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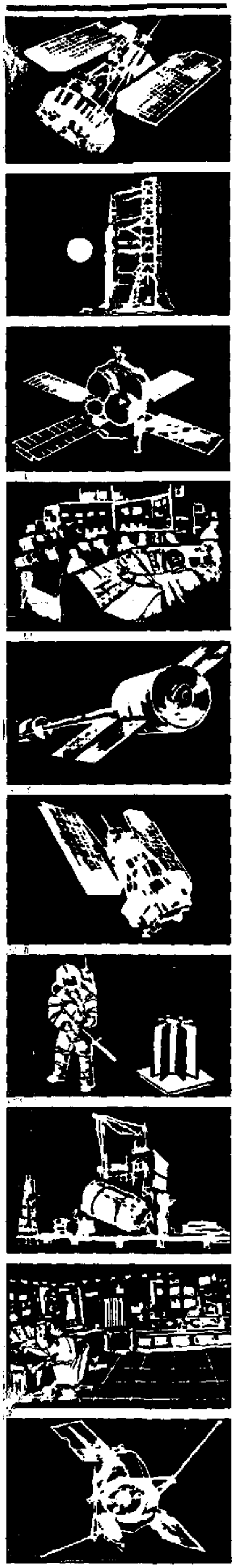

CONTRACT NAS 9-13518
DRL T-900
LINE ITEM NO. 4
DRD MA --183T
GE DOC. NO. 74SD4221
NASA CR-
140227

(NASA-CR-140227) SOLID METABOLIC WASTE TRANSPORT AND STOWAGE INVESTIGATION Technical Report, 1 Jun. 1973 - 31 May 1974 (General Electric Co.) 361 p HC $21.25 CSCL 06I
N74-32561
Unclas
G3/05 48548

SOLID METABOLIC WASTE TRANSPORT

AND

STOWAGE INVESTIGATION

AUGUST 21, 1974

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SOLID METABOLIC WASTE TRANSPORT

AND

STOWAGE INVESTIGATION

AUGUST 21, 1974

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FOREWARD

This report has been prepared by the Environmental Engineering Operation of the General Electric Company's Space Division for the National Aeronautics and Space Administration in accordance with the requirements of Contract NAS 9-13518, Solid Metabolic Waste Transport and Stowage Investigation. The report covers work accomplished during the period from 1 June 1973 through 31 May 1974 during the further development and verification of the GE Dry John Waste Collection System.

General Electric personnel responsible for the conduct of this program included: Mr. R. A. Burt, Project Engineer; Mr. M. G. Koesterer, Microbiologist; Dr. S. R. Hunt, Biomedical Programs Manager, and Mr. R. W. Murray, Program Manager. Appreciation is expressed to Mr. J. A. Geating, Biomedical Laboratory Supervisor, and Mrs. Louise Walker who spent numerous hours reviewing and proofing the final report and to Mrs. H. M. Ross, Secretary for Environmental Engineering, whose perserverance at the typewriter was indispensable in the completion of the reports for the program. Appreciation is also expressed to numerous NASA personnel who took part in the program with special recognition to: Mr. A. Behrend, Technical Monitor for NASA-JSC; Mr. D. Griggs, Chief, Zero Gravity Operations; Mr. J. Slight, Zero Gravity Test Director and Mr. A. Lucero, Aerial Photographer.

A very special note of recognition and gratitude is extended to the USAF Reserve Nurses who served as the primary volunteers for the zero gravity flight tests Similar recognition and thanks is extended to other individuals from NASA and GE who also served as test volunteers for various phases of the program. Without the outstanding cooperation of the test volunteers, success in the conduct of this program would have been more difficult, if not impossible.

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SECTION 1

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

1.0 SUMMARY

1.1 Objectives

The Solid Metabolic Waste Transport and Stowage Investigation (NAS 9-13518) had three basic objectives:

- Determine and optimize in a separation/transport study the separation forces and transport velocities required for solid waste transport in the Dry John/Slinger concept.
- Incorporate system improvements identified in the separation transport studies into the existing GE Dry John Zero Gravity Test Unit and perform zero gravity tests to verify:
  - Proper separation/transport air flows for feces and urine collection
  - Feces slinger and urine separator performance
  - Human factors design and operational procedures.
- Perform an engineering evaluation of air drying as an alternate approach to vacuum drying solid metabolic waste (feces) and tissue wipes for possible application to Space Shuttle.

1.2 Feces Separation/Transport Investigation

An experimental investigation of solid waste (feces) separation and waste transport air velocities was conducted to assess and optimize the GE "Dry John" Solid Waste Collection System (WCS). Using design features of the GE WCS, simulations of the anal area and fecal stools were used in a neutral bouyancy test chamber. Static forces associated with stool separation were measured for several transport tube inlet configurations at varied air flow rates. High speed photography was used to record dynamics of stool transport after separation. Anomalies including improper seat seal, airflow orifice plugging, and diarrhetic movement collections were also investigated.

1.3 Zero Gravity Testing of a Waste Management System

A study was conducted to demonstrate the functional capability of a GE Shuttle Type Dry John for waste collection in a zero gravity environment. System improvements for the Dry John suggested by previous studies were utilized during these tests. The tests verified separation/transport air flows for the feces and urine processors; slinger and urine separator performance in zero "g"; and human factors design and operation.

Limited ground baseline tests and extensive aircraft zero "g" tests resulted in extensive data derived from motion picture film, user/subject experience, as well as other experimenter and engineering observations. A total of 242 parabolas were completed in the NASA KC-135 Zero "G" aircraft resulting in an available zero "g" test time approaching two hours. A total of 12 female and seven male subjects participated in the study. Forty-five urine collections and 10 fecal collections were obtained.

1.4 Investigation of Air Drying of Fecal Wastes as an Alternative for the Shuttle Orbiter Waste Management System

Vacuum drying of fecal waste is the current baseline for spacecraft usage. In view of the potential advantages of air drying, which would reduce external spacecraft equipment contamination, a feasibility study assessing air drying as an alternate to vacuum drying was performed using a GE Dry John. Studies identified the possible sources of air for drying, and evaluation of bacterial activity has shown that drying conditions adequate for safe storage of fecal material for the duration of Shuttle Orbiter missions are possible. Tests have also established requirements for equipment configuration and airflows to obtain proper drying conditions in the GE Dry John. A 120 man-day user test was initiated to simulate a nominal 4 man crew usage of a Dry John with air drying. Results indicate that this approach is eminently feasible as either a primary system or a backup to the present vacuum-drying space-venting approach.

2.0 GENERAL CONCLUSION

2.1 Fecal Separation/Transport Investigation

The basic WCS design under consideration in these studies utilized air flow to separate the stool from the WCS user and to transport the fecal material to a slinger device for subsequent deposition on a storage bowel. The major parameters governing stool separation and transport were found to be the area of the air inlet orifices, the configuration of the air inlet orifice and the transport air flow. Separation force and transport velocity of the stool were studied. The GE developed inlet orifice configuration was found to be an effective design for providing fecal separation and transport. The inlet ring configuration had a 10 cm (4 in) diameter, 4.4 cm (1.75 in) height and included twenty-four 0.6 cm (1/4 in) diameter holes directed radially inward at an angle of 0.61 radians (35°) above horizontal essentially forming a cone-like configuration with the apex at the inlet ring centerline. Significant separation forces ($\sim$ 1/3 g) were found to be provided by moderate transport airflow (0.85 sm^3/min or 30 scfm).

2.2 Zero Gravity Testing of a Waste Management System

Simulated urine tests and female user tests in zero gravity established air flow rates between 0.08 and 0.25 sm^3/min (3 and 9 scfm) as satisfactory for entrapment, containment and transport of urine using the unique GE urinal. A nominal air flow rate of 0.23 sm^3/sec min (8 scfm) was found to be entirely satisfactory for both male and female users in the zero "g" tests. For fecal separation and transport, an air flow rate of 0.85 sm^3/sec min (30 scfm) was found to be satisfactory. No significant waste management equipment breakdowns were encountered during the test; overall performance of the system was found to be excellent throughout the zero "g" tests. Both males and females were accommodated by the urine and fecal collection system. User acceptance of the system was excellent. A number of suggestions regarding design features and operational procedures were obtained during the conduct of the study. Many of these suggestions resulted in modifications and improvements in design or procedures.

Data from the study indicated that the GE WCS should function entirely satisfactorily in a Spacecraft System. The basic features and designs of the current GE system tested in this program could be directly incorporated into a Shuttle Orbiter WCS without further subject testing in zero "g".

2.3 Investigation of Air Drying of Fecal Wastes as an Alternative for the Shuttle Orbiter Waste Management System

The investigation of air drying of fecal material as a substitute for vacuum drying in a GE WCS breadboard system showed that using baseline conditions anticipated for the Shuttle cabin ambient atmosphere, flow rates of 0.14 sm^3/min (5 cfm) were adequate for drying and maintaining biological stability of the fecal material. Slung fecal material in the amounts expected in a Shuttle WCS can be dried to a moisture content approaching 50% in a 24 hour period. Higher air flows were found to be of no particular advantage in drying the fecal material. The recommended air flow for the system was 0.14 sm^3/min (5 scfm) with continuous operation of the slinger for 2-4 hours after each defecation.

