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IMPROVED ORBITER WASTE COLLECTION SYSTEM STUDY

Final Report

NOVEMBER 16, 1984

MDC H1360

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THERMODYNAMICS, ENVIRONMENTS & BIOTECHNOLOGY
DESIGN & TECHNOLOGY

CONTRACT NASA 9-17181
DRL: T-1837, LINE ITEM 1
DRD: MA-183TH

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FINAL REPORT

IMPROVED ORBITER WASTE COLLECTION

SYSTEM STUDY

1.0 ABSTRACT

This report is the result of a three month study under NASA contract NAS 9-17181 to develop design concepts for improved fecal waste collection both on the Space Shuttle Orbiter and as a precursor for Space Station. The Study was initiated to resolve the inflight usage problems associated with the existing Orbiter waste collection subsystem and to provide a basis for the selection of an optimum waste collection system concept which may utlimately result in the development of an Orbiter flight test article for concept verification and subsequent production of new flight hardware.

Two concepts have been selected for Orbiter and are shown in detail in Section 6.0, Task 4. Additionally, Section 6.0, Appendix A contains one concept selected for application to Space Station. The contractually required Systems Requirements Definition Document and a packet of layouts are included as appendices under separate covers.

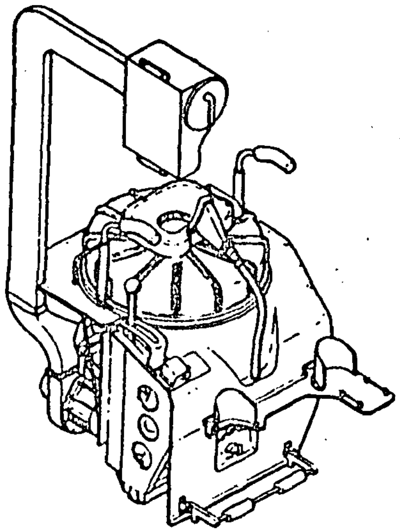
This document constitutes completion of the final task in the study.

2.0 RESULTS

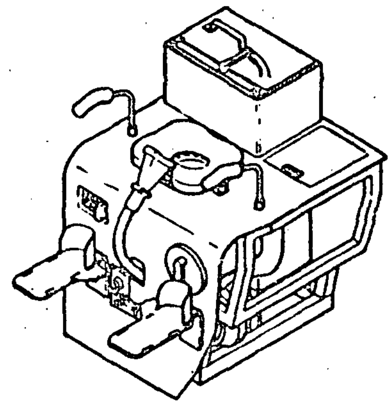
The study culminated in the selection of two concepts which are feasible for installation into the Orbiter. The first concept is a repackaged Skylab waste collection system (WCS) requiring very little development. The second concept is a centrifugal compaction device which requires additional development but is retrofittable directly into the existing Orbiter commode structure. A third system, the closed loop macerator, is suggested as a Space Station WCS as it has no venting requirements (see Figure 1). These concepts are discussed in detail in the text of Section 6. The data is in the format of the Design Concept Presentation given at Johnson Space Center on November 2, 1984.

The Design Concept Presentation is organized as shown below. Note the addition of Appendices D and E which are under separate cover.

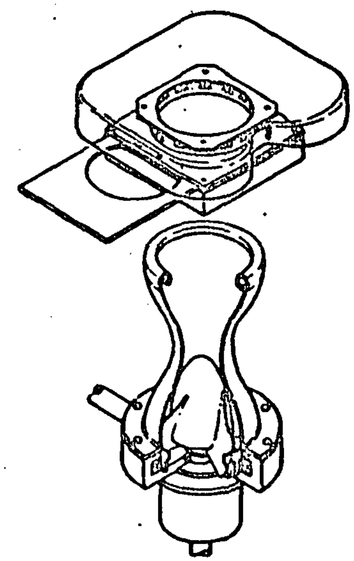
SELECTED CONCEPTS



CENTRIFUGAL COMPACTION CONCEPT



1-G SKYLAB CONFIGURATION



CLOSED LOOP MACERATOR CONCEPT

FIGURE 1

Organization of Design Concept Presentation (Section 6.0):

3.0 CONCLUSIONS

The 1-G Skylab Configuration and Centrifugal Compaction Concept Waste Collection Systems have been defined as optimal choices for retrofit into the Shuttle Orbiter. The first concept has the advantages of being a simple, proven system with minimal risk and low development. The need for fecal bag handling is present, but bag sealing and handling methods have been significantly improved over the original Skylab system. Similarly, the Centrifugal Compaction Concept utilizes a collection method similar to that of the existing Shuttle system while adding the ability to compact waste to increase storage capacity. Additionally, this concept utilizes the existing commode structure and plumbing network, making it easier to retrofit into the Orbiter. Key features of both concepts include their use of existing Orbiter commode flight hardware when possible and the capability to perform in-vehicle turnaround.

4.0 RECOMMENDATIONS

Implementation of follow-on tasks such as additional study, preliminary design, development of specific concepts, or test hardware procurement are options recommended to NASA.

5.0 APPLICABLE DOCUMENTS

The documents applicable to the Improved Orbiter Waste Collection System Study are given below.

5.1 NASA Documents

	Shuttle Flight Operations Manual, Vol. 12 - Crew Systems, Basic PCN-6, JSC, November 15, 1983
WCS 2102B	Waste Collection System Workbook, JSC, March 2, 1984
TM X-64814	MSFC Skylab Mission Report - Saturn Workshop, October, 1974
MSC-01549	Skylab Program Operational Data Book, Vol. IV, Skylab-I Performance Data, Revision A, JSC, October 1972
	Improved Waste Collection System Initial Review [Handout], JSC, July 20, 1984

5.2 MDAC Documents

1B87234-1	Separator, Centrifugal Urine, February 2, 1971

5.3 Rockwell International Documents

MC282-0069	Waste Collection Subsystem Procurement Document, January 24, 1984

5.4 General Electric Documents

47J232750	WCS Assembly [Drawing], October 5, 1982

6.0 DESIGN CONCEPT PRESENTATION MATERIAL

The following text contains material from the November 2, 1984 Design Concept Presentation at Johnson Space Center.

VEC899

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IMPROVED ORBITER WASTE COLLECTION SYSTEM DESIGN CONCEPT PRESENTATION JSC

2 NOVEMBER 1984

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BACKGROUND

McDONNELL DOUGLAS CORPORATION

CHRONOLOGY OF EVENTS

VEC901

Initial Contact by JSC	
RFP	March 30, 1984
Study Proposal Submitted	May, 1984
ATP	July 6, 1984
JSC Initial Review	July 20, 1984
Midterm Review	September 27, 1984
Formal Presentation	November 2, 1984
Final Report Due	November 16, 1984

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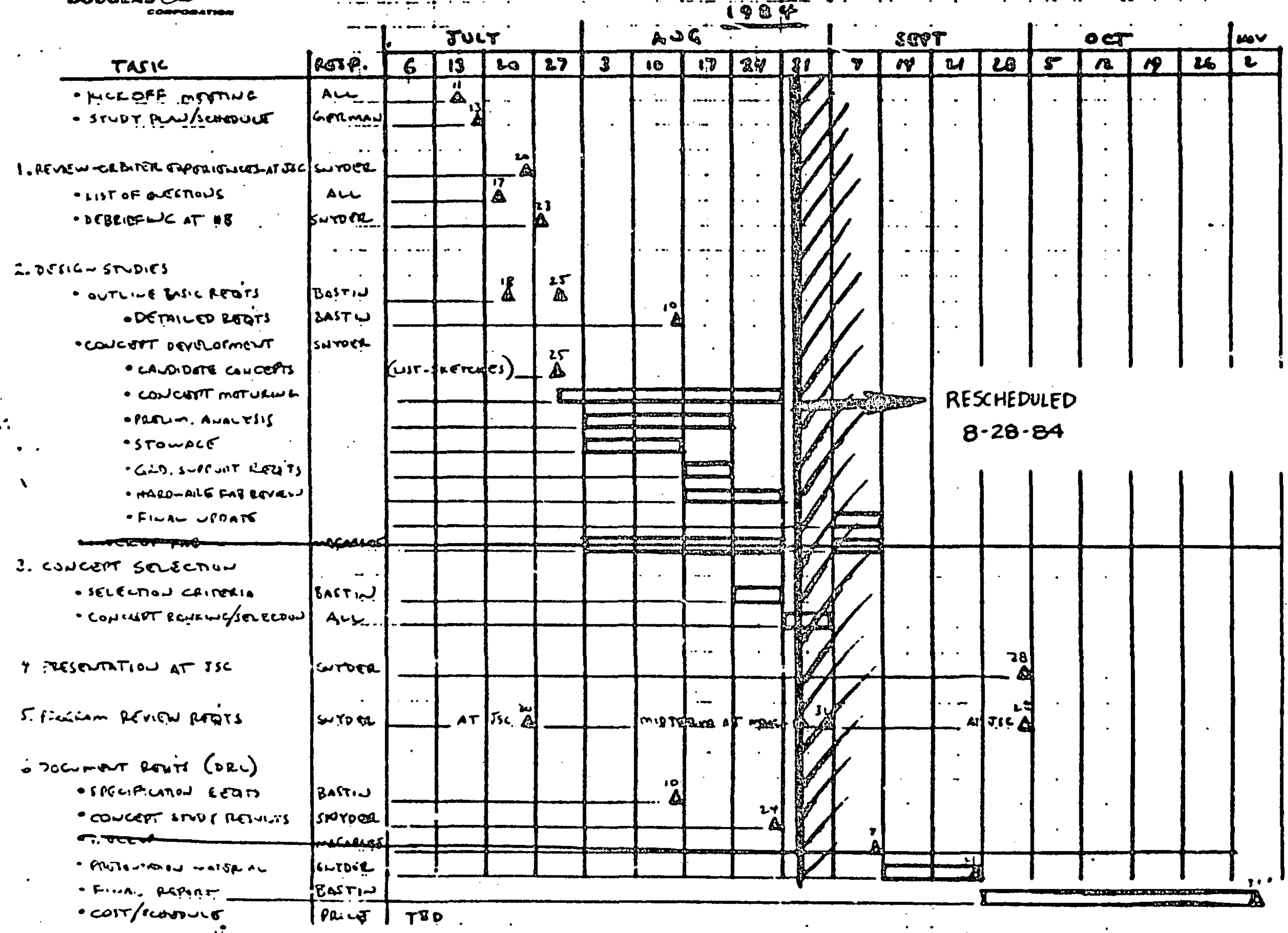
ORBITER WASTE COLLECTION SYSTEM - PLAN

7-13-8[illegible]
German



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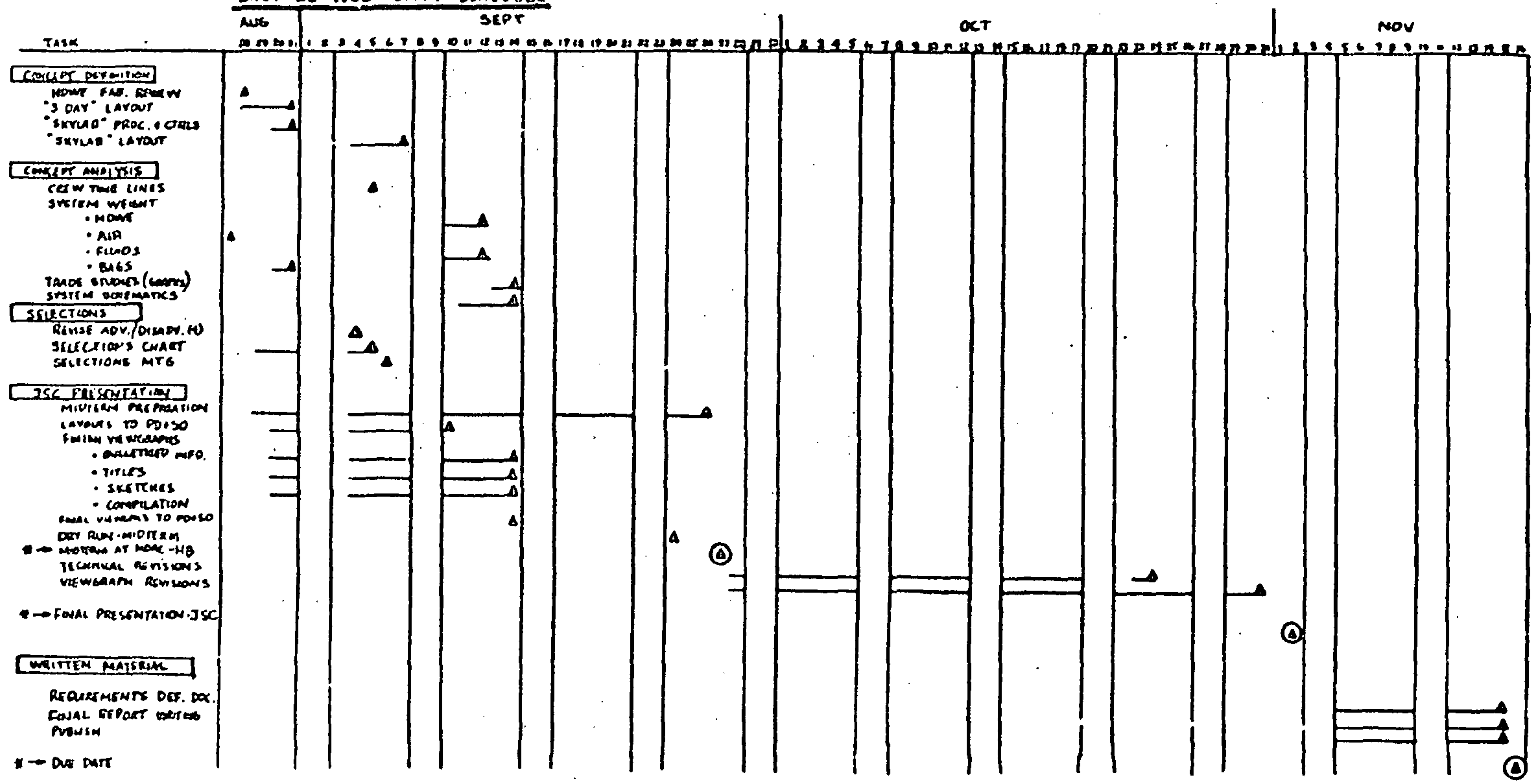
SHUTTLE WCS STUDY SCHEDULE



TASK 1
ORBITER WASTE COLLECTION SYSTEM INITIAL REVIEW

- Overview of Existing Shuttle WCS
- Subsystem Operating History
- Identification of Development Needs

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TASK 1
ORBITER WASTE COLLECTION SYSTEM INITIAL REVIEW
20 JULY 1984

VEC903

Summary of Inflight Problems to Resolve in Improved Waste Collection System

- Generation of Fecal Dust/Particulate Matter
- Odor
- Paper Storage Separate From Feces
- Lack of Compaction Capability
- Corrosion
- Buildup of Urine Solids
- Noise
- Lengthy Turnaround Time
- Component Failures
- Excessive Crew Involvement and Cleanup

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VEC904

TASK 2
DESIGN STUDIES

- Analytical Studies
- Sketches and Layouts

REQUIREMENTS

GENERAL REQUIREMENTS

- O EFFECTIVELY AND HYGIENICALLY SEPARATE WASTES FROM THE CREWMEMBER
- O STORE THE WASTES IN A SAFE, ODORLESS FORM SEPARATE FROM THE CREW COMPARTMENT

SPECIFIC REQUIREMENTS

- O ACCOMMODATE USE BY BOTH MALES AND FEMALES
- O URINE COLLECTION INTERFACE SHOULD BE INDIVIDUAL
- O BE STRAIGHT-FORWARD AND SIMPLE IN USE AND NOT TAKE EXCESSIVE TIME
- O CAPACITY SHOULD NOT BE LIMITED BY PAPER; I.E., SEPARATE PAPER COMPARTMENT OR COMPACTION FOR PAPERS AND/OR FECES.
- O REQUIRE ONLY MINIMAL TRAINING FOR SUCCESSFUL CREW USE
- O PROVIDE NO HANDLING OF WASTES BY THE CREW
- O PROVIDE PROPER STOOL SEPARATION DURING USE
- O PROVIDE ADEQUATE BODY STABILIZATION FOR USE
- O PROVIDE POSITIVE COLLECTION AND RETENTION OF WASTES AND PAPER FOR A MINIMUM OF 210 MAN-DAYS OF USE
- O INCLUDE PROVISIONS FOR BACTERIA AND ODOR CONTROL
- O BE QUIET DURING OPERATION; NOT DISTURB SLEEP (GOAL: NOISE CRITERIA (NC) 40)
- O BE MAINTAINABLE AT THE LAUNCH SITE; REQUIRE MINIMAL TURNAROUND TIME/IMPACTS (GOAL: IN-VEHICLE GROUND MAINTENANCE)
- O MINIMIZE EXPENDABLES, WEIGHT, POWER, AND VOLUME WITHOUT COMPROMISING SUBSYSTEM OPERATIONAL CHARACTERISTICS
- O BE RELIABLE AND SHOULD INCUDE REDUNDANT ELECTRICAL COMPONENTS AND DUAL SEALS WHERE PRACTICAL
- O BE RETROFITTABLE WITHIN CURRENT SYSTEM COMPARTMENT INTO THE ORBITER FLEET IN THE FIELD, I.E., KSC

CRITICAL DESIGN/TRADEOFF PARAMETERS

VEC905

- Feces Separation, Collection, and Containment
- Paper Disposal
- Ease of Operation
- Body Stabilization
- Noise
- Maintainability
- Weight
- Power
- Retrofittability
- Design Risk
- Cost

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VEC906

TASK 3
DESIGN CONCEPT SELECTION

- Evaluate Concepts With Respect to Waste Collection Subsystem Requirements
- Ranking of Concepts in Order of Desirability
- Selection of an Optimum Concept

SELECTION PROCESS

VEC907

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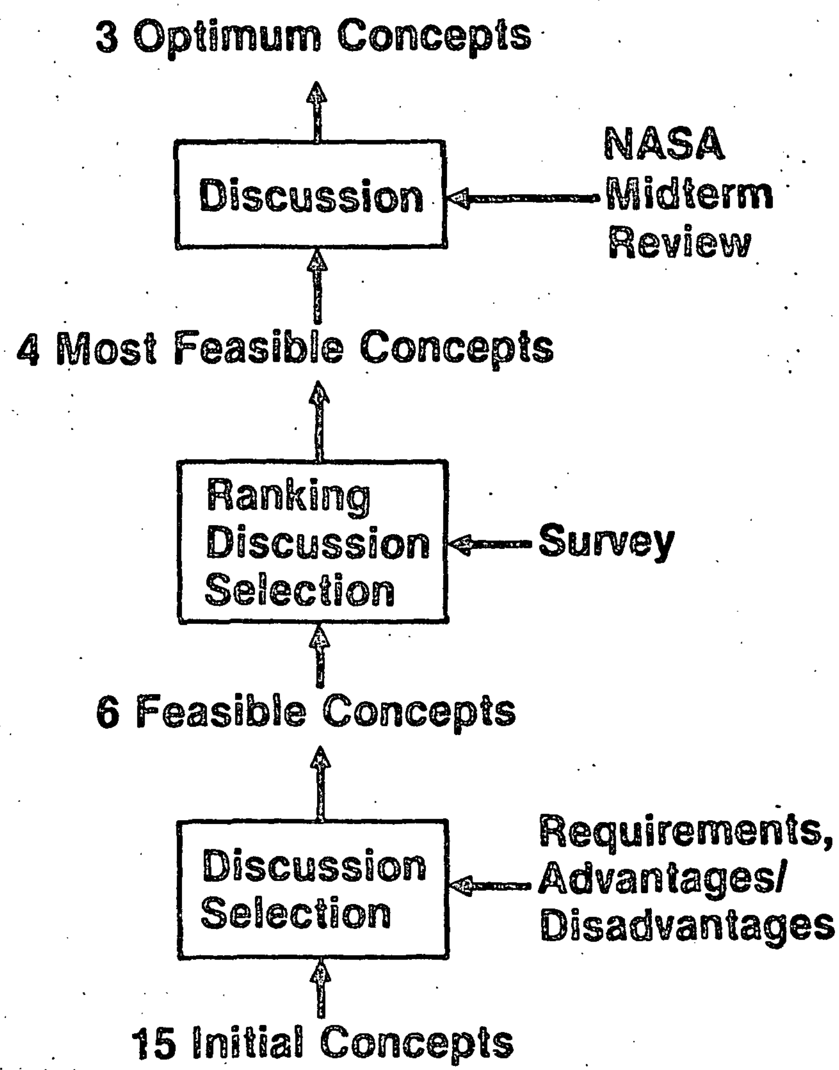

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WCS SURVEY RESULTS

VEC908

Rank →	Score
1	6
2	5
3	4
4	3
5	2
6	1

Sample Size: 10

Concept	Avg Score	Std Dev
Centrifugal Compaction	4.2	1.4
Closed Loop Macerator	4.0	2.4
Skylab Repackaged	3.9	1.4
Modified Skylab	3.3	0.9
MDTSCO Trash Ejector	2.9	2.5
1 Week Wall Mount	2.7	0.8

Respondents:
1. Snyder
2. Bastin
3. Hofbauer
4. Gallo
5. Secord
6. Kelly
7. A-MDTSCO
8. B-MDTSCO
9. C-MDTSCO
10. D-MDTSCO

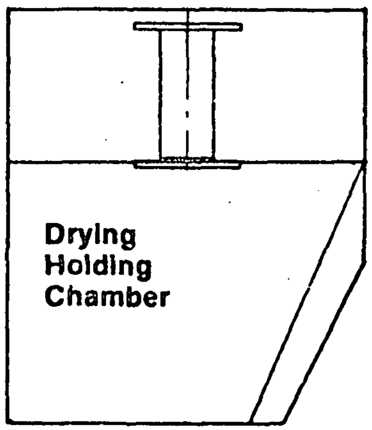
TASK 4
DESIGN CONCEPT PRESENTATION

- Summary of Candidate Concepts
- Rationale and Analyses Leading to Selection of the Optimum Concept
- Provide NASA With a Total Understanding of the Selected Concept
- Define GSE and Hardware Impacts on the Shuttle System

CANDIDATE CONCEPTS

PRELIMINARY WCS CONCEPTS

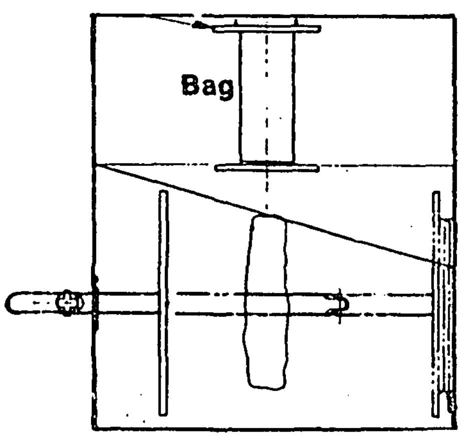
Simple Drop Through



Eliminated Due To . . .

- Large Volume — High Air Loss
- Inefficient Packing

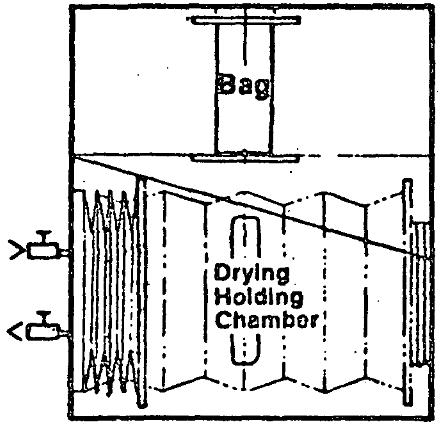
Push-Pull Compactor



- Large Volume — High Air Loss
- Active Sliding Seals
- Handle Protrudes Into Crew Compartment

PRELIMINARY WCS CONCEPTS (Cont'd)

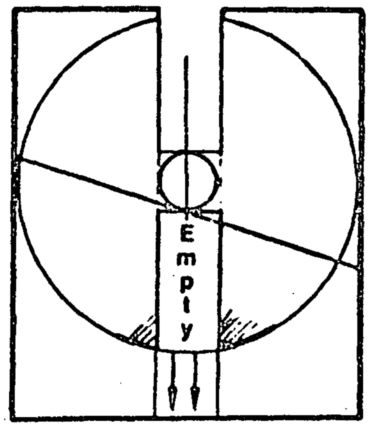
Bellows Compactor



Eliminated Due To . . .

- Large Volume — High Air Loss
- Bag Hang-Up
- Bellows Decreases Usable Volume

Two Station Rotating Wheel

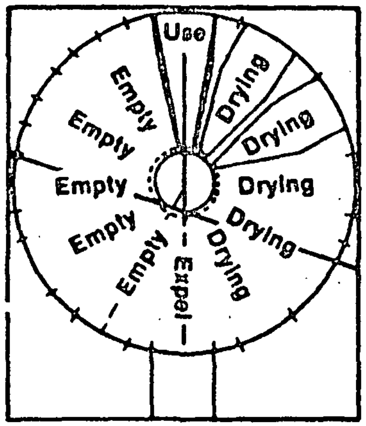


- Inefficient Use of Volume
- No Area for Stowage
- Active Sliding Seals

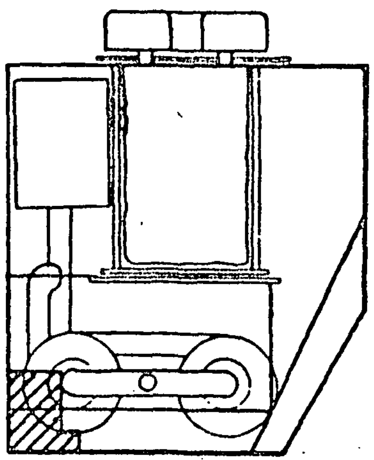
PRELIMINARY WCS CONCEPTS
(cont'd)

VEC893

12/24 Station Rotating Wheel



One Week Push Through



Eliminated Due To . . .

