Space Station

WORK PACKAGE 2
ADVANCED DEVELOPMENT

SSS87-0073

CREW SUPPORT REPORT (FINAL)

PROJECT 30 MANNED SPACE STATION HABITABILITY

JANUARY 16, 1987

Prepared by: Project Engineering-Advanced Development/
Rockwell/Grumman
For NASA Lyndon B. Johnson Space Center

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This document is submitted by the Rockwell Space Station Systems Division Advanced Development Project Office in compliance with the Advanced Development Plan (DR-05), Rockwell document No. SSS 85-0011, Revision 4, dated November 10, 1986.

The data contained in this document was generated as part of the project identified in the Space Station Advanced Development Plan as Project 30, Manned Space System Habitability. This corresponds to Grumman IR&D Project S143-301 under the direction of G. Harms. This data was identified and released to the Space Station Systems Division as Grumman document SS005-ATD-10.

ABSTRACT

The objective of Grumman's Manned Space Systems Habitability IR&D project is to develop guidelines and design criteria for Space Station habitat modules by focusing in three related functional disciplines: human factors, internal architecture, and crew support. Specific objectives for the crew support systems study are to identify the advanced technology development needs for crew support systems which can satisfy the long-duration mission and high crew productivity needs of Space Station, and which efficiently interface with the Habitation module systems, and to develop advanced design concepts for selected systems which will complement development efforts undertaken by NASA.

This report addresses the development of requirements in the areas of waste collection, personal hygiene, low pressure storage of fresh fruits and vegetables, food preparation, clothes washing and drying, trash management, and internal contamination control. Initial identification of key technology development needs and approaches, as well as preliminary concept formulations, are discussed.

CONTENTS

ILLUSTRATIONS

TABLES

TABLES (Contd)

1 - INTRODUCTION

This is the final report planned for the Crew-Support Systems Study conducted within Grumman's Manned Space Systems Habitability IR&D project (described in Ref 1).

The overall objective of the Manned Space Systems Habitability project has been to develop guidelines and design criteria for Space Station habitat modules by focusing on the three related functional disciplines: human factors, internal architecture, and crew support.

This report deals specifically with the Crew Support discipline. Human Factors and Habitability treated in separate reports.

CREW SUPPORT SYSTEM STUDY OBJECTIVES

The crew support contribution to this project was completed in September 1986. The tasks performed included:

- Investigation and assessment of crew support technology throughout NASA, subcontractors, and others in the field to determine status and develop requirements
- Establishment of initial requirements based on module design needs and limitations for comparison with developing crew support systems
- Selection of those specific areas where active interfacing and/or development assistance in a team effort promises a useful contribution to Space Station design
- To advance the state of the art technology in these specific areas where possible and report.

This report addresses the areas of waste collection, personal hygiene, and low pressure storage of fresh fruits and vegetables. Basic information related to food preparation and clothes washing and drying technology is included. The areas of trash management and contamination control are addressed in this report. However much ongoing work and study is needed in these areas.

2 - SUMMARY

A system study addressing the functional performance, and interface requirements for Space Station habitability was conducted. The purpose of this study is to identify key technological approaches and alternative subsystem concepts to advance crew support systems state of the art.

Subcontractors who have contributed to our studies are:

- Bell and Trotti
  - Personal hygiene design studies and mockup fabrication
- Fairchild Republic Corporation (FRC)
  - waste management (Fecal, Urine, Trash) design studies
- General Electric Houston (GEH)
  - waste management design analysis and trade studies
  - washer systems design analysis and trade studies
  - food system design analysis and trade studies
  - galley/wardroom subsystems design and Houston mockup fabrication
- Hamilton Standard Corporation (HSC)
  - Waste collection/compaction (fecal) and urine collection design information
- Warner, Burns, Toan and Lunde
  - Habitation module design studies and mockup fabrication
- Whitmore Enterprises
  - Fecal waste collector/compactor subsystem and mockup fabrication.

Systems studies of waste collection and personal hygiene systems have been conducted to better understand the equipment and its impact on the Space Station.

Investigation of low pressure storage of fresh fruits and vegetables was accomplished by literature review and consultation with experts.

Study of basic information related to food preparation plus clothes washing and drying technology was initiated.

Evaluation of crew gallery activities were conducted in Bethpage and Houston mockups. Additional galley wardroom arrangements have been identified for investigation.

3 - WASTE COLLECTION SYSTEM

This section addresses the problem of collecting, processing, and storing human waste on-board the Space Station.

Human waste will consist of fecal matter in varying degrees of solidity, liquid urine, vomitus, and female menses. Management of this waste material remains one of the more difficult problems confronting the space vehicle designer. The total process includes provisions for the act of elimination, processing the waste materials for storage, temporary on-orbit storage, and ultimate disposition.

The successful design must involve the user in the process of eliminating waste material in a manner that is esthetically acceptable, sanitary, and provides control for odors and vapors. Nominal operation of the design must not require the user to handle or manually process the waste material in any way. Other functional and operational requirements deal with rendering the waste matter biologically inert, and the removal and transportation of the storage container.

Included in this section are the waste collection concepts that have been defined by the General Electric Co. -Houston, Fairchild Republic Corp., Whitmore Enterprises - San Antonio, and United Technologies, Hamilton Standard Division, under Grumman's direction.

A special working group examined the existing waste collection system requirements and derived additional requirements based on ongoing trade studies and other analysis being performed. The results of these activities will provide a set of criteria by which the various concepts can be compared and evaluated. This critical review of the systems presently being designed leads to a more complete understanding of the equipment performance characteristics and the overall habitat design requirements.

Table 3-1 summarizes Waste Collection methodology (objectives), drivers, issues and technology development.

Table 3-1 Waste Collection

METHODOLOGY
• IDENTIFY & DEFINE REQMTS • FORMULATE CONCEPTS • ESTABLISH CONCEPT SELECTION CRITERIA • PERFORM BASELINE SELECTION OF CONCEPTS • DEFINE INTERFACES • POSTULATE EQUIPMENT DEFINITION & SIZING • DEFINE POWER, LOGISTIC, MAINTENANCE REQMTS • PREPARE SPECIFICATION
KEY DRIVERS
• WEIGHT, VOLUME, & POWER MINIMIZATION • SAFETY: ODOR & BACTERIAL CONTAMINATION • PERFORMANCE: EASE OF USE, WASTE TRANSPORT, & PROCESSING • COST
ISSUES & CONCERNS
• SELECTIVE BIOMEDICAL SAMPLING • CREW ACCEPTANCE • WASTE CONTAINMENT & STABILIZATION • ODOR & BACTERIAL CONTROL • NOISE CONTROL • FECAL BOLUS SEPARATION • STORAGE AVAILABILITY • VENTING OF STORED MATERIAL • REPAIR & MAINTENANCE • BACK-UP PROVISIONS • DEGREE OF AUTOMATION
TECHNOLOGY DEVELOPMENT
• PRESENT TECH LEVEL = 5 – 7   – TESTED IN SPACE BUT STILL UNSATISFACTORY • KEY TECH ISSUE = FECAL COLLECTION, FECAL STABILIZATION
R86-1578-022

3.1 GE SEPARATE URINAL

The GE Separate Urinal is similar to flight-qualified systems previously used, or presently in use, aboard the Space Shuttle. The systems are designed for ease of use in a zero-G environment. These systems are strictly for use with liquid waste products, incorporating various transport methodologies. The selected system is a separate urine system which utilizes air flow for the transport and separation mechanism. Air and urine are drawn into the transport hose, and then into the fan separator. Urine is separated out and flows into a storage tank, while air is filtered and returned to the cabin. See Fig. 3-1.

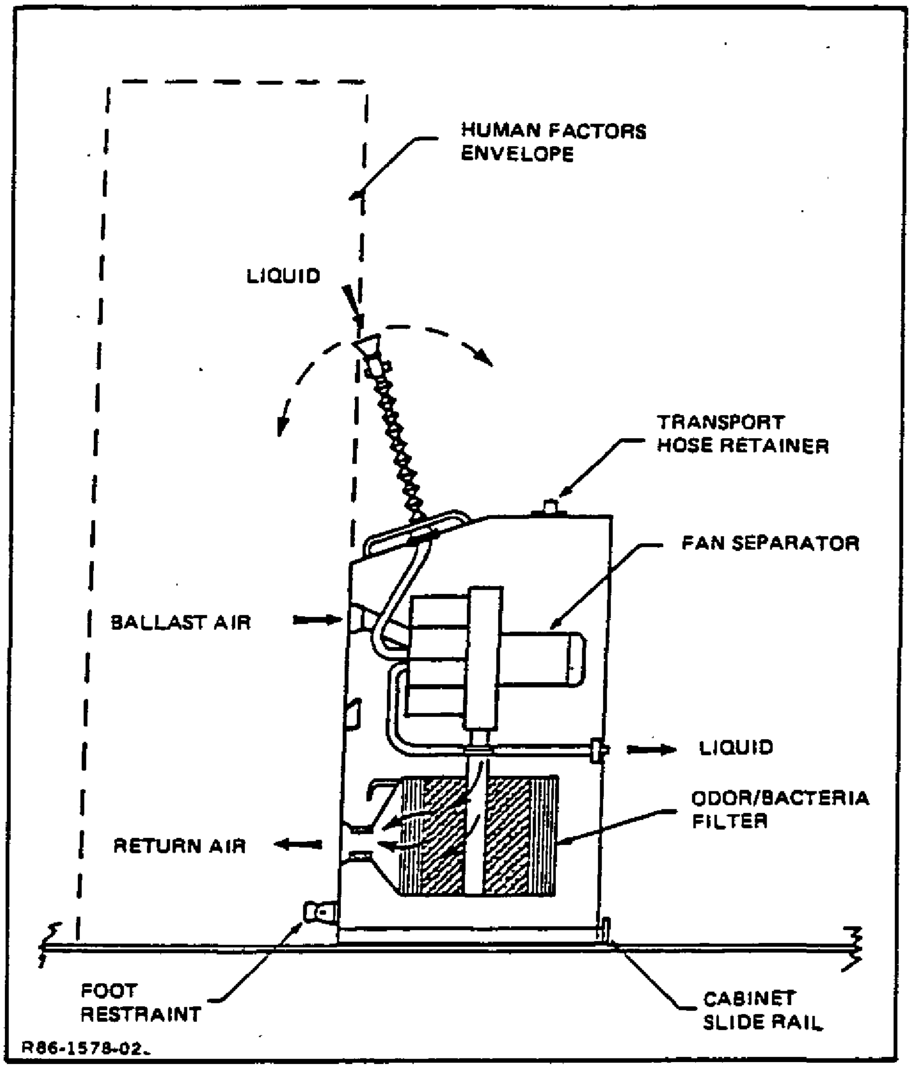


Fig. 3-1 GE Separate Urinal

The concept of separate urinals is based on the premise that crewmembers will be located in diverse areas of the Space Station, presenting the need for several urinal stations. Extensive testing of new urine cups has resulted in improvement to the basic spaceflight proven system. This concept modularizes the urinal, and through slide rail mounting, provides accessibility for repair and recessed mounting for maximizing stowage. Accordingly, envelope dimensions within the habitability area are minimized.

DESCRIPTION

- Liquid/Gas Separation - An improved version of the fan separator, providing greater air flow with shortened tubing pathways enhances urine collection and separation. All component parts are removable in-flight and replaceable as subassemblies. A simplified control system is utilized as no redundancy is required
- Odor/Bacteria Control - Odor/Bacteria Control is accomplished through the use of an improved long-life filter assembly. To further enhance this design, the filter is removable by opening a front panel. The filter external dimensions have been slightly increased to provide optimum air flow, with no filter degradation
- Crew Restraint - In addition to the spring-loaded crewmember foot restraint, the transport hose contains a memory retaining wire which allows it to remain in a crewmember set position. Additional grasp handles are provided to aid in zero-G stabilization
- Redundancy - Serviceability is emphasized in this concept and is combined with long-life components. No redundant systems are required in each unit. Redundancy is provided through multiple units
- Operation - Operation of the Space Station urinal is similar to the combined commode/urinal except it is an individual urine system. Controls consist of an ON-OFF switch for the fan separator and air flow indicators to

assess pre-filter and odor/bacteria filter degradation. Operational life expectancy of component parts is discussed in the technical data

- Envelope - Envelope dimensions are based on current configuration WCS components and the space required for optimum operation. Human factors are imposed based on orbital flight experience and anthropometric data.

DETAILED DATA

System Name: GE Separate Urinal
Peak Power Requirements: 0.35 kW
Power Requirements (kWH/year):
30 Min/Day x 0.35 kW x 1/60 x 365 days x 8 CM = 511 kW Hr/year
where CM = crewmember
Weight: 25 kG
Volume:

Height (meters)	1.0
Length (meters)	0.76
Width (meters)	1.0
Total	0.76 cu meters

3.2 GE COMMODE/URINAL

This concept (Fig. 3-2) utilizes current shuttle technology in combination with design improvements dictated by crewmember comments and extensive testing. It is an integrated system which is based on proven components and techniques. Proposed enhancements include increased capacity, containerization, and odor/bacterial filtration. Performance improvements include air drying and assembly replacement of critical components.