The basic results of the drying tests and microbiological studies conducted during this program indicate that air drying of fecal material in a Dry John commode is a feasible alternative to vacuum drying. Sufficient moisture can be extracted from slung fecal material in a GE WCS system with modest air flow and power costs.

2.4 Space Shuttle Interface Requirements

Basic interface requirements for incorporating a GE WCS into the Space Shuttle are provided. A photo of a mockup of a proposed WCS is provided along with a preliminary assembly drawing showing anticipated interfaces.

3.0 RECOMMENDATIONS

3.1 Fecal Separation/Transport and Zero Gravity Testing

Sufficient data is available from the neutral buoyancy and zero "g" test to recommend that additional zero "g" verification tests of the Shuttle Waste Collector Subsystem (WCS) be deleted. This of course is predicted on only minimal changes to the proven transport air jet configuration and represents a cost effective approach to this critical subsystem. Secondly, if slight modifications are made to the proven configuration, it will be expedient to evaluate the new design using neutral buoyancy techniques rather than zero "g" tests. This is possible because of the good correlation between the two types of tests and the inability to truly test a flight WCS without modifying the construction materials to permit visibility to the transport and collection processes.

3.2 Air Drying Investigations

While air drying has been demonstrated as a feasible alternate to vacuum drying for a Shuttle Waste Management system, the results of the program conducted to date suggest a variety of areas where further studies would be highly beneficial.

First, extended duration air drying tests should be conducted for simulated mixed crew sizes of 8-12 individuals. Rates of air or vacuum drying are significantly influenced by rate of loading of waste into a Waste Collection System. Air flow rates, characteristics of drying air, stool size and configuration and other system parameters should be evaluated and optimized for larger crew sizes. This study could include more refined and simplified microbiological techniques for assessing the effects of air drying on the fecal microbial population. Additional biocide studies could also be conducted as part of these tests to further improve the effectiveness of various biocides for supplementing or replacing air drying techniques. These efforts could be directed toward evaluation of biocides other than the Betadine used in the current studies and also at optimization of the methods for disseminating the biocide in the WCS.

Second, studies should be conducted for optimizing sanitation and housekeeping procedures associated with the WCS. Relatively simple microbiological studies could be conducted to assess the actual transmission of microorganisms from hardware to user and hardware to atmosphere to minimize and optimize sanitation and housekeeping procedures while maximizing crew safety. These studies could be separately conducted or could be conducted as part of or during an extended 8-12 simulated crew member test.

Third, studies to optimize odor and bacterial filter characteristics for an air drying system could result in significant weight and power savings while still insuring totally adequate filtration capability. Odor filter studies could be conducted separately or as part of an extended use 8-12 crew member study.

3.3 Advanced Mission Study

Since preliminary plans indicate that the Spacelab experimenters will also use the Shuttle Waste Collection Subsystem, it is recommended that the feasibility of transversing the airlock connecting Spacelab to Shuttle and/or alternate means of waste collection be investigated. Such facets as time lines, user acceptability and temporary collectors should be investigated as well as potential hardware impact. Other potential effects on Spacelab and Shuttle designs should also be determined.

SECTION 2

FECES SEPARATION/TRANSPORT INVESTIGATION

FECES SEPARATION/TRANSPORT INVESTIGATION

1.0 BACKGROUND

Stool separation from the anus during the use of waste management systems in zero "g" is a major concern in that the external sphincter squeezes the feces to a small cross section but does not cause complete separation. In a normal environment, gravity will cause the stool to break away; however, in zero "g" airflows must be used to induce the separation. In GE's zero "g" flight tests (See Appendix A) with simulated stools, separation was induced by a number of means including the transport air, air jets, and vertical movement similar to the normal sphincter movement. The major concerns were the limited number of tests conducted and the need for more control over significant test parameters.

Past tests with neutral buoyancy techniques for the NASA Biosatellite, contract NAS 2-1900, have proven to be a vital tool in the design of waste management systems. Specifically, neutral buoyancy testing has been shown to be a cost effective approach in defining problems and refining designs prior to the still necessary testing in a zero "g" aircraft. Many test conditions and hardware configurations can be evaluated in the laboratory under controlled conditions in a short time period as opposed to much more rigorous preparation and time restrictions imposed during aircraft tests.

2.0 OBJECTIVE

The primary objective of this study was to investigate stool separation and transport phenomona. In addition, information derivable from the study provides parametric data on relationships involving transport airflows and fecal transport inlet configuration relevant to the next series of manned spacecraft, Shuttle Orbiter.

3.0 APPROACH

Using these GE zero "g" tests (Appendix A) as a baseline, neutral bouyancy techniques were developed to investigate the effect of a series of system perturbations and configuration changes on stool separation and transport. A neutral bouyancy test rig was designed to include a transparent test chamber simulating the flow conditions from the fecal transport tube inlet down to slinger entry of the GE Dry John. It was sized at a 1:1 scale to allow common use of inlet rings and associated components from the zero "g" test program. With water as a test fluid, water velocities of 1/16 that of air were used to develop equivalent fluid dynamic effects. This assumes that similitude of the two conditions is assured by holding the Reynolds number constant. The testing program was divided into static tests, in which the simulated stool was held in a fixed position in order to determine force measurements; and dynamic tests, in which the stool was released for observation of its "Free Floating" behavior using High Speed Motion pictures for data recording. The effects of several "off-design" conditions such as imperfect air seal of user to seat and plugged air inlet holes were also observed in the dynamic test mode.

4.0 EQUIPMENT

Equipment for this investigation included a Neutral Buoyancy Test Chamber, Flow Measurement Gauges, Flow Control Valving, Force Measurement Gauges, Simulated Stools and Photographic Apparatus.

Figure 4.0-1 shows an overall view of the test equipment as rigged for static stool force measurement. The test chamber is a 25.4 cm (10 in) diameter transparent tube enclosing a simulation of the seat/anal interface, inlet ring and transport tube as shown in Figure 4.0-2. Test fluid enters the