- No Area For Stowage
- Active Sliding Seals
- Complexity

- Inadequate Stowage Volume
- Psychologically Undesirable

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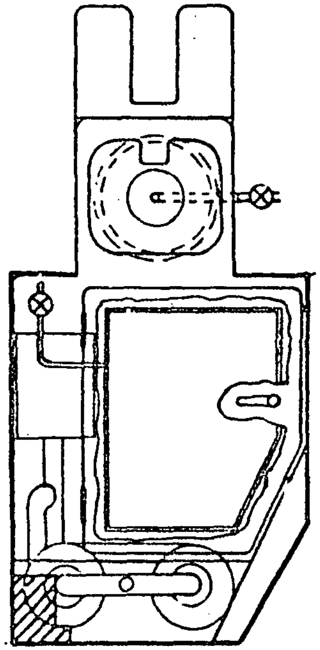
PRELIMINARY WCS CONCEPTS
(Cont'd)

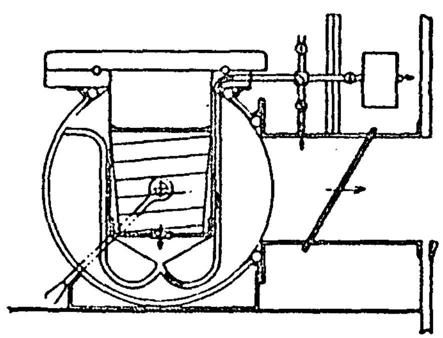
One Week Wall Mount



Eliminated Due To . . .

- Poor Psychological Acceptance
- Weight
- Marginal Stowage Volume

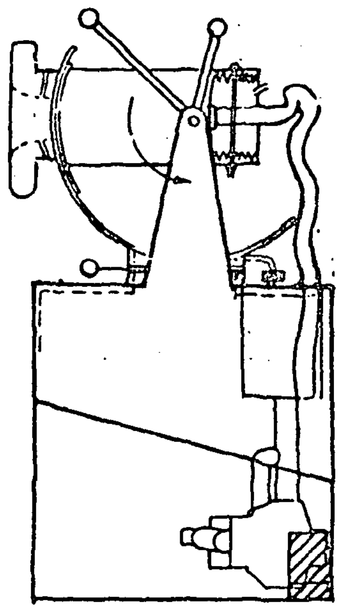
Trash Ejector



- Mechanical Complexity
- Active Sliding Seals
- Weight
- No Area For Stowage

PRELIMINARY WCS CONCEPTS
(Cont'd)

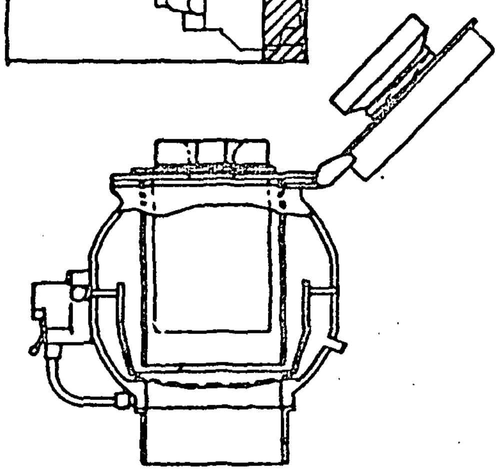
Modified Trash Ejector



Eliminated Due To . . .

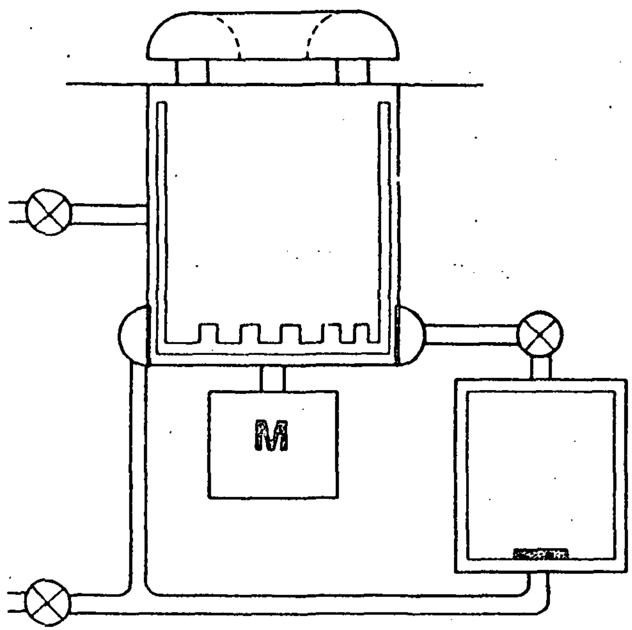
- Active Sliding Seals
- Mechanical Complexity
- Inefficient Packing

Trash Airlock



- Weight
- Mechanical Complexity
- No Area For Storage

PRELIMINARY WCS CONCEPTS
(Cont'd)



Disposer/Shredder/Grinder

Eliminated Due To . . .

- Mechanical Complexity
- Questionable Feasibility

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MOST FEASIBLE CONCEPTS

1. **Skylab Repackaged Configuration**

   A Repackaged Version of the Proven Skylab Collection System With a Re-configured Processor

2. **Modified Skylab Concept**

   A "Large Bag" Concept (Similar to Skylab) With Significantly Reduced Crew Handling, Weight, and Air Loss

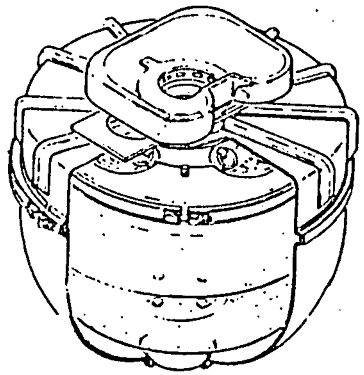
3. **Centrifugal Compaction Concept**

   An Air Entrainment System Featuring Compaction of Paper and Wastes in a Rotating Chamber

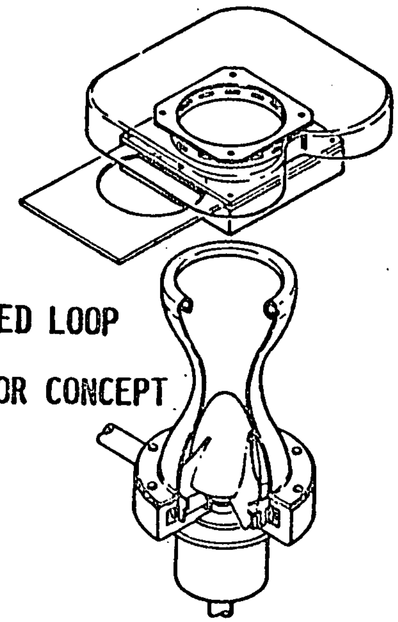
4. **Closed Loop Macerator Concept**

   A Recirculating Fluid System Which Creates a Filterable Slurry of Waste and Water Soluble Biocide

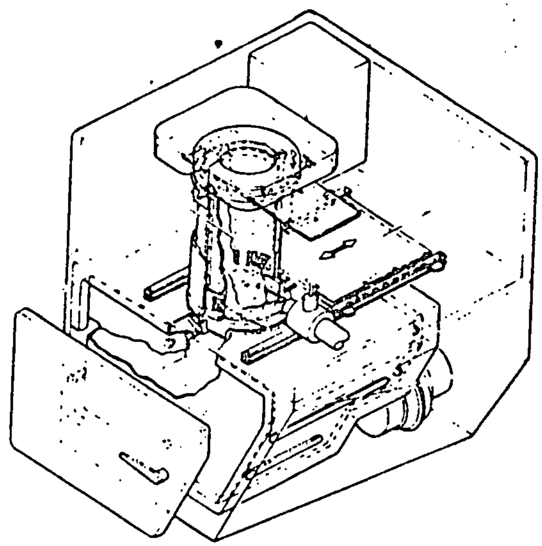
MOST FEASIBLE CONCEPTS



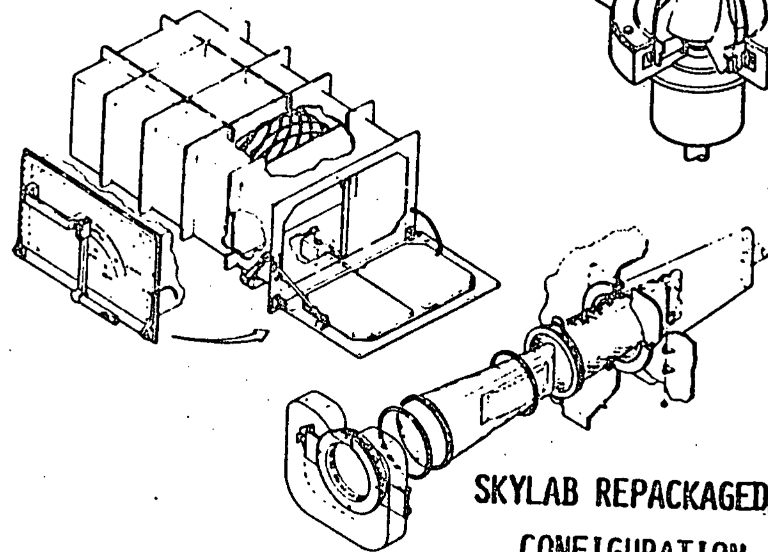
CENTRIFUGAL COMPACTION CONCEPT



CLOSED LOOP MACERATOR CONCEPT



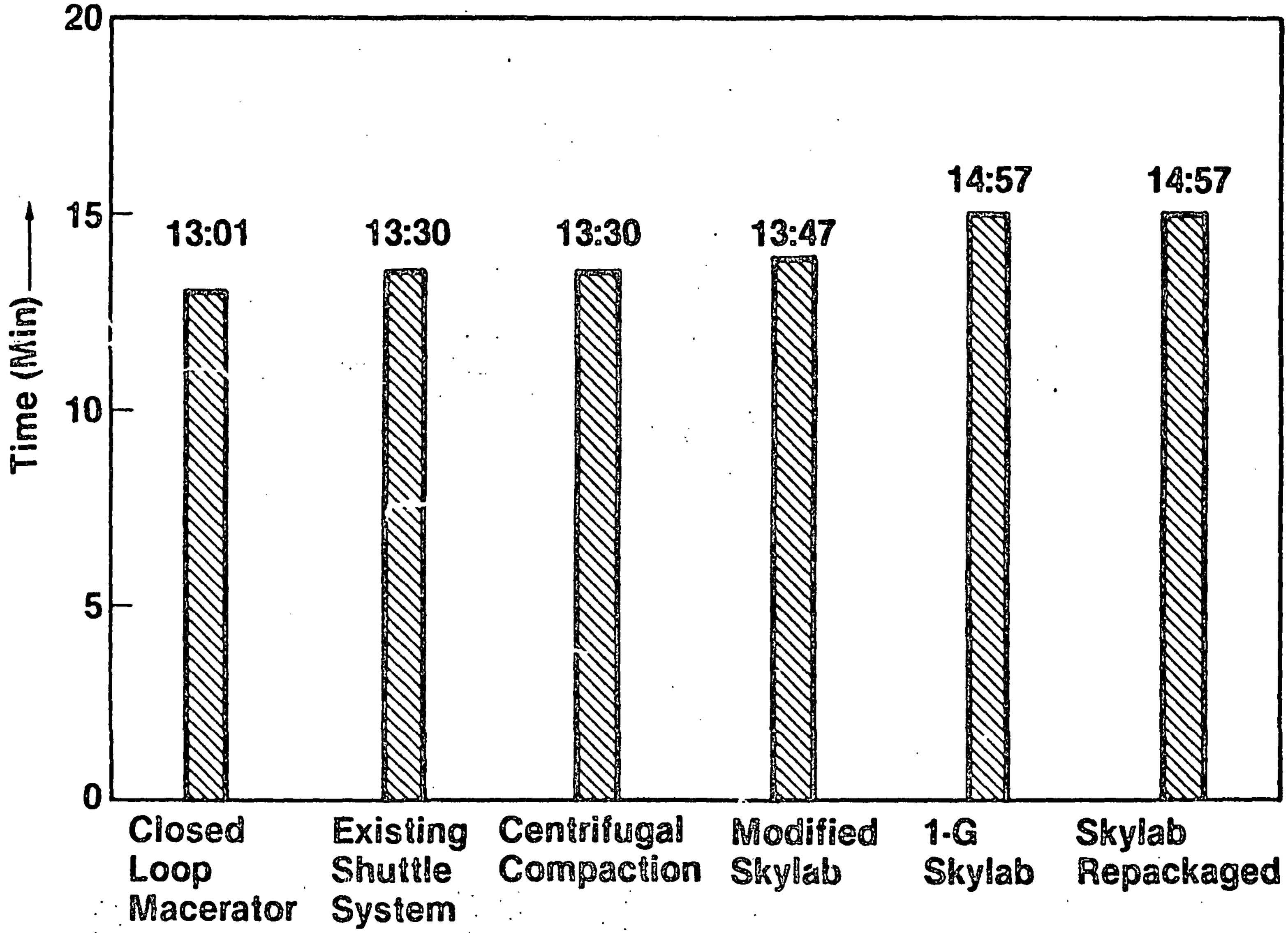
MODIFIED SKYLAB CONCEPT



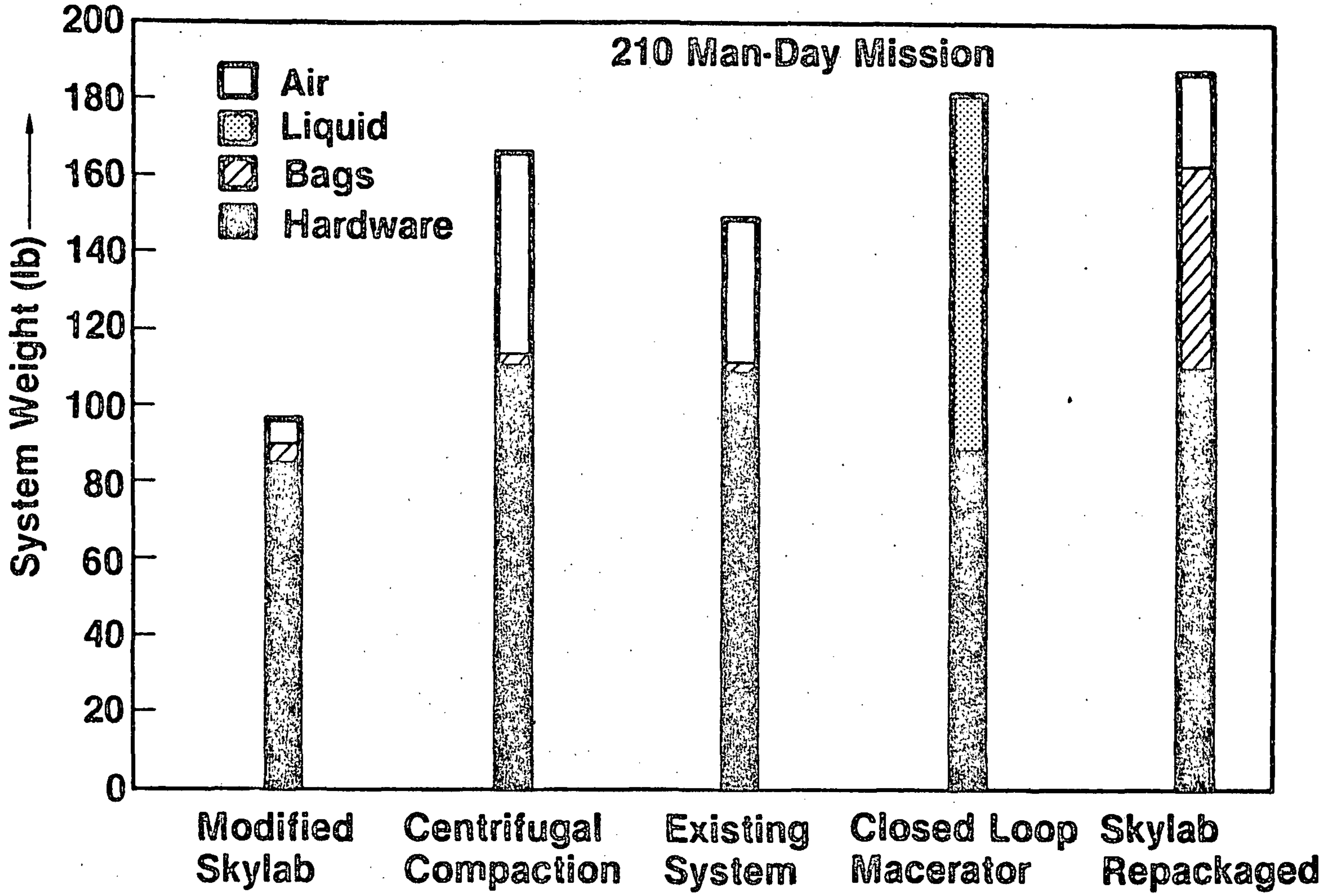
SKYLAB REPACKAGED CONFIGURATION

WCS CONCEPT CREW USE TIME

VEC914



ORBITER WCS CONCEPT WEIGHT



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EXISTING SHUTTLE WCS SYSTEM

VEC916

Estimated Weight Breakdown

Component	Wt (lb)
Pressure Vessel Drum	50.0
Bacteria Filter	6.0
Fiberglass Shroud	9.0
Seat Assy	3.0
Restraint System + Hdwe	7.0
2 Fan/Separators	5.0
Gate Valve + Hdwe	3.0
Hoses/Ducts	5.0
Brackets, Supports, Base, Fasteners	14.0
Controls/Wiring	7.0
Hardware Total	109.0
Bag	1.5
Total System Weight	110.5 lb

Note: Current System Omits Motor and Slinger Apparatus

Air Loss:

$$210 \text{ Uses} \times \frac{2.4 \text{ ft}^3}{\text{Use}} \times \frac{.0752 \text{ lb}}{\text{ft}^3} = \underline{37.9 \text{ lb}}$$

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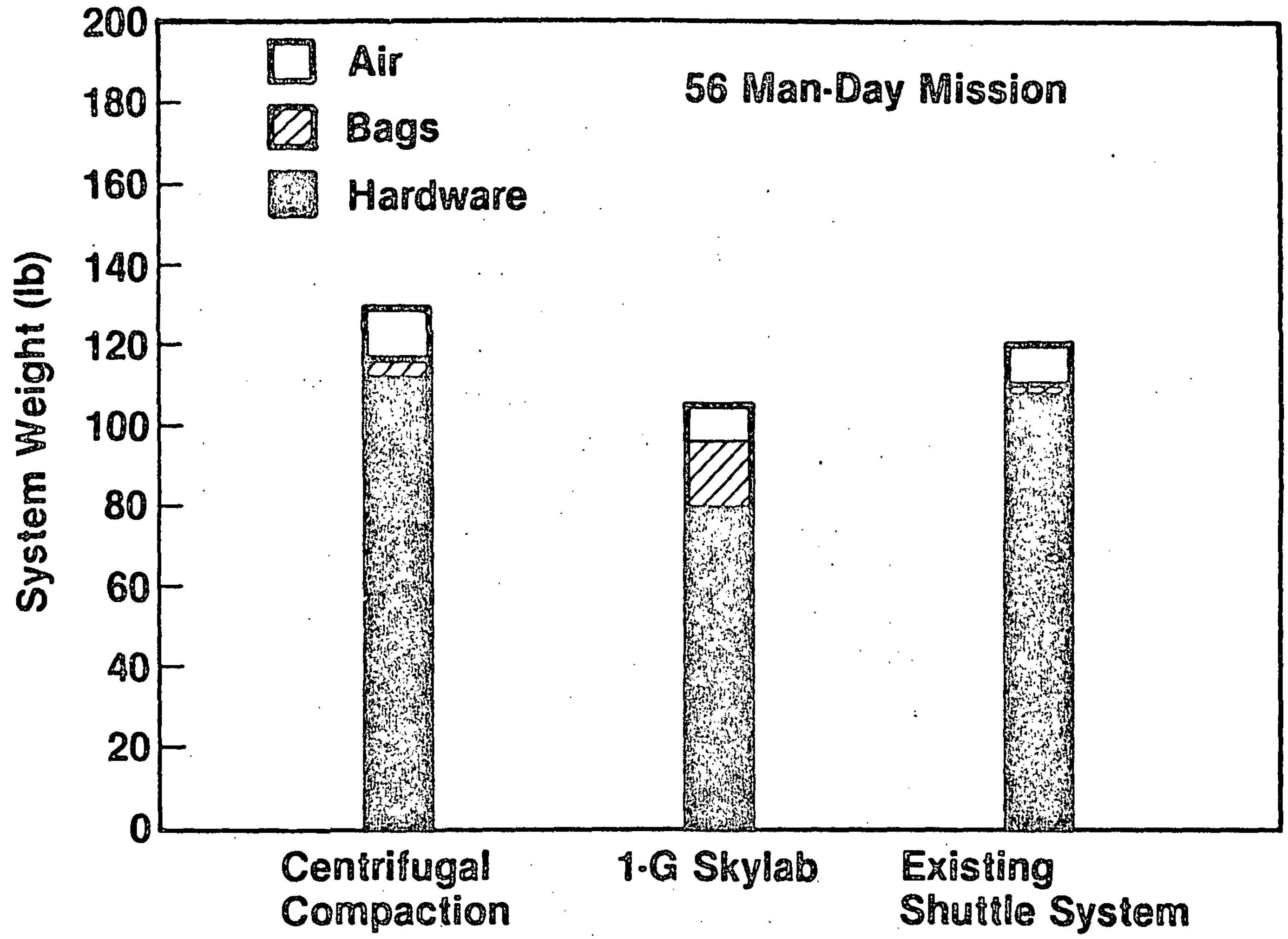
ORBITER WCS CONCEPT WEIGHT



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SELECTION OF OPTIMUM WCS CONCEPTS BASED ON

VEC917

- Practicality
- Proven Capability
- Ease of Retrofittability into Orbiter Structure and Interfaces
- Use of Existing Concepts and Flight Qualified Hardware
- In-Vehicle Maintenance
- Psychological Acceptability

SELECTED CONCEPTS

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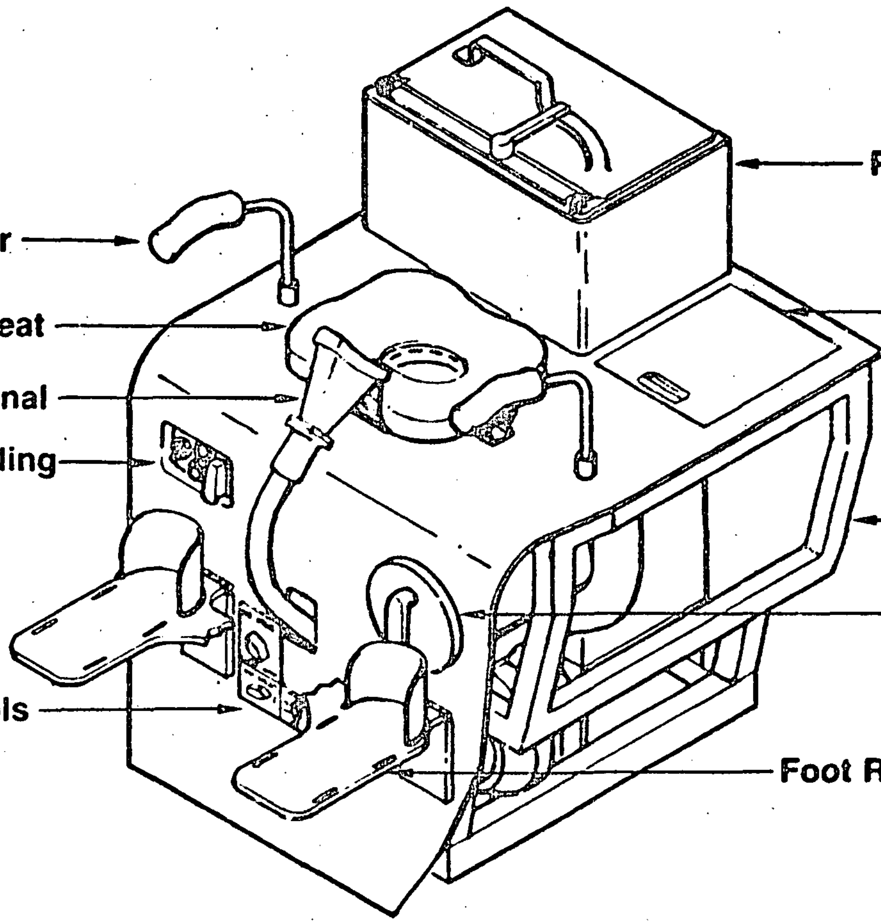
1-G SKYLAB CONFIGURATION