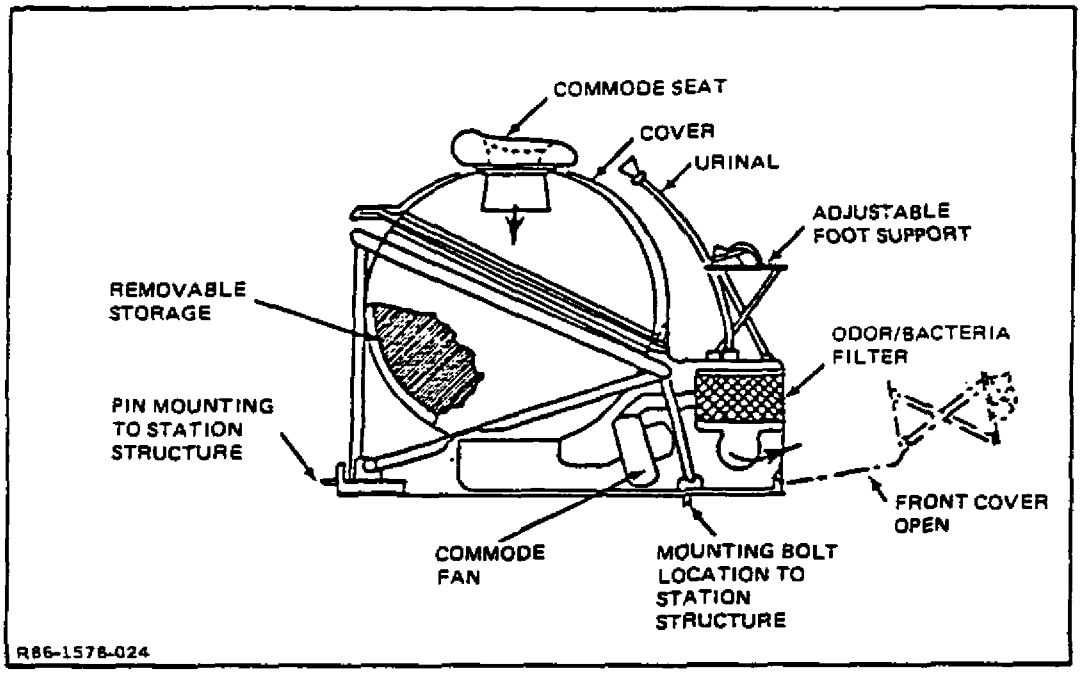


Fig. 3-2 GE Commode/Urinal

DESCRIPTION

- Capacity - Additional capacity can be derived by enlarging the shuttle commode container within the proposed envelope. Compaction methodology within the holding tank is presently under evaluation. When available, results may be applicable to Space Station
- Containerization - A basic requirement for containerization of waste products is that the container must be nonpermeable to microbes. In order to effectively provide microbial protection and facilitate crew servicing, a nonwoven, hydrophobic, soft bag system is proposed. This concept offers ease of removal and handling when incorporated within the improved commode tank design
- Redundancy - Redundancy is provided within the commode/urinal unit for comfort and convenience of crewmembers. These are dual fan/separator units which can be operated singularly or in parallel to provide commode/urinal air flow. These fan separator units are identical and replaceable in space by crewmembers.

A single urinal hose is provided with the commode/urinal unit which provides redundancy in that it can be plugged into receptacles which are internally plumbed to either of the fan separators. Therefore, if a problem exists with one separator, the other can be selected by connecting to the alternate receptacle. Redundancy is provided for urinal cups in that each crewmember has his own individual unit with a spare provided should it be needed.

The commode waste collector is a replaceable unit which provides microbial integrity during the removal cycle. The commode waste collector is replaced periodically as the need exists for more capacity. Dual odor/bacterial filters are provided. The secondary filter is in the air discharge from each fan/separator which protects the crew from noxious odors and provides backup for the primary commode bacteria filters

- Operation - Operation of the WMS commode/urinal is similar to the present Shuttle WCS, except for simplification and the removable bag container. Since air drying is utilized, the valving is greatly simplified and certain switching can be eliminated. Fecal air drying with a small air fan which operates continuously is provided, eliminating overboard vacuum venting. Containerization is accomplished by a removable bag. In operation the bag container would be capped on top and bottom when removed. The entire container would then be placed into a compactor and a replacement installed into the commode. The urine system is enhanced by newly-designed individual cups which provide optimum air flow, separation, and last drop collection.

DETAILED DATA

System Name: GE Commode/Urinal
Peak Power Requirements (kW): 0.505
Fan Separator = 0.312 peak (kW)
Power Requirements (kWH/year): 2037
Volume: 0.8 cu m
Weight: 91.0 kG

The Shuttle WCS weight is 62 kG. Certain components such as the fan separator, basic tank, piping, valves, and motors will require manufacture from stainless steel to increase reliability and eliminate corrosion. A further weight increase is due to addition of the drying blower motor with integrated system components, and an increased capacity odor/bacteria filter assembly.

3.3 FRC COMMODE/URINAL

The Fairchild Republic Company (FRC), subcontractor to Grumman in this effort, has provided in-depth information on their Space Station Waste Management System design.

The FRC commode/urinal uses a modified Skylab commode seat and a 20 CFM air flow rate to direct the bolus into the chamber. After defecation, a piston removes the feces from the chamber, compacting it and leaving the collecting chamber relatively "clean" for the next use. Waste stabilization is primarily by drying - a process depended upon by all proposed Waste Collection Systems. Urine collection is achieved by air jets in the personalized urinal. The urine-air mixture is processed by a centrifugal separator. Odor and bacterial filters separate the wastes from the cabin atmosphere.

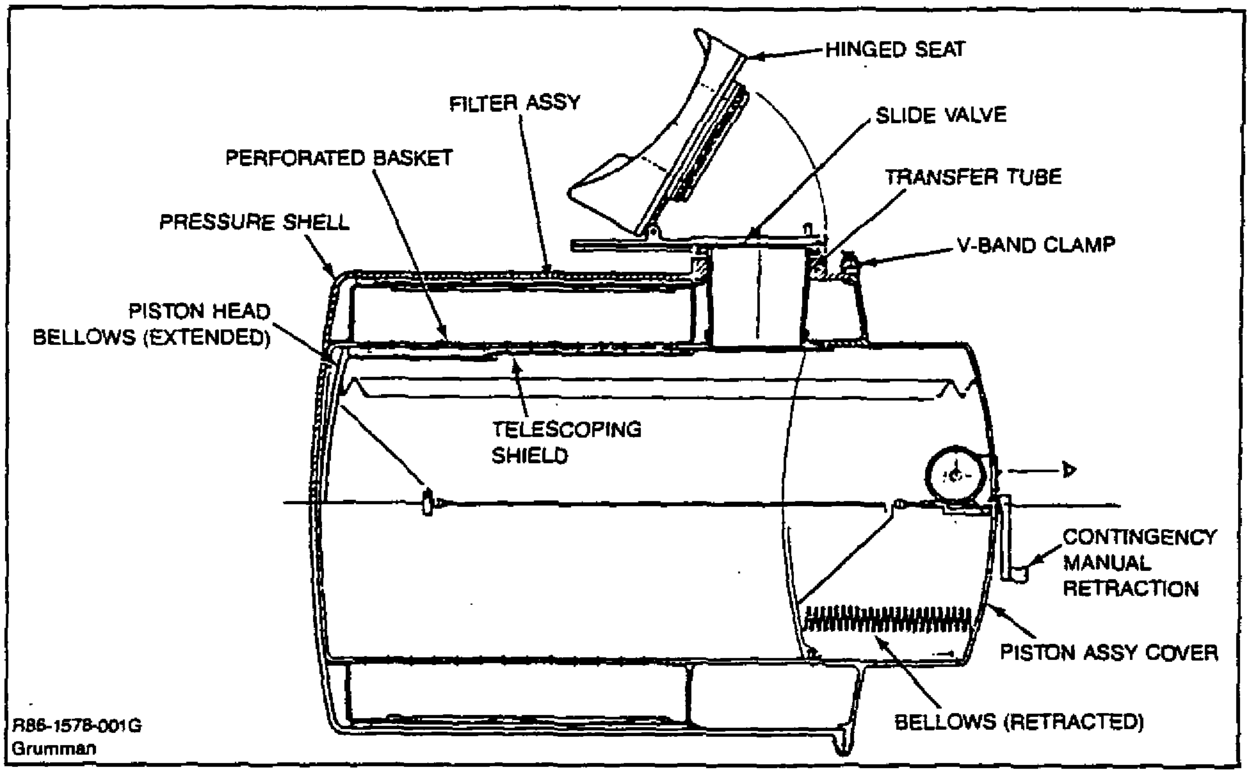


Fig. 3-3 Fairchild Republic Commode

DETAILED DATA:

System Name: Fairchild Commode/Urinal
Peak Power Requirements (kW): 0.225
Fan Separator = 0.03 peak (kW)
Power Requirements (kWH/year): TBD
Volume: 16.3 ft^3
Weight: 193.5 lb.

3.4 WHITMORE COMMODE

Whitmore Enterprises' commode is limited to fecal collection only. It is similar in design to the FRC unit. The major difference is that the Whitmore unit adds a paper wiper to the piston, thus enhancing the piston's ability to clean the collecting chamber and leaves the piston head "clean". The wiper remains with the removed feces after the removal/compaction process, apparently assisting the fecal drying procedure. (Fig. 3-4).

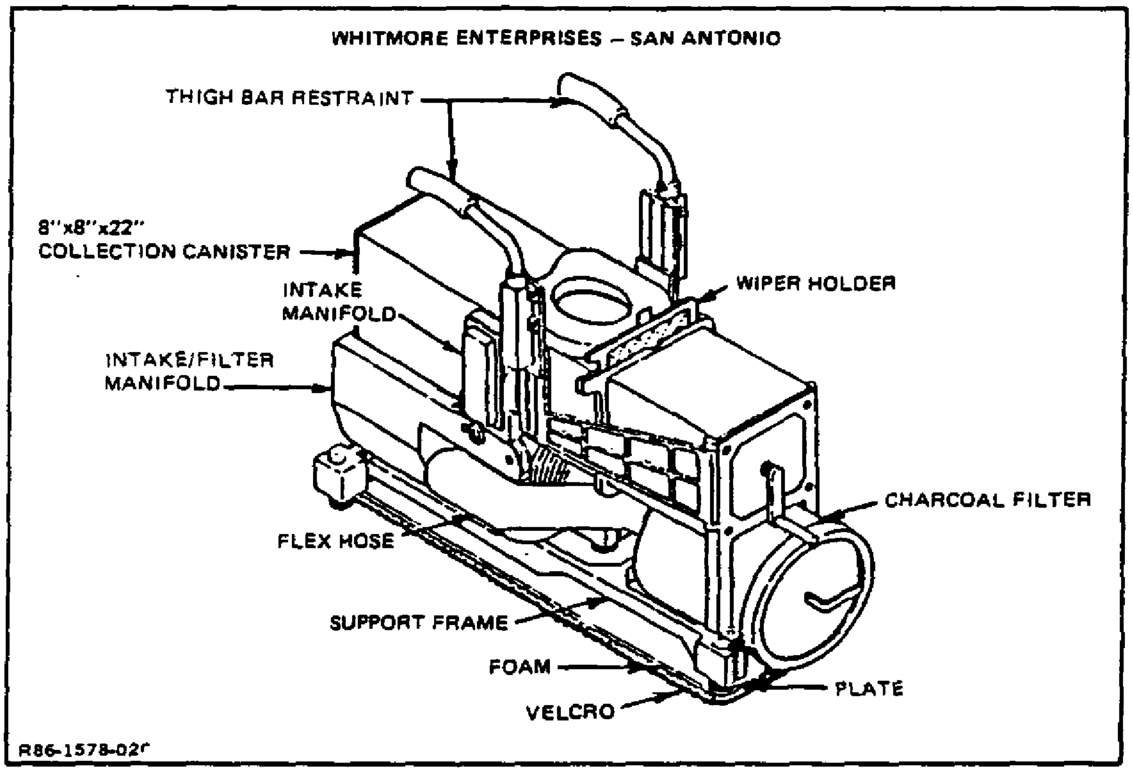


Fig. 3-4 Whitmore Commode

DETAILED DATA:

System Name: Whitmore Commode
Peak Power Requirements (kW): 0.33
Power Requirements (kWH/year): TBD
Volume: 9.4 ft^3
Weight: 60 lb.

3.5 HSC COMMODE/URINAL

The Hamilton Standard Commode/Urinal incorporates a hydrophobic bag into their system. Airflow will entrain the bolus into a cylinder lined by the bag. Then, either manually or automatically, a lid is placed onto the bag. The cylinder is then rotated so that a piston can compact the bag to the bottom of the canister. The clean cylinder is then restored, with a new bag, to its original position (Fig. 3-5).