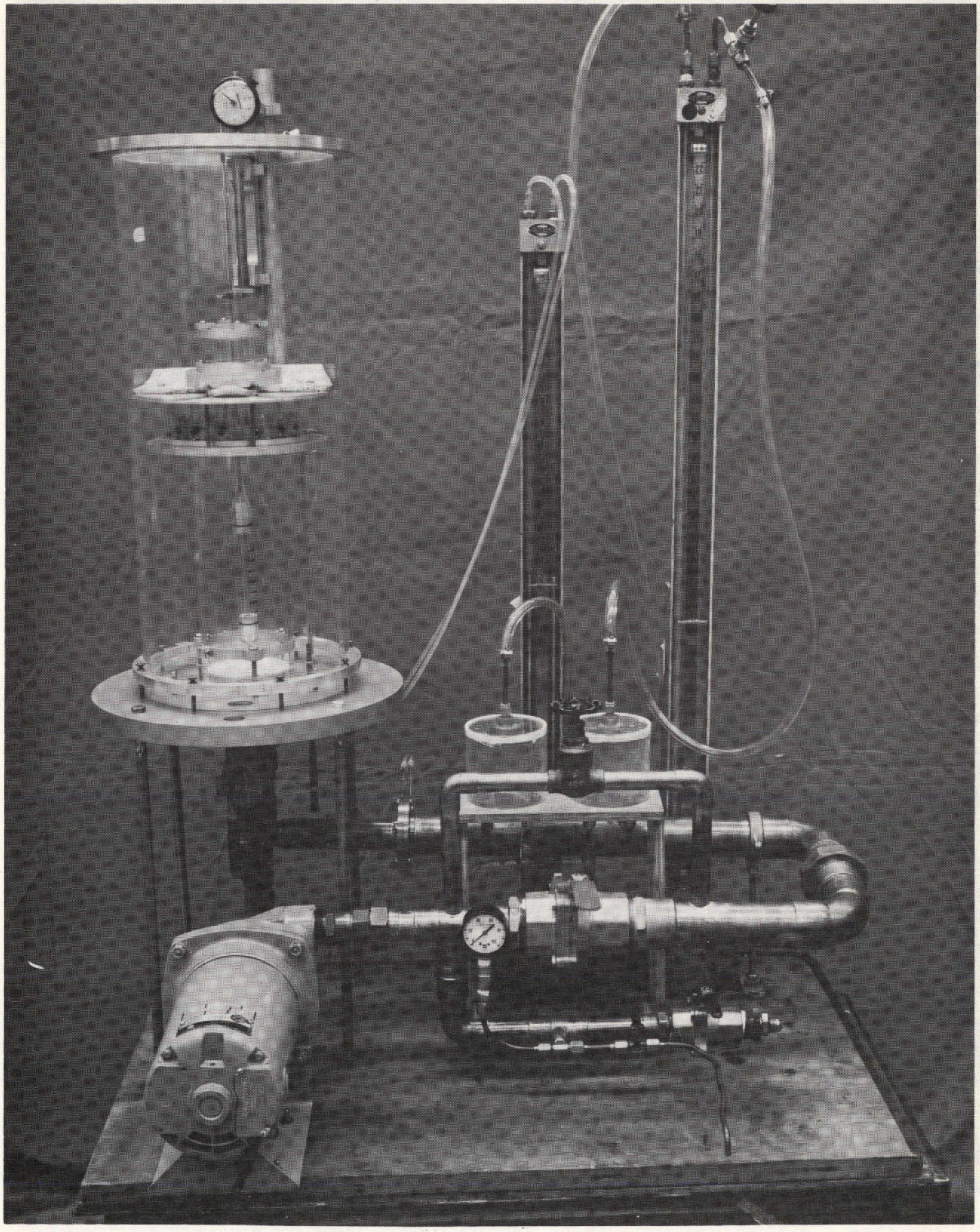


Figure 4.0-1 Overall View of Neutral Buoyancy Test Rig

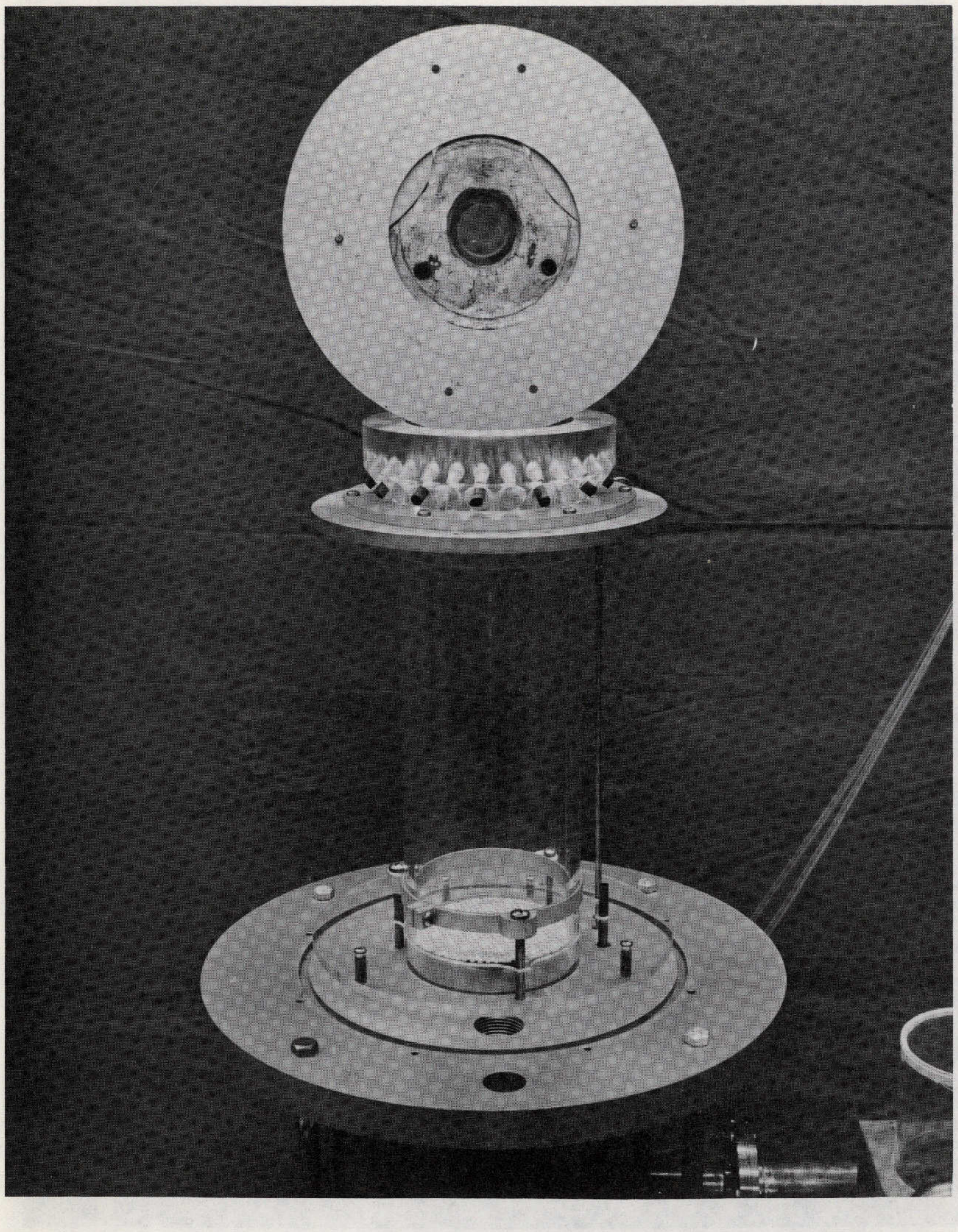


Figure 4.0-2 Simulation of Seat/Anal Interface Inlet Ring and Transport Tube

outer annulus at the base and flows upward to the inlet ring, then through the inlet orifices, then downward thru the 10.16 cm (4 in.) diameter transport tube past the simulated stool, and finally out of the chamber to the external pump and control circuit. Figure 4.0-3 is a flow schematic of this system.

For static measurement of axial force on simulated stools, the device shown in Figure 4.0-4 was devised. A 0.32 cm (1/8 in.) diameter vertical rod attached to the stool penetrates the anal simulation thru a clearance seal and clamps to the calibrated spring device. Two parallel cantilever springs and a 0.00025 cm (0.0001 in.) division displacement indicator are the basic force measurement elements which provide a spring gradient of 5.78 kg/cm (31.85 lbs/inch) with a range of 0.45 kg (1 lb) force. Water flow rates were measured with a sharp edge orifice plate and water manometer. The appropriate equation for orifice flow is

$Q = k\,(\Delta p)^n$ in which

Q = Volume flow rate, cm^3/sec ($in.^3/sec$)

Δp = Pressure drop, cm water column (inches WC)

k = A constant including orifice area, flow contraction and similar effects

n = An exponent

Calibration tests on a 2.5 cm (1.0 inch) orifice gave the following values:

$n = 0.47$

$k = 676\ cm^3/sec/cm$ WC

(63.9 cu in/sec/inch WC)

Photography equipment included a "Nova" 16-3 camera operating at a nominal 200 frames/second. An auxiliary timer provided 10 hz marks on the film. A black and white Kodak TRI-X reversal film was used for dynamic test recording.