MCDONNELL DOUGLAS CORPORATION

1-G SKYLAB CONFIGURATION

VEC841



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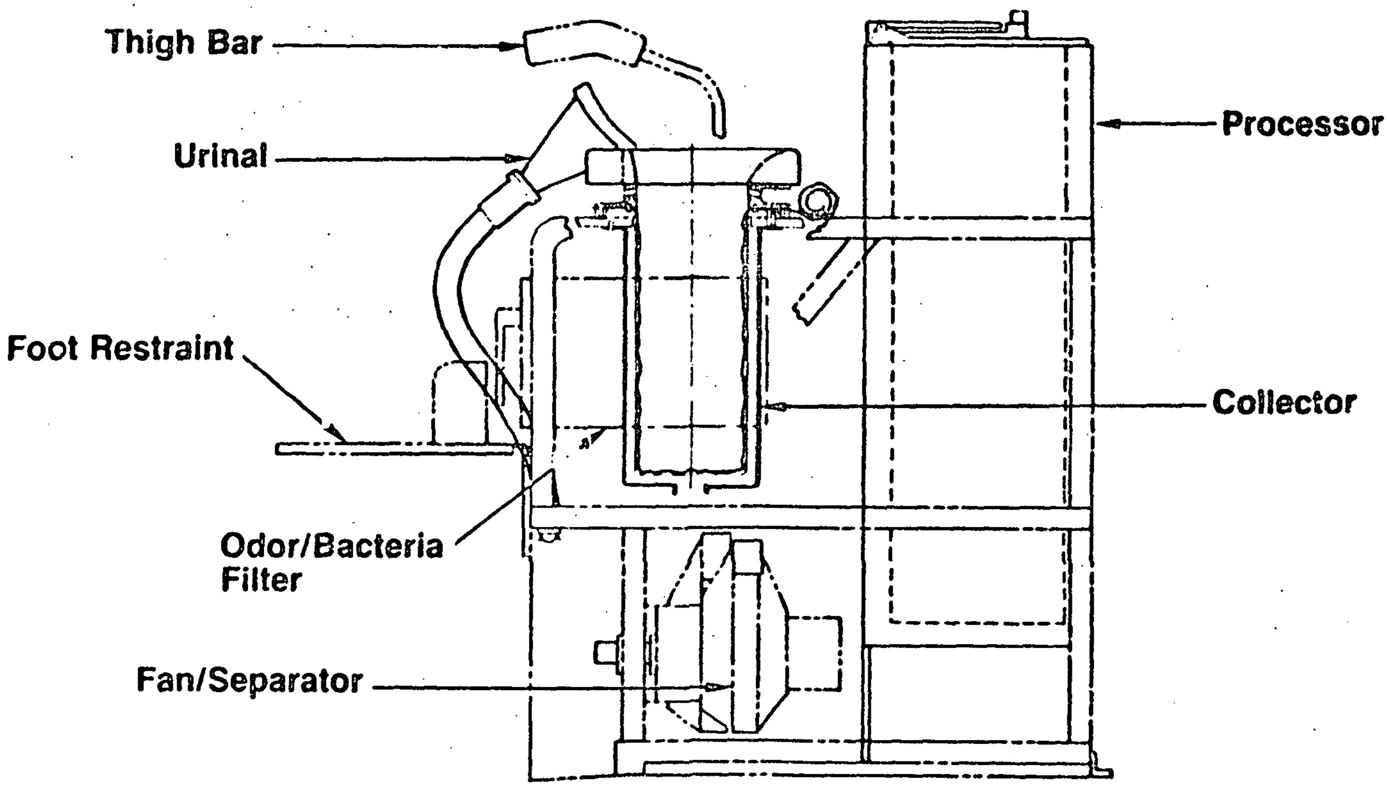
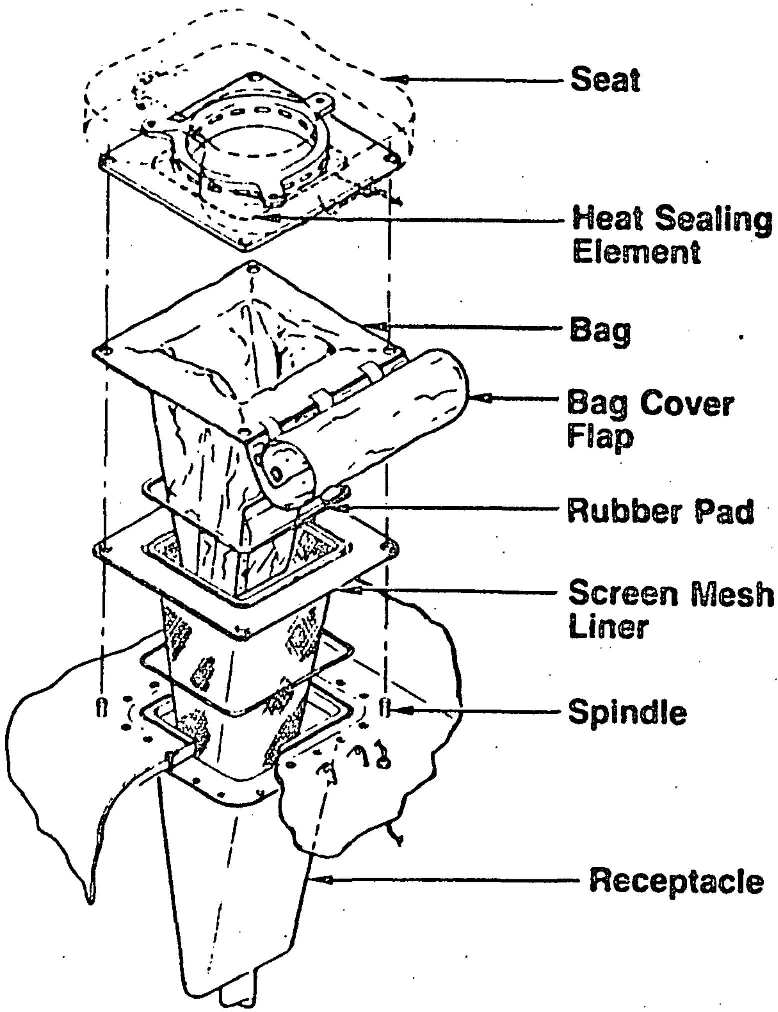
1-G SKYLAB CONFIGURATION

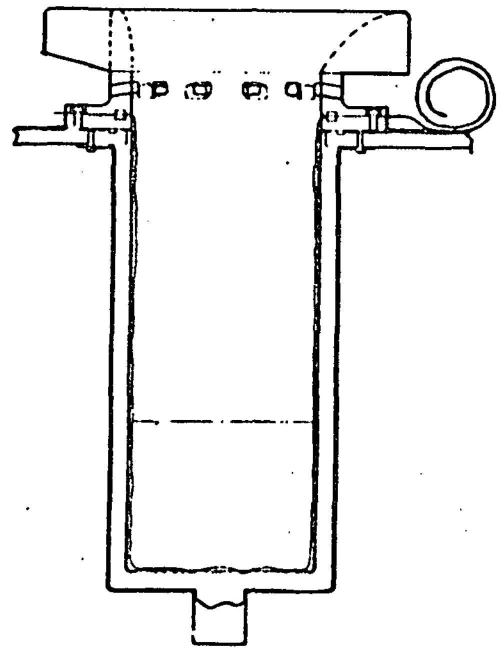


Outboard Side

VEC843

1-G SKYLAB CONFIGURATION
COLLECTOR





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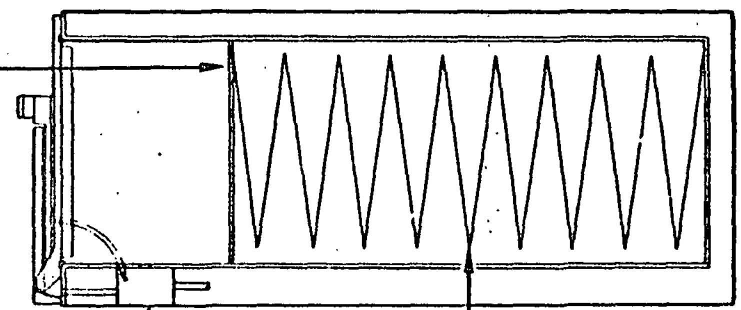
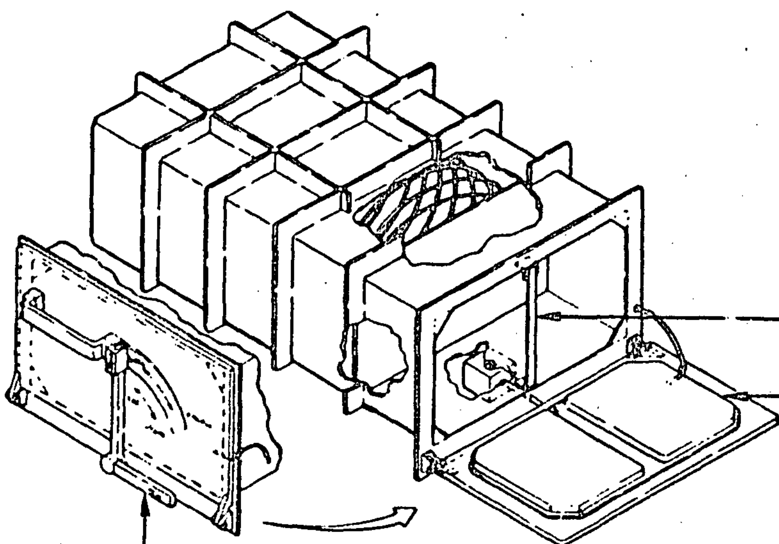
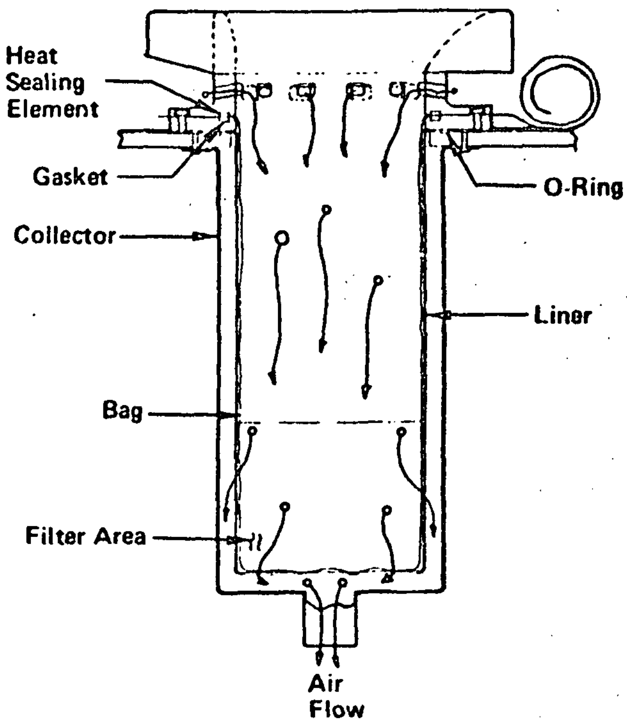
1-G SKYLAB CONFIGURATION
PROCESSOR





VEC846

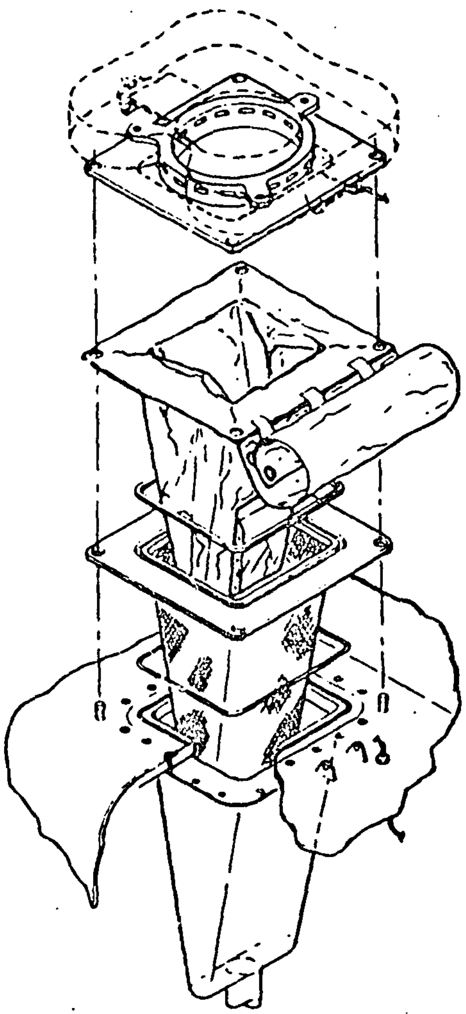
1-G SKYLAB CONFIGURATION
COLLECTION



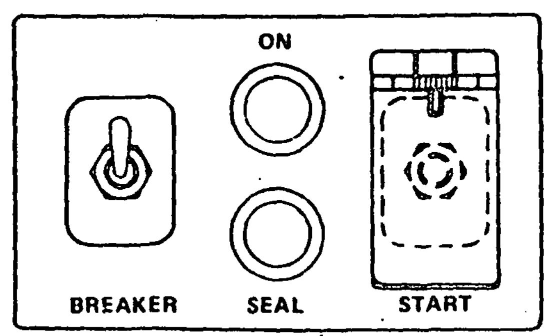
- Bolus Entrained by Airflow From Holes Around Base of Seat

- Air Passes Through Hydrophobic Filter, Mesh Liner and Out of Receptacle

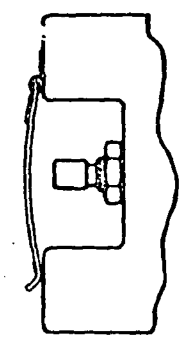
1-G SKYLAB CONFIGURATION
BAG SEALING



- Seat Hinged Up
- Bag Cover Flap Secured On Spindles
- Seat Down and Latched
- Push Start Button, Allow Cycle to Finish
- Seat Hinged Up
- Remove Sealed Bag From Spindles



HEAT SEALING



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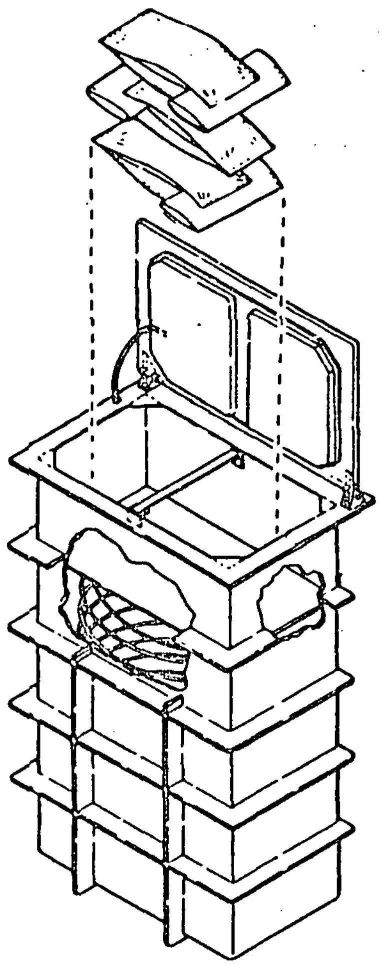
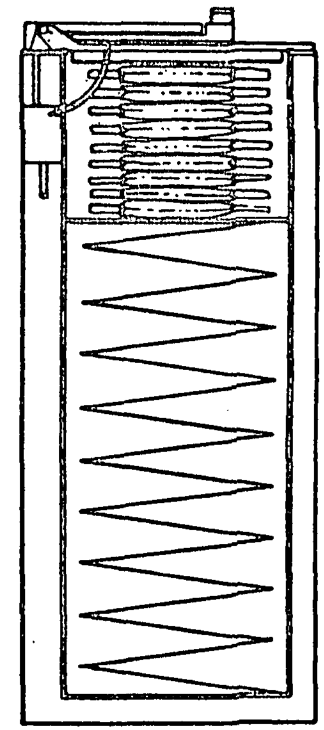
1-G SKYLAB CONFIGURATION
BAG STOWAGE

VEC848

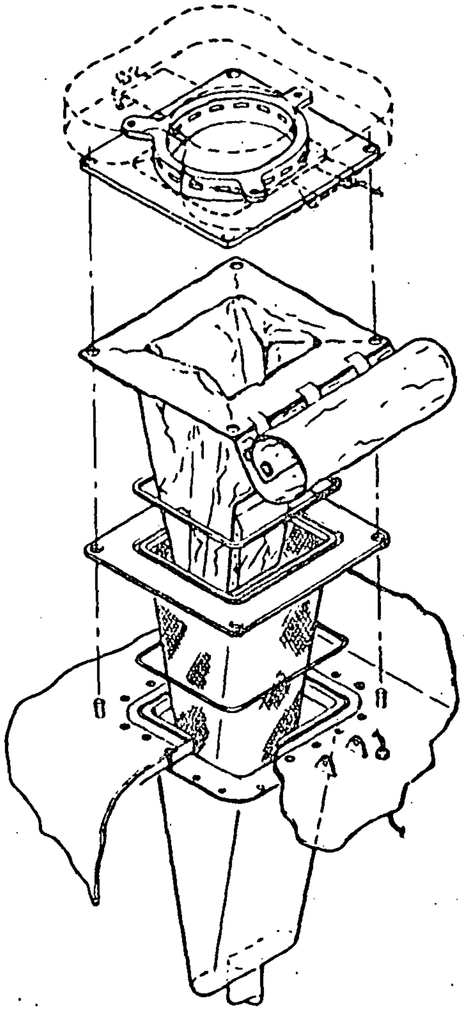


- Sealed Bag Is Folded at Creases
- Processor Vacuum Valve to Cabin
- Open Processor Door
- Release Bag Retaining Bar
- Insert Bag
- Replace Retaining Bar
- Close Processor Door
- Processor Vacuum Valve to Vacuum



1-G SKYLAB CONFIGURATION
BAG INSTALLATION

VEC845

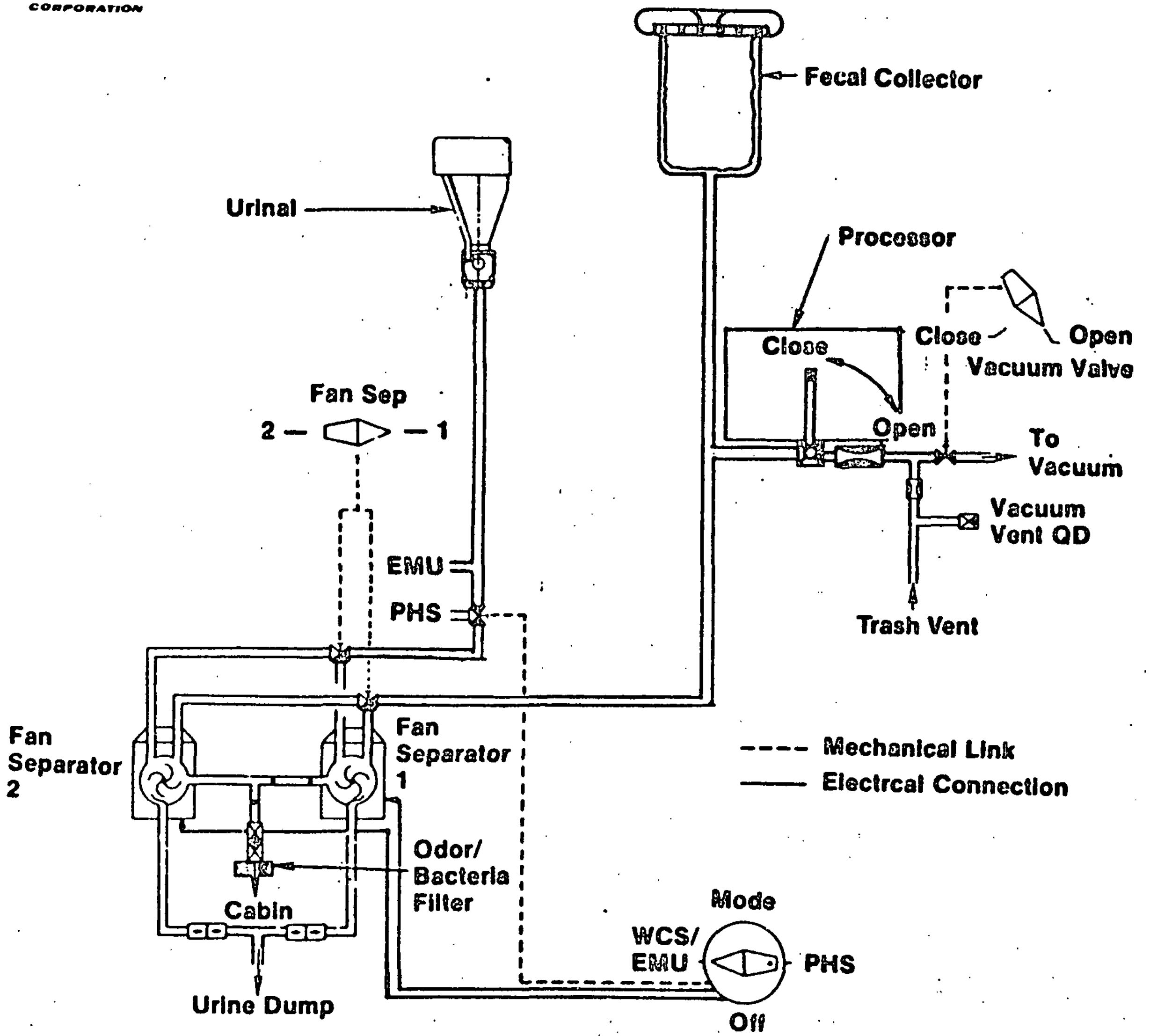


- Unfold Bag
- Place Bag in Receptacle
- Secure Four Corners on Spindles
- Hinge Seat Down and Latch

1-G SKYLAB CONFIGURATION
SYSTEM SCHEMATIC

MCDONNELL DOUGLAS CORPORATION

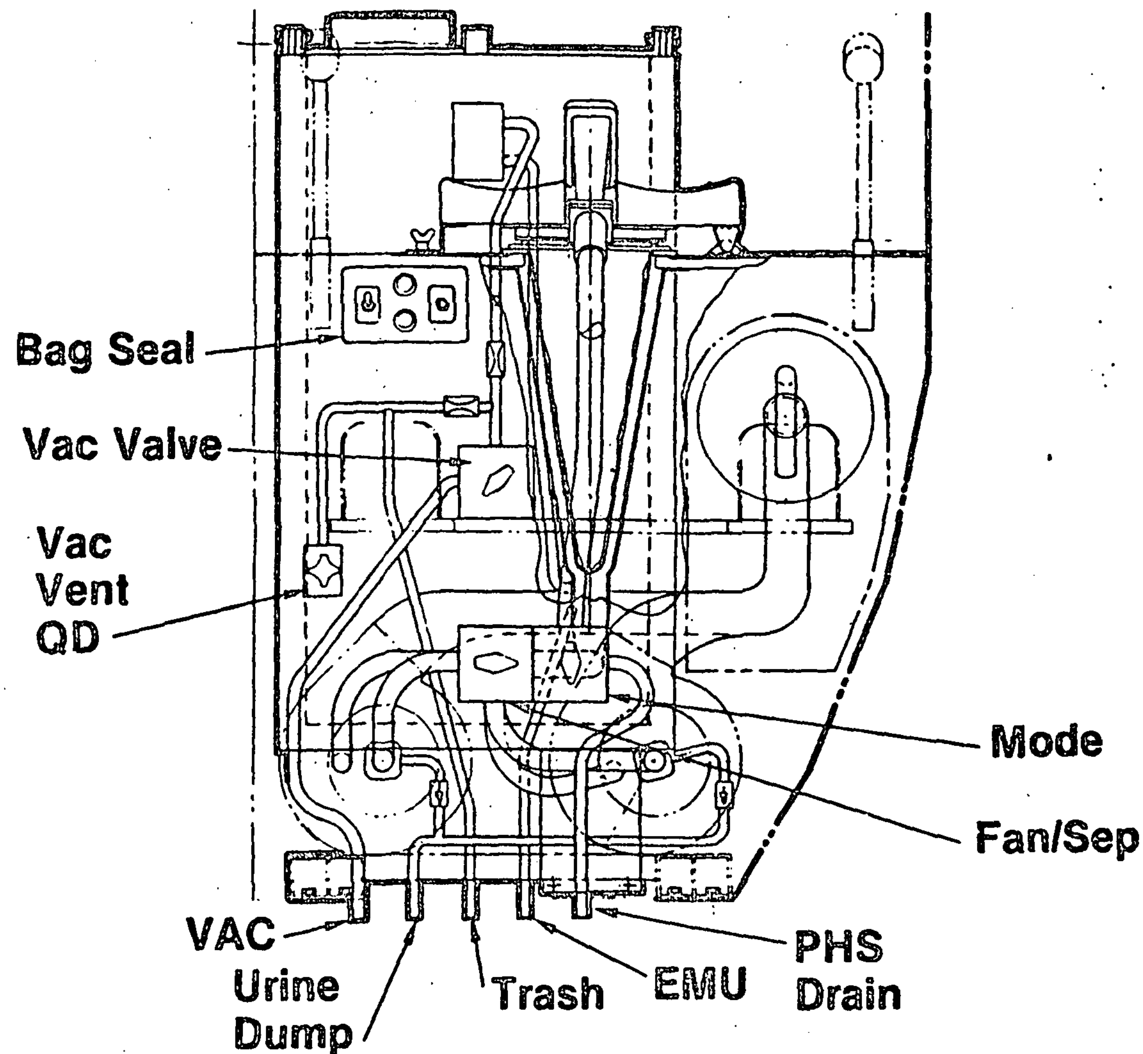
VEC849



1-G SKYLAB CONFIGURATION DUCTING AND INTERFACES

McDONNELL DOUGLAS CORPORATION

VEC918

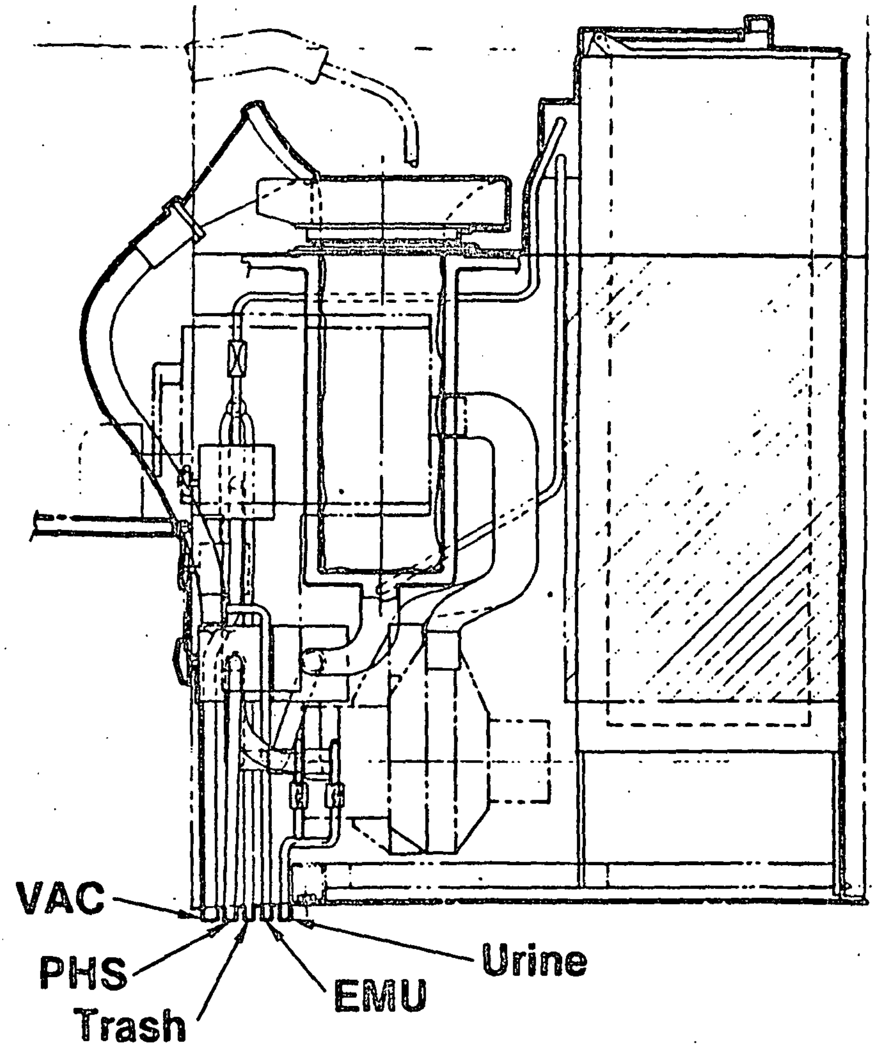


Front View

1-G SKYLAB CONFIGURATION DUCTING AND INTERFACES

MCDONNELL DOUGLAS CORPORATION

VEC919



Side View

MCDONNELL DOUGLAS CORPORATION

1-G SKYLAB CONFIGURATION
CREW PROCEDURES

	CREW TIME Min.	Sec.
1. TURN MODE SWITCH TO WCS/EMU*		2
2. POSITION BODY AND RESTRAINT SYSTEM		30
3. PERFORM DEFECATION AND CLEANUP	12	0
4. REMOVE RESTRAINT SYSTEM		15
5. UNLATCH AND LIFT SEAT		10
6. SEAL BAG		15
7. VERIFY OR CLOSE PROCESSOR VACUUM VALVE, WAIT FOR REPRESSURIZATION		5
8. OPEN PROCESSOR DOOR		5
9. REMOVE BAG FROM COLLECTOR		5
10. PLACE BAG INTO PROCESSOR		15
11. CLOSE PROCESSOR DOOR		5
12. OPEN PROCESSOR VACUUM VALVE		3
13. DISINFECT SEAT		30
14. OPEN CLEAN BAG DISPENSER		5
15. INSTALL CLEAN BAG		15
16. CLOSE CLEAN BAG DISPENSER		5
17. LOWER SEAT & LATCH		10
18. TURN MODE SWITCH TO OFF		2
Total time	14 Min.	57 Sec.