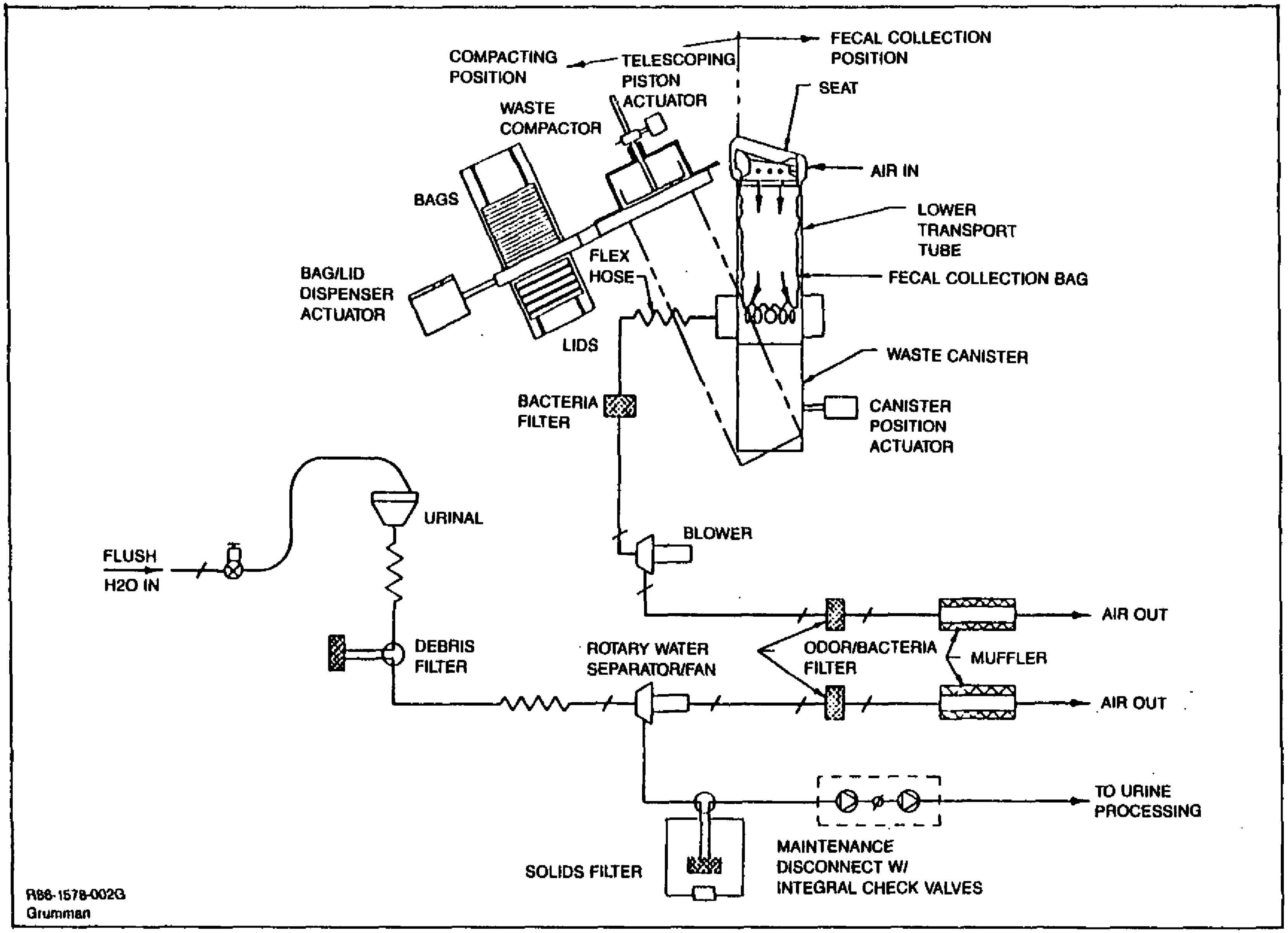


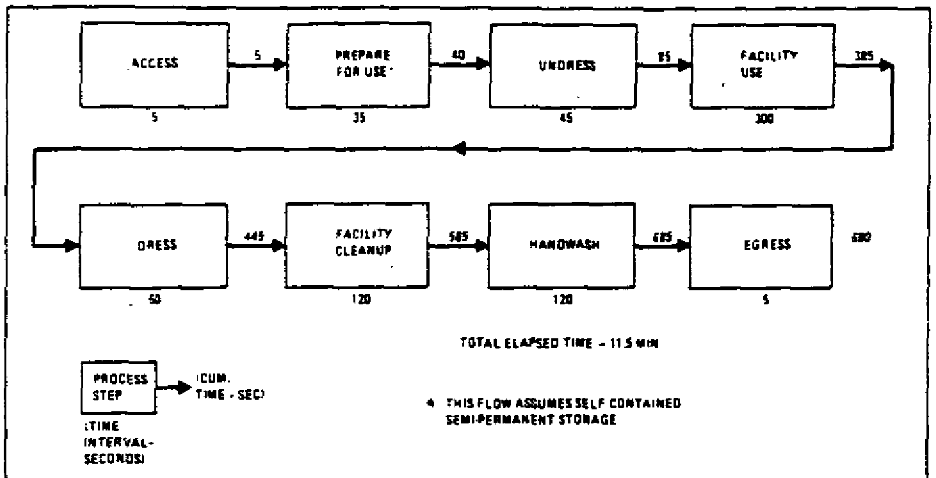
Fig. 3-5 Hamilton Standard Commode/Urinal

DETAILED DATA:

System Name: Hamilton Standard Commode/Urinal
Peak Power Requirements (kW): 0.460
Fan Separator = 0.36 peak (kW)
Power Requirements (kWH/year): TBD
Volume: 50.5 ft^3
Weight: 193.5 lb.

3.6 WASTE COLLECTION TASK TIMELINE

A systems study of Waste Collection Systems was conducted to better understand the equipment and its impact on the Space Station. A block diagram of the "Process Flow" is presented below together with the cumulative times and time intervals for each process step. In Fig. 3-6, all activities of each process step are broken down to permit detailed examination. The interfaces and support equipment associated with each activity, as well as trades and issues, are listed. The logistics supply/resupply (e.g., power, water, etc) are then tabulated by quantity and duration (Fig. 3-7).



ACTIVITY	SUPPORT EQUIP RQD	INTERFACES	TRADES	ISSUES
ACCESS				
OPEN DOOR	FIXED HAND HOLD LATCH RELEASE GRIP (DOOR KNOB OR EQUIV)	LIGHTED AREA		DOOR OPENING DIRECTION
ENTER	HAND HOLD		HAND HOLD DESIGN, NO. & LOCATION	
TURN ON LIGHT	LIGHT SWITCH	ELECTRICAL	AUTOMATIC OR ACTUATED	
CLOSE DOOR	LATCH REACTIVE HAND HOLD			
PREPARE FOR USE				
SANITIZE	WIPE LIQUID/BOTTLE (WIPE/BOTTLE HOLDER) FOOT RESTRAINTS		PRE-MOISTENED, PKGED WIPE VS WIPE & PLASTIC CONTAINER	
UNDRESS				
UNDRESS	(FOOT) RESTRAINTS CLOTHES ATTACHMENT STRAPS			EXTENT OF UNDRESS (FOR COMFORT)
FACILITY USE				
POSITIONING	FOOT RESTRAINTS			
MOVEMENT				COMFORT AMENITIES • (READING LAMP, MAGAZINES, TV, RADIO) • CONDITIONED AIR FLOW • SPECIAL READING LIGHT
WASTE RETENTION (TEMPORARY STORAGE)	WASTE FACILITY OPERATION			
PERSONAL CLEANUP	WIPES, WIPE HOLDER		WIPE MAT'L & SIZE *LOGISTIC RESUPPLY*	WET/DRY CLEANING SHOULD FILTER/DEODORANT FAN BE ON PERMANENTLY?
DRESS				
DRESS	(FOOT) RESTRAINTS CLOTHES ATTACHMENT STRAPS			
FACILITY CLEANUP				
SANITIZE	WIPE LIQUID/BOTTLE (FOOT RESTRAINT)			(SEE 'PREPARE FOR USE')
HANDWASH				
POSITION FOR USE	*RESTRAINTS*		*TYPE/LOCATION*	
OPERATE HANDWASH	(FOOT) RESTRAINTS	HOT/COLD WATER SOAP AIR FLOW ELECTRIC	HEATING CONTROLS (LOCAL/REMOTE) SOAP (LIQ VS SOLID)	HANDWASH IN COMPARTMENT OR OUTSIDE COMPARTMENT
DRY HANDS	WIPES (WIPE HOLDER)	WIPE DISPOSAL CONTAINER	WIPE VS ELECTRIC FAN DRYER WIPE, SIZE & MAT'L	STANDARDIZED WIPES (PERSONAL AND HAND)
EGRESS				
OPEN DOOR	SEE 'ACCESS'			
EXIT	SEE 'ACCESS'			
TURN OFF LIGHT	SEE 'ACCESS'			
CLOSE DOOR	SEE 'ACCESS'			

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Fig. 3-6 Waste Collection Process Flow

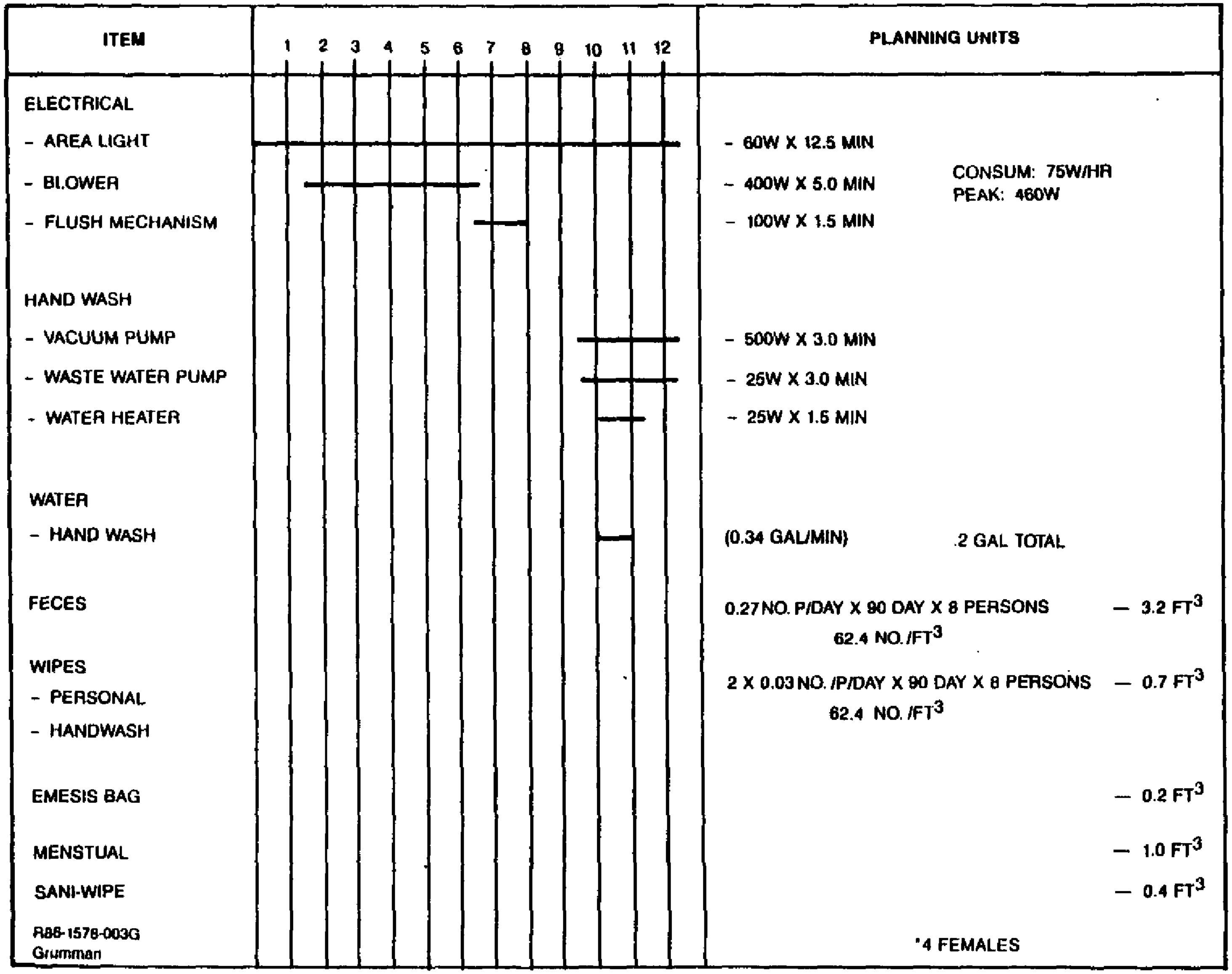

Fig. 3-7 Waste Collector Derived Logistics Parameters

4 - PERSONAL HYGIENE SYSTEM

The personal hygiene system aboard the Space Station will provide the means for all crewmembers to conduct body cleansing and grooming activities in a reasonably comfortable and private manner for the mission duration of 90 days. The personal hygiene system will be equipped to provide crewmembers with the facilities for whole and partial body cleansing, shaving, oral hygiene, vomit collection, feminine hygiene, and other grooming activities.

A systems study of each of the subsystems of the Personal Hygiene System was conducted in a similar manner to that discussed for the Waste Collection System: a block diagram of the "process flow" was created and interval and cumulative times were estimated for each process step. All activities of each process step were then examined in detail. The interfaces and support equipment associated with each activity as well as trades and issues were listed. Logistics parameters (e.g., power, water, etc) were derived from this flow analysis. The logistic parameters were tabulated by quantity and duration.

To avoid repetition, only the block diagram of the shower process flow is presented here. However, the derived logistics parameters for each of the subsections of the Personal Hygiene System (shower, handwash, shaving, etc) are shown in Fig. 4-1 through 4-6.

Some concepts of whole body bathing that have been studied are shown in Fig. 4-7.

Grumman's preliminary evaluation of the existing concepts has resulted in the tentative selection of the "rotating vacuum squeegee" concept (Table 4-1). Tentative selections of other Personal Hygiene concepts are shown in Table 4-2.