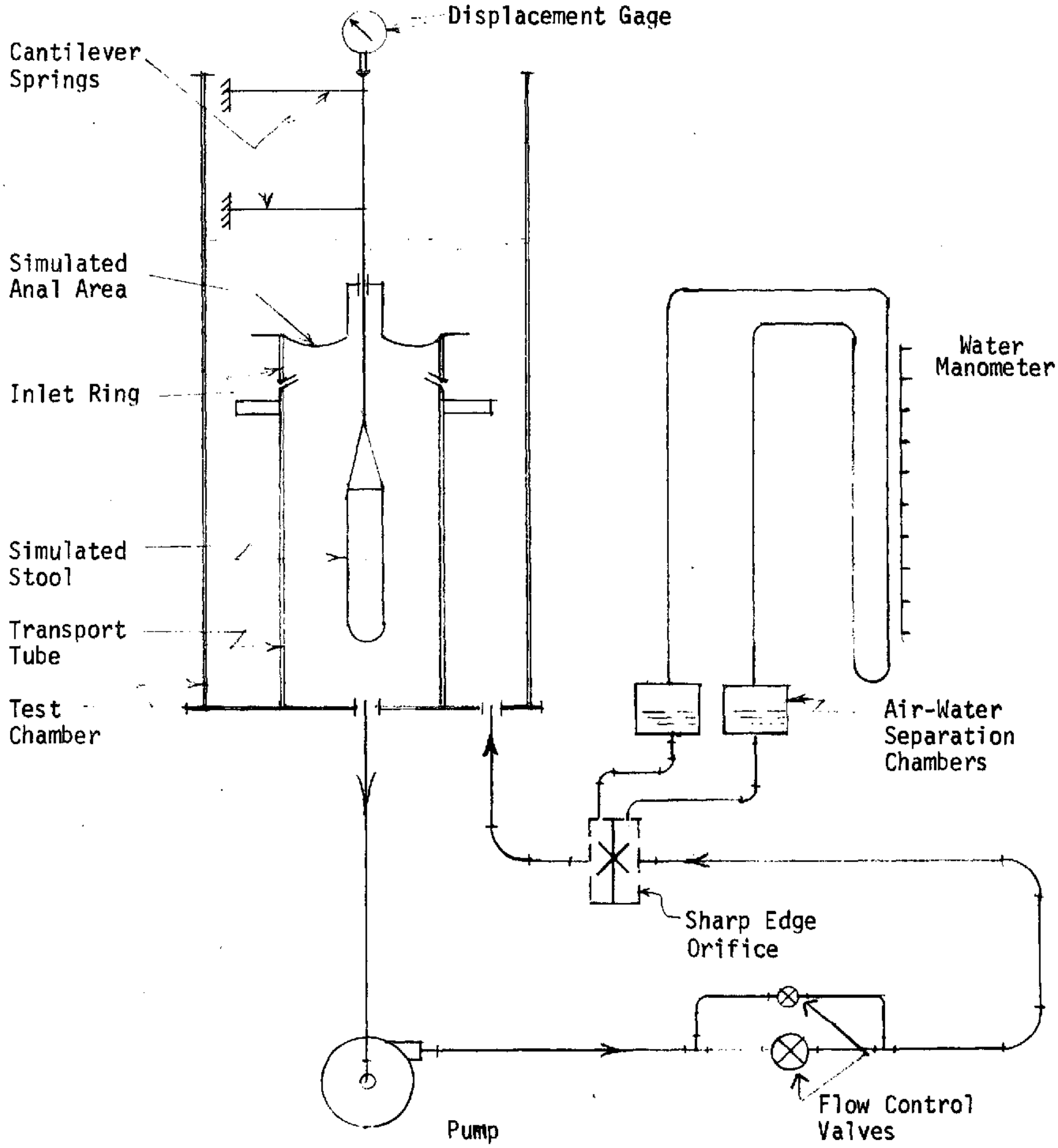


Figure 4.0-3 Neutral Bouyancy Test Rig Schematic

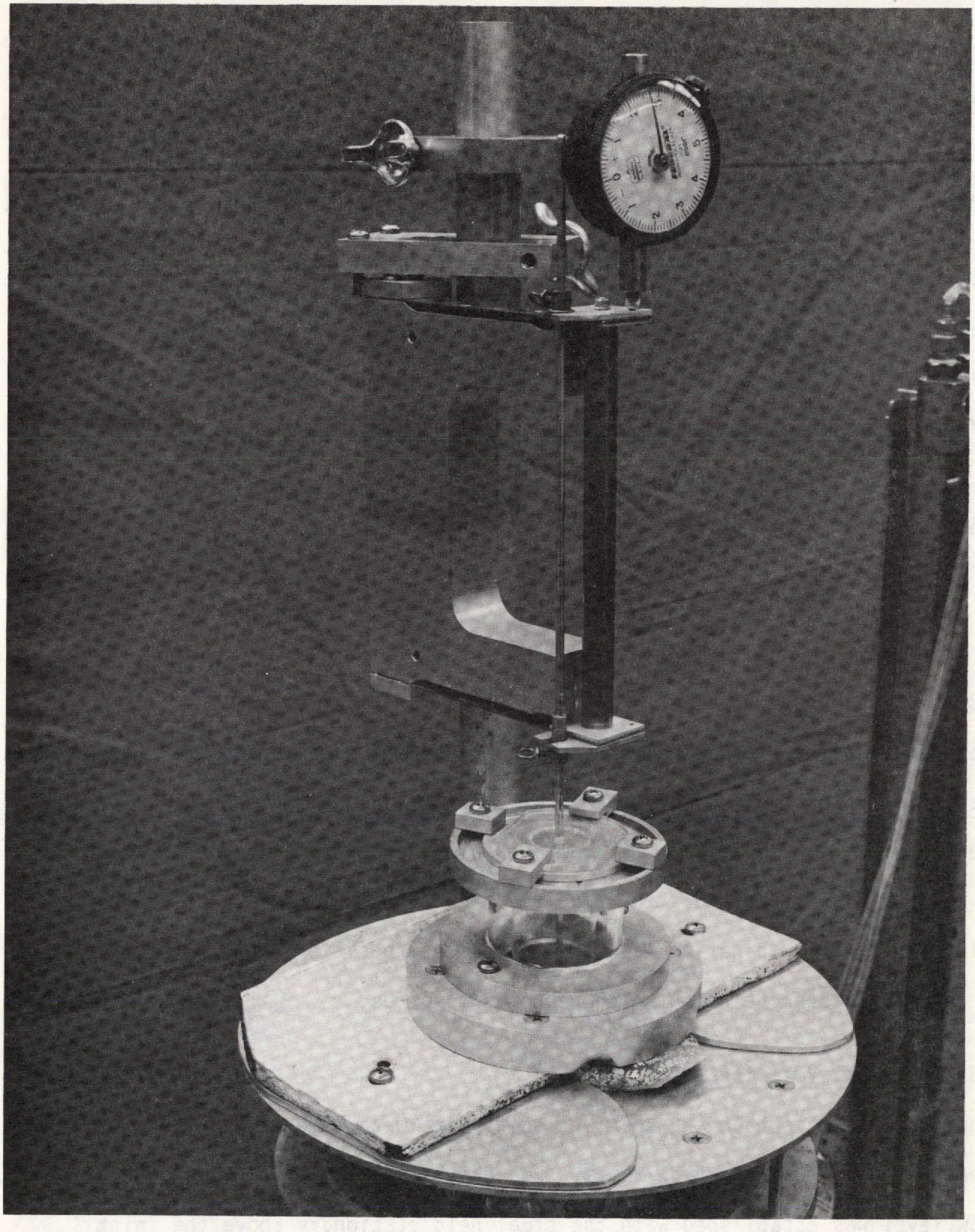


Figure 4.0-4 Device for the Measurement of Axial Force on Simulated Stools

5.0 PROCEDURE

After equipment calibrations, separate procedures were established for the static force tests, transport velocity test, and observation of effects of off-design conditions.

5.1 Calibrations

Initial force gage calibrations were run over a range of 0 to 0.45 kg (1.0 lb) using a standard spring balance. Flow calibrations were made of three different orifice plates: 1.83 cm (0.72 in), 2.54 cm (1.00 in), and 3.32 cm (1.33 in) throat diameter. Calibration was by the timed volume method at flow Δp's from 2.5 cm (1.0 in) to 75 cm (30 in) W.C. For all runs using the 20 cm (8 in) or 10 cm (4 in) stools adjustment of stool weight was made to obtain neutral bouyancy within ± 2%.

5.2 Static Force Tests

Static force tests were made with varied inlet ring configurations, stool size, flow rates, and axial position of the stool along the centerline of the transport tube. Table 5.2-1 contains a matrix listing the combinations of these variables tested. The specific test procedure for a particular inlet and stool combination was to set the stool position and then at each of four flow rates to read the corresponding forces.

5.3 Transport Velocity Tests

Dynamic tests to obtain transport velocity data were made with varied inlet areas, stool sizes, and flow rates. For each combination of conditions the flow level was established with the stool held stationary above the inlet ring. After starting the movie camera, the stool was released and photography continued while the stool was in transit to the bottom of the test chamber. Table 5.3-1 presents a matrix showing the conditions for each test run.

Table 5.2-1 Matrix of Conditions for Static Force Tests - Neutral Bouyancy Testin

	Inlet Ring					Stool Length - cm	
	0.64 cm Holes Opened			Slotted - cm			
Test	24	12	6	0.64 (1/4 in.)	0.32 (1/8 in.)	20 (8 in.)	10 (4 in.)
1			X				X
2		X					X
3			X			X	
4		X				X	
5	X					X	
6				X			X
7				X		X	
8					X	X	

Table 5.3-1 Matrix of Conditions for Neutral Buoyancy Dynamic Transport Tests

Run No.	Inlet Number of Holes Open: 24	12	6	Stool Length, cm: 20 (8 in)	10 (4 in)	Diarrhetic	Flow sm^3/Min (1) (SCFM): 0.28 (10)	0.57 (20)	0.85 (30)	1.41 (50)	Lateral Decentration: 0	.64 CM (1/4 in)	Axial Angle (5): 0°	12°
1	X			X					X		X		X	
2		X		X					X		X		X	
3			X	X					X		X		X	
4		X			X				X		X		X	
5						X			X		X		X	
6		X		X			X				X		X	
7		X		X				X			X		X	
8		X		X						X	X		X	
9		X		X					X			X	X	
10		X				X			X			X	X	
11		X		X					X		X		X	
12		X		X					X		X			X
20		10 (2)		X					X		X		X	
21		8 (2)		X					X		X		X	
22		10 (2)				X			X		X		X	
23		8 (2)				X			X		X		X	
24		X (3)		X					X		X		X	
25		X (4)		X					X		X		X	
26		10 (2)				X	0 TO 30				X		X	

(1) Equivalent Standard Cubic Meters per Minute of Air

(2) Asymmetrical To Simulate Plugged Holes

(3) Seat Unsealed 0.76 cm (0.03 in) on One Side

(4) Seat Unsealed 0.25 cm (0.10 in) on One Side

(5) The Angle Between Anal Centline of Stool and Centerline of Transport Tube is the Axial Angle.