*FOR URINATION ONLY (AFTER STEP 1), PERFORM URINATION AND CLEANUP AND GO TO STEP 18.

MCDONNELL DOUGLAS CORPORATION

1-G SKYLAB CONFIGURATION
GROUND TURNAROUND

	TIME (HR.)
1. MOVE PROCESSOR VALVE TO CABIN POSITION 2. OPEN PROCESSOR DOOR 3. REMOVE BAGS, PLACE INTO AIR-TIGHT TRANSPORT CONTAINER 4. REMOVE SPENT ODOR/BACTERIA FILTER 5. PLACE FILTER IN TRANSPORT CONTAINER 6. REMOVE TRANSPORT CONTAINER FROM ORBITER	.5
7. CLEAN & DISINFECT INTERIOR OF COLLECTOR, PROCESSOR AND URINE SYSTEM	1.0
8. CLEAN & DISINFECT EXTERIOR OF WCS	.5
9. INSTALL FRESH BAG 10. INSTALL FRESH ODOR/BACTERIA FILTER 11. RETURN SYSTEM TO INITIAL CONDITION CONFIGURATION	.5
12. VERIFY OPERATION OF SYSTEM	.5
13. MOVE TRANSPORT CONTAINER TO SERVICE AREA 14. REMOVE WASTE FROM TRANSPORT CONTAINER 15. CLEAN AND STORE TRANSPORT CONTAINER	1.0
TOTAL TIME	4.0 HR.

MCDONNELL DOUGLAS CORPORATION

1-G SKYLAB CONFIGURATION
POTENTIAL GSE REQUIREMENTS

- o BIOLOGICAL ISOLATION GARMET
- o CLEAN UP EQUIPMENT
  - o BRUSHES
  - o WIPES
  - o BIOCIDE/CLEANER
  - o TRASH BAGS
- o FLUID CIRCULATION AND FLUSH SYSTEM (FOR FLUSHING OUT URINE SYSTEM)
- o STANDARD TOOLS
- o TRANSPORT CONTAINER

MCDONNELL DOUGLAS CORPORATION

1-G SKYLAB CONFIGURATION
POWER CONSUMPTION

VEC852.

- Fan/Separator (Existing) 100W Air 200W Air/Liq

- Processor Htr (if Req'd) 86W Peak 30W Avg.

Total Max 286W

1-G SKYLAB CONFIGURATION FILTER SIZING

VEC920

- **Assumptions**
  - ΔP Same as Present Bag $= 0.6$ in H_2O at 30 CFM
  - Laminar Flow Through Filter Material

- **Test Results of Pall Filter Material**
  $\Delta P = 4.9$ in H_2O, $Q = 28$ CFM, As $1/20\ Ft^2 = .05\ Ft^2$

- **Calculations:**
  $\Delta P = K\ Q/A$ or $K = \Delta PA/Q$
  $K = 4.9 \times .05/28 = .00875$
  Bag Area $A = .00875\ Q \times 144/\Delta P = .00875 \times 30 \times 144/.6 = 63\ In.^2$

- **Use Two 8 in. × 4 in. Filters**

MCDONNELL DOUGLAS CORPORATION

1-G SKYLAB CONFIGURATION

VEC921

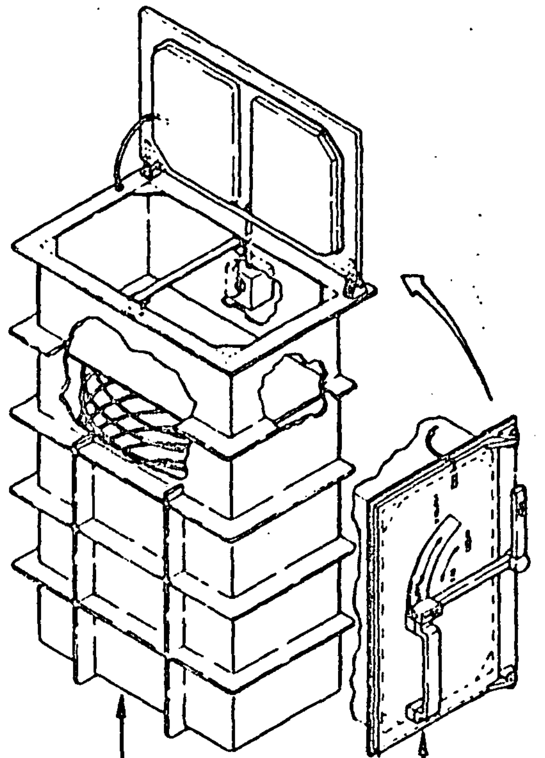
Expendables; 56 Man-Days + Contingency

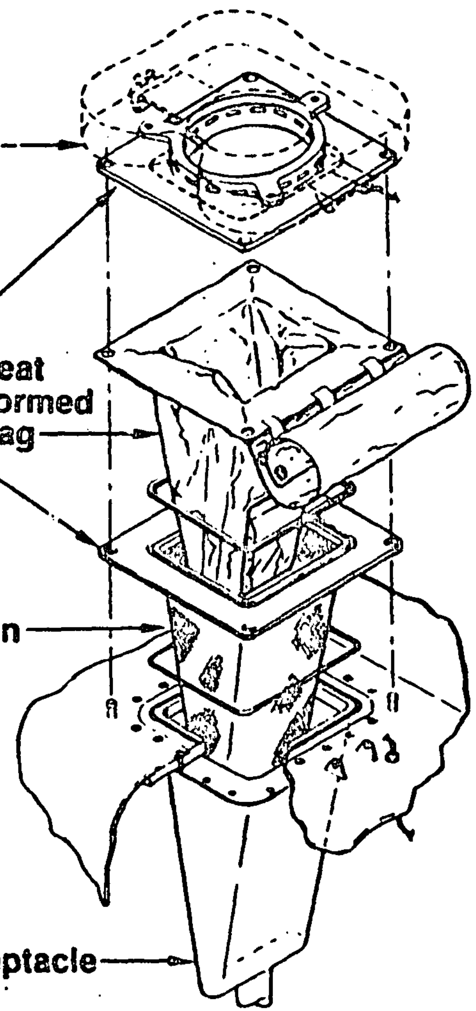
- Total Bag Weight = Bag No. × Weight/Bag
  = 75 × 2.2 lb = 17.0 lb

- Overboard Air Loss = No. of Uses × Air Loss Per Use
  Air Loss/Use = Processor Volume × Air Density
  = 1.62 Ft^3 × .0752 lb/Ft^3 = .122 lb

- Total Air Loss Overboard (Max) = 75 × .122 lb = 9.14 lb

1-G SKYLAB CONFIGURATION
HARDWARE FABRICATION FEASIBILITY





McDONNELL DOUGLAS CORPORATION

1-G SKYLAB CONFIGURATION BAG COST

VEC922

Skylab Bag Cost = $100/Bag in 1972

Add Inflation Factor of 2.90 From 1972 to 1985

Cost of 75 New Bags = $100 × 2.90 × 75 = 21,750.00 Bag Cost Per Mission

MCDONNELL DOUGLAS CORPORATION

VEC853

1-G SKYLAB CONFIGURATION
DEVELOPMENT ITEMS

- Heat Sealing Device
- Heat Sealable Material Compatibility/Outgassing
- Adjustment of Airflow/ΔP of System
- Compaction Plate/Spring Constant

MCDONNELL DOUGLAS CORPORATION

1-G SKYLAB CONFIGURATION REQUIREMENTS REVIEW

GENERAL REQUIREMENTS

- O AIRFLOW SEPARATES WASTE FROM CREWMEMBER
- *O WASTES STORES IN PROCESSOR UNDER VACUUM

SPECIFIC REQUIREMENTS

- O MALE/FEMALE FECES AND URINE COLLECTION INTERFACES SAME AS EXISTING SYSTEM
- O INDIVIDUAL URINE CAPS PROVIDED
- *O USE TIME EXCEEDS THAT OF EXISTING SYSTEM BY ONLY 1-1/2 MINUTES (APPROX.)
- O PAPER IS DEPOSITED INTO FECAL COLLECTOR DURING USE
- *O CREW TRAINING SIMILAR TO CURRENT CONTINGENCY MODE OPERATIONS WITH SIMPLIFICATIONS
- *O CREW HANDLES ONLY CLEAN OR SEALED BAGS
- O SEPARATION METHOD IDENTICAL TO EXISTING SYSTEM
- O BODY STABILIZATION SAME AS EXISTING SYSTEM
- **O CAPACITY FOR 56 BAGS (7 MAN X 8 DAY) PLUS 12% TO 34% (6 TO 19 BAGS) CONTINGENCY (ASSUMING BAGS ARE BETWEEN 0.40 AND 0.33 INCHES THICK)
- O BACTERIA AND ODOR CONTROLLED BY VACUUM STORAGE AND ODOR FILTERS
- O NOISE LEVEL EQUIVALENT TO EXISTING SYSTEM
- *O MAINTENANCE IS IN-VEHICLE
- *O WEIGHT, POWER AND EXPENDABLES ARE LESS THAN OR EQUAL TO EXISTING SYSTEM
- *O MECHANICAL AND ELECTRICAL SYSTEMS ARE SIMPLIFIED TO INCREASE RELIABILITY
- O SYSTEM IS RETROFITTABLE INTO ORBITER

*DIFFERS FROM EXISTING SYSTEM
**PER REDIRECTION OF D. GERMANY DURING MIDTERM REVIEW

MCDONNELL DOUGLAS CORPORATION

VEC850

1-G SKYLAB CONFIGURATION
WEIGHT ESTIMATE SUMMARY

Component	Wt (lb)
Collector Receptacle	1.0
Mesh Screen Liner	0.4
1 Processor (Enlarged 50%)	27.0
1 Storage Compartment	6.0
Seat + Heat Sealer	5.0
Structural Supports	14.0
Switches, Cables, Elect. Conn.	3.0
Odor Bacteria Filter*	6.0
Restraint System*	7.0
2 Fan/Separators*	5.0
Hoses, Ducts*	5.0
Hardware Total	79.4
75 Bags**	17.0
Air** (75 Uses)	9.1
Total System Wt	105.5 lb

*Existing System Hardware
**Expendables

WCS WEIGHT ESTIMATE SUMMARY (POUNDS)

System	Man-Days	Hdwe	Bags	Air	Liquid	Total
1-G Skylab	56	79.4	17.0	9.1	0	105.5
Centrifugal Comp	56	112.0	1.5	14.1	0	127.6
Centrifugal Comp	210	112.0	1.5	52.9	0	166.4
Skylab Repackaged	210	110.4	52.3	24.6	0	187.3
Modified Skylab	210	85.3	4.0	7.0	0	96.3
Closed Loop Macerator	210	88.5	0	0	93.6	182.1
Existing System	56	109.0	1.5	10.1	0	120.6
Existing System	210	109.0	1.5	37.9	0	148.4

MCDONNELL DOUGLAS CORPORATION

VEC854

1-G SKYLAB CONFIGURATION
SUMMARY

ADVANTAGES

1. Skylab Collection Method Is Proven
2. Hardware Is Practical and Proven
3. Valves and Airflow System are Simple and Straightforward
4. Unit is Immediately Retrofittable Into Orbiter Structure and Interfaces
5. Air Loss Is Low Due to Smaller Processor Volume
6. Compaction and Heat Application are a Feature of Processor
7. Advanced Bag Sealing Concept Assures That Handling Is Limited to Clean or Sealed Bags
8. Existing Fan/Separators are Used
9. Direct Valve Linkages are Mechanically Simple
10. Unit Is Serviceable on Orbit
11. Odor Is Contained by Airflow During Bag Sealing
12. Used Bag Processing and Storage Occur in Same Chamber
13. Odor From Used Bags in Processors Is Contained by Airflow During Bag Insertion
14. Orderly Used Bag Storage in Processors Is More Volume Efficient and Simplifies Ground Changeout
15. Fresh Bag Stowage Area Is Provided
16. Sized to Accomodate Orbiter Mission and Crew Requirements

DISADVANTAGES

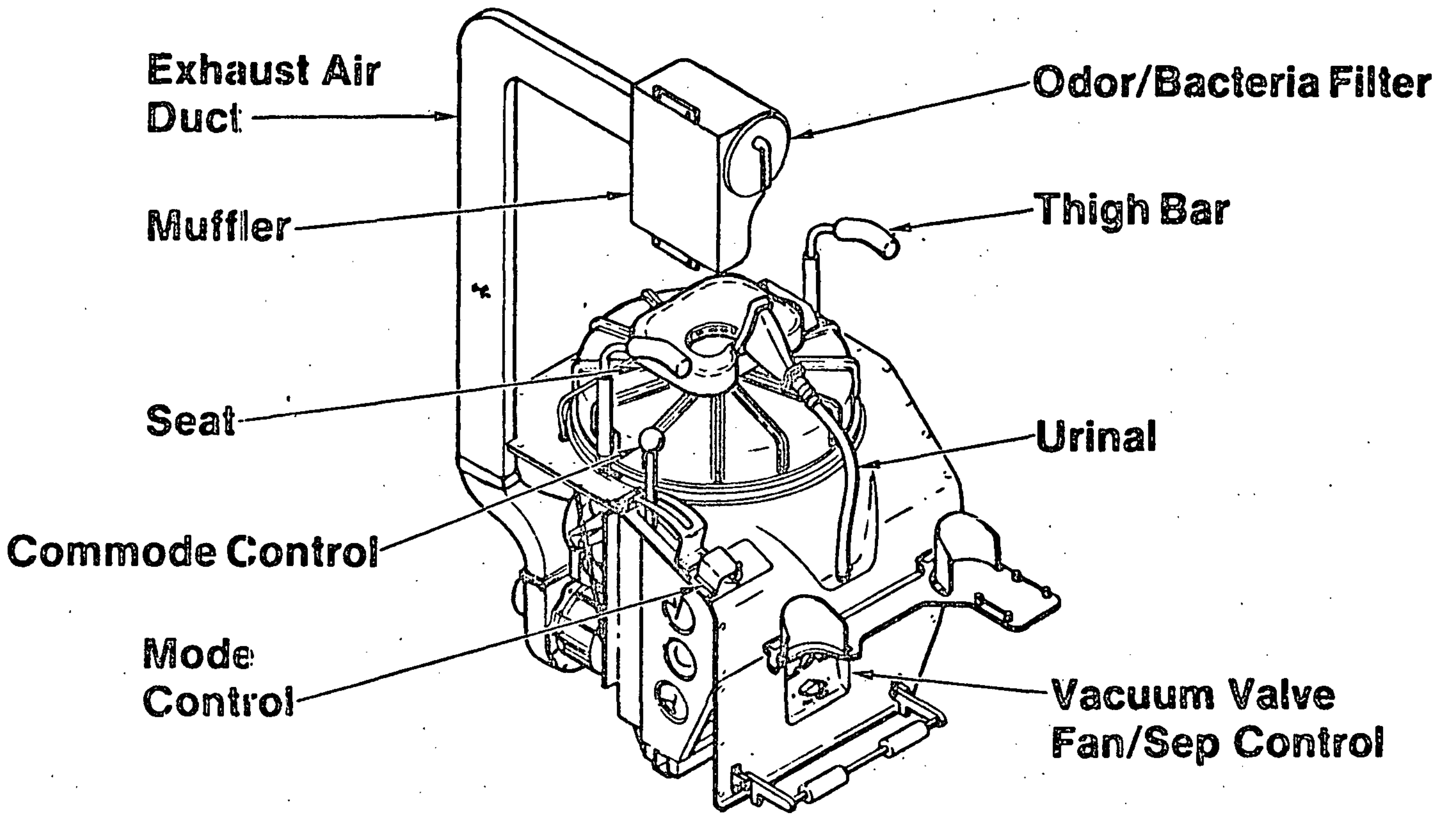
1. Fecal Bag Handling and Sealing are Present

CENTRIFUGAL COMPACTION CONCEPT

MCDONNELL DOUGLAS CORPORATION

VEC939

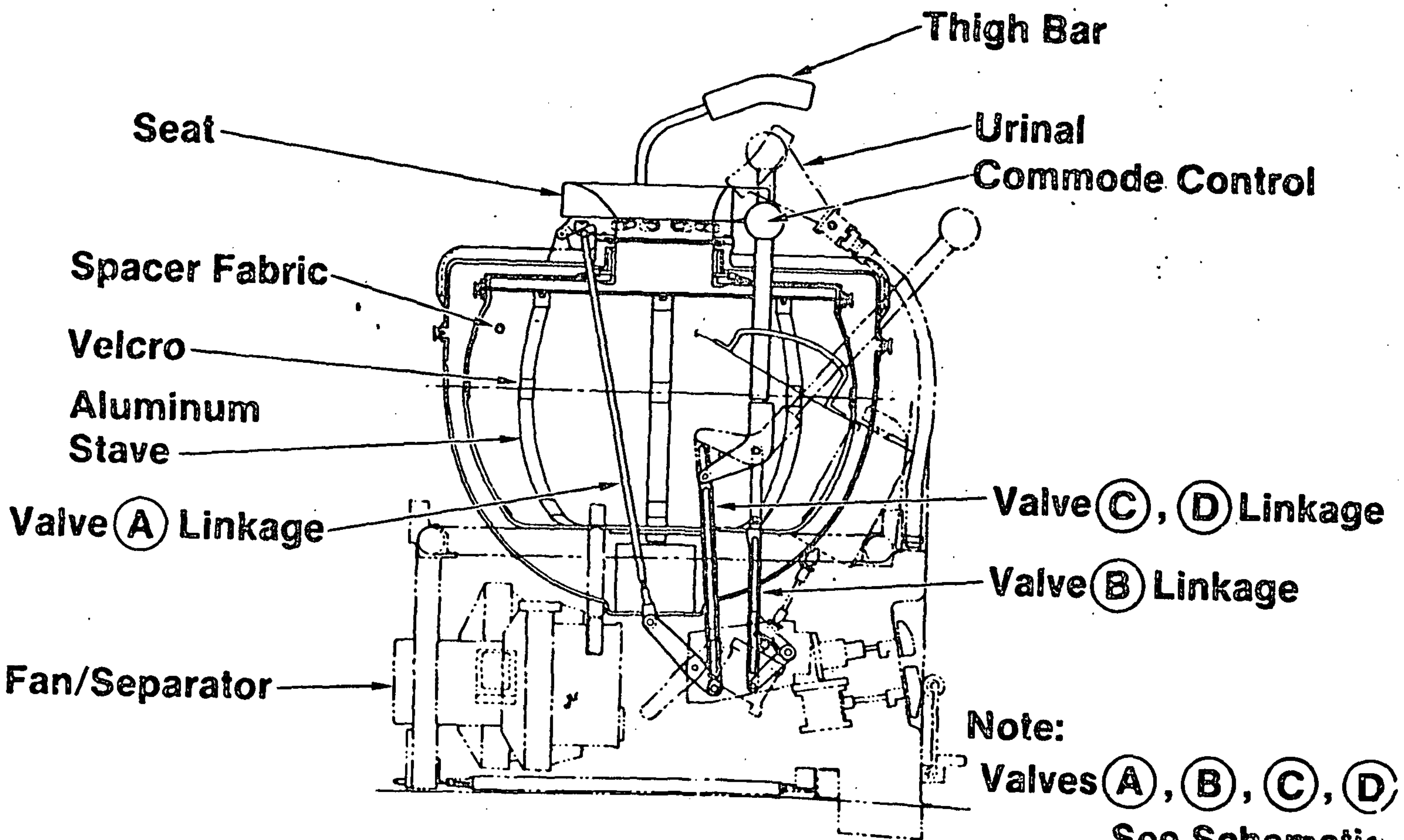
CENTRIFUGAL COMPACTION CONCEPT



MCDONNELL DOUGLAS CORPORATION

VEC940

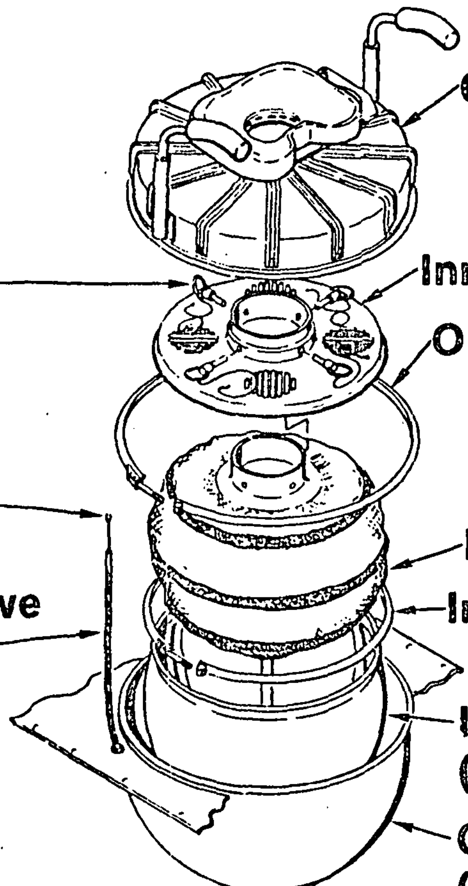
CENTRIFUGAL COMPACTION CONCEPT

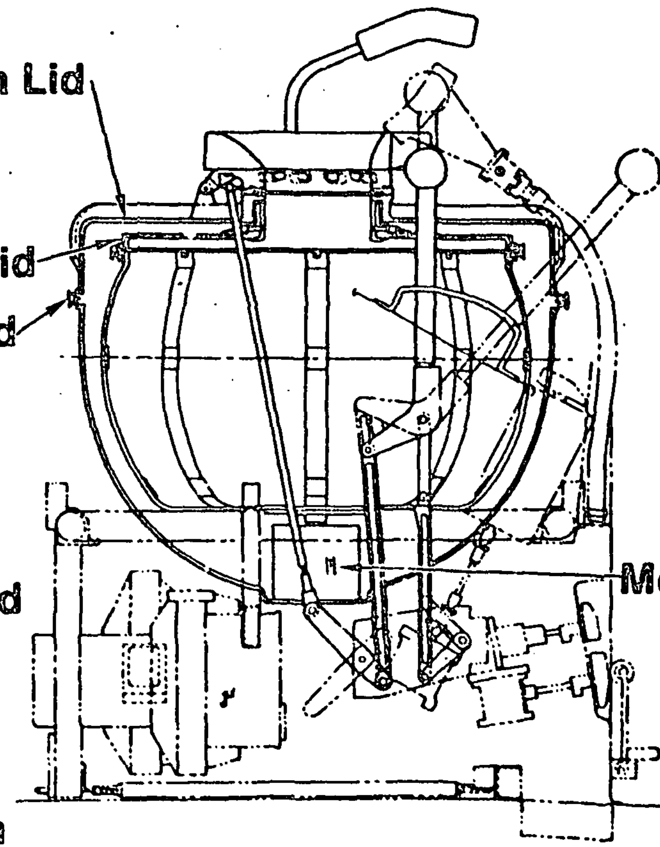


Side View

CENTRIFUGAL COMPACTION CONCEPT
COLLECTION AND PROCESSING CHAMBER

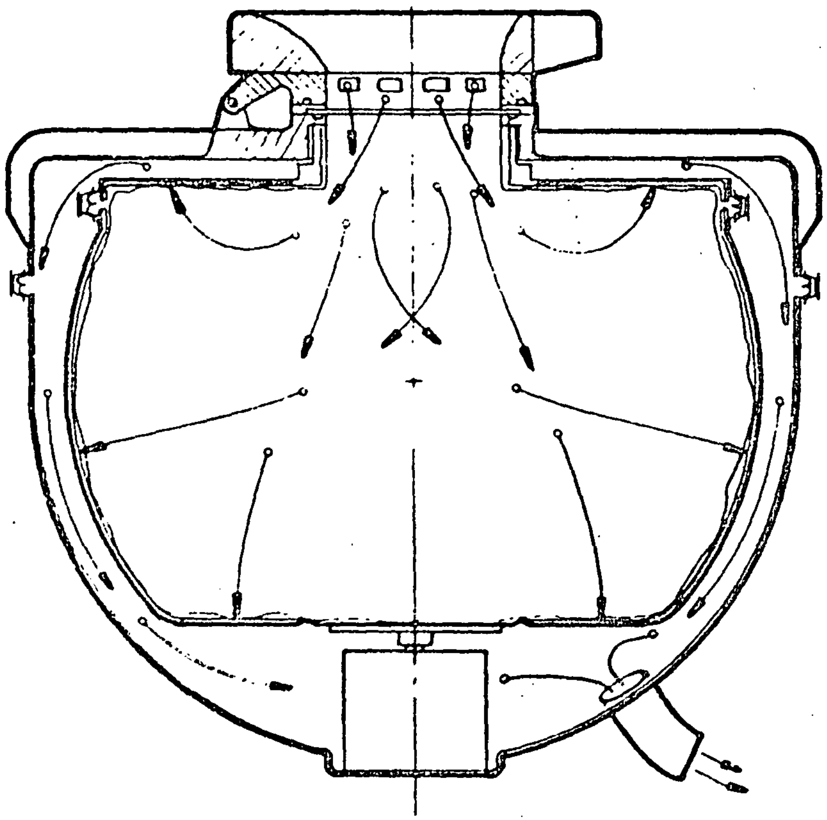
VEC941





MCDONNELL DOUGLAS CORPORATION

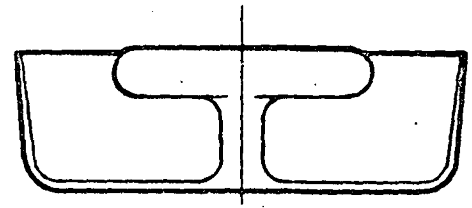
CENTRIFUGAL COMPACTION CONCEPT COLLECTION