In addition to deriving logistics parameters and selecting tentative concepts for the mechanical subsystems, Grumman is also involved in constructing and evaluating full scale models of the functional architecture. At Grumman's Bethpage facility, the configuration was constructed as shown in Fig. 4-8A. Bell and Trotti Inc assisted Grumman in this effort by constructing the handwashers, the storage compartments and the shower, which shows the rotating squeegee and a sliding door entrance. This facility contains a representation of the Hamilton Standard Waste Collector.

At the Grumman Houston facility, Whitmore Enterprises has furnished Grumman a mockup of their waste collector. Grumman is also in the process of obtaining a mockup of the Hamilton Standard waste collector. These waste collectors are to be installed in the proposed habitation mockup in Houston.

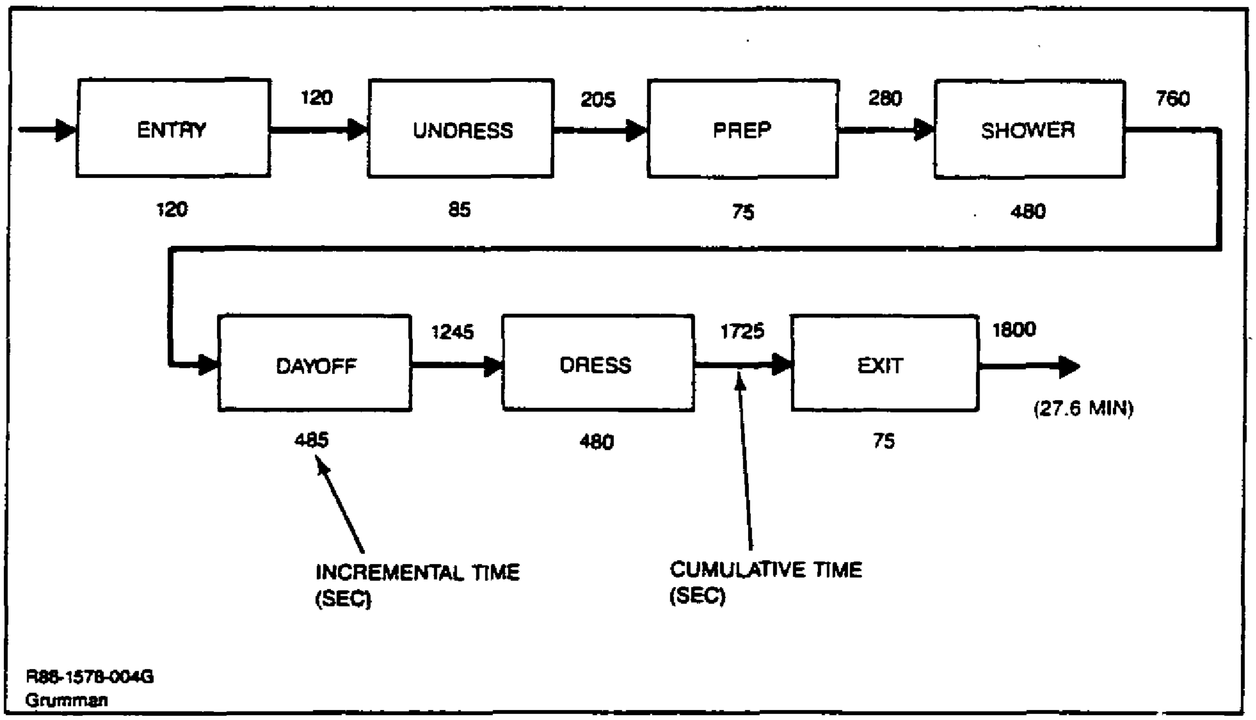

Fig. 4-1A Shower Process Flow

ITEM	ELAPSED TIME (MINUTES) 0 3 6 9 12 15 18 21 24 27 30	PLANNING UNITS	
ELECTRICAL			
- AREA LIGHT		- 60W X 30 MIN	
- SHOWER LIGHT		- 40W X 28 MIN	CONSUM: 674W/HR
- COMPARTMENT AIR BLOWER		- 150W X 30 MIN	PEAK: 1600W
- VACUUM PUMP		- 1000W X 24 MIN	
- WASTE WATER PUMP		- 25W X 24 MIN	
- AIR HEATER/COOLER		- 150W X 30 MIN	
- WATER HEATER		- 25W X 12 MIN	
- SHOWER AIR HEATER		- 150W X 24 MIN	
WATER			
- SHOWER		(0.34 GAL/MIN)	0.75 GAL TOTAL
DIRTY CLOTHES			
- CLOTHES			
- TOWELS			
- WASH CLOTH			
SOAP			
SHAMPOO			
R86-1576-005G Grumman			

Fig. 4-1B Shower Derived Logistics Parameters

ITEM	ELAPSED TIME (MINUTES) 0 1 2 3	PLANNING UNITS	
ELECTRICAL			
- AREA LIGHT		- 60W X 3.0 MIN	
- VACUUM PUMP		-500W X 3.0 MIN	CONSUM: 30W/HR
- WASTE WATER PUMP		- 25W X 3.0 MIN	PEAK: 610W
- WATER HEATER		- 25W X 3.0 MIN	
WATER			
- HANDWASH		- (0.34 GAL/MIN)	0.125 GAL TOTAL
SOAP			
TOWELS			
R86-1578-006G Grumman			

Fig. 4-2 Handwash/Face Wash Derived Logistics Parameters

ITEM	ELAPSED TIME (MINUTES) 0 1 2 3 4	PLANNING UNITS	
ELECTRIC SHAVE			
ELECTRICAL			
- AREA LIGHT		- 60W X 4.0 MIN	CONSUM: 12W/HR
- SHAVER/VACUUM		- 160W X 3.0 MIN	PEAK: 220W
WET SHAVE			
ELECTRICAL			
- AREA LIGHT		- 60W X 4.0 MIN	CONSUM: 36W/HR PEAK: 610W
HANDWASH			
- VACUUM PUMP		- 500W X 3.5 MIN	
- WASTE WATER PUMP		- 25W X 3.5 MIN	
- WATER HEATER		- 25W X 3.0 MIN	
WATER		(0.34 GAL./MIN)	0.1 GAL. TOTAL
CONSUMABLES			
- LATHER/GEL			
- NEW BLADES			
TOWELS			
R86-1578-007G Grumman			

Fig. 4-3 Shaving Derived Logistics Parameters

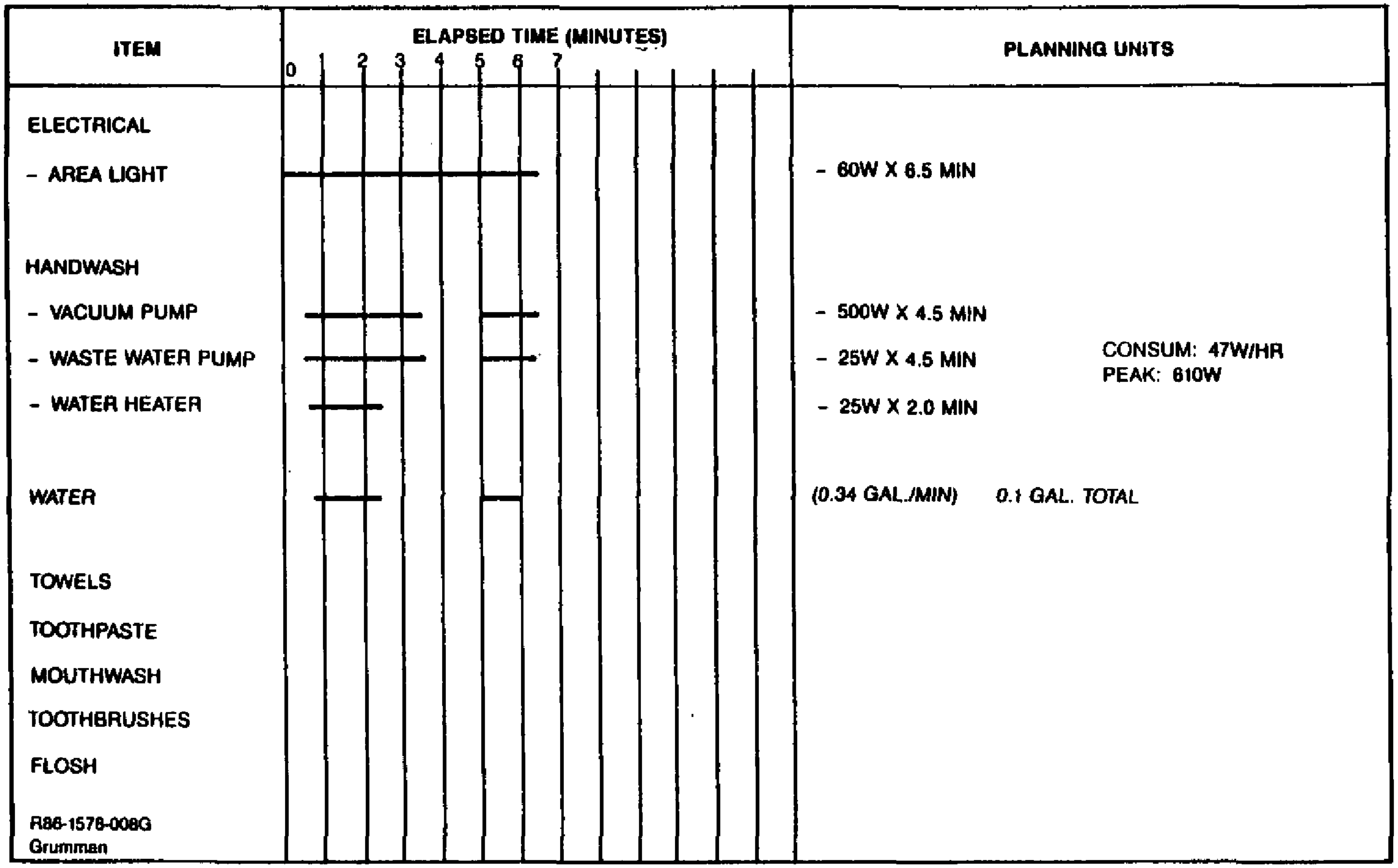

Fig. 4-4 Oral Hygiene/Expectoration Derived Logistics Parameters

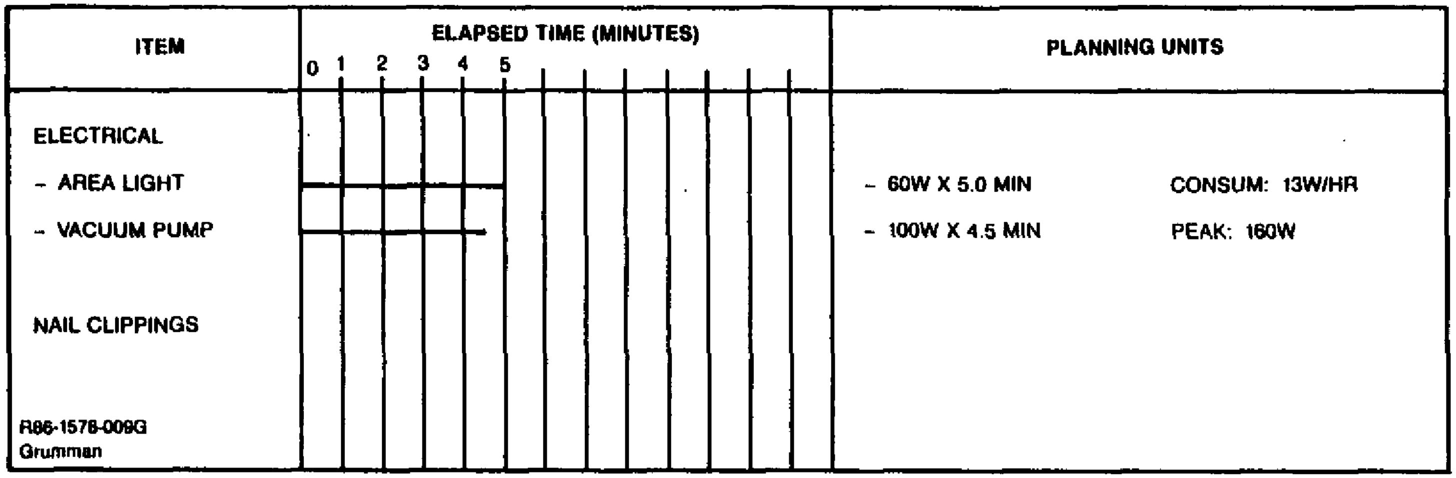

Fig. 4-5 Manicure/Pedicure

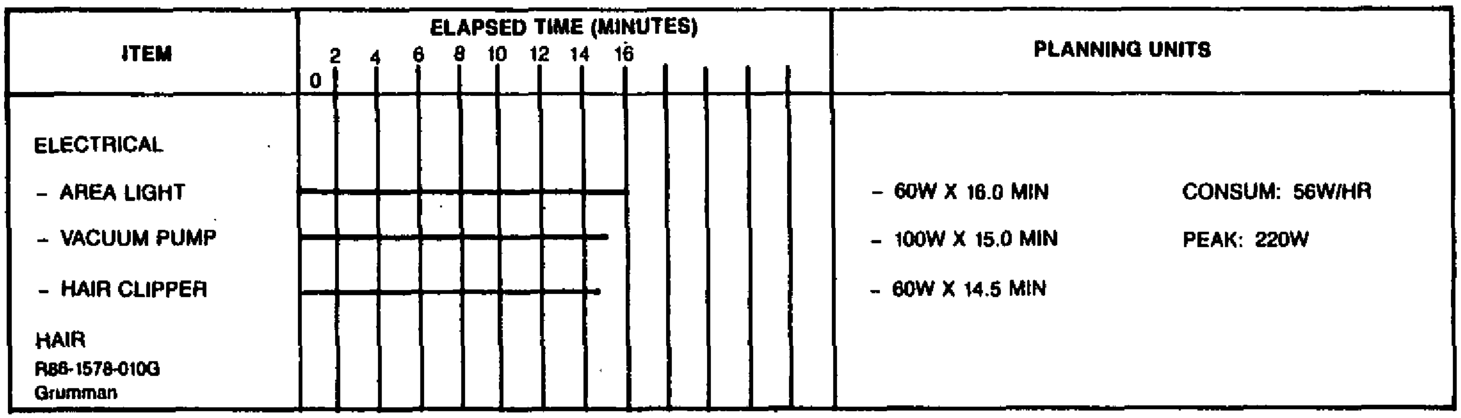

Fig. 4-6 Hair Cutting Derived Logistics Parameters

Table 4-1 Preliminary Shower Ranking

1 = EXCELLENT 5 = POOR CONCEPTS	SKYLAB SHOWER	VACUUM CLEAN-UP	CENTRIFUGAL CLEAN-UP	ROTATING* SQUEEZE
PERFORMANCE	1	1	1	1
RISK	1	1	1	1
USER FRIENDLINESS	1	1	1	1
COMMONALITY	2	1	1	1
SAFETY	1	1	1	1
MAINTAINABILITY	4	2	2	2
RELIABILITY	1	1	1	1
AUTOMATION	3	2	3	2
TECHNOLOGY READINESS	1	1	1	1
OPERATIONS SUPPORT	1	1	1	1
COST	1	2	3	1
TOTALS	17	14	16	13
AVG TOTALS	1.5	1.3	1.4	1.2