For photo analysis, a grid of lines spaced 2.54 cm (1 in.) apart on the transport tube was used for displacement measurement. The time base used was the 10 Hz timing marks on the film.

5.4 "Off-Design" Tests

Several abnormal conditions including poor seat seal, misaligned and off-center stool positions, and diarrhetic stools were simulated and photographed during the dynamic test series as noted in Figure 5.3-1. Two different diarrhetic simulations were used. On Test #5, 0.64 cm (1/4 in.) diameter plastic spheres of 0.96 specific gravity were used. For Tests #22, #23 and #26 plastic cylinders having a diameter of 0.32 cm (1/8 in.) and a specific gravity of 1.03 were used. Injection of these diarrhetic stools was done normally with the stool generator and push rod. However, on Test #26 the spheres were accumulated in the upper anal chamber with the pump turned off. Start up of the pump automatically accomplished the injection.

6.0 RESULTS

Results of this investigation are contained in plots of test data for static force tests and dynamic velocity test, qualitative observations of effects associated with off-design conditions, as well as a 16 mm data film recording the dynamic tests.

6.1 Static Force

Data from static tests show that axial forces on a stool are affected by inlet area, flow rate, and position along the transport tube axis. Theoretical considerations also suggest inlet configuration influences such as inlet orifice direction angles. Due to program scope limitations, however, inlet configuration was held constant for testing rather than being treated as an additional variable test parameter.

Figure 6.1-1 plots force versus stool position for several flow rates, showing a substantial drop off of the axial force as the stool moves beyond 5-7.5 cm (2- 3 in) from the anal area. Figure 6.1-2 plots on log-log co-ordinates static force as a function of both flow and inlet area at stool positions over the range of 0 to 3.8 cm (1 1/2 in). The 2:1 slope of plotted data shows force to be a function of $(\text{Flow})^2$. Spacing of the plotted lines shows that force is also an inverse function of inlet area.

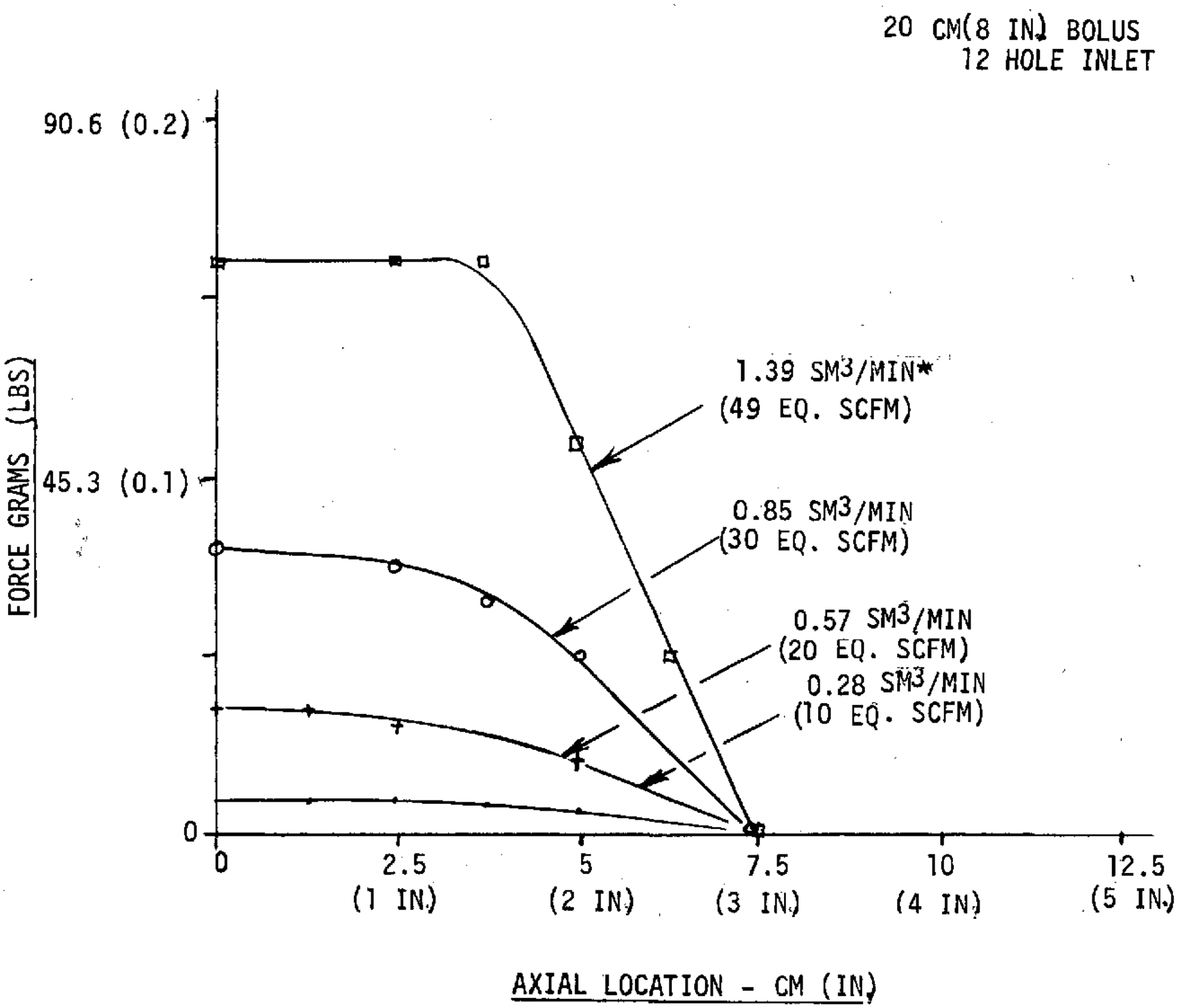
For one test, the 20 cm (8 in) stool was rigged to measure static differential pressures between several points. These results as plotted showed a pattern similar to the force versus position data on Figure 6.1-1.

6.2 Dynamic Velocity

Data from movie films of "free floating" stools show a systematic relationship of axial velocity (down the transport tube axis) to axial position, flow rate and inlet area. However, measurement of lateral and pitching displacement did not yield similar relationships.

Figure 6.2-1 plots axial velocity as a function of axial postion for several transport flow rates which showed that during the first 5 cm (2 in) of travel after separation, the stool velocities increase. Thereafter, velocities tended to decrease slowly. In general, higher flow rates give higher velocities.

A comparison of the limited trial data on the two different stool sizes shows that the 10 cm (4 in) long stool had essentially the same final velocity, but that the initial acceleration was roughly two times that of the 20 cm (8 in) stool.



*SM^3/SEC - STD. CUBIC METERS PER MINUTE (STD. CUBIC FEET PER MIN)