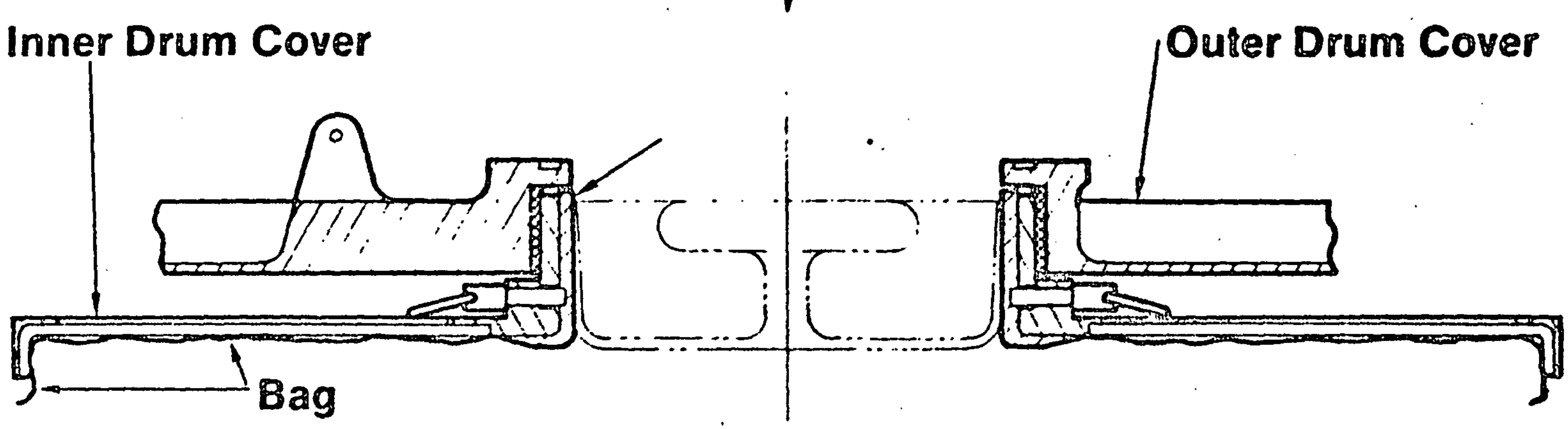
- Bolus Entrained by Airflow From Holes Around Base of Seat
- Inner Drum Rotates — Airflow and Centrifugal Force Move Bolus Toward Bag Liner
- Waste Is Compacted Against Inner Drum Wall — Center Collection Area Is Open
- Air Flows Out Through Bag, Spacer Fabric, Vents, and Outlet at Bottom

Rotation Speed	Compaction Force
1 RPS	1 G Approx
2 RPS	4 G Approx
3 RPS	12 G Approx

CENTRIFUGAL COMPACTION CONCEPT
BAG PLUGGING

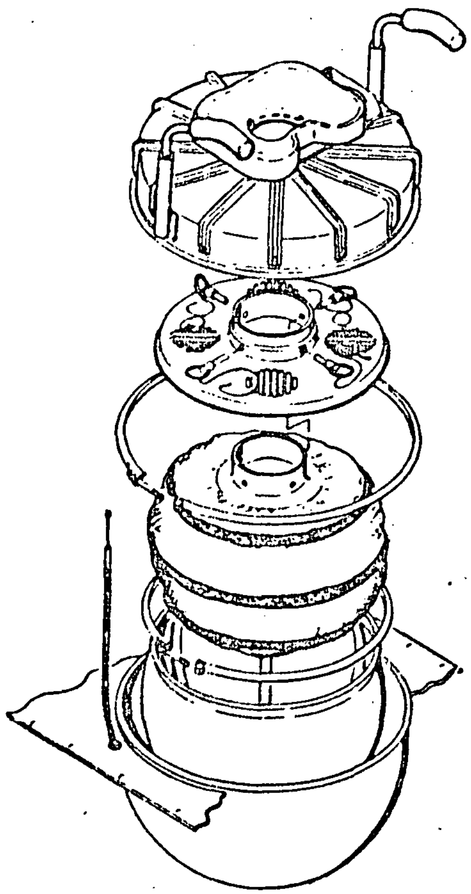


Stopper/Sealing Plug
Used Prior to
Bag Replacement



CENTRIFUGAL COMPACTION CONCEPT
BAG REMOVAL

VEC938



- Raise Seat
- Unfasten Slide Valve Clevis From Slide Valve and Swing Slide Valve Link Out of the Way
- Lower Seat
- Remove Outer V-Band Clamp
- Remove Outer Drum Lid
- Remove Inner V-Band Clamp
- Remove Inner Drum Lid and Bag Liner From Inner Drum
- Remove Pip Pins From Neck of Inner Drum Lid
- Detach Bag Liner From Underside of Inner Drum Lid

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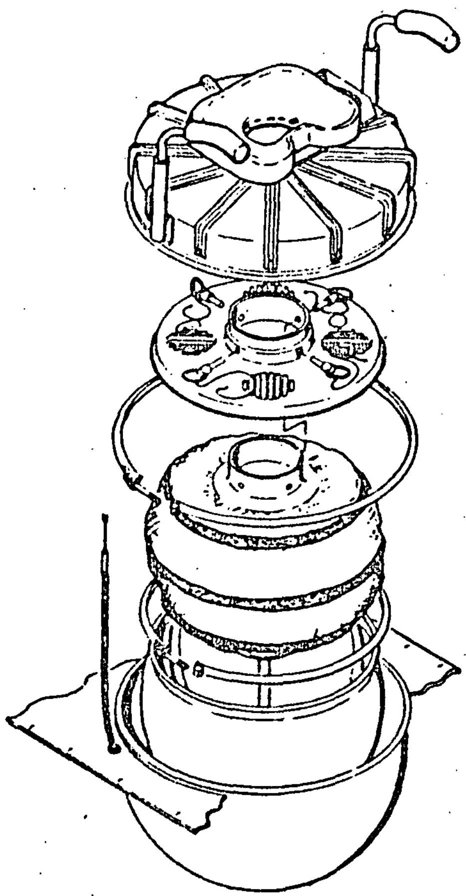
CENTRIFUGAL COMPACTION CONCEPT
BAG INSTALLATION

VEC937

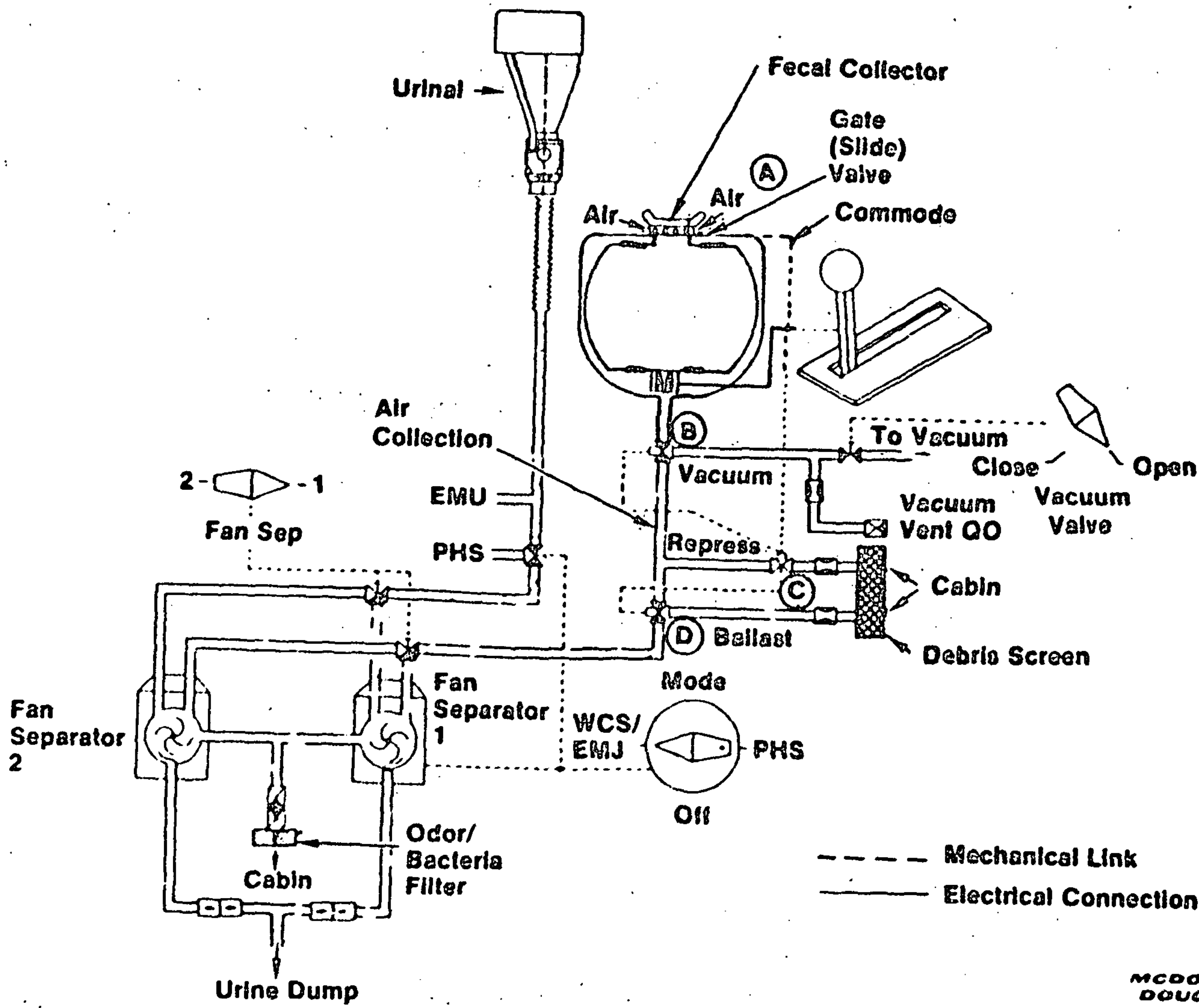


- Insert Neck of Fresh Bag Into Underside of Inner Drum Lid
- Replace Pip Pins
- Insert Bag Into Inner Drum, Secure Velcro Attachment Points
- Align Inner Drum Lid and Replace Inner V-Band Clamp
- Align Outer Drum Lid and Replace Outer V-Band Clamp
- Raise Seat
- Re-Attach Slide Valve Clevis and Linkage to Slide Valve
- Lower Seat

MCDONNELL DOUGLAS CORPORATION

CENTRIFUGAL COMPACTION CONCEPT
SYSTEM SCHEMATIC

VEC856



MCDONNELL DOUGLAS CORPORATION

CENTRIFUGAL COMPACTION CONCEPT

VALVE POSITIONS (SEE SCHEMATIC)

Mode-Off

(A) Closed

(B) Open to Vacuum

(C) Open

(D) Open to Ballast Line

Urine Collection:
Model–WCS/EMU

(A) Closed

(B) Open to Vacuum

(C) Open

(D) Open to Ballast Line

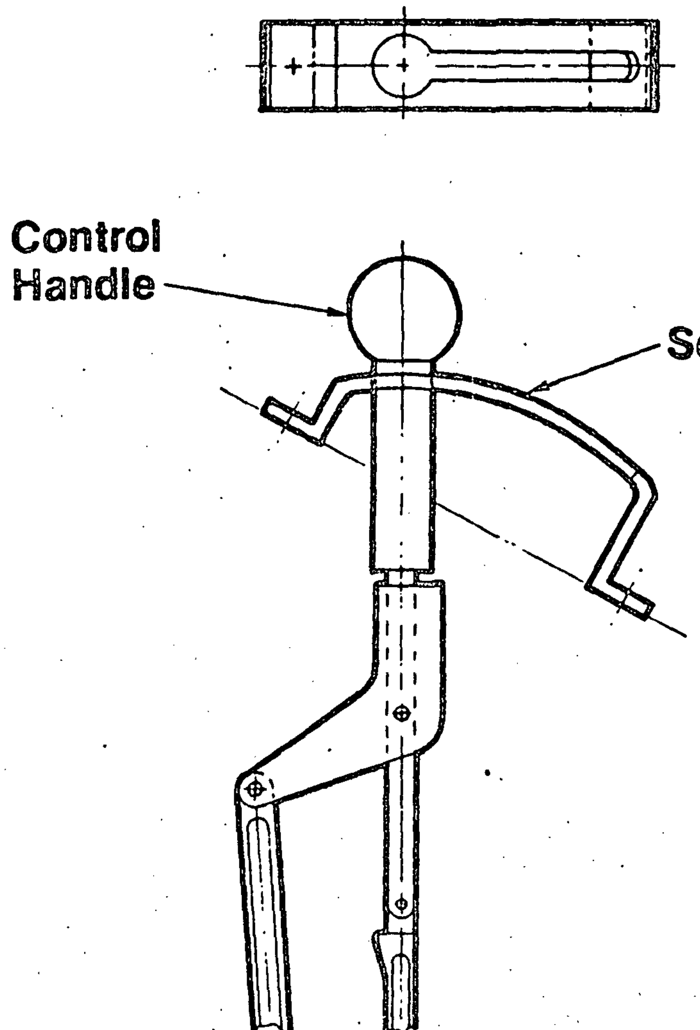
Urine/Feces Collection:
Mode–WCS/EMU

- Handle Up
  - (A) Closed
  - (B) Open to Air Collection Line
  - (C) Open
  - (D) Open to Ballast Line

- Handle Forward
  - (A) Open
  - (B) Open to Air Collection Line
  - (C) Closed
  - (D) Open to Commode

CENTRIFUGAL COMPACTION CONCEPT
VALVE LINKAGE IMPROVEMENT

VEC921

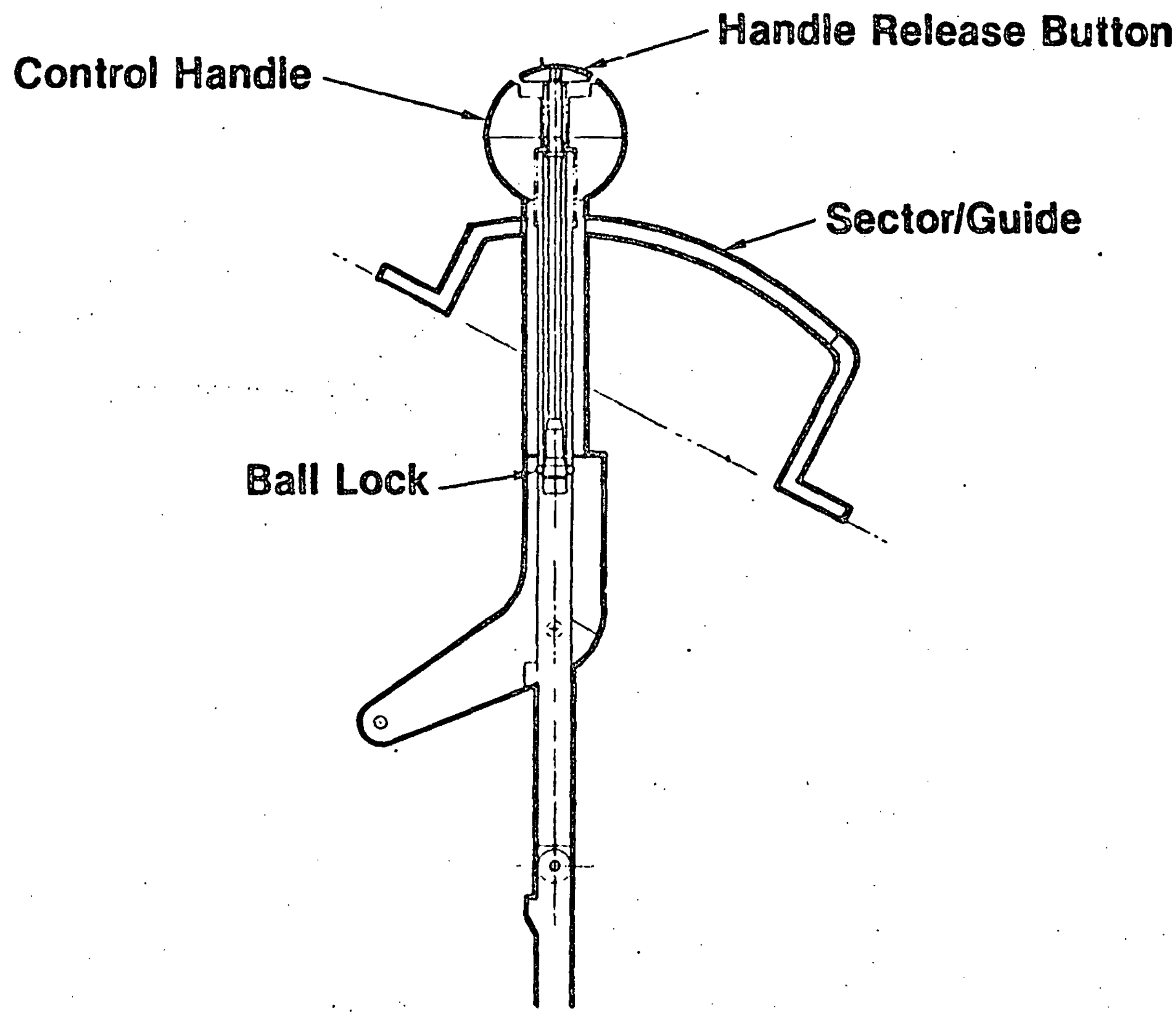


MCDONNELL DOUGLAS CORPORATION

McDONNELL DOUGLAS CORPORATION

VALVE LINKAGE IMPROVEMENT OPTION 1

VEC922



MCDONNELL DOUGLAS CORPORATION

CENTRIFUGAL COMPACTION CONCEPT
CREW PROCEDURES

TYPICAL USE CYCLE

		CREW TIME MIN.	CREW TIME SEC.
1.	TURN MODE SWITCH TO WCS/EMU*		2
2.	PULL UP ON COMMODE CONTROL		3
3.	POSITION BODY AND RESTRAINT SYSTEM WHILE WAITING (20 SECONDS MIN.)		30
4.	PUSH COMMODE CONTROL FORWARD		3
5.	PERFORM DEFECATION AND CLEANUP	12	0
6.	REMOVE RESTRAINT SYSTEM		15
7.	PUSH COMMODE CONTROL TO REAR AND DOWN (OFF)		5
8.	TURN MODE SWITCH TO OFF		2
9.	DISINFECT SEAT (STOW PAPER IN WET TRASH)		30
	TOTAL TIME .	13 MIN.	30 SEC.

*FOR URINATION ONLY (AFTER STEP 1), PROCEED TO PERFORM URINATION AND CLEANUP AND GO TO STEP 8.

CENTRIFUGAL COMPACTION CONCEPT
GROUND TURNAROUND

STEP	TIME (HR.)
1. OPEN VACUUM VALVE 2. OPEN SLIDE VALVE 3. INSTALL PLUG INTO BAG NECK	.25
4. RAISE SEAT 5. DISCONNECT SLIDE VALVE CABLE CLEVIS 6. LOWER AND LATCH SEAT	.25
7. REMOVE OUTER V-CLAMP 8. REMOVE OUTER VESSEL LID 9. REMOVE INNER V-CLAMP	.25
10. LIFT INNER DRUM LID, PULL BAG OUT OF INNER DRUM 11. REMOVE PIP PINS FROM BAG NECK 12. PULL BAG FREE, PLACE IN TRANSPORT CONTAINER 13. REMOVE SPENT ODOR/BACTERIA FILTER, PLACE IN TRANSPORT CONTAINER 14. REMOVE TRANSPORT CONTAINER FROM ORBITER	.50
15. CLEAN & DISINFECT INTERIOR OF DRUM, OUTER VESSEL AND URINE SYSTEM	1.50
16. CLEAN & DISINFECT EXTERIOR OF WCS	.50
17. INSTALL NEW BAG INTO INNER DRUM LID 18 REPLACE PIP PINS IN BAG NECK 19. LOWER INNER DRUM LID WHILE INSTALLING BAG INTO DRUM	1.00
20. REPLACE INNER V-CLAMP	

CENTRIFUGAL COMPACTION CONCEPT
GROUND TURNAROUND
(CONTINUED)

Step	TIME (HR.)
21. REPLACE OUTER VESSEL LID 22. REPLACE OUTER V-CLAMP	.25
23. RAISE SEAT 24. RE-CONNECT SLIDE VALVE CABLE CLEVIS 25. LOWER AND LATCH SEAT	.25
26. INSTALL NEW ODOR/BACTERIA FILTER 27. RESTORE TO INITIAL CONDITIONS CONFIGURATION	.25
28. VERIFY OPERATION OF SYSTEM	.50
29. MOVE TRANSPORT CONTAINER TO SERVICE AREA 30. DISPOSE OF FECAL BAG 31. CLEAN & STORE TRANSPORT CONTAINER	1.00
TOTAL TIME	6.50 HR.

MCDONNELL DOUGLAS CORPORATION

CENTRIFUGAL COMPACTION CONCEPT
POTENTIAL GSE REQUIREMENTS

- BIOLOGICAL ISOLATION GARMET
- CLEAN UP EQUIPMENT
  - BRUSHES
  - WIPES
  - BIOCIDE/CLEANER
  - TRASH BAG
- FLUID CIRCULATION AND FLUSH SYSTEM (FOR FLUSHING OUT URINE SYSTEM)
- STANDARD TOOLS
- TRANSPORT CONTAINER

MCDONNELL DOUGLAS CORPORATION

CENTRIFUGAL COMPACTION CONCEPT
POWER CONSUMPTION

- Fan/Separators (Existing) 100W Air 200W Air/Liq.
- Drum Motor 40W Max
  - Modify Existing Flight Qualified Slinger Motor
  - Add a 39:1 Reduction Gear Box

CENTRIFUGAL COMPACTION CONCEPT

- Bag Pressure Drop:
  - Bag Approximately Same Area as Existing Bag
    ΔPmax = 6 in. H_2O at 30 CFM
- Overboard Air Loss:
  - Air Loss Per Usage = Volume × Air Density
    = 3.35 ft^3 × 0.0752 lb/ft^3 = 0.252 lb
  - Total Air Loss for 210 Man Day Uses
    = Man Days × Air Loss/Usage = 210 × 0.252 lb = 52.9 lb
  - Total Air Loss for 56 Man Day Uses
    = Man Days × Air Loss/Usage = 56 × 0.252 lb = 14.1 lb

CENTRIFUGAL COMPACTION CONCEPT

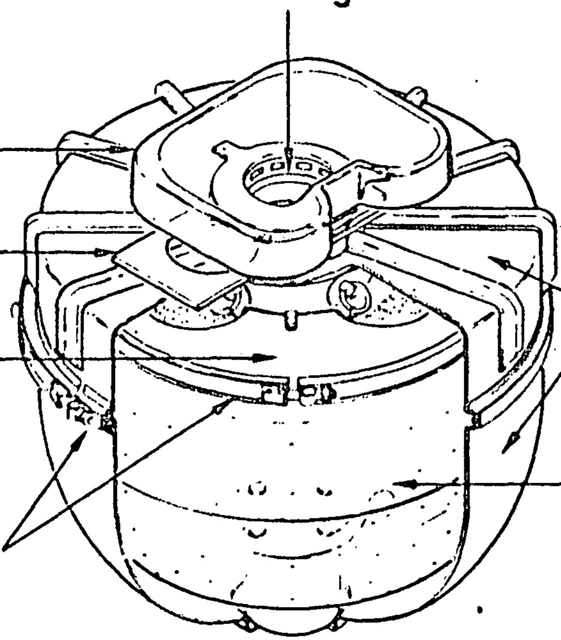
- Sizing of Rectangular Exhaust Air Duct Extension To Have Same ΔP as Present 1.5 in. OD Duct
  - Let Outside Width (W) = 1 in. for Personal Hygiene Tray Clearance. Wall Thickness = 0.030 in.
  - Let Hydraulic Dia.,(DH) = 4 × Area (A)/Perimeter (S), Equal Diameter of Round Duct
  - ID of Round Duct × 1.5 - 0.060 = 1.44 in.
    Inside Width (WINS) of Rect. Duct = 1 - 0.060 = 0.94 in.

$$\text{LINS} = \frac{\text{DH WINS}}{(2\ \text{WINS} - \text{DH})} = \frac{1.44 \times 0.94}{2 \times 0.94 - 1.44} = 3.08\ \text{in.}$$

Outside Dimensions = 1 in × (3.08 + 0.060) = 1 in. × 3.14 in.