*RATINGS BASED ON DRAWING (FIG. 4-7)

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Table 4-2 Concept Selection

SHOWER	- ROTATING VACUUM SQUEEGEE
HANDWASH	- ZERO-G HANDWASH
FACEWASH	- ZERO-G FACE WASH OR HANDWASH & WASHCLOTH
ORAL HYGIENE	- TOOTHBRUSH, CONSUMABLE TOOTHPASTE, FLOSS, & MOUTHWASH
EXPECTORATION	- DISPOSABLE TOWEL & VACUUM SINK
SHAVING	- BOTH WET RAZOR & ELECTRIC RAZOR
FEMININE HYGIENE	- STANDARD TAMPONS, PADS, & DISPOSABLE DOUCHE
VOMIT COLLECTION	- COMMODE & COLLECTION BAGS
HAIR BRUSHING/COMBING	- STANDARD COMBS & BRUSHES
MANICURE/PEDICURE	- ENCLOSED CLIPPERS & VACUUM FILE
HAIR CUTTING	- HAIR CLIPPERS, RAZOR COMB, & VACUUM

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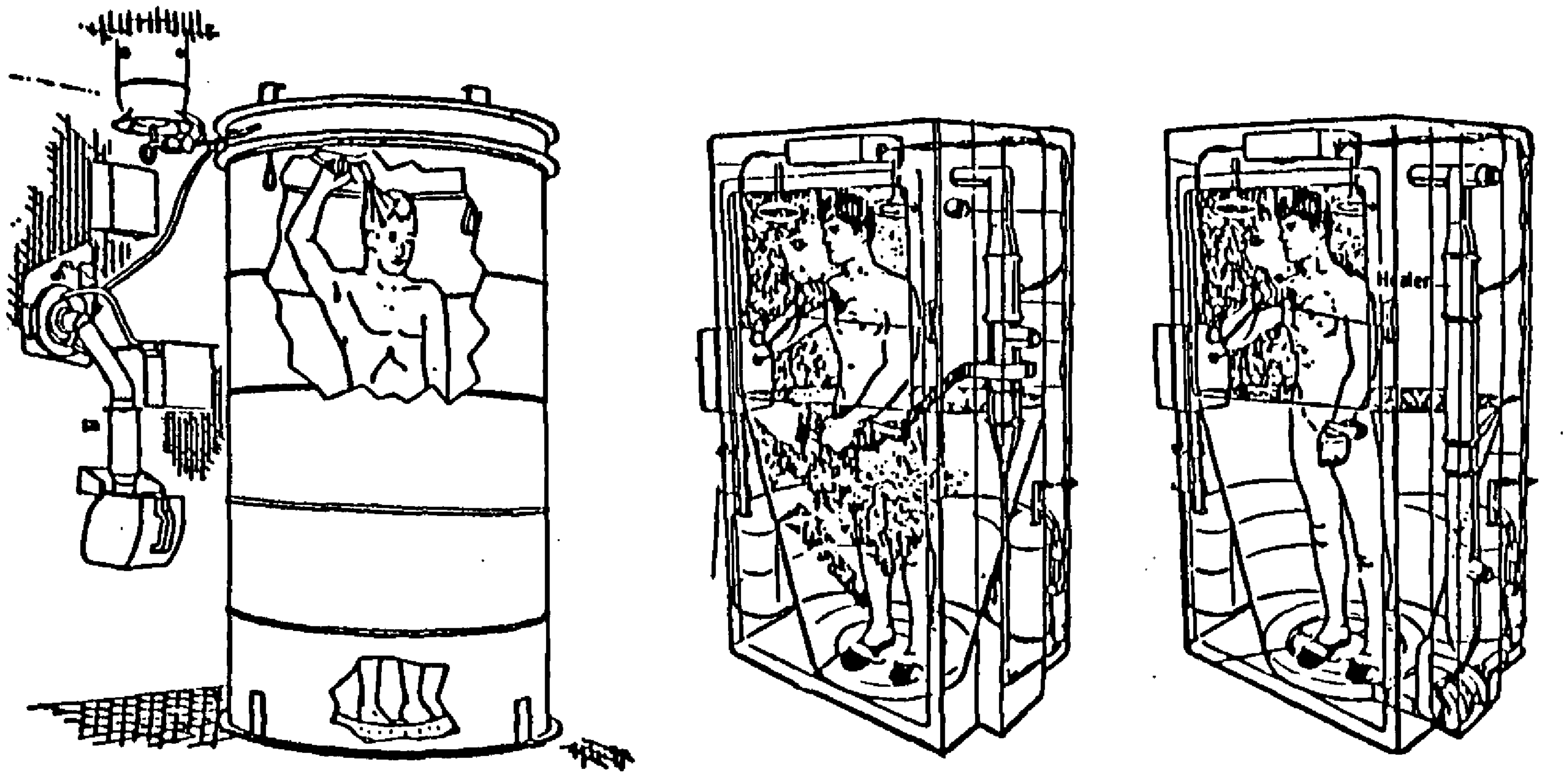
CONCEPT A | CONCEPT B | CONCEPT C



SKYLAB SHOWER | VACUUM CLEAN-UP SHOWER | CENTRIFUGAL CLEAN-UP SHOWER

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Fig. 4-7A Whole Body Bathing Other Concepts

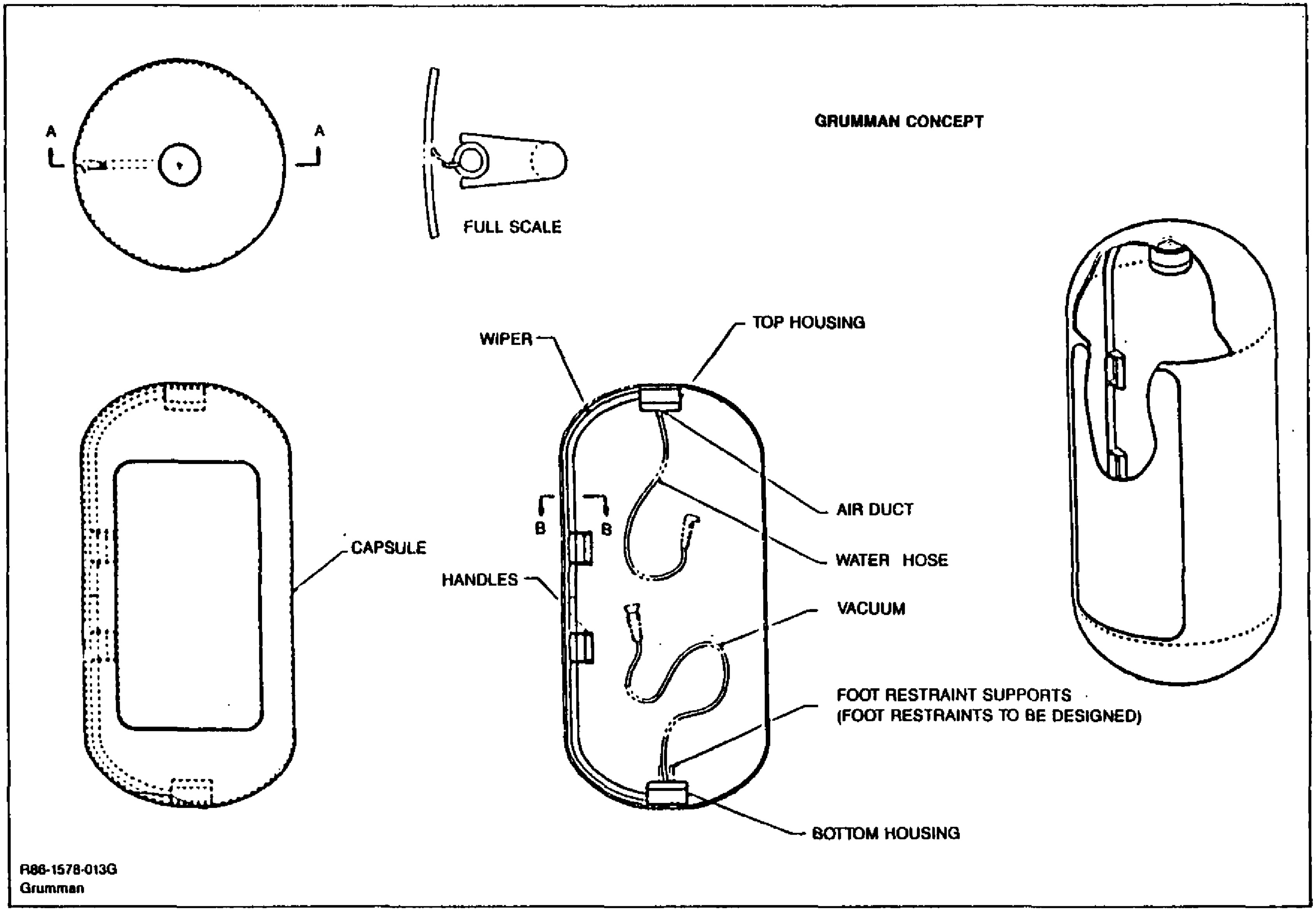

Fig. 4-7B Rotating Vacuum Squeegee Clean-up Shower

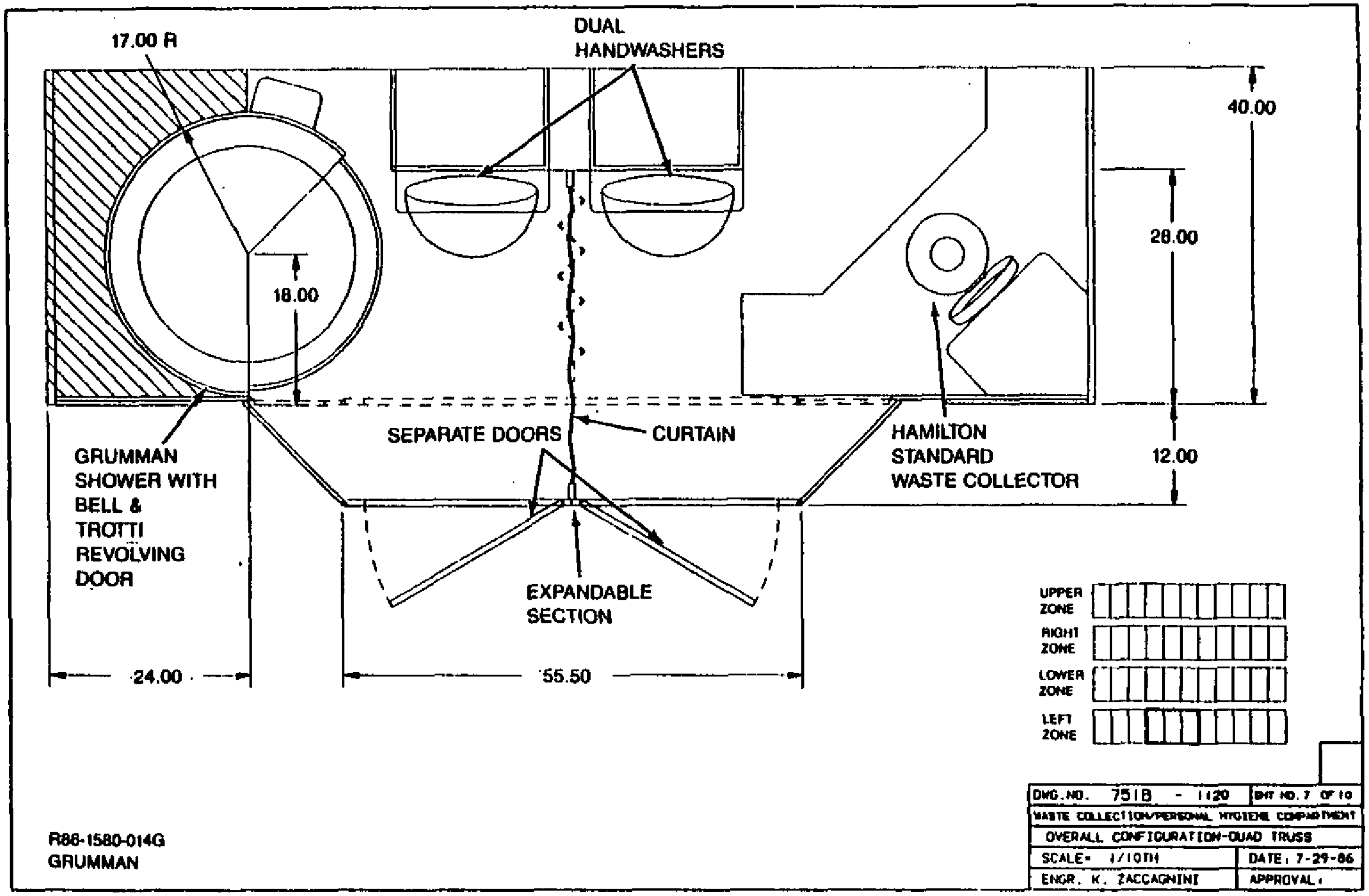

Fig. 4-8A Architectural Study (Plan View)