Figure 6.1-1 Stool Separation Forces as a Function of Axial Location

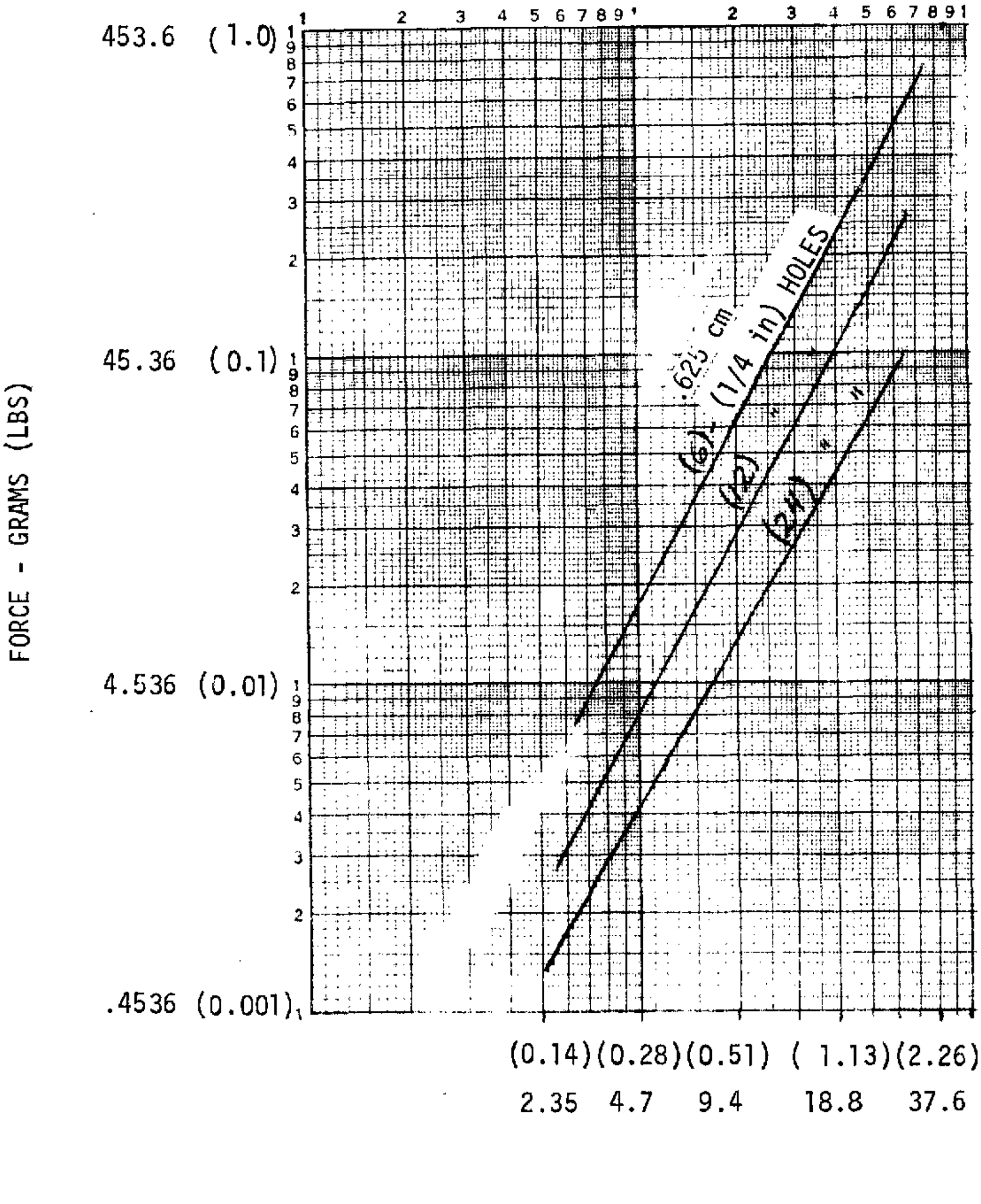


Figure 6.1-2 Effect of Static Forces Vs Transport Air Flow for Three Inlet Areas

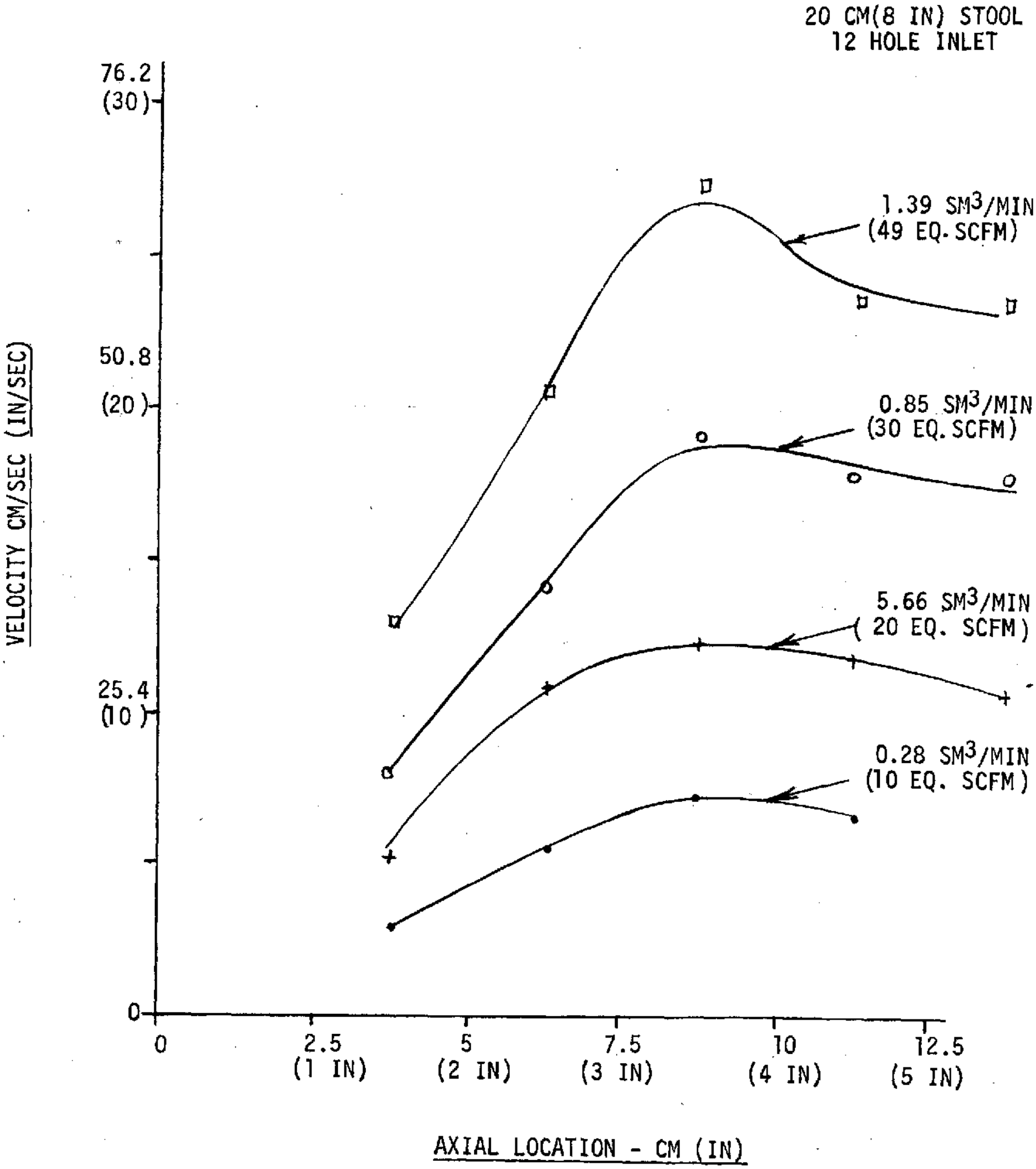


Figure 6.2-1 Velocity of Simulated Stools

Inlet area effects were tested at three levels using 24, 12, and 6 holes (0.64 cm (1/4 in) diameter) of total area, 7.61 (1.18), 3.81 (0.59), and 1.87 (0.29) cm^2 (in^2), respectively. Stool velocities as observed from the film data were inversely related to inlet area with the change downward from 24 to 12 holes demonstrating an increased velocity of $\sim$ 200%, while the change from 12 holes to 6 holes resulted in a velocity increase of only 10 to 20 percent.

6.3 Diarrhetic Stools

Transport of diarrhetic stools was simulated by injecting small plastic shapes into the test chamber. Two sizes were used with the 0.64 cm (1/4 in) diameter spheres being slightly bouyant (0.96 sp. gr.) and the 0.32 cm (1/8 in) cylinders slightly negative ($\sim$ 1.03 sp. gr.). Some general observations about flow patterns and velocities were derived from the photographic data.

The general flow pattern observed was a central high velocity core diffusing rapidly as the flow progressed down the transport tube. Associated with this downward core flow was a small counter flow upward along the tube periphery. Considerable turbulance permeated the whole pattern. Occasionally a turbulence resembling torrodial vorticies (smoke rings) could be recognized. Rough measurement of axial velocities along the tube central section showed initial diarrhetic stool velocities comparable to solid stool velocities. At points downward along the axis, the velocity progressively decreased to values much lower than those of solid stools.

6.4 Off-Design Conditions

The effects of several variations from normal operation were studied. Plugged inlet orifice holes, misalignment and loss of seat seal were simulated in the neutral bouyancy test rig and the results photographed. Stool velocities were measured and flow pattern changes observed.

When two and four adjacent holes in a normal 12-hole inlet ring were plugged, transport velocities were reduced and asymmetrical flow patterns generated. Velocity/position profiles of test runs #20 and #21 showed lower velocities after travels of approximately 5 cm (2 in) with as much as 30% velocity loss when 4 adjacent holes were plugged. Test runs #22 and #23 with diarrhetic stools produced some clues about effects on flow patterns. These were displaced off center toward the plugged hole side.

Misalignment of the simulated anal axis from coincidence with transport tube axis did not produce significant effects. Off center shifts of 0.64 cm (1/4 in) and angles of 0.21 radians (12°) were used in runs #9, #10 and #12 without noticeable changes in velocities or flow patterns.

Based upon observations of the simulation, significant performance degradation would result from loss of air seal between the user's buttocks and the commode seat. To simulate this condition one edge of the buttocks simulator was raised above the "seat" (0.08 cm (0.03 in) for run #24 and 0.25 cm (0.1 in) for run #25). Film data showed reductions in flow velocities of 40 to 50% along with considerable asymmetry in flow patterns, as indicated by a lateral shift of the stool trajectory away from the leakage gap.

Velocity profiles for the off-design cases not including diarrhetic, are portrayed in Figure 6.4-1.

7.0 DISCUSSION

The theoretical basis of separation force is discussed together with comparison of results from static force, dynamic velocity and differential pressure tests with the theoretical model.