CENTRIFUGAL COMPACTION CONCEPT
HARDWARE FABRICATION FEASIBILITY

VEC859



Bag: Porous Filter Medium
Bonded at Joints

MCDONNELL DOUGLAS CORPORATION

VEC861

CENTRIFUGAL COMPACTION CONCEPT
DEVELOPMENT ITEMS

- Motor Drive/Gearbox
- Rotating Bearing
- Drum Spin Speed

McDONNELL DOUGLAS CORPORATION

CENTRIFIGUAL COMPACTION CONCEPT
REQUIREMENTS REVIEW

GENERAL REQUIREMENTS

- O AIRFLOW SEPARATES WASTE FROM CREWMEMBER
- O WASTES STORED EN MASSE IN VACUUM CONTAINER

SPECIFIC REQUIREMENTS

- O MALE/FEMALE FECES AND URINE COLLECTION INTERFACES SAME AS EXISTING SYSTEM
- O INDIVIDUAL URINE CAPS PROVIDED
- O CREW PROCEDURES IDENTICAL TO EXISTING SYSTEM
- O PAPER IS DESPOSITED INTO FECAL COLLECTOR DURING USE
- O CREW TRAINING IDENTICAL TO EXISTING SYSTEM
- O NO HANDLING OF WASTE
- O SEPARATION METHOD IDENTICAL TO EXISTING SYSTEM
- O BODY STABILIZATION SAME AS EXISTING SYSTEM
- *O CAPACITY EQUAL TO EXISTING SYSTEM WITH COMPACTION CAPABILITY ADDED
- O BACTERIA AND ODOR CONTROLLED BY VACUUM STORAGE AND FILTERS
- O NOISE LEVEL EQUIVALENT TO EXISTING SYSTEM
- *O MAINTENANCE IN VEHICLE
- O WEIGHT, POWER, AND EXPENDABLES ARE EQUIVALENT TO EXISTING SYSTEM
- *O VALVE MECHANISM RELIABILITY IS INCREASED; ROTATING CHAMBER IS DESIGNED WITH FAIL-OPERATIONAL CHARACTERISTICS
- O SYSTEM IS RETROFITTABLE INTO ORBITER

*DIFFERS FROM EXISTING SYSTEM

MCDONNELL DOUGLAS CORPORATION

VEC858.1

CENTRIFUGAL COMPACTION CONCEPT
WEIGHT ESTIMATE SUMMARY

Component	Wt (lb)	
Inner Drum	11.0	
Outer Drum (Composite)	41.0	
Slide Valve	3.0	
Seat	3.0	
Motor	3.0	
Structural Supports	14.0	
Switches, Cables, Elect. Conn.	7.0	
Odor Bacteria Filtcr*	6.0	
Restraint System*	7.0	
Fiberglass Shroud	7.0	
2 Fan/Separators*	5.0	
Hoses, Ducts*	5.0	
Hardware Total	112.0	
Bags**	1.5	
Air**	52.9	14.1
Total System Wt	166.4	127.6

*Existing System Hardware	210 Uses	56 Uses
**Expendables		

WCS WEIGHT ESTIMATE SUMMARY (POUNDS)

System	Man-Days	Hdwe	Bags	Air	Liquid	Total
1-G Skylab	56	79.4	17.0	9.1	0	105.5
Centrifugal Comp	56	112.0	1.5	14.1	0	127.6
Centrifugal Comp	210	112.0	1.5	52.9	0	166.4
Skylab Repackaged	210	110.4	52.3	24.6	0	187.3
Modified Skylab	210	85.3	4.0	7.0	0	96.3
Closed Loop Macerator	210	88.5	0	0	93.6	182.1
Existing System	56	109.0	1.5	10.1	0	120.6
Existing System	210	109.0	1.5	37.9	0	148.4

MCDONNELL DOUGLAS CORPORATION

CENTRIFUGAL COMPACTION CONCEPT

VEC862

SUMMARY

ADVANTAGES

1. Collector Mounts Directly Onto Existing Commode Structure Which Is Immediately Retrofittable Into Orbiter Compartment
2. Existing Fan/Separators, Valves, Hardware and Interfaces are Used
3. Commode Control and Valve Linkage Is Improved
4. Compaction of Tissues and Fecal Material Is Provided By Centrifugal Force
5. Rotation Moves Fecal Material Out of View of Crew
6. Large Bag Collection Method Is Simple and Proven
7. Low Rotation Speed Enhances Mechanical and Functional Reliability
8. Motor and Rotating Drum Revert to Simple Bag Operation in Event of Failure
9. Motor and Shaft Located Within Pressure Vessel – Eliminates Need for a Rotating Seal Around Shaft
10. Crew Handles No Waste
11. Waste Material Is Deactivated by Vacuum Drying and/or Freezing
12. Air Loss Similar to Current System
13. Complete Enclosure of Bag Minimizes Stress on Bag Material
14. Plug Provides for Simple, Positive, and Hygienic Closure of Bag for Convenient and Sanitary Ground Handling
15. Big Bag Concept Eliminates Bag Handling for Shuttle Application
16. Bag May be Easily Changed on Orbit for a Longer Duration Space Station Mission

DISADVANTAGES

1. Rotating Bearing at Bag Opening Is Required
2. An Out of Balance Condition Due to Non-Uniform Buildup of Fecal Material May Lead to Bearing Wear or the Need for a Balancing Device

McDONNELL DOUGLAS CORPORATION

VEC912

TASK 5
PROGRAM REVIEW REQUIREMENTS

- Initial Subsystem Review at JSC
- Mid-Term Status Review at MDAC-HB
- Formal Presentation at JSC

TASK 6
PROGRAM DOCUMENT REQUIREMENTS

- Final Report

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APPENDIX A SPACE STATION WCS CONCEPT

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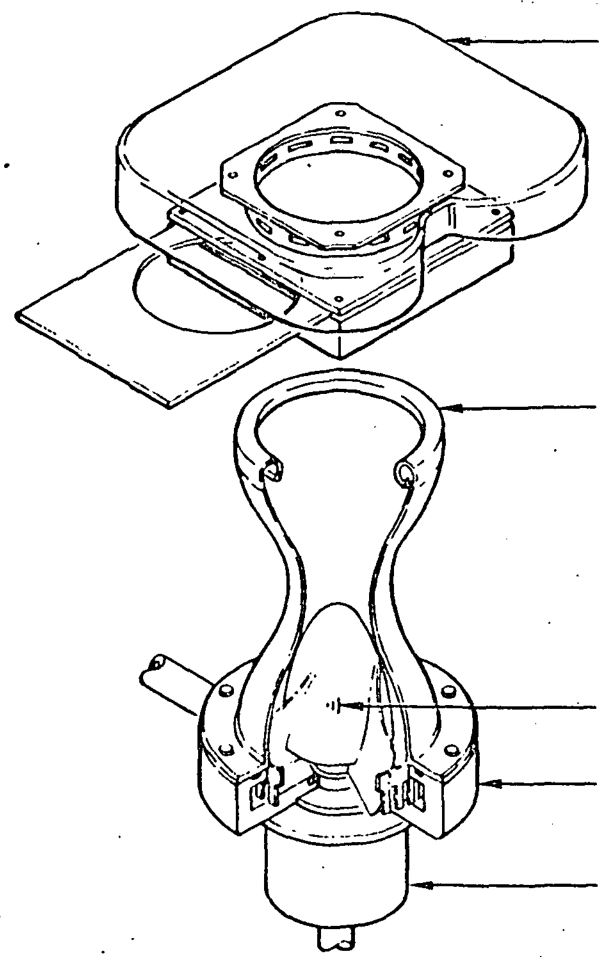
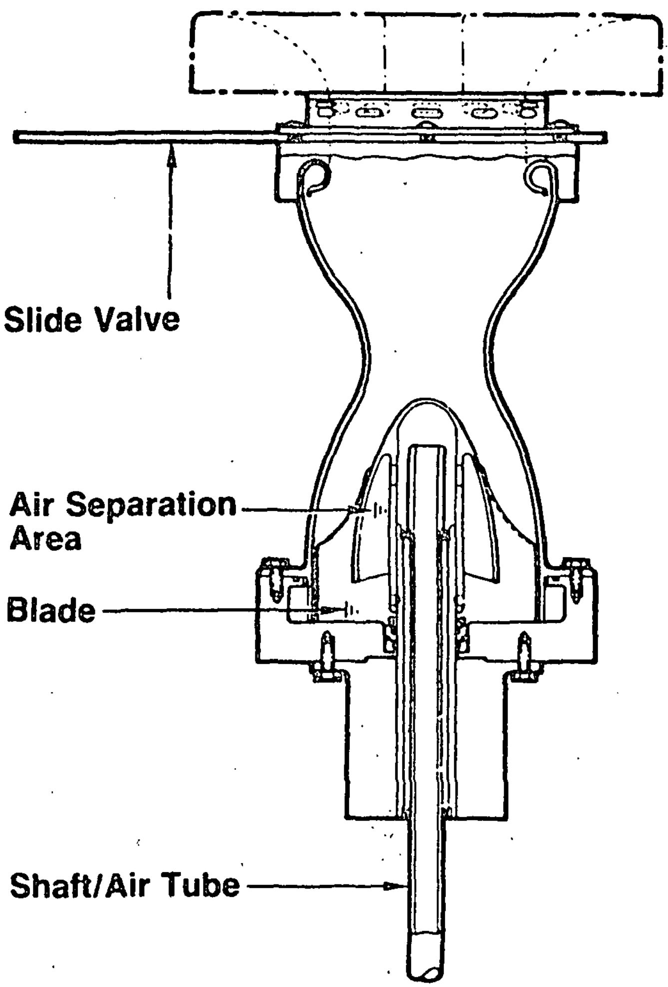
CLOSED LOOP MACERATOR SYSTEM CONCEPT

VEC865

CLOSED LOOP MACERATOR CONCEPT

MCDONNELL DOUGLAS CORPORATION

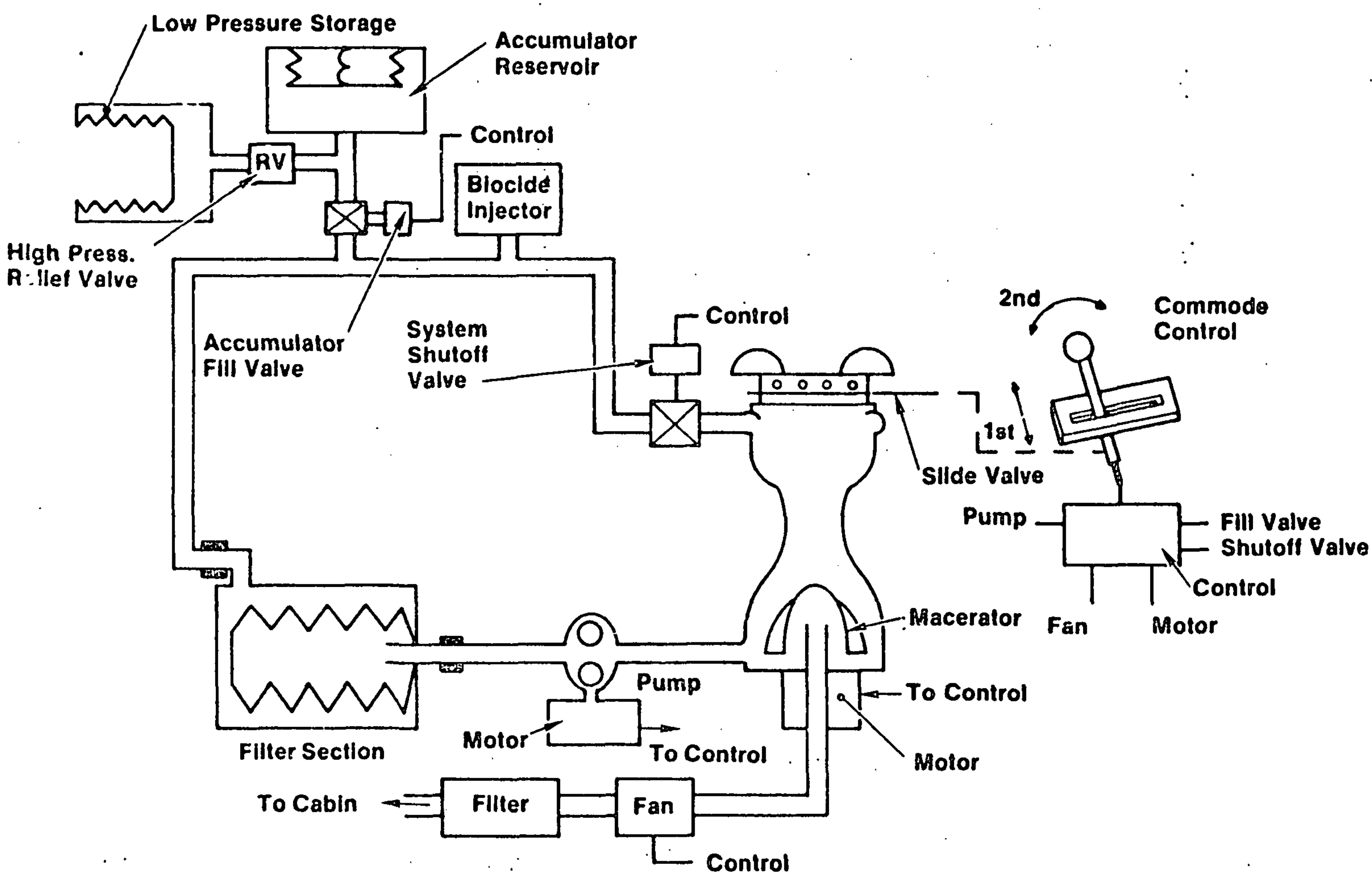




CLOSED LOOP MACERATOR SYSTEM CONCEPT
SYSTEM SCHEMATIC

VEC866

MCDONNELL DOUGLAS CORPORATION



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CLOSED LOOP MACERATOR SYSTEM CONCEPT
GROUND OPERATIONS

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1. Close filter isolation valves
2. Disconnect bellows/filter unit
3. Place bellows/filter unit in transport container
4. Remove transport container from orbiter
5. Connect fluid flush/recharge system to line shutoff valve connectors
6. Open line shutoff valves and flush out system to disinfect
7. Cycle volume control reservoir, biocide injector, and slurry pump while flushing
8. Stop flushing momentarily, open slide valve
9. Inspect slide valve, clean if necessary, close
10. Continue flushing to clear system of slide valve debris
11. When fluid is clear, fill volume control reservoir
12. Stop flushing, close filter isolation valve
13. Disconnect fluid flush system
14. Install new fluid charged bellows/filter unit
15. Open filter isolation valves
16. Recharge biocide injector
17. Install new odor/bacteria filter
18. Verify system back to initial conditions
19. Service bellows/filter unit as necessary

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CLOSED LOOP MACERATOR SYSTEM CONCEPT
POTENTIAL GSE REQUIREMENTS

- o BIOLOGICAL ISOLATION GARMET
- o ODOR/BACTERIA FILTER
- o RECHARGED BELLOWS/FILTER UNIT
- o CLEAN UP EQUIPMENT
    - o BRUSHES
    - o WIPES
    - o BIOCIDE/CLEANER
    - o TRASH BAGS
- o FLUID CIRCULATION AND FLUSH/RECHARGE SYSTEM
- o STANDARD TOOLS
- o TRANSPORT CONTAINER
- o SERVICING EQUIPMENT FOR BELLOWS/FILTER UNIT

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CLOSED LOOP MACERATOR SYSTEM
EXPENDABLES SUMMARY

No Expendables

- Air Used Only for Collection and Entrainment — Recirculated Back to Cabin Through Odor/Bacteria Filter

- Liquid Used Only to Circulate Fecal Material and Carry Biocide for Deactivation — Recirculated Through System and Filter

C-2

CLOSED LOOP MACERATOR SYSTEM

VEC881

Biocide Data

Material	Formula	Solvents	Dosage*	Toxicity	Cost
Cupric Bromide	$CuBr_2$	Water[1] Ethanol[2]	7 — 8 g/100g Feces	Minimal	$13.00/100g
Silver Sulphate	$AgSO_4$	Water[2]	8 — 10 g/100g Feces	Minimal	$220.00/100g
Silver Oxide	Ag_2O	Ethanol[3]	~8g /100g Feces	Minimal	$240.00/100g

* Dosage is Amount of Crystalline Material Mixed Into Feces To stop Production of Gaseous Byproducts

1 Very Soluble
2 Moderately Soluble
3 Low Solubility

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VEC868

CLOSED LOOP MACERATOR CONCEPT
HARDWARE FABRICATION FEASIBILTY

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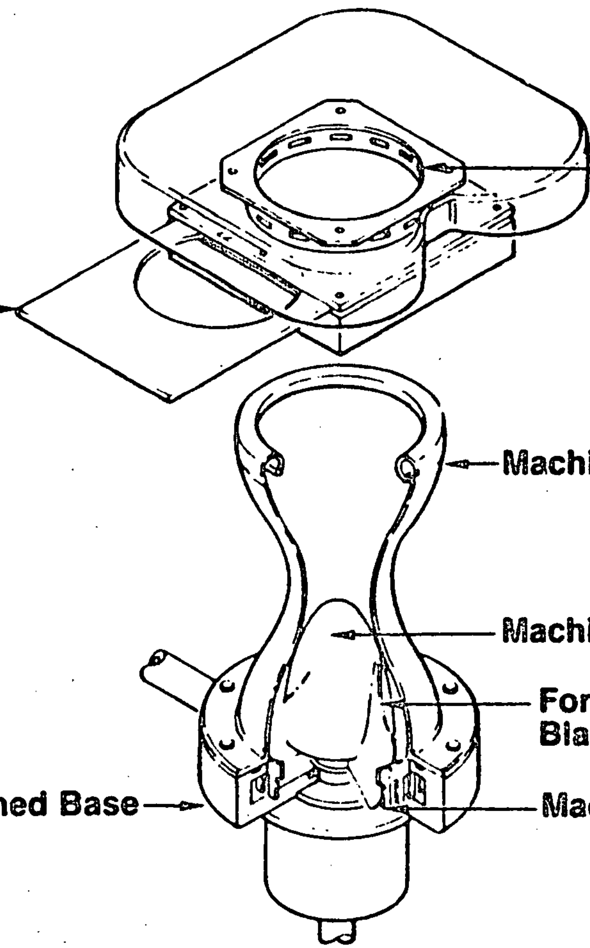
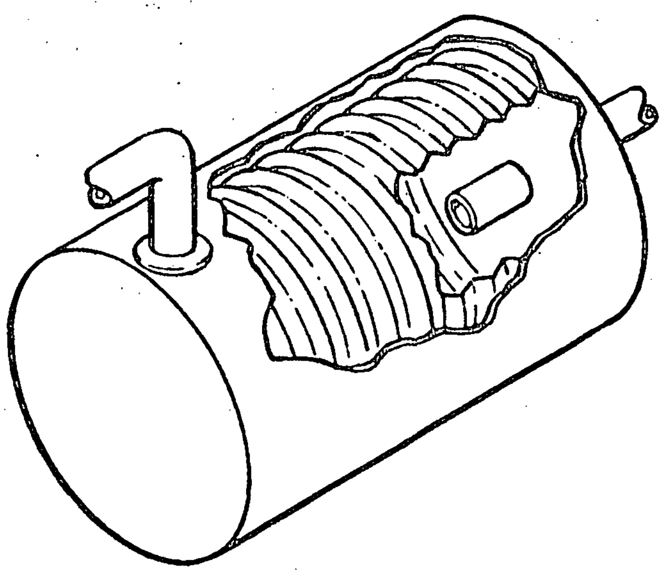


VEC869

CLOSED LOOP MACERATOR CONCEPT
HARDWARE FABRICATION FEASIBILITY (CONT'D)

TBD



Filter Section

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MCDONNELL DOUGLAS CORPORATION

CLOSED LOOP MACERATOR CONCEPT
DEVELOPMENT ITEMS

- Macerator/Separator
- Collection Bowl
- Filter Section
- Macerator Motor and Seals
- Slurry Pump
- Volume Control Reservoir
- Sensors
- Biocide Quantity and Type
- Adjustment of Flow/ΔP Characteristics of System

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CLOSED LOOP MACERATOR SYSTEM
WEIGHT ESTIMATE SUMMARY

Component	Wt (lb)
Collector Vessel	3.1
Seat Adapter	0.5
Bottom Plate	0.5
Macerator Blades	0.3
Spinner	2.3
Seat	3.0
Slide Valve	3.0
Motor	3.0
Slurry Pump	4.0
Filter Section	31.2
Accumulator, Injector, Valving	10.0
Piping	10.0
Structural Supports	14.3
Switches, Cables, Elect. Conn.	2.6
Hardware Total	88.5
Fluid	93.6
Total System Wt	182.1

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WCS WEIGHT ESTIMATE SUMMARY (POUNDS)

System	Man-Days	Hdwe	Bags	Air	Liquid	Total
1-G Skylab	56	79.4	17.0	9.1	0	105.5
Centrifugal Comp	56	112.0	1.5	14.1	0	127.6
Centrifugal Comp	210	112.0	1.5	52.9	0	166.4
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Closed Loop Macerator	210	88.5	0	0	93.6	182.1
Existing System	56	109.0	1.5	10.1	0	120.6
Existing System	210	109.0	1.5	37.9	0	148.4

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CLOSED LOOP MACERATOR SYSTEM

ADVANTAGES

1. Configuration is Applicable to Space Station
2. Air and Water Entrainment is More Effective Than Air Alone
3. Crew Use Time is Minimal-Similar to Conventional Toilet
4. Crew Training Time is Minimal
5. Waste is Flushed Completely Out of Sight
6. Water Continually Cleans Collection Surface During Use
7. Unit is Psychologically Very Acceptable
8. Biocide is Thoroughly Mixed With Feces to Provide Deactivation
9. No Air Loss – Closed System
10. Entire System Operates in a Cabin Pressure Environment
11. Compaction and Containment Capability are Provided by a Macerator and Filter
12. Filter Section is Self Contained and Can be Hygienically Changed Out on Orbit or Ground
13. With Removal of Filter Only, Entire Unit Can be Flushed Out on Ground
14. Use of Slide Valve Permits More Flexibility in Choice of Biocide – Scent is Isolated From Cabin Environment

DISADVANTAGES

1. A Biocide Which is Effective Yet Non-Toxic to Crew Must be Found
2. Macerator/Air Separator Requires Development
3. Filtration Section Requires Development
4. Development Cost May be High
5. System is Somewhat Complex Due to Mechanical, Electrical, and Sensing Devices

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APPENDIX B
Other Semi-Final Concepts

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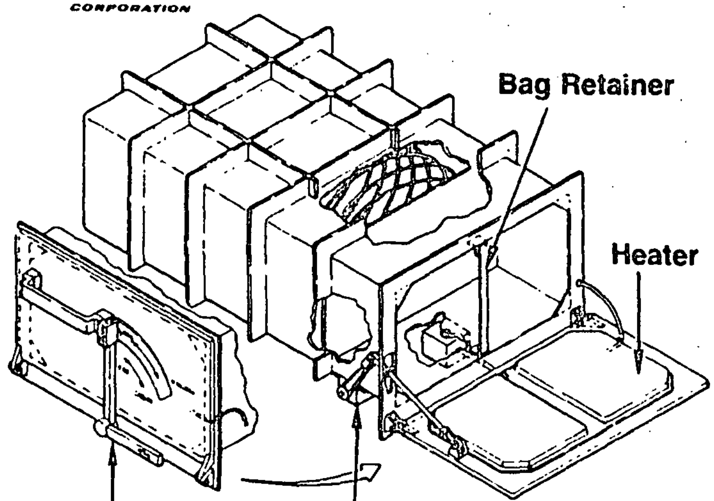
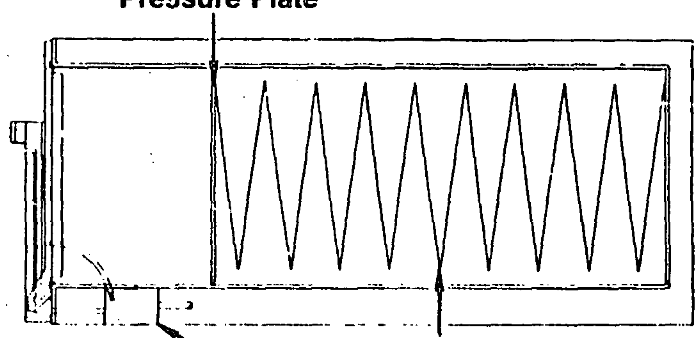
SKYLAB REPACKAGED CONFIGURATION