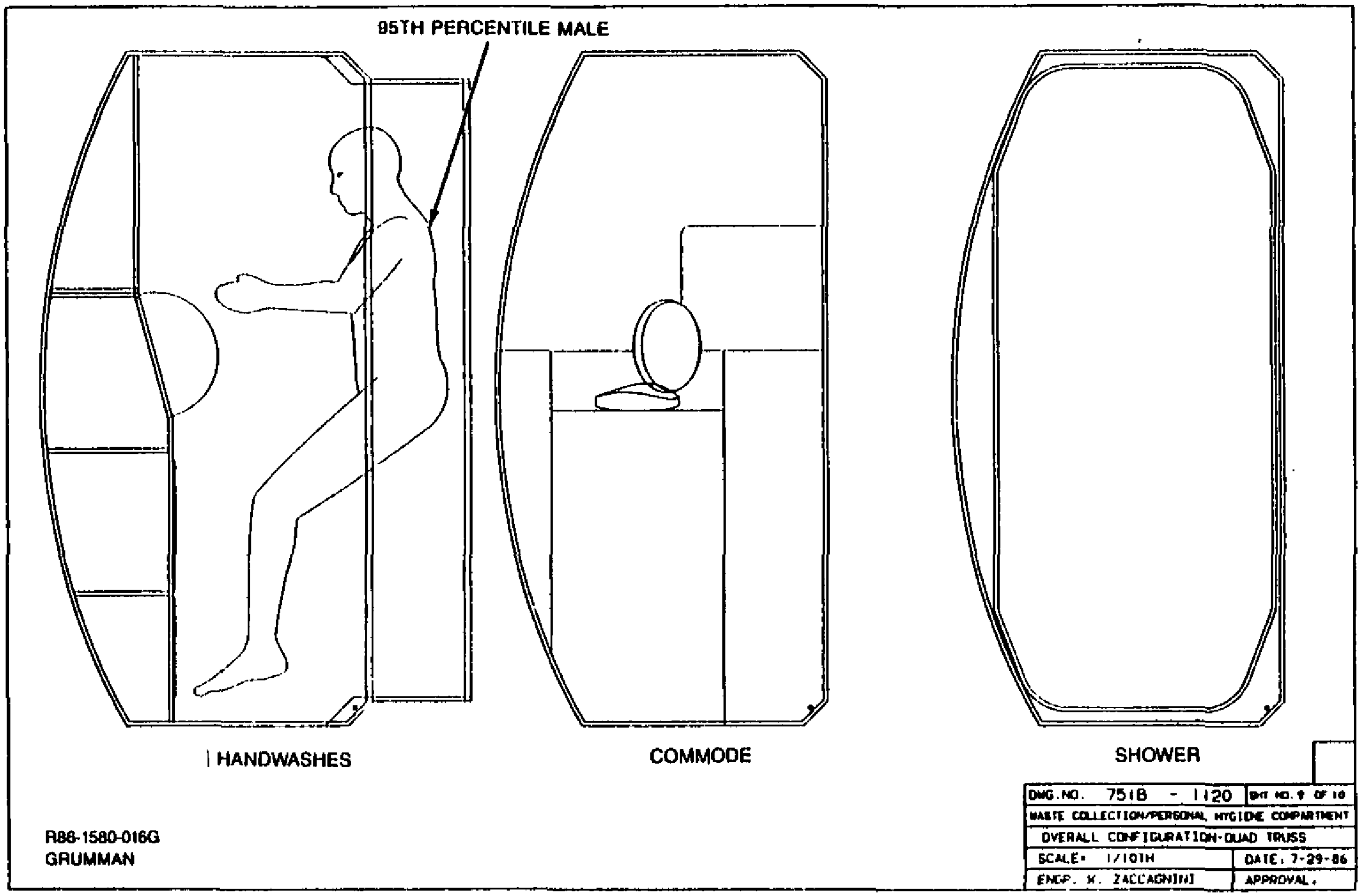

Fig. 4-8B Architectural Study (Side View)

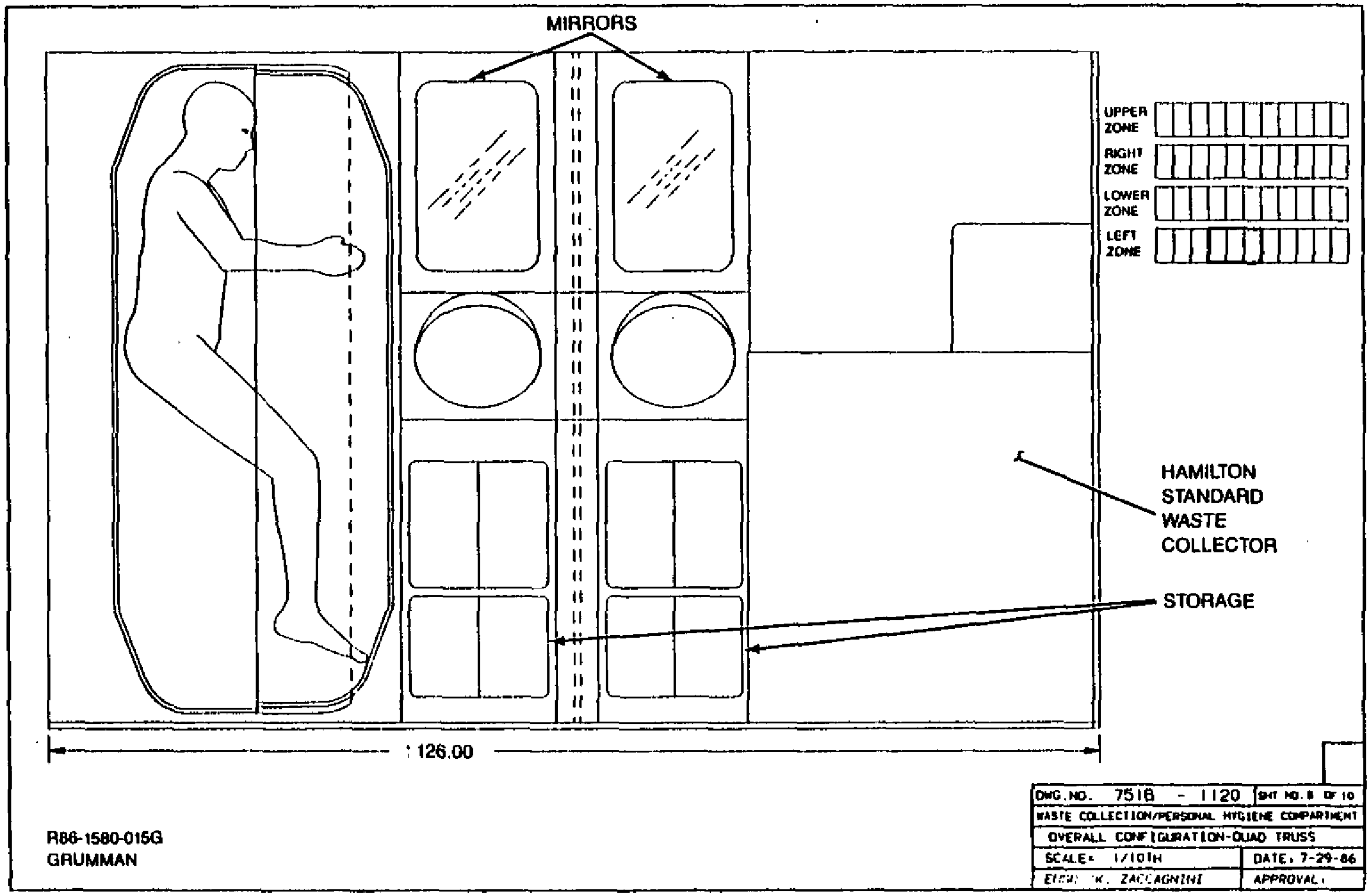

Fig. 4-8C Architectural Study (Front View)

5 - LOW PRESSURE STORAGE

Until now, the astronaut diet, although meeting nutritional requirements and being reasonably palatable, has lacked the variety and interest that can only be provided by the availability of a broad range of fresh foods . This has been of relatively minor importance for the short duration of most space flights, but the desire to provide a more diversified and normal diet increases with the need to sustain a high crew morale for the longer flight time of the Space Station. It is difficult to preserve many fresh fruits and vegetables by "normal" means for extended periods. However, a food preservation system based on Low Pressure Storage (LPS) principles can preserve many "nonfreezable" fresh foods well beyond the abilities of normal refrigeration. Moreover LPS, in combination with other food preservation technologies such as those discussed below, may be capable of extending the shelf life of fresh food even further.

During 1985 Grumman conducted an extensive food preservation literature search augmented by a series of interviews with experts. The results of this program are discussed below.

Low Pressure Storage consists of placing the commodity in an environment in which pressure, air temperature, and humidity are precisely controlled. In addition, the rate at which the air in the storage environment is changed is closely regulated. Each of these four factors acts both individually and in combination with the other three to provide an excellent environment for the storage of perishable agricultural products. No gas other than air need be supplied in a LPS system, whereas in modified atmosphere and controlled- atmosphere storage, other gases are usually required.

The total pressure within the LPS chamber is important since the oxygen level is directly proportional to that pressure. For example, if a chamber is operated at one-half an atmosphere rather than at normal atmospheric pressure (760 mm Hg), the partial pressure of oxygen is likewise approximately one-half normal. However, at lower chamber pressures the partial pressure of water vapor makes up a larger percentage of the total pressure and must be considered in calculating the percent oxygen. For example, at 10 mm Hg and 30°F, there are 4.4 mm Hg of water vapor and 5.6 mm Hg of air. The oxygen level is only 21% of 5.6 (= 1.18 mm Hg) or 11.8% of the total pressure. This lower oxygen content has a profound effect on the respiration rate of agricultural products during storage, thus slowing the aging process. Spoilage is also reduced as a result of the effects of lower oxygen tension on the growth rate of spoilage bacteria.

It is not desirable however, to reduce the oxygen level to zero. Below a certain oxygen partial pressure, the metabolic processes change to anaerobic - thus encouraging fermentation of the commodities. Nor is it desirable to reduce the oxygen level by simply replacing it with another gas. As discussed below, lower oxygen partial pressures are best achieved by reducing the total pressure in order to achieve high gas diffusion and gas exchange rates through the surface openings of the commodities.

The effect of temperature control at atmospheric pressure on the storage life of agricultural products has been extensively studied and is well documented. Respiration is a function of temperature and it is usually desirable to store the commodity at a point just above that temperature at which cold damage might occur. The same is true of LPS. However, LPS systems use cold walls to trap heat and do not rely on conventional convective cooling systems. In the latter, air is forced over freon coils which are at least 5° colder than the food temperature. This conventional arrangement has several undesirable results. Water vapor is condensed on the coil surface making it difficult to maintain a high relative humidity at the temperature prevailing in the storage area. For coil temperatures below 35°F, the coil needs a defrost cycle during which the storage temperature increases. There is also a tendency for the product which is close to the point of discharge of air from the coil surface to be cooled below the "set" temperature. LPS systems use "cold plates" rather than freon coils. Heat evolved from the product is transferred to the inner skin of the container. A glycol-water mixture flowing through coils welded to the inner skin removes this heat as well as heat which enters the container from the outside. The coolant transfers the heat to a heat exchanger located externally. With the "cold plate" method, the temperature is uniform throughout the cold-storage area and is constant through the storage period.