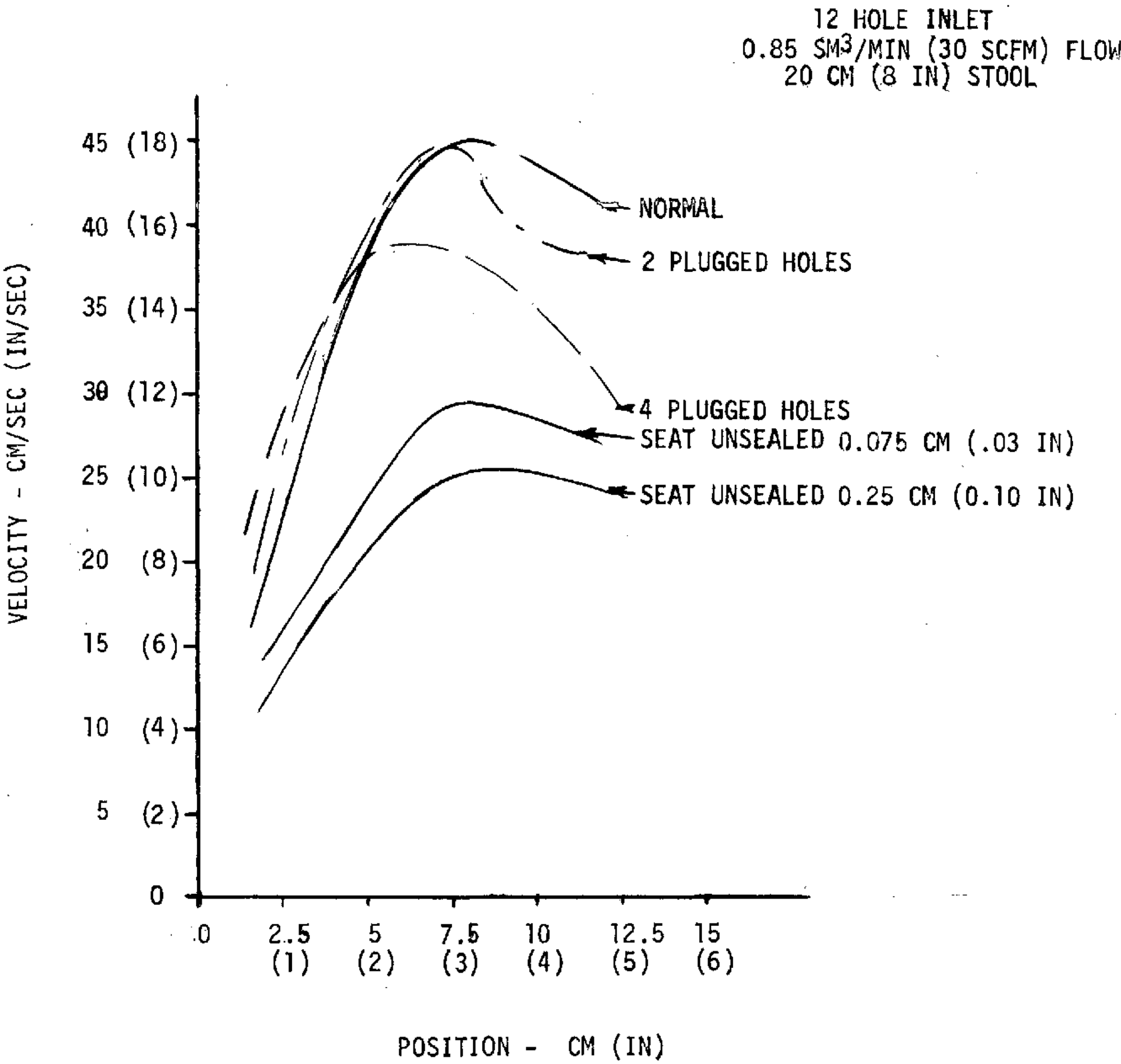


Figure 6.4-1 Effect of Off-Design Conditions on Transport Velocity

A first approximation of the inlet flow pattern is represented by Figure 7.0-1. Control Volume represents conditions at the anal area where an inflow Q_1 from the inlet jets enters and turns downward along the transport tube axis exiting the control volume as Q_2. A total reaction force due to the momentum change is exerted on the anal surface and represented as

$$F_Z = \rho \; A_1 \; V_1^2 \sin \theta + \rho \; A_2 \; V_2^2$$

in which

F_Z = Reaction Force

ρ = Mass Density of Fluid

A_1 = Area of Inlet Orifice

V_1 = Inlet Fluid Velocity

A_2 = Effective Area of Submerged Jet Along Transport Tube Axis

V_2 = Effective Velocity of Submerged Jet

θ = Angle of Inlet Orifice from Plane Normal to Transport Tube Axis

For the case where 12 inlet orifices of 0.64 cm (1/4 in) diameter are employed, Figure 7.0-2 plots the total Z reaction force on the users anal area as a function of flow rate and outflow "core velocity". Forces are related but not identical to this reaction force. The coupling of these forces involves the non-uniform overpressure distribution in a three dimensioned zone into which the stool protrudes. Earlier tests of pressure distribution indicated an air stagnation pressure of approximately 3.18 cm (1-1/4 in) W.C. In addition, tests in the neutral bouyancy facility of differential pressures on a stool showed + 2.54 cm (+ 1 in) W.C. at a point half way down the tapered

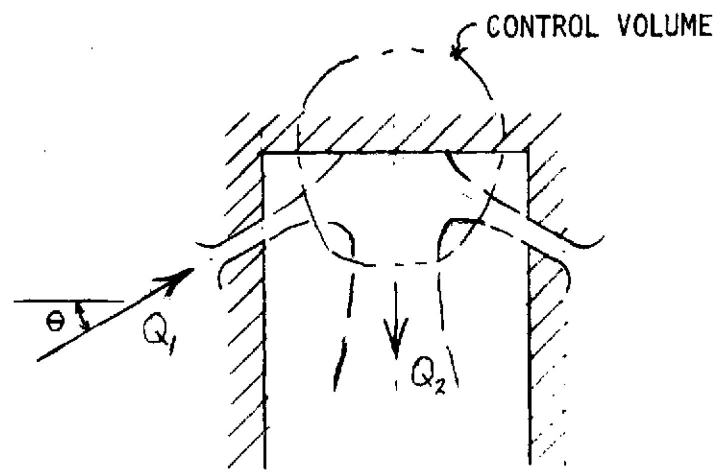


Figure 7.0-1 Diagram of Approximate Inlet Flow

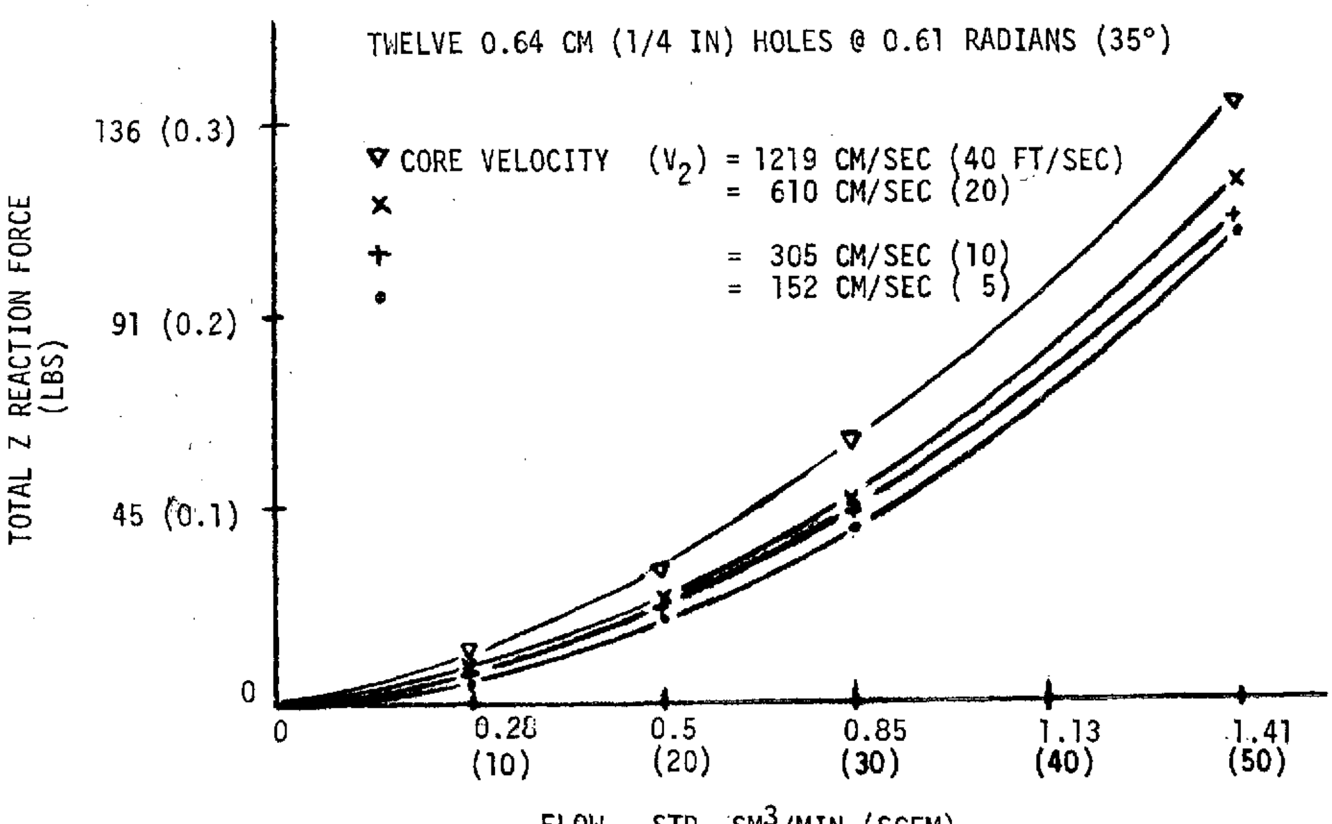


Figure 7.0-2 Estimated Total Reaction Force on Exposed Anal Area

end of the stool. All of these results indicate the presence of a concentrated three dimensional high pressure zone which has an effective diameter on the order of 2.54 cm (1 in) to 4.08 cm (20 in), an effective height along the transport tube of 2.54 cm (1 in) to 4.08 cm (2 in) and a stagnation value of just over 2.54 cm (1 in) water for the 0.85 sm^3/min (30 scfm) flow and 12 hole inlet case.