VEC874

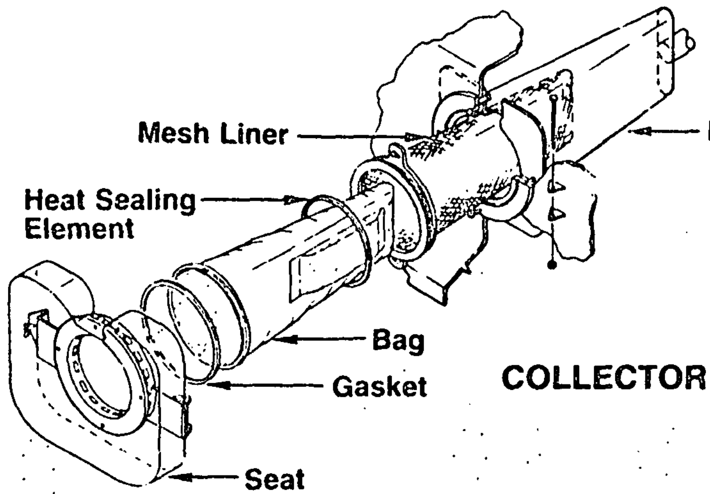
SKYLAB REPACKAGED CONFIGURATION

MCDONNELL DOUGLAS CORPORATION

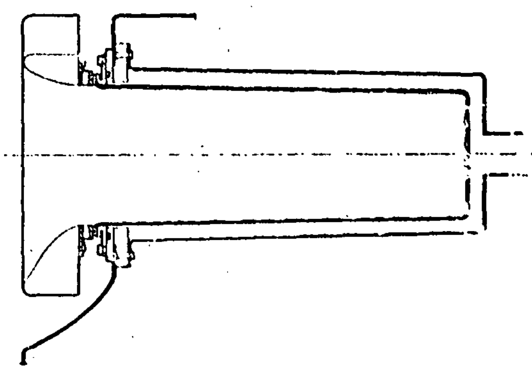




PROCESSOR

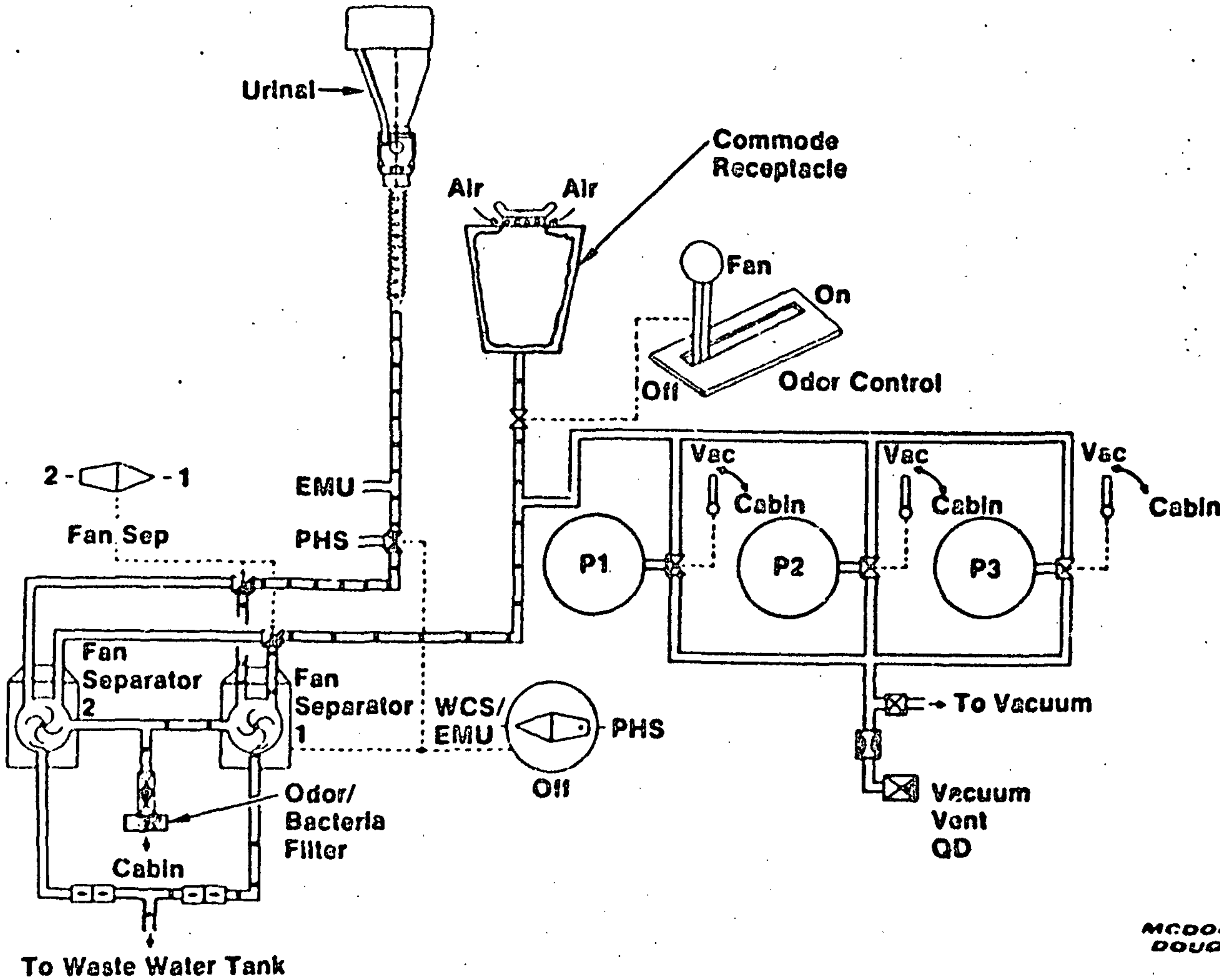


COLLECTOR



SKYLAB REPACKAGED CONFIGURATION
SYSTEM SCHEMATIC

VEC886



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MCDONNELL DOUGLAS CORPORATION

SKYLAB REPACKAGED CONFIGURATION

CREW PROCEDURES

		CREW TIME Min.	Sec.
1.	Turn on air collection system		2
2.	Position body and restraint system		30
3.	Perform defecation and cleanup	12	0
4.	Remove restraint system		15
5.	Unlatch and lift seat		10
6.	Seal bag		15
7.	Verify or close processor vacuum valve, wait for repressurization		5
8.	Open processor door		5
9.	Remove bag from collector		5
10.	Place bag into processor		15
11.	Close processor door		5
12.	Open processor vacuum valve		3
13.	Disinfect seat		30
14.	Open clean bag dispenser		5
15.	Install clean bag		15
16.	Close clean bag dispenser		5
17.	Lower seat & latch		10
18.	Turn off air collection system		2
	Total time	14 Min.	57 Sec.

SKYLAB REPACKAGED CONFIGURATION
GROUND OPERATIONS

1. Attach filter (GSE*) to vacuum line(s)
2. Start cabin ventilation fan
3. Open vacuum line(s) to atmosphere
4. Open processor door(s)
5. Remove bags, place into air-tight transport container
6. Remove spent odor/bacteria filter
7. Place filter in transport container
8. Remove transport container from orbiter
9. Clean & disinfect interior of collector, processors and vacuum system
10. Clean & disinfect exterior of WCS
11. Install fresh bag
12. Install fresh odor/bacteria filter
13. Return system to initial condition configuration
14. Remove filter (GSE) from vacuum line(s)
15. Move transport container to service area
16. Remove waste from transport container
17. Clean & store transport container

*Ground Support Equipment

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SKYLAB REPACKAGED CONFIGURATION
POTENTIAL GSE REQUIREMENTS

- BIOLOGICAL ISOLATION GARMET
- ODOR/BACTERIA FILTER
- CLEAN UP EQUIPMENT
  - BRUSHES
  - WIPES
  - BIOCIDE/CLEANER
  - TRASH BAGS
- FLUID CIRCULATION AND FLUSH SYSTEM (FOR FLUSHING OUT VACUUM LINES AND AIR FLOW SYSTEM)
- STANDARD TOOLS
- TRANSPORT CONTAINER

SKYLAB REPACKAGED CONFIGURATION

- AIR LOSS = USES X PROCESSOR VOL X AIR DENSITY (STD COND)

$$= 210 \text{ USES} \times \frac{1.55 \text{ ft}^3}{\text{USE}} \times \frac{.0752 \text{ LB}}{\text{ft}^3} = \underline{24.6 \text{ LB}}$$

- BAG WEIGHT = NO. OF BAGS X WT PER BAG X CONTINGENCY FACTOR

(SKYLAB BAG WEIGHED 103g = .2266 LB)

$$= 210 \text{ BAGS} \times \frac{.2266 \text{ LB}}{\text{BAG}} \times 1.10 = \underline{52.3 \text{ LB}}$$

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SKYLAB REPACKAGED CONFIGURATION

HARDWARE FABRICATION FEASIBILITY

VEC876

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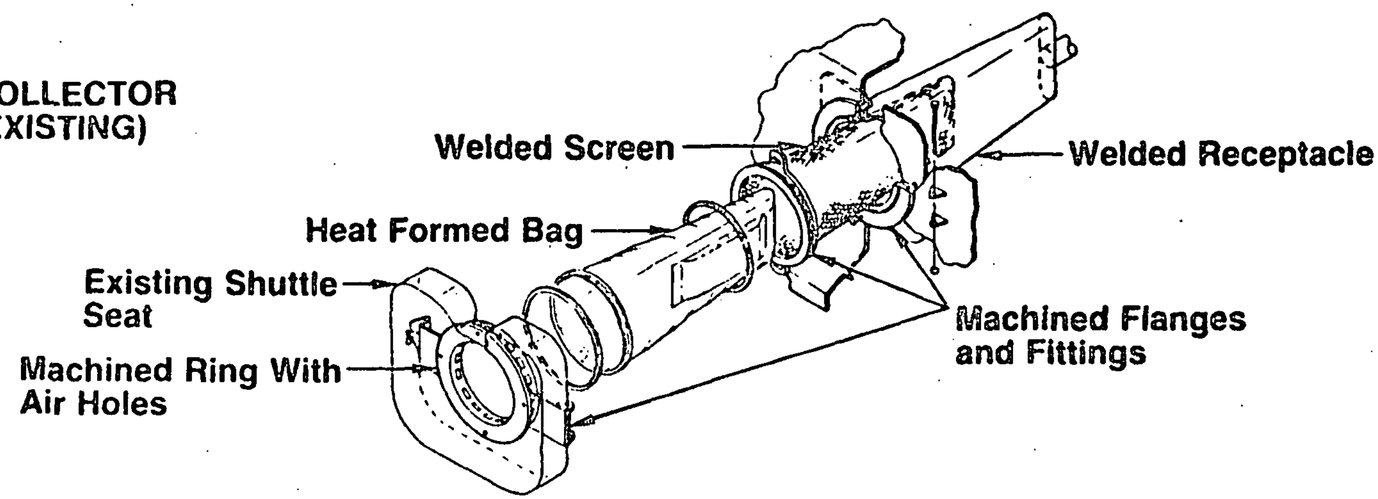
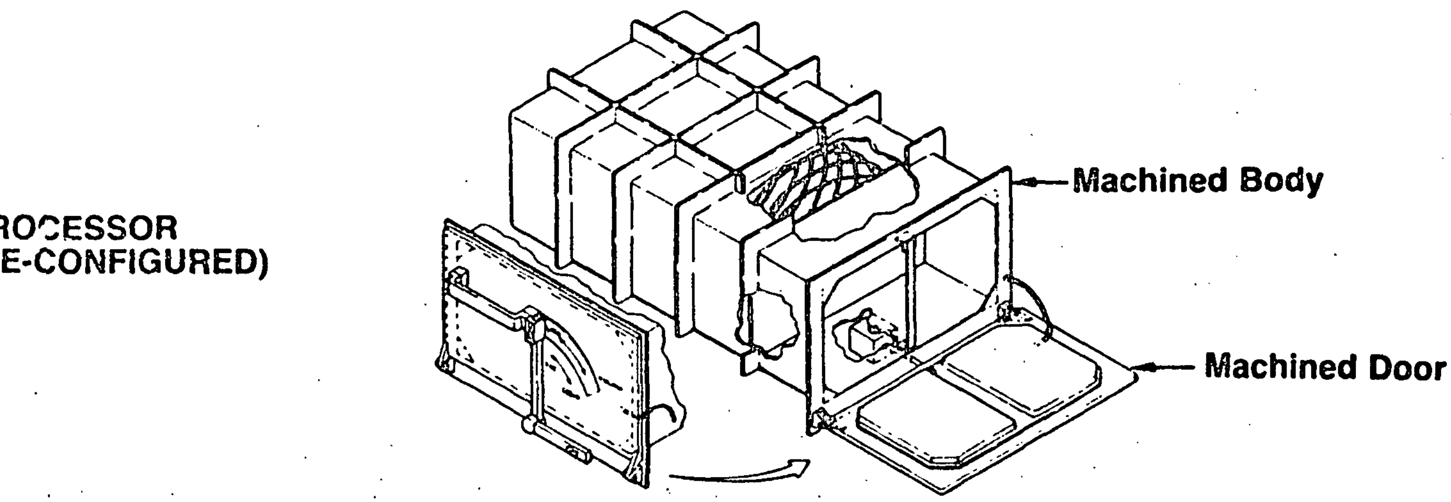
COLLECTOR
(EXISTING)



PROCESSOR
(RE-CONFIGURED)



ANALYSES TO BE COMPLETED BY END OF DESIGN PHASE

- AIRFLOW: ΔP OF BAG FILTER MATERIAL
  INTERACTION OF SYSTEM COMPONENTS - CORRECT FLOWS, ETC
- EXPENDABLES: AIR LOSS (COMPLETED)
  BAGS - VOLUME, WEIGHT (COMPLETED)
- CREW TIME: CREW TIME LINES (COMPLETED)
- THERMAL: HEAT TRANSFER OF BAG MATERIAL
  MULTIPLE BAG EFFECTS ON DEACTIVATION
- STRUCTURAL: MOUNTING OF SYSTEM COMPONENTS ON ORBITER PRIMARY STRUCTURE
  STRUCTURAL INTEGRITY OF COLLECTOR AND PROCESSORS
  SYSTEM WEIGHT ESTIMATE (COMPLETED)
- MASS BALANCE: EFFECTS OF SYSTEM ON VEHICLE ORBITAL AND FLIGHT DYNAMICS
- POWER: POWER CONSUMPTION OF FAN/SEPARATOR
  POWER CONSUMPTION OF HEATER ELEMENT

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SKYLAB REPACKAGED CONFIGURATION WEIGHT ESTIMATE SUMMARY

COMPONENT	WT (LB)
COLLECTOR RECEPTACLE	1.0
MESH SCREEN LINER	0.4
4 PROCESSORS	47.0
3 STORAGE COMPARTMENTS	19.0
SEAT	3.0
STRUCTURAL SUPPORTS	14.0
SWITCHES, CABLES, ELECT. CONN.	3.0
ODOR/BACTERIA FILTER *	6.0
RESTRAINT SYSTEM *	7.0
2 FAN-SEPARATORS *	5.0
HOSES, DUCTS *	5.0
HARDWARE TOTAL	110.4
BAGS **	52.3
AIR **	24.6
TOTAL SYSTEM WT	187.3 LB

* EXISTING SYSTEM HDWE

** EXPENDABLES

VEC875

SKYLAB REPACKAGED CONFIGURATION SUMMARY

MCDONNELL DOUGLAS CORPORATION

ADVANTAGES

1. Storage Is Orderly – Easier Ground Changeout
2. Processing and Storage Occur in Same Container
3. Skylab Collection Method Is Proven
4. Efficient Use of Shuttle Envelope
5. Low Air Loss Due to Smaller Volume of Processor
6. Compaction and Heat Application are a Feature of Processor
7. Crew Handles Only Clean or Sealed Bags With Advanced Bag Sealing Concept
8. Utilizes Existing Fan/Separator System
9. Mechanically Simple
10. Serviceable on Orbit
11. Airflow Is Used to Contain Odor During Bag Sealing
12. Airflow Is Used to Contain Odor From Processors During Bag Insertion
13. Stowage Area for Fresh Bags Is Provided

DISADVANTAGES

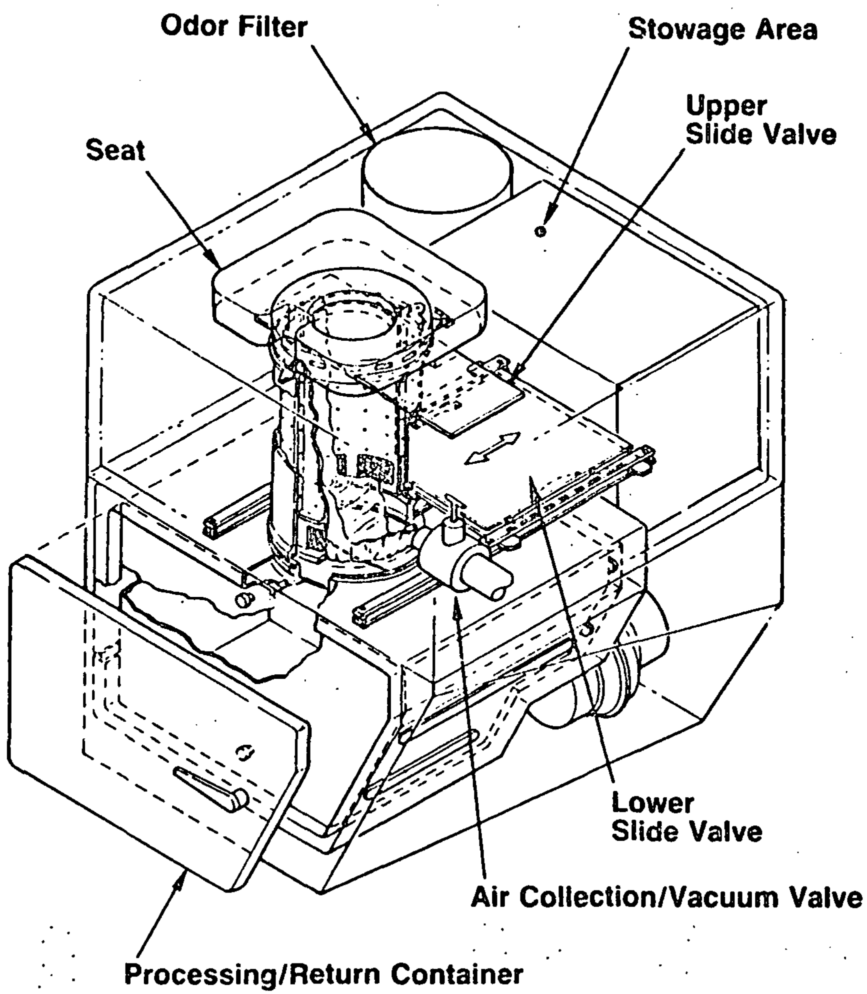
1. Fecal Bag and Associated Handling, Sealing, and Outgassing are Present
2. Required Bag Stowage Space Is Large but Adequate
3. Door to Personal Hygiene Compartment May Need to be Removed and a More Compact Restraining Device Installed
4. Use of Wall Towel Restraints and Personal Hygiene Stowage Compartment May be Lost on Orbiter
5. Space Station Applicability Is Low
6. Old Fecal Bags May Have to be Touched While Inserting Newly Used Bags Into Processor
7. Crew Acceptance May be Low

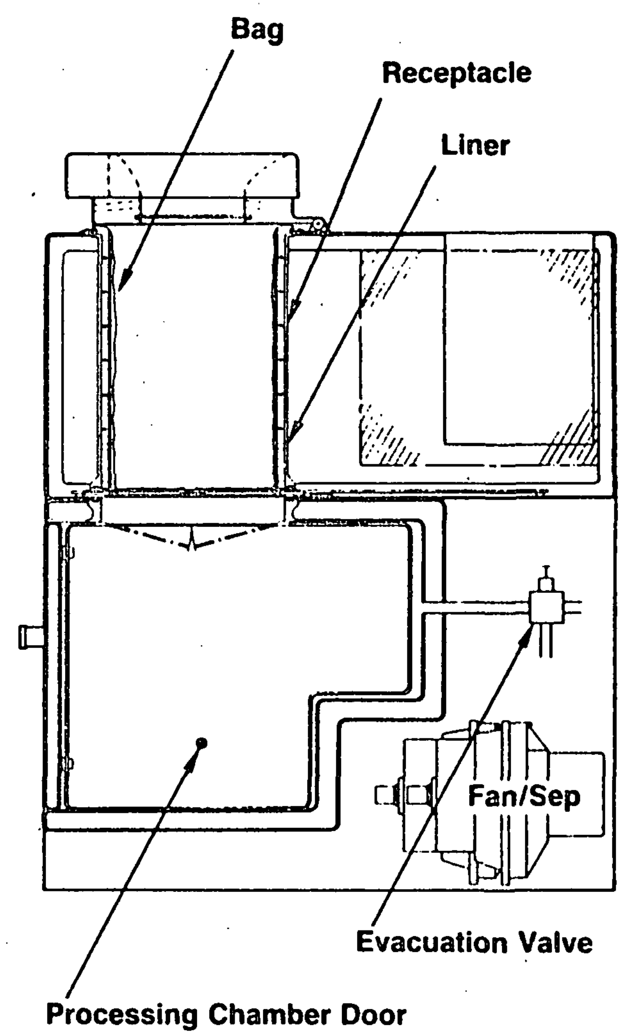
MCDONNELL DOUGLAS CORPORATION

MODIFIED SKYLAB CONCEPT

MCDONNELL DOUGLAS CORPORATION

MODIFIED SKYLAB CONCEPT

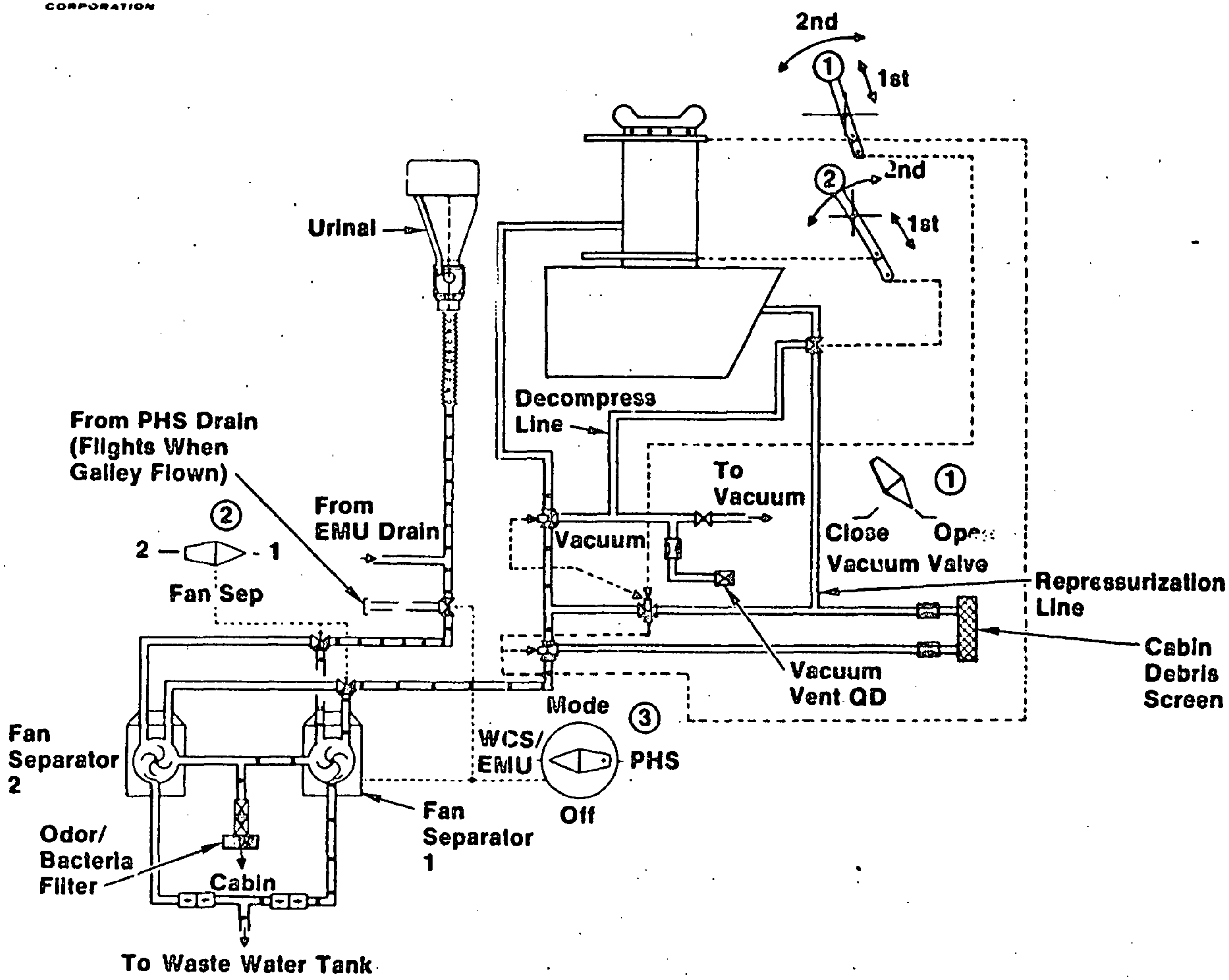




MODIFIED SKYLAB CONCEPT
SYSTEM SCHEMATIC

MCDONNELL DOUGLAS CORPORATION

VEC888



MCDONNELL DOUGLAS CORPORATION

MODIFIED SKYLAB CONCEPT

CREW PROCEDURES

		CREW TIME Min.	CREW TIME Sec.
1.	Verify or close vacuum valve 1, wait for repressurization		15
2.	Open slide valve 1		5
3.	Turn on air collection system		2
4.	Position body and restraint system		30
5.	Perform defecation and clean up	12	0
6.	Remove restraints		15
7.	Close slide valve 1		5
8.	Turn off air collection system		2
9.	Open vacuum valve 1		3
10.	Disinfect seat		30
	Total Time	13 Min.	47 Sec.