One feature of LPS storage which is frequently overlooked is the role which it plays in "out-gassing" the product. All perishables produce carbon dioxide and consume oxygen so that carbon dioxide escapes and atmospheric oxygen enters the commodity. Other gases and volatile substances which have an adverse effect on storage life are also produced. Table 5-1 lists the most important of these vapors and indicates the effects which they have on "keeping quality." Since these gases are present at much higher concentrations within the commodity than in the air around it, they are forced out across the concentration gradient. Usually these gases move out through air-filled pores located in the surface of the product. The rate at which gas is moved out depends on the following factors:

- The Magnitude of the Concentration Gradient - The concentration gradient may be increased by removing the noxious gases accumulating around the commodity. This is accomplished in LPS systems by the ventilating effect of providing a constant supply of fresh air (at low pressure) to the chamber

Table 5-1 Volatiles & Their Effects

VOLATILE	PRODUCED BY	EFFECT
CARBON DIOXIDE	ALL PRODUCTS	2% CAUSES BROWN STAIN TO LETTUCE; 2 -10% CAUSES "SCALING" OF FRUITS AND VEGETABLES
ETHYLENE	PLANT MATTER AND MOLDS	0.00003 -0.0001% CAUSES FRUIT RIPENING, ABSCISSION OF LEAVES, RUSSET SPOT ON LETTUCE, FORMATION OF "BITTER" PRINCIPLE (ISOCOUMARIN) IN CARROTS AND DECAY IN CITRUS FRUITS AND OTHER PRODUCTS. ALSO INFLUENCES DORMANCY, RESPIRATION BUD GROWTH, AND RETENTION OF GREEN COLOR
ACETALDEHYDE ETHYL ALCOHOL	PLANT MATTER ESPECIALLY AT VERY LOW OXYGEN CONCENTRATIONS. ALSO PRODUCED BY PATHOGENS	LOW CONCENTRATIONS ENHANCE CHILL DAMAGE AND CAUSE PHYSIOLOGICAL DAMAGE IN FRUITS AND VEGETABLES
FARNESENE	APPLES	CHILL DAMAGE
OFF – ODORS	PATHOGENS	OBJECTIONAL QUALITIES ON FRUITS AND VEGETABLES

R86-1578-025

- The Cross-Sectional Area of Available Pores - The total cross-sectional area of the pores available for gas exchange may sometimes be increased by increasing the relative humidity in the storage area. When water enters cells at the surface of fruit the cells assume a more spherical shape, thereby causing the air spaces between them to enlarge sufficiently to increase the pore area available for gas movement. For example, the pore area of an apple peel has been reported to approximately double when the relative humidity is increased from 75% to 95% (Fockens and Meffert, 1972). The humidification equipment inherent in the LPS system can provide this high humidity level, whereas conventional refrigeration limits the highest humidification which can be obtained - the colder coils condense much of the water in the warm air flowing through them, and therefore the system usually cannot maintain a relative humidity higher than 80%. The cold-plate technique used in LPS chambers eliminates cold spots, making humidity levels approaching 100% possible - thus easily assuring attainment of the desired 90 to 95% range

- <u>Gas Mobility</u> - Or the ease which gases move through the air contained in the pores. Since at low pressure there are fewer gas molecules per cubic foot, each molecule moves a greater distance before colliding with another. Their mobility is therefore greater, allowing the gas molecules to diffuse more readily through surface openings.

It is particularly important to remove the internal and external concentration of these undesirable gases. Not only do they damage the stored commodities, but some (e.g., ethylene) act as ripening hormones. LPS removes these gases by the means discussed earlier: low pressure, ventilation, and high humidity.

The minimum LPS longevity (per present knowledge) and the maximum longevity in ordinary refrigeration of some fruits and vegetables are presented in Table 5-2. It should be pointed out that the listed longevity of the LPS stored foods is the minimum known and not necessarily the maximum. A concise definition of the term "longevity" is elusive because it incorporates human taste, opinion, and preference. Hence, although there is room for disagreement, the values listed under "ordinary refrigeration" in Table 5-2 are Grumman's estimate of that point at which a commodity's palatability, texture and visual appeal are still close to peak and have not as yet quite begun a steep decline. By contrast, the meaning of "longevity" as used for LPS is slightly different. It is used to mean 'that point of freshness that a prudent and somewhat demanding buyer would accept without question at the time of purchase,' (freshness at delivery to the consumer marketplace.) Therefore there is an additional storage life expectancy after LPS storage - an additional brief period at normal refrigeration. Grumman experience indicates that this "brief period" is usually half or less than half the values listed under "ordinary refrigeration" in Table 5-2.

Table 5-2 Storage Time in Days

FOOD	ORDINARY REFRIGERATION	LPS (MINIMUM PER PRESENT KNOWLEGE)
ORANGES	21	70
GRAPEFRUIT	21	60
APPLES	21	360
BANANAS	–	60
PEARS	21	60
MELONS	14	30
BERRIES	5	21
PLUMS	14	20
PEACHES	7	14
GRAPES	14	28
PAPAYA	7	30
"BREAKER" TOMATOES	14	28
LETTUCE	14	60
CUCUMBERS	14	30
PEPPERS	14	50
RADISHES	14	30
AVOCADOS	7	35
CORN ON THE COB	5	30

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It is expected that the LPS longevity of some commodities will extend to the order of 90 days - thereby roughly coinciding with the Space Station resupply cycle. It is also expected that the longevity of most commodities will fall short of this goal. It is for this reason that there is a need to investigate the feasibility of supplementing LPS technology with other technologies to further extend freshness and shelf life. Some processes which require investigation are refrigeration at harvest, prechilling prior to permanent storage, hot and cold dips, and various forms of irradiation. These processes are discussed below.

Refrigeration at harvest is a technique that has been used for some years now. It definitely seems worth investigation. One of the most effective preservation techniques should be immediate removal of heat at the time of harvest to slow the respiration rate and to lower the growth rate of spoilage microorganisms. The obvious disadvantage of this technique is the expense and inconvenience of special equipment in the field at the time of harvest of each commodity.

Prechilling prior to permanent storage would be of greatest value if it could be accomplished at the time of harvest. Its purpose is to remove heat quickly - without cold damage - rather than the more gradual heat removal of permanent storage. The rate of cooling of any commodity is primarily dependent upon four factors: (1) accessibility to the refrigerating medium, (2) the temperature difference between the product and the refrigerant, (3) the velocity of the refrigerating medium, and (4) the kind of cooling medium. Cooling with rapidly moving air is one widely used method of prechilling produce. It is the passage of cold air around the product by pressure differential. The use of contact ice and top ice can give effective pre-cooling; both use crushed ice either in direct contact or on top of packed containers. This method is widely used for root crops and melons. Hydrocooling is a method wherein produce is flooded with or immersed in cold water. It is effective if the water is kept cold enough and is changed often enough to reduce the accumulation of decay producing organisms. Asparagus, sweet corn, celery, and peaches are often prechilled by this method. Vacuum cooling is widely used for lettuce, cauliflower, and green peas. This method uses hermetically sealed chambers that are rapidly evacuated and the cooling occurs via evaporation. Moisture loss can be controlled by misting or prewetting.

Hot and cold dips seem to offer some promise of increasing shelf life. Their purpose is primarily to remove pathogens and to some extent to counter the loss of moisture.

Exposure to radiation is perhaps the most hopeful of the supplemental technologies. Ionizing radiation whether from radionuclides or from devices that generate beta rays and X-rays can prolong the useful life of food in several ways:

- *Delay of ripening:* Low-dose *irradiation can delay the* ripening of some fruits, including bananas, mangos, tomatoes, papayas, guavas, pears, and avocados. It apparently alters the biochemical reactions involved in fruit ripening
- The reduction or elimination of insect infestation
- The reduction of the number of microorganisms: At doses much lower than required for sterilization, the shelf life of such highly perishable fruits as strawberries can be extended by delaying mold growth.

High sterilization dosages are not recommended at this time because of their attendant changes in texture, appearance flavor, and unknown safety. With the accumulation of information on this technique, however, then factors may be satisfactorily mitigated.

6 - FOOD PREPARATION-COOKING

Cooking is basically an energy transfer process. A joule of energy delivered to the food will cook the food at approximately the same rate independent of the source of the energy.

Given this viewpoint, comparisons of cooking systems can best be made in terms of efficiency. The efficiency of a cooking device is derived by comparing the power input to the device to the power delivered to the food, i.e.

$$eff = P\ food\ /\ P\ input$$
$$P = Power$$

Using a water load for comparison, current commercial system efficiencies are shown in Table 6-1.

Table 6-1 Current Commercial System Efficiencies

ELECTRIC SKILLET	85-95%
ELECTRIC SURFACE UNIT	60-70%
MICROWAVE OVEN	45-50%
TOASTER OVEN	20-25%
THERMAL/CONVECTION OVEN	15-20%
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To some extent, the efficiencies for these commercial units are limited by economic rather than technical considerations. For example, most of the losses in the microwave oven are in the power supply circuit. A gain of perhaps 20% (from 45-65%) in efficiency could be achieved by exchanging the transformer.

Two other areas of interest impact the choice of cooking systems. These are the flexibility of the system in food preparation methods and the degree to which the process may be automated.

FLEXIBILITY:

In One-G, cooking processes can be basically assigned to one of the following categories:

- Baking & Roasting - Convective heating of food through contact with heated air
- Boiling - Contact and convective heating of food through contact with heated water
- Frying - Direct heating of food through contact with a heated cooking vessel - usually in the presence of some added fats or oils
- Broiling - Radiative heating of food by exposure to a strong IR source
- Defrosting, Warming & Browning.

The processes of boiling, frying, and broiling in space are perhaps, at best, debatable because of their tendencies to release food aerosols into the cabin atmosphere and their lower safety quotients. It appears that a combination forced convection/microwave self-cleaning oven offers high flexibility together with the advantages of speed and reasonable power efficiency.

The main technical challenge in system development will be increasing the efficiency and scaling down the size of the system.

The nature of the gases released during the self-cleaning process is understood. A compact and efficient system for scrubbing these gases from the effluent air stream will have to be developed. This is a well understood process and should present no great difficulties technically.

COOKING AUTOMATION

The cooking automation system will be an intelligent, centralized control point for the entire food system. It will be responsible for the automatic control of food heating, system power budgeting, crew dietary monitoring, inventory control, meal planning, and food system diagnostics.

COOKING CONTROL

In the oven and in skillets, the system is programmed with a standard preparation cycle for each food item. This cycle could be adjusted through manual intervention via crew controls, or a crewmember specific cycle could be associated with the foods to allow the system to custom cook foods to individual taste.

The food items and crewmembers would be identified to the system through a bar code reader attached to the cooking units.

DIETARY MONITORING

Identifying the crewmember associated with each food item provides other benefits as well. The system will monitor crew nutrient intake and recommend supplements to be added to the diet. These supplements could be made available through dietary restrictions and also in pill form. This feature of the system will allow the crew to eat foods they prefer, while still maintaining necessary nutrient control.

MEAL PLANNING

The system would accept crew menu selections through a CRT screen. This could be local to the food area or on the Space Station computer system. The meal selections will be used to generate an ordered picklist. This list will display the foods required for a meal in stowage location order, thus allowing for efficient retrieval of the meal components by the crewmember(s) doing the cooking.

Once all the items have been retrieved, the system will display recommended processing steps for food preparation. For example, the system could plan for all of the heavy entrees to be prepared in one oven that would cycle on high power to heat these items, while the other items are using lower power. Combined with proper portion sizing, this system could reduce most meals to a single 'load and go' cycle for the crewmember.

When the automatic cooking process is completed, the system informs the crewmember that their meal is ready, and holds the food at serving temperature.

INVENTORY CONTROL

The centralized meal planning system would allow for efficient inventory control. Adding a bar code reader at the food storage locations would adapt the system to "ad hoc" food removal. Food items removed on an unplanned basis; i.e., snacks and drinks, could be quickly scanned at removal. This will update the inventory without impacting crew time.

The inventory data would be collected for the generation of a resupply order. This order would (by the nature of the system) reflect crew preference "on orbit" and should improve the responsiveness of the resupply system.

Given the extended nature of the Space Station mission, the system would also monitor the shelf life of the foods and print out a list of expired foods to be disposed of at resupply time.

SYSTEM POWER BUDGETING

Cooking is an energy intensive process and energy is in short supply on the Space Station. As part of its function, the system will control the on/off cycling of the various cooking and clean up elements of the food system on a real time basis. At a minimum, the system will monitor continuous power and cooking schedule.

The control system will be designed to take advantage of the pulsed nature of many of the cooking processes to reduce peak power and continuous power demands while holding cooking times to a reasonable value.

FOOD SYSTEM DIAGNOSTICS

The control system will provide local status and fault detection for the food system. The system will (at a minimum) isolate faults to crew replacable modules in the system. The control system is shown in Fig. 6-1.

Fig. 6-1 Galley Computer Control System

7 - FOOD SERVICE SYSTEM

The Space Station Food Service System is critical to successful manned operations. This study, accomplished with General Electric Houston under contract, provides an understanding of the system, its needs, its many functions, and the advanced system hardware essential to its performance. The system should be adaptable to varying work schedules and personal preferences, as well as being capable of minimizing the labor required in meal preparation.

The food system is an interdependent collection of subsystems for food packaging, storage, preparation, consumption, and clean-up. For example, the choice of food storage techniques has a large impact on the amount of time, labor, and energy required to prepare the food for consumption.

For the purposes of this study, the food system has been broken down into the following components:

FOOD PACKAGING - MODULAR & LIQUIDS
This subsystem addresses the food itself - its size, shape, volume, weight, and packaging. The choices made for this subsystem are most dependent on the available storage and preparation subsystem. The packaging selected will have a large impact on the cleanup and trash handling subsystems.

FOOD STORAGE
This subsystem addresses the storage requirements for the food prior to preparation and consumption. The choices made for these subsystems are related to the selection of foodstuffs, the ways

in which these foods are packaged, and the amount of food to be stored.

- Cold storage - freezer/refrigerator packaged food and some liquid
- Ambient storage - modular and bulk storage plus some liquid.

FOOD PREPARATION

This subsystem addresses the several categories for preparation of food for consumption. The choices made for this subsystem will depend on the selection of foods and food storage systems.

- Ambient food preparation
- Hot food preparation
- Bulk food preparation
- Liquid food preparation.

