/Electromechanical parts shall be traceable by lot in accordance with MF0004-400, as a minimum.

3.3.5.2 Traceability Identification. Each item identified as traceable (refer to 6.1 for T_S, T_L, T_M) shall have a traceability identifier including the manufacturer's code identification number as listed in DoD Handbook H 4-1 and a serial, lot, or member number. The traceability identifier number shall be assigned by the manufacturer and shall not exceed 10 characters (alphas, numerics, dashes, etc.).

3.3.6 Interchangeability and Replaceabililty. The FCS components shall be interchangeable in accordance with the definition of MIL-STD-280. Interchangeability and replaceability (reference 3.2.4.1, b) shall be a design feature for all removable items/subassemblies/parts designated as LRU's or SRU's. When removable items/subassemblies contain controls, wiring, hydraulic lines, etc., interchangeability shall be provided at the attachments of these items to their next assembly, as well as for structural attachment of the assembly.

3.3.6.1 Design Tolerances. Provisions shall be made for design tolerances such that items having the dimensions and characteristics permitted by the item specifications or drawing are interchangeable without selection or department from the specified equipment performance.

3.3.6.2 Use of Standard Parts. When standard parts (refer to 3.3.1.2) are not available and permission is granted for use of a non-standard part due to unavailability of the standard part, the equipment shall be designed so that the non-standard part can be replaced by the standard part. Appropriate space, mounting holes, and other necessary provisions shall be provided for this purpose.

3.3.7 Safety. The design and operation shall comply with the following safety requirements:

a. All handholds and handrails shall provide a minimum clearance of 2.0 inches between the gripping surface and any adjacent structure and provide a minimum of 5.5 inches of straight grasping surface.

b. Equipment shall revert to a safe configuration when an input power loss occurs.

c. All materials including seals, gaskets, and lubricants shall be compatible with the service commodity.

d. Lines shall be firmly supported and shall be independently clamped or supported.

e. All pressure vessels and reservoirs shall have an isolation shutoff valve located as the first component downstream of the vessel and as close as possible to the vessel.

f. The FCS plumbing shall be marked to identify the function and direction of fluid flow.

g. Filters shall be replaceable without requiring removal of filter housing, and shall be designed such that bacteria is prevented from escaping during filter replacement, and such that the crew is sanitarily protected.

h. Torque values for all bolts, connectors, and similar threaded components shall be specified in the design.

i. All mechanical actuating devices shall have positive mechanical stops.

j. Access doors or covers which are not removable shall be of self supporting when open.

k. All fan blades, pump impellers and similar rotating mechanisms shall have protective devices such as a shear pin, friction clutch, magnetic clutch or a similar device to protect the drive mechanism.

l. Equipment utilizing rotating mechanisms shall incorporate provisions for containment of failed parts. Lock or latching mechanisms shall be operable by a single control and provide clear visual indication of latch position.

m. Controls shall be designed and located to minimize inadvertent activation.

n. Material which can shatter shall not be used unless positive protection is provided to prevent fragments from entering cabin environment or striking personnel.

o. Exposed sharp surfaces or protrusions shall be eliminated.

3.3.8 Human Performance/Human Engineering.

The design shall consider the capabilities and limitations of the human operator wherever a man-machine interface exists, including torques, forces, and other functional design characteristics of controls, displays, and work stations. The principal design guide for the man-machine interface shall be MIL-STD-1472.

3.3.9 Acoustical Noise. The FCS equipment shall not generate noise in excess of the following sound pressure levels (SPL) at the associated octave band center frequency (OBCF) during operation with the seat valve open and closed. Noise level microphones shall be three feet from the test unit at four locations ninety degrees apart around the unit. (SPL values include ambient background noise corrections).

Max. SPL (dB re 20 N/m^2)	OBCF (Hz)
58	63
66	125
70	250
69	500
71	1000
64	2000
64	4000
56	6000

APPENDIX B

Non Recurring and Recurring Cost Estimates

SHUTTLE

	Fecal System	Non Recurring Phase I DDTE/Proof	Phase II 1 Proto System	Recurring Cost (per S/S based on 5 S/S)
1.	Fecal Coll Bag Vac/Heat Drying	625K	670K	\$520K (Basic) + 7K (Bags/Flight)
2.	Fecal Coll Bag Microwave Oven	610K	530K	\$450K + 7K (Bags/Flight)
3.	Archimedean Screw/Vac Drying	955K	620K	\$550K
4.	Bladder Coll/ Vac Drying	1,025K	575K	\$600K
5.	Cartridge Compactor Vac. Drying	625K	410K	\$380K