MODIFIED SKYLAB CONCEPT

CREW PROCEDURES (CONTINUED)

BAG DISPOSAL	CREW TIME Min.	Sec.
1. Close vacuum valve 1		15
2. Close vacuum valve 2		20
3. Turn on air collection system		2
4. Open slide valve 1		5
5. Unlatch and lift seat		15
6. Seal bag		15
7. Obtain push through tool		10
8. Use push through tool to compact/deflate bag		20
9. Open slide valve 2		5
10. Push bag into return container using push through tool		15
11. Close slide valve 2		5
12. Turn off air collection system		2
13. Install new bag in receptacle		15
14. Lower seat and latch		15
15. Close slide valve 1		5
16. Open vacuum valve 1		5
17. Open vacuum valve 2		5
Total Time	2 Min.	54 Sec.

MCDONNELL DOUGLAS CORPORATION

MODIFIED SKYLAB CONCEPT*
GROUND OPERATIONS

1. Attach filter (GSE**) to vacuum line(s)
2. Vent vacuum line(s) to atmosphere
3. Open return container compartment door
4. Remove return container
5. Install lid (GSE) on return container
6. Remove spent odor/bacteria filter
7. Briefly remove lid of return container
8. Place spent filter into return container
9. Re-cap return container
10. Remove return container from orbiter
11. Clean and disinfect interior of collector and return container compartment
12. Clean and disinfect exterior of WCS
13. Install a replacement return container
14. Install a new bag in receptacle
15. Install fresh odor/bacteria filter
16. Return system to initial conditions/configuration
17. Remove filter (GSE) from vacuum line(s)
18. Transport return container to service area
19. Remove waste from return container
20. Clean and store return container for future use

*Assumes no bag in collector area upon return to earth

** Ground Support Equipment

MODIFIED SKYLAB CONCEPT

POTENTIAL GSE REQUIREMENTS

- BIOLOGICAL ISOLATION GARMET
- ODOR/BACTERIA FILTER
- RETURN CONTAINER
- CLEAN UP EQUIPMENT
  - BRUSHES
  - WIPES
  - BIOCIDE/CLEANER
  - TRASH BAG
- FLUID CIRCULATION AND FLUSH SYSTEM (FOR FLUSHING OUT VACUUM LINES AND AIR FLOW SYSTEM)
- STANDARD TOOLS
- VACUUM PUMP ASSEMBLY (FOR CONTINGENCY USE ONLY - TO COMPLETE PROCESSING AND ALLOW EXAMINATION OF WCS EQUIPMENT WHILE WASTE IS STILL PRESENT)

MODIFIED SKYLAB CONCEPT

- AIR LOSS = LOSS DUE TO USE + LOSS DUE TO BAG CHANGE (STD COND)

$$= \text{USES} \times \frac{\text{VOL}}{\text{USE}} \times \text{AIR DENSITY} + \text{CHANGES} \times \frac{\text{VOL}}{\text{CHANGE}} \times \text{AIR DENSITY}$$

$$= 210 \text{ USES} \times \frac{.34 \text{ FT}^3}{\text{USE}} \times \frac{.0752 \text{ LB}}{\text{FT}^3} + 10 \text{ CHANGES} \times \frac{2.19 \text{ FT}^3}{\text{CHANGE}} \times \frac{.0752 \text{ LB}}{\text{FT}^3}$$

$$= 5.4 \text{ LB} + 1.6 \text{ LB} = \underline{7.0 \text{ LB}}$$

- BAG WEIGHT = WT PER BAG X NO. OF BAGS X CONTINGENCY FACTOR

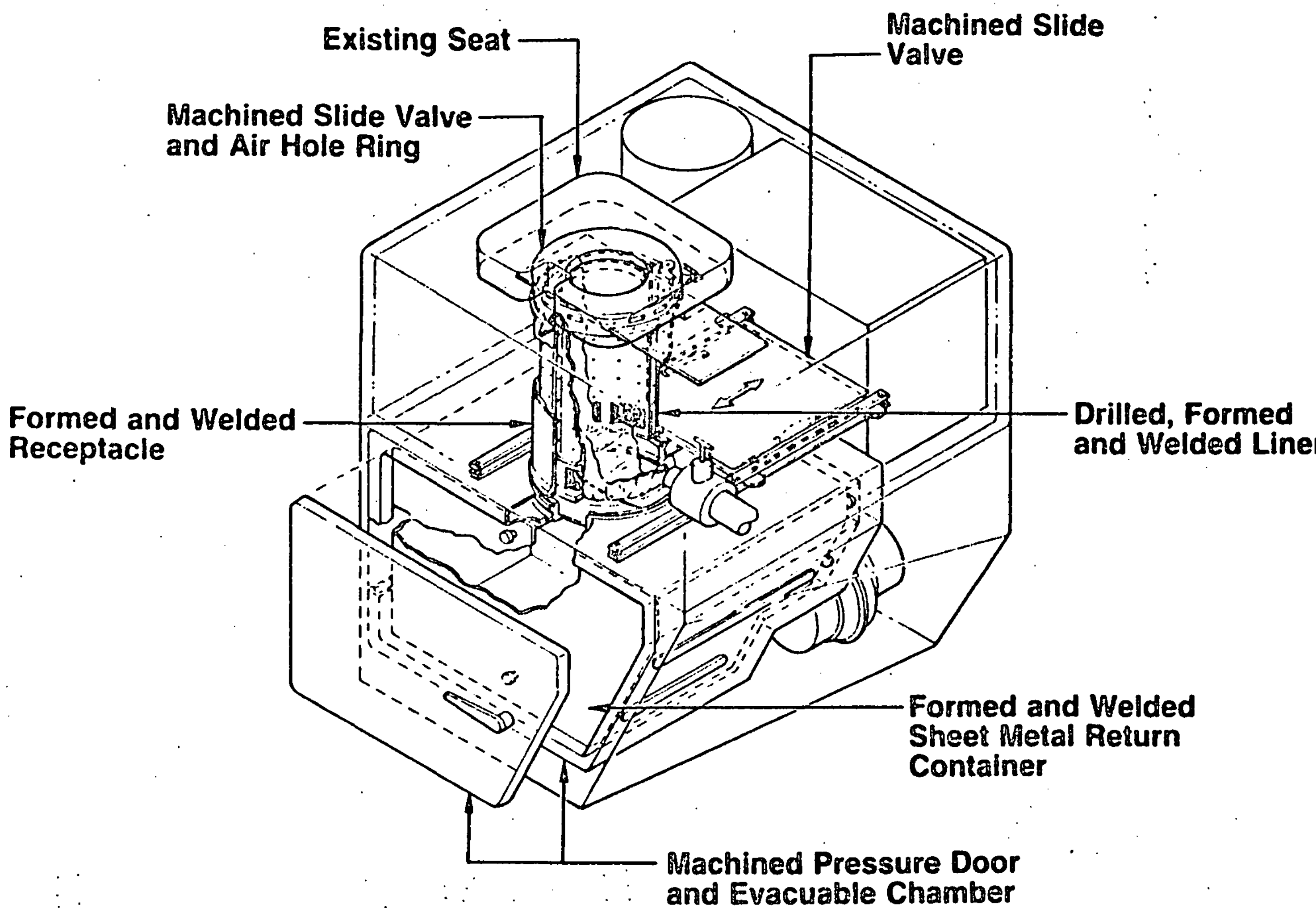
(ESTIMATE BAG WT = 162 g PER BAG = .356 LB)

$$= \frac{.356 \text{ LB}}{\text{BAG}} \times 10 \text{ BAGS} \times 1.10 = 3.92 \approx \underline{4.0 \text{ LB}}$$

VEC878

MCDONNELL DOUGLAS CORPORATION

MODIFIED SKYLAB CONCEPT
HARDWARE FABRICATION FEASIBILITY



MODIFIED SKYLAB CONCEPT

McDONNELL DOUGLAS CORPORATION

ANALYSES TO BE COMPLETED BY END OF DESIGN PHASE

- AIRFLOW: ΔP OF BAG FILTER MATERIAL
  INTERACTION OF SYSTEM COMPONENTS - CORRECT FLOWS, ETC
- EXPENDABLES: AIR LOSS (COMPLETED)
  BAGS - VOLUME, WEIGHT (COMPLETED)
- CREW TIME: CREW TIME LINES (COMPLETED)
- THERMAL: HEAT TRANSFER OF BAG MATERIAL AND RECEPTACLE/LINER
  EFFECT OF MULTIPLE DEFECATIONS ON DEACTIVATION
- STRUCTURAL: MOUNTING OF SYSTEM COMPONENTS ON ORBITER PRIMARY STRUCTURE
  STRUCTURAL INTEGRITY OF COLLECTOR AND EVACUABLE AREAS
  SYSTEM WEIGHT ESTIMATE (COMPLETED)
- MASS BALANCE: EFFECTS OF SYSTEM ON VEHICLE ORBITAL AND FLIGHT DYNAMICS
- POWER: POWER CONSUMPTION OF FAN/SEPARATOR

VEC889

MODIFIED SKYLAB CONCEPT

Weight Estimate Summary

Component	WT (lb)
Collector Receptacle	2.3
Collector Liner	3.2
Upper Slide Valve	3.0
Lower [Double] Slide Valve	6.0
Seat	3.0
Return Container	6.1
Storage Chamber	26.2
Structural Supports	10.0
Switches, Cables, Elect. Conn.	2.5
Odor/Bacteria Filter*	6.0
Restraint System*	7.0
2 Fan/Separators*	5.0
Hoses, Ducts*	5.0
Hardware Total	85.3
Bags**	4.0
Air**	7.0
Total System Weight	96.3

* Existing System Hardware
**Expendables

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MODIFIED SKYLAB CONCEPT SUMMARY

VEC887

- Advantages
  1. Periodic Bag Ejection Removes Waste From Cabin
  2. Utilizes Existing Hardware Concepts
  3. Low Air Loss During Evacuation of Collecting Chamber Between Defecations
  4. Crew Operations Minimized by Extending Bag Use Period To Three Days
  5. Fecal Material Deactivated by Vacuum and Heat Absorbtion Between Defecations
  6. Serviceable On Orbit
  7. Bag Push Through Done at Cabin Pressure — Not a Remote Operation
  8. Space Station Applicability
  9. Moderate to Low Bag Consumption
  10. Utilizes Existing Fan/Seperator System
  11. Storage/Processing Area Is Pressurized During Pass Through
  12. Skylab Collection Method Is Proven
  13. Airflow Is Used to Contain Odor During Pass Through
  14. Crew Handles Only Clean or Sealed Bags With Advanced Bag Sealing Concept
- Disadvantages
  1. Fecal Material From Previous Defecations Will Be In View of Other Crew Members
  2. Old Fecal Material In Bag May Obstruct Collection of New Waste
  3. Fecal Bag and Associated Handling, Sealing, and Outgassing Are Present
  4. Randomly Stored Bags Do Not Utilize Stowage Space Efficiently
  5. PsychologicalAcceptance May Be Poor

APPENDIX C
SKYLAB SYSTEM DATA

SKYLAB URINE/FECAL COLLECTOR

Flow Schematic

Performance of Urine System

Airflow Only — 1 CFM ΔP(A-C) = 1.9 In. H_2O ΔP(A-B) $\approx$ 1 In. H_2O

Urine Only — 45ML/SEC ΔP(A-B) $\approx$ 1.8 In. H_2O

No Flow — Max. ΔP(A-C) = 8 In. H_2O

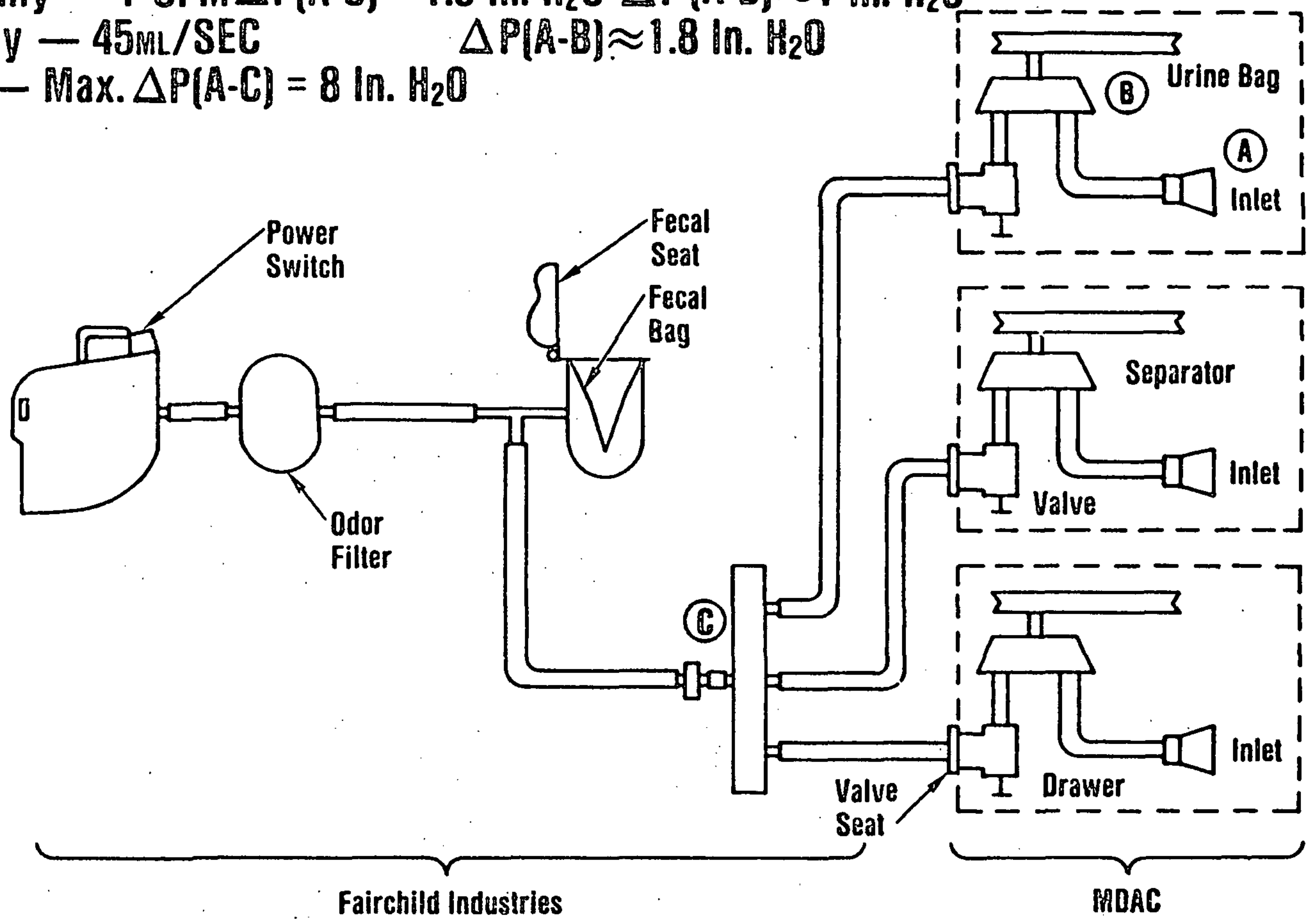

Table 3-95. Fecal/Urine Collection Module Characteristics

Characteristics	Values
Blower/Motor Assembly (1B83241)	
Flow Rate (Nominal)	
Fecal	10.4 cfm (S), 8.7 to 9.2 scfm (T)*
Urine	1.0 cfm (S), 0.83 scfm (T)*
Differential Pressure at Flow Rate	14.0 in. H_2O across blower
Motor Input Voltage	24 to 30 Vdc (28 Vdc nominal)
Power	
Steady Run Mode	115 W (max.) (S) (109.2 W nominal) (T)
Starting Transient	14 A @ 28 Vdc for 1.0 msec
Locked Rotor (Current limited)	5 A @ 28 Vdc
Overload Protection (Circuit breaker)	5 A
Pressure Range	
Nominal Operating Gas Inlet Pressure	Cabin ambient (5 psia nominal)
Temperature Range	
Nominal Operating	58° to 90°F
Operational	58° to 90°F
Nonoperating (Storage)	0° to 140°F
Operational Life	250 hr
Odor Removal Assembly (Charcoal bed)	
Charcoal Weight	613 gm
Flow Rate Across Bed	11.4 cfm
Differential Pressure at Flow Rate	2 in. H_2O
Operating Pressure Range	Cabin ambient (5 psia nominal)
Centrifugal Urine Separator Assembly (CUSA) (1B87234)	10 units (5 with motors) (5 without motors)
Separator	
Flow Rate	
Urine (Through inlet)	0 to 45 ml/sec
Urine (Through outlet with 3 ±0.25 in. H_2O ΔP)	5 ml/sec (nominal)
Gas (Cabin air @ 5 psia)	1 cfm (S), 1.03 to 1.195 cfm (T) (seated)**, 1.145 to 1.150 cfm (T) (unseated)**
Pressure Range	
Operating	Cabin ambient
Proof	37.3 psid
Burst	52.0 psid

*Drawers 1, 2, and 3 tested at 28 Vdc, 14.7 psia, and 70°F.
**Drawers 1, 2, and 3 tested at 28 Vdc and ρ = 0.0271 lb/ft³.
(S) = SPECIFICATION
(T) = TEST

Table 3-95. Fecal/Urine Collection Module Characteristics (Continued)

Characteristics	Values
Urine Inlet to Plenum Differential (Blower running)	
With Astronaut Standing (Urine inlet closed)	14.0 in. H_2O (min.)
With Astronaut Seated on Fecal Collector (Urine inlet closed)	12.2 in. H_2O (min.)
With Astronaut Seated (Urine inlet open)	1.9 in. H_2O (min.)
Temperature Range	
Urine Inlet	98.6°F
Gas Inlet	58° to 90°F
Separator Capacity	
Range (Micturition input)	35 to 600 ml
Nominal	350 ml*
Quantity of Gas in Discharged Liquid	1%/day (max.)
Quantity of Liquid in Discharged Gas	0.0
Leakage Rate	
Gas	1.4 sccs (max.)
Liquid	None
Electrical	
Voltage	24 to 30 Vdc (28 Vdc nominal)
Power	
Nominal	28 W
Locked Rotor	3 A @ 28 Vdc
Overload Protection (Circuit breaker)	3 A
Motor Speed @ 28 Vdc	15,000 rpm
Drum Speed (Dry)	
@ 24 Vdc (Drawers 1,2, and 3)	205, 198, 184 rpm
@ 26 Vdc (Drawers 1,2, and 3)	228, 218, 208 rpm
@ 28 Vdc (Drawers 1,2, and 3)	250, 239, 229 rpm
@ 30 Vdc (Drawers 1,2, and 3)	271, 258, 250 rpm
Time Delay Between Uses	5 min (min.)
Time Period Between Blower Motor Off and Separator Motor Off	4 min 59 sec to 5 min 19 sec
Filter Rating (Separator)	10 to 20 μ
Chiller Assembly	
Refrigerant Loop Flow Characteristics	See Paragraph 3.1.2.6
Urine Sample Chilled Temperature	41° to 59°F
Urine Pool Chilldown Time to 59°F	2 hr (max.)
Bladder Assembly (1B89060)	
Volume	4000 ml (min.)
Bladder Internal Pressure (Pressure plate)	0.5 to 4.0 in. H_2O
Umbrella Valve Cracking Pressure (Urine inlet)	0.5 in. H_2O

*Filling above 700 ml results in degraded flow.

Table 3-95. Fecal/Urine Collection Module Characteristics (Continued)

Characteristics	Values	
Temperature Range		
Nonoperating	-40° to 160°F	
Operational	58° to 90°F	
Leakage (Max.)		
Shutoff Valve (Bladder pressurized with GN_2 to ΔP of 12 ±2 in. H_2O)	None detectable at 12 ±2 in. H_2O ΔP of GN_2	
Umbrella Check Valve	None detectable at 12 ±2 in. H_2O ΔP of GN_2	
Collection Capability	Fecal	Urine
Maximum Collection Capability (Using blower motor)	300 g (feces) 500 ml (diarrhea)	4000 ml
Maximum Initial Preparation Duration	30 sec	30 sec
Maximum Duration of Each Complete Cycle (Including preparation and initiation of processing but excluding elimination)	8 min	1 min
Normal Collection Unit Usage		
Cycles/Day/Man	1	10 max.
Daily Duration (3 crewmen)	45 min	150 min
Operational Life	1400 cycles	7000 cycles
Maximum Time for Removal and Replacement of 3 Urine Collection and Sample Bags and Preparation for Freezing		20 min
24-hr Urine Pooling Volume Measurement Accuracy		
Mechanical Method (On-orbit)	±15%	
Lithium Chloride (LiCl) Method (on ground after sample return)	±2%	

Table 3-96. Waste Processor Characteristics

Characteristics	Values
Processor (1B79136)	
Processing Chambers (Drawers)	6
Processing Chamber Volume	304 in^3
Processing Operating Temperature (Controlled via heater controller/sensor)	105 ±5°F Ⓢ, 109.6°, 106.9°, 104.8°, 108.8°, 106.2°, 105.4°F (Drawers 1 through 6, respectively, @ 28 Vdc) Ⓣ
Input Voltage Range	24 to 30 Vdc (28 Vdc nominal)
Power Rating	
Heater (Drawers 1 through 6)	93.5 W @ 28 $^{+2}_{-4}$ Vdc Ⓢ, 81.2 to 81.8 W @ 28 Vdc Ⓣ
Heater Controller/Sensor	2.5 W
Timer	2.1 W
Timer Delay Relay	
During First 15-min Processor Operation	1.0 W
After 15-min Processor Operation	0.4 W
Overload Protection (Circuit breaker)	5.0 A
Vacuum Line Flow Rate	400 gm/hr @ 0.015 psid and 50° to 105°F
Over-Temperature Control Circuit	
Opens	165 ±5°F*
Closes	145 ±5°F
Timer Range (Manually adjustable and set as a function of sample weight, automatic shutoff at end of selected drying cycle)	0 to 20 hr
Temperature Range	
Operational	58° to 90°F
Nonoperating	-40° to 160°F
Operational Life	280 heating cycles/processor
Processed Waste Volume/Dump	0.176 ft^3
Waste Processor Exhaust Pressure (Vacuum vent valve open)	0.0005 to 0.06 psia
Vent Screen Mesh Opening	0.062 in.

*The heater and timer stops, showing required drying time remaining.

Ⓢ = SPECIFICATION

Ⓣ = TEST

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Table 3-96. Waste Processor Characteristics (Continued)

Characteristics	Values
Processor Control Valve (1B78648)	1 per processor
Flow Rate	2.0 in. H_2O ΔP @ 5.5 scfm chamber to vacuum flow
Nominal Pressure Range	0 to 6 psid
Proof	$39\,^{+2}_{-0}$ psid
Burst	65 psid
Temperature Range	
Nonoperating	45° to 90°F
Operational	45° to 105°F
Flow Media	55° to 105°F
Handle Torque (Manual)	20 in lb (max.)
Leakage	
Internal at $6\,^{+2}_{-0}$ psid GN_2	<0.6 scim
External at $6\,^{+2}_{-0}$ psid GN_2	<0.1 scim
Pressure Indicator Range	0 to 0.2 psia

FECAL PROCESSOR POWER REQUIREMENTS

- 3 DEFECATIONS / DAY TOTAL
- 200 GM/DEFECATION AVERAGE
- 300 GM/DEFECATION MAXIMUM
- 8.5 HOURS REQUIRED TO PROCESS 200 GM AT 105°F HEATER TEMPERATURE
- 10.5 HOURS REQUIRED TO PROCESS 300 GM AT 105°F HEATER TEMPERATURE
- 86 WATTS PEAK POWER PER PROCESSOR
- 35 WATTS AVERAGE POWER PER PROCESSOR DURING OPERATION

DIARRHEA PROCESSING POWER REQUIREMENTS (CONTINGENCY)

- THREE DIARRHEA DEFECATIONS/WEEK
- 1000 CC/WEEK
- 200 CC/DEFECATION MINIMUM
- 300 CC/DEFECATION AVERAGE
- 500 CC/DEFECATION MAXIMUM
- 13.7 HOURS REQUIRED TO PROCESS 200 CC AT 105^{O}F HEATER TEMPERATURE
- 18.2 HOURS REQUIRED TO PROCESS 300 CC AT 105^{O}F HEATER TEMPERATURE
- 31.2 HOURS REQUIRED TO PROCESS 500 CC AT 105^{O}F HEATER TEMPERATURE
- 86 WATTS PEAK POWER PER PROCESSOR
- 30 WATTS AVERAGE POWER PER PROCESSOR DURING OPERATION

VOMITUS PROCESSING POWER REQUIREMENTS (CONTINGENCY)

3 VOMITUS COLLECTIONS PER WEEK

1000 CC/WK

200 CC MINIMUM

300 CC NOMINAL

500 CC MAXIMUM

8.1 HOURS REQUIRED TO PROCESS 200 CC AT 105°F HEATER TEMPERATURE

11.7 HOURS REQUIRED TO PROCESS 300 CC AT 105°F HEATER TEMPERATURE

27.0 HOURS REQUIRED TO PROCESS 500 CC AT 105°F HEATER TEMPERATURE

86 WATTS PEAK POWER PER PROCESSOR

35 WATTS AVERAGE POWER PER PROCESSOR DURING OPERATION

SKYLAB - Fecal and Urine Collection Expendable Items Usage Summary

Item	Quantity onboard at launch	First manned period			Second manned period			Third manned period			Remarks
		Expected usage	Actual usage	Total remaining	Expected usage	Actual usage	Total remaining	Expected usage	Actual usage	Total remaining	
Fecal bags	465	84	48	417	168	135	282	168	192	90	
Contingency fecal bags	185	*	1	184	*	7	177	*	0	177	*As required
Urine collection bags	432	84	75	360	168	178	185	168	185	0	Includes 3 bags carried by the first and second crews
Urine sample bags	375	66	63	312	132	108	204	132	204	0	
One-half urine sample bags	125	18	21	104	36	71	33	36	53	0	Includes 20 bags carried by the third crew
MISSION DURATION		28 DAYS			59 DAYS			84 DAYS			

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APPENDIX D

SYSTEM REQUIREMENTS

DEFINITION DOCUMENT

(CONTAINED IN OTHER BOOKLET)

APPENDIX E

LAYOUTS OF WCS DESIGN CONCEPTS