FOOD CONSUMPTION & CLEANUP

This subsystem encompasses those items, i.e., dishes, utensils, required for food consumption, and the cleaning of these items and the entire galley system. It is also responsible for trash collection and processing.

A number of different concepts were considered for each of the above food service subsystem elements; two or three of the most promising were evaluated in detail to support the selection of the most promising. Evaluation and trade-offs were made of the following:

- Food System
  - Meal selection and retrieval
  - Automation
  - Packaging
  - Storage
- Refrigerator/Freezer
  - Vapor compression
  - Thermoelectric

- Dedicated radiator

- Hot Food Preparation
  - Microwave/convection oven
  - Reusable microskillets
  - Disposable microskillets
- Drink Dispensing
  - Liquid concentrate
  - Drink cups
- Food Consumption/Cleanup
  - Trash collection
  - Trash compaction.

A summary of the trade-off study, including the preferred selection (indicated by the numeral 1), is provided in Table 7-1. This is followed by a summary table of the logistic evaluation of these same elements (Table 7-2).

Table 7-1 Trade Study Summary

CATEGORY	DESCRIPTION	WEIGHT (KG)	VOLUME (M^3)	PANEL SPACE (M^3)	HEAT REJECTION		KWH POWER (PER YR)	MAINTENANCE MAN HOURS (PER YEAR)	CREW TIME (MAN YEAR)	FINAL RELATIVE COST	SELECTION RECOMMENDATION
					BTU/HR	KWH					
REF/FRZR	VAPOR COMPRESSION	121	0.96	1.24	125/225	37/66	533/964	4	73	6,016	1
REF/FRZR	THERMOELECTRIC	102.3	0.81	1.05	125/225	37/66	719/2321	6	73	4,441	2
REF/FRZR	DEDICATED RADIATOR	236.4	0.81	1.05	125/255	37/66	228/403	6	73	4,4889	3
FOOD PREP	COMBO OVEN	31.8	0.101	0.137	7445	2182	796	32	245	58,221	1
FOOD PREP	REUSABLE MICROSKILLET (INCLUDES CONTAINMENT)	13.5	0.101	0.137	1382	405	850	20	1971	49,915	2
FOOD PREP	DIPOSABLE MICROSKILLET (INCLUDES CONTAINMENT)	11.4	0.101	0.137	1603	470	986	20	1971	51,324	3
TRASH COLLECTOR	RIGID	22.7	0.27	0.346	N/A	N/A	4818	5	245	6,703	1
TRASH COLLECTOR	FLEXIBLE	18.2	0.09	0.117	N/A	N/A	4818	5	365	8,442	2
TRASH COLLECTOR	TRASH BAG	0.23	0.002	N/A	N/A	N/A	0	0	548	11,276	3
TRASH COMPACTOR	SCISSOR DRIVE	54.5	0.35	0.455	N/A	N/A	1095	35	18	1,598	1
TRASH COMPACTOR	TELESCOPING SCREW	61.36	0.323	0.420	N/A	N/A	1095	35	18	1,640	2
TRASH COMPACTOR	MULTIPLE SCREW	72.73	0.323	0.420	N/A	N/A	1095	35	18	1,713	3

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Table 7-2 Logistics Spares & Consumables

ITEM	LOGISTICS SPARES	90-DAY EXPENDABLES	WEIGHT (KG)	VOLUME (M^3)	WEIGHT (KG)	VOLUME (M^3)	REMARKS
VAPOR CYCLE REF/FRZR	2 EQUIV UNITS	0	242	1.92	0	0	
THERMOELECTRIC REF/FRZR	3 EQUIV UNITS	3 SPARE THERMOELECTRIC MODULES	307	2.43	41	0.08	
DEDICATED RADIATOR REF/FRZR	2 EQUIV UNITS	2 SPARE PUMPS	205	1.62	14	0.06	DOES NOT INCLUDE DEDICATED RADIATOR
COMBO OVEN	4 EQUIV UNITS	0	127	0.40	0	0	
REUSABLE MICROSKILLET	250	60	114	0.75	27	0.18	
MICROSKILLET CONTAINMENT SYSTEM	4 EQUIV UNITS	3 WIRING SETS	38	0.40	3	0.03	
DISPOSABLE MICROSKILLET	450	1850	31	5.62	97	23.13	
RIGID TRASH COLLECTOR	4 EQUIV UNITS	0	54.5	1.08	0	0	
FLEXIBLE TRASH COLLECTOR	4 EQUIV UNITS	0	63.6	0.37	0	0	WALL HOOKS, BAG OUTSIDE, FAN IN RACK
TRASH BAG TRASH COLLECTOR	N/A	N/A	N/A	N/A	N/A	N/A	WALL HOOKS FOR BAG REQUIRED
SCISSORS DRIVE TRASH COLLECTOR	2 EQUIV UNITS	0	109	0.7	0	0	
TELESCOPING SCREW TRASH COMPACTOR	2 EQUIV UNITS	0	123	0.65	0	0	
MULTIPLE SCREW TRASH COMPACTOR	2 EQUIV UNITS	0	146	0.65	0	0	
TRASH COMPACTOR BAGS	125	30	14.2	1.31	3.41	0.32	
TRASH COLLECTOR BAGS	1750	432	150	18.34	49	4.53	

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The food service element selection indicated was taken as the recommended starting point for further definition and preliminary design. The culmination was the design and construction of two Galley/Wardroom rearrangeable mockups.

- The Bethpage mockup is part of the overall habitat. While it is essentially an appearance mockup, it has been used to examine crew activity and task timelines
- The Houston galley/wardroom mockup was a joint effort with GEH and consists of two mockups. One is high fidelity with the capability of component functional demonstration to the level of opening/closing storage, oven access, freezer food containment, and computerized menu planning, etc. In addition, it is readily capable of configuration rearrangement. It has been used for several one-G simulations and permits design evaluation with crew task insight. The second is limited in total size but provides functioning components permitting actual food preparation, including heating, freezing, trash compaction, and a functioning Coca-Cola dispenser.

These mockups have and may continue to offer an engineering tool which will support further investigation into galley/wardroom technology and the related crew operations.

8 - CLOTHES WASHING & DRYING

The process of washing clothes is basically one of applying mechanical forces to clothes in a cleaning solution, the main objective being to generate a large amount of interfacial scrubbing between the layers of fabric.

The amount of energy required to wash a load of clothes greatly depends on the material from which the clothes are made. Using 100% hard finish cotton as a standard, we have the following energy input ratios:

Cotton	1.0
50/50 Blend	0.5
Polyester	0.1

In cotton, the cleaning action is primarily mechanical. In synthetic materials, cleaning is predominately chemical in nature.

For the drying cycle, the dominant influence on energy consumption is the residual water content of the fabric at the beginning of the cycle. In cotton, this can be as high as 200% by weight, while for synthetics normal values range from 10% to 20% by weight.

To achieve effective washing action for a mixture of fabrics, the selected system should provide for thorough agitation during the wash and rinse cycles. Three basic methods for providing this agitation have been identified:

- Variable Volume - Agitation is provided by varying the spacing between two or more system components. (wringer, pistons, plunger, etc)

- Body Forces - Agitation is provided by changing the momentum vector or one or more system components relative to fabric motion (agitator, rotating basket, paddles, etc)
- Momentum Transfer - Agitation provided through a working fluid (jet spray, vortex, fluidic oscillators, etc).

Each of these approaches to washing can be configured in a system that also allows for drying the clothes in the same unit. For each of these systems the basic cycle is the same, the only significant difference being the method by which interfacial scrubbing is achieved.

A typical cycle might be as follows:

- Load clothes into washing cavity and secure cavity seals
- Fill the cavity with a water detergent solution, allowing as much of the air as possible to escape from the cavity
- Agitate the water clothes mixture (the length of this cycle will depend on the fabric)
- Drain (water is pumped from the cavity assisted by an airflow system)
- Extraction (residual water is removed from the fabric by the application of mechanical energy)
- Rinse (the fill process is repeated, this time with clear water to dilute the detergent residual in the fabric)
- Agitate the rinse water clothes mixture to facilitate dilution of residual detergent
- Drain and extract rinse water as for wash cycle
- The rinse cycles (steps 6 - 8) are repeated as needed to achieve sufficient dilution of the residual detergent. The determining factor in the rinse will be the amount of detergent that can be safely left in the dry clothes

- Drying cycle (heated air is forced through the cavity while some gentle agitation is provided). The agitation promotes tumbling in the clothes for softness in the final product. This process is continued under the control of a dryness sensor(s) until residual water content of clothes is at or below 3% by weight.

9 - SPACE STATION TRASH MANAGEMENT SYSTEM STUDY

A study was performed as a preliminary step in the development of a comprehensive trash management system for the Space Station. Problems related to trash management were first defined. Systems to control these problems were then investigated. The effects of trash on Space Station operations were examined along with the types and quantities of trash expected to be produced in the Station. The next steps taken were to develop groundrules for the system development and to lay out a generic system for trash management.

Once the generic system was outlined, comparisons were made between different options for system components. Each component was rated for its performance in a number of different categories. Possible backup components for each component were also considered.

After examining the components, a baseline trash management system and five alternate systems were proposed and rated using the same evaluation criteria used in scoring system components. The baseline system using a rigid collector, compactor, and freezer storage, (all of which are fairly simple to operate and could likely be developed for space use with the least development effort) appears at this stage of analysis to be a good choice.

This study, of necessity, was often based on assumptions or rather tentative information. It should be constantly updated as related systems (food, waste management, housekeeping, health service, etc) are developed. As more is learned of the type and quantity of trash, the trash management system options must be further investigated. All of this information gathering and analysis will provide the necessary background for selecting a trash management system complete with the necessary feedback and controls.

Liquid trash is an example of the many unresolved questions relating to trash management. For example, what does the crewmember do to dispose of an unfinished cup of beverage? Does he throw it and its container into the trash collector or does he first pour the liquid into the ECLSS waste water system? Another major unresolved concern is the need for a backup for storing frozen trash should the food freezer fail. Since it will be virtually impossible to sterilize the trash prior to freezer storage, gas production and attending obnoxious odors can be expected as frozen trash thaws and microbial action commences.

10 - INTERNAL CONTAMINATION CONTROL SYSTEM STUDY

The object of the study was to identify the problems which may be created in the Space Station by contaminants and to examine applicable internal contaminant control systems.

Our approach was to first identify the contamination sources and the general types of contaminants expected from them. Next, we selected specific, likely contaminants from each of these sources and noted the manner in which they are transmitted and their adverse effects on crew or equipment. Maximum limits, proposed by various groups, on internal contaminants were reviewed along with suggested methods of prevention, control and monitoring.

Finally a typical, or baseline, air contamination control management system for both the habitation and laboratory modules was outlined and discussed. It is anticipated that these systems will become more detailed and probably modified as this study continues.

The importance of a complete and efficient Internal Contamination Control System cannot be overemphasized. The Space Station will be a closed environment with an unlimited life and a change of crew every ninety days. A buildup of contaminants, microbial or otherwise, must be avoided. Expected contaminants can be broken down to five basic categories: pathogens, chemicals, particulates, radiation, mechanical (vibro-acoustics) and thermal. All these classifications are causes for concern and require reliable monitoring and control systems. Prior to the design of these systems, the contaminants must be identified and their effect on both the crew and on instrumentation (electronic and optical) must be assessed.

Potential emergencies such as fire, explosions, chemical/ biological spills and epidemics must be studied and corrective actions planned.

As more is learned of the nature of experiments to be conducted, a better understanding of the experiment-specific contaminantes will be gained. Likewise, as the various systems such as Waste Management, Trash Management, ECLSS, etc, are further defined, the new information should be used to constantly update this study.

11 - RECOMMENDATIONS

Studies of Waste Collection and Personal Hygiene Systems have been conducted to better understand the equipment and its impact on the Space Station. With the exception of Full Body Showers, it is believed that sufficient IRAD efforts have been expanded to satisfy those objectives and therefore no further investigation is recommended. Additional technology development efforts are recommended as follows:

- Full Body Shower
  - Design and build a prototype of the Grumman proposed radial wiper and shower stall. Test in 1 g and 0 g environments to verify radial wiper operation, optimum cone angle, delta P, velocity and flow rate of air and water and CO_2 removal and management.
- Low Pressure Storage
  - Establish, by test and/or literature review, realistic LPS storage life expectancies for selected agricultural commodities
  - Determine the ability of other food preservation technologies to still further extend the shelf life of fresh foods
  - Prepare a conceptual design of the LPS equipment and determine the weight, volume, power and cost impacts
- Trash Management and Internal Contamination
  - Conduct a literature search of Soviet Trash Management and Internal Contamination experience
  - Determine the volume and weight of the accumulated compacted trash for the various food packaging methods presently under consideration
  - Establish the optimum filtration requirements for microbial control by analysis and consulation with experts

- Galley Architecture and Design
  - Conduct mockup simulations and scenarios of various additional galley/wardroom arrangements to determine optimum human productivity and crew acceptance
  - Design, build and test in zero gravity: a prototype clothes washer-drier
  - Design, build and test in zero gravity: a brassboard model of automatic defrosting equipment for refrigerator-freezers
  - Conduct galley/wardroom mockup simulations and crew activities to establish the impact of galley/wardroom equipment on other interfacing systems and vice-versa.

12 - REFERENCES

1. Advanced Development Plan, WP2, Space Station Definition and Preliminary Design Phase, Grumman Report 751B/GR05-01, 1 May 1985.

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3. Manned Space Systems Habitability, Crew Support Systems Interim Report, Grumman Report SS005-ATD-07, 11 April 1986.