Whenever a stool intrudes into this high pressure zone forces are developed which assist in squeezing down the exiting material and expelling it out of the high pressure zone.

Additional corroboration of the characteristics of these high-pressure zones can be drawn from the dynamic velocity test data (Figure 6.2-1). Initial accelerations occur over a distance of about 4.08 cm (2 in). Magnitudes of these accelerations correlate with static force test values.

8.0 CONCLUSIONS

The major parameters governing stool separation and transport are inlet orifice area (A), orifice configuration, and transport air flow (Q).

$$\text{Separating Force} = f\left(Q^2, \frac{1}{A}, \text{Orifice Angle}\right)$$

$$\text{Transport Velocity} = f\left(Q, \frac{1}{A}, \text{distance along tube}\right)$$

The nature of the above parametric relationships is the result of a small high-pressure zone created by momentum effects of the transport flow. Effective design of the inlet orifice should focus and concentrate this zone at the rectal opening for best use of the "squeeze off" and impulsive characteristics of this zone.

SECTION 3

ZERO GRAVITY TESTING OF A WASTE MANAGEMENT SYSTEM

1.0 BACKGROUND

1.1 General Background

Management of human waste material has probably been one of the more unsavory tasks encountered during manned spaceflight and has been relatively difficult to satisfactorily provide, both from the engineering as well as the esthetic viewpoint. In the absence of gravity, liquids are difficult to collect and store safely, especially when the liquid is urine which can provide nutrients for microbial growth.

The chronology of the techniques for human waste collection during Gemini, Apollo and Skylab and future systems for Shuttle provide some insight into evaluation of waste management systems for space applications and indicates those areas where difficulties have been encountered or improvements are needed. The Apollo Waste Management System (WMS), originally used on the Gemini program, is quite crude principally due to strict limitations on equipment weight, power and volume. Basically, urine was collected via a roll-on cuff or funnel arrangement and jettisoned to space. Feces were collected in a plastic bag attached to the buttocks and stool separation was accomplished by a gloved finger insert. Following collection, a biocide was added to the bag and mixed by manual manipulation, then stored. These procedures can take 45 to 60 minutes to accomplish and have resulted in odor release and potential contamination to the cabin of the spacecraft.

The SKYLAB WMS, more sophisticated than the Apollo system, utilizes air flows to entrain and transport the urine and feces into separate collection areas. This system permits less user involvement and less odor release but requires relatively more complicated equipment such as blowers, air filters and liquid/air separators.

The urinal in the SKYLAB system, designed for male users, is basically a funnel with an air flow to capture and transport the urine. The urine/air mixture is processed in a phase separator to dynamically separate air from the urine. The air is subsequently removed from the separator by a blower, filtered and returned to cabin ambient. The urine is pumped to a chilled bag for storage.

The SKYLAB feces collector also uses an air flow to separate, entrain and transport the stool. The stool is collected in a porous bag which retains liquid and solid wastes while permitting passage of the transport air which is subsequently filtered and returned to cabin ambient. The bag is manually sealed and the wastes are dried for storage and return to earth.

SHUTTLE ORBITER will require improvements to the Waste Management Systems not only because long-term experience with the previous system suggested changes, but also because crewmembers in the future will probably employ male/female. For Shuttle then, simplified user procedures are needed and female users must be accommodated. In addition, more "earth-like" accommodations are highly desirable, if not necessary with automated processing, preferably without the use of bags.

1.2 General Electric Dry John And Previous Programs

The GE Dry John was developed in 1965 for feces collection in a spacecraft application. In this system, the stool is conveyed by transport air into a storage container. Within this container, the feces impinge on a rotating slinger and are centrifugally accelerated through the slinger. This action separates the transport air from the feces, shreds, and then spreads the feces in a thin layer over the internal surface of the container. The large surface area over which the feces is spread is important in subsequent drying of the waste material. Toilet tissue enters the storage container in a manner similar to the feces and is distributed by slinger action.

The GE developed urinal is a funnel-like device that can be positioned or held by the user. Both males and females are accommodated by the system. The urinal system design requires only low air flows approximately 0.14 to 0.23 m^3/min (5 to 8 cfm) to insure entrainment and transport.

The basic GE system provides user procedures comparatively similar to normal earth oriented waste collection systems, with seating and positioning basically similar to typical situations.

During the further development and testing of the GE WMS, a number of GE and NASA sponsored programs have been conducted. While all of these efforts have contributed to the improvement and testing of the system, two of these studies are relatively direct precursors of the zero "g" program here. One of these studies, performed as part of IR&D activities at GE and supported by NASA JSC dealt with the optimization and evaluation of the GE waste management system for zero gravity applications.

The basic objective of this IR&D program was to prove the functional design of the GE Dry John for waste collection in the zero gravity environment expected for Space Shuttle. Zero gravity and baseline normal gravity tests of the Dry John WMS confirmed the soundness of approach and established the basis for future tests by actual male and female users in zero gravity.

The zero gravity tests, conducted as part of this program, established preliminary air flow rates for urine and fecal collection. Testing included simulated urination and simulated normal and diarrhetic stools. Baseline ground tests confirmed that the system could accommodate male and female users. Several specific advantages of the system, including elimination of the need for vaginal wipes were observed during the tests. Female user acceptance was excellent with a high degree of confidence in urine containment and urinal comfort. A detailed account of this study can be found as a part of this report in Appendix A.

The second study which is also a direct precursor of this effort is the Fecal Separation/Transport Investigation described in Section 2 of this report. Basically the Fecal Separation/Transport Study defined some values of parameters tested in the zero "g" tests.

2.0 OBJECTIVES

The objectives of this program were to:

- Incorporate improvements, identified from earlier fecal separation/-transport studies, into the existing GE Dry John-Zero Gravity Test System.
- Verify in zero gravity fecal separation/transport defined in preceding studies.
- Verify total GE Dry John system performance in zero gravity.

Specifically, the objectives of the zero "g" operation were to verify:

- Proper separation/transport flows for the feces and urine processors.
- Slinger and urine separator performance.
- Human factors design and operation of the system.

3.0 APPROACH

The zero "g" user test was basically a continuation of earlier work[1] performed by GE. The general approach was to evaluate the GE WMS in a zero "g"

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[1] A report of the work preceding and leading to this activity can be found in the Appendix A.

environment produced in a KC-135 aircraft. The results of previous studies were used to define test parameters, optimize equipment, and insure a high degree of success of system test procedures in the zero "g" environment.

The zero "g" testing environment was provided by a KC-135 aircraft flying a parabolic maneuver resulting in short periods of weightlessness.

From results of the previous zero "g" simulated fecal and urine collection tests, as well as the neutral bouyancy tests, baseline air flow settings were established and some equipment improvements devised. These included a different urinal support, relocation of test instrumentation and addition of a privacy enclosure. Procedures used earlier were altered principally to accommodate simultaneous fecal and urine collection.

U. S. Air Force Nurses and local NASA test flight personnel were used as test subjects. This subject population had the advantage of being flight qualified, and in the case of the flight nurses, had substantial training and experience relevant to the nature of the user test work.

The test aircraft (KC-135-NASA-930), flight crew and support were provided by NASA-JSC Aircraft Operations at Ellington AFB, Houston, Texas.

4.0 EQUIPMENT

The equipment included a "Dry John" commode for fecal collection, a urine collection system, instrumentation, and control equipment together with a privacy enclosure provided by General Electric. In addition to the test aircraft, NASA-JSC provided photographic equipment, electrical power, high pressure nitrogen and provision for draining urine from the system. A functional diagram of the system is shown as Figure 4.0-1 and a schematic of the electrical system in Figure 4.0-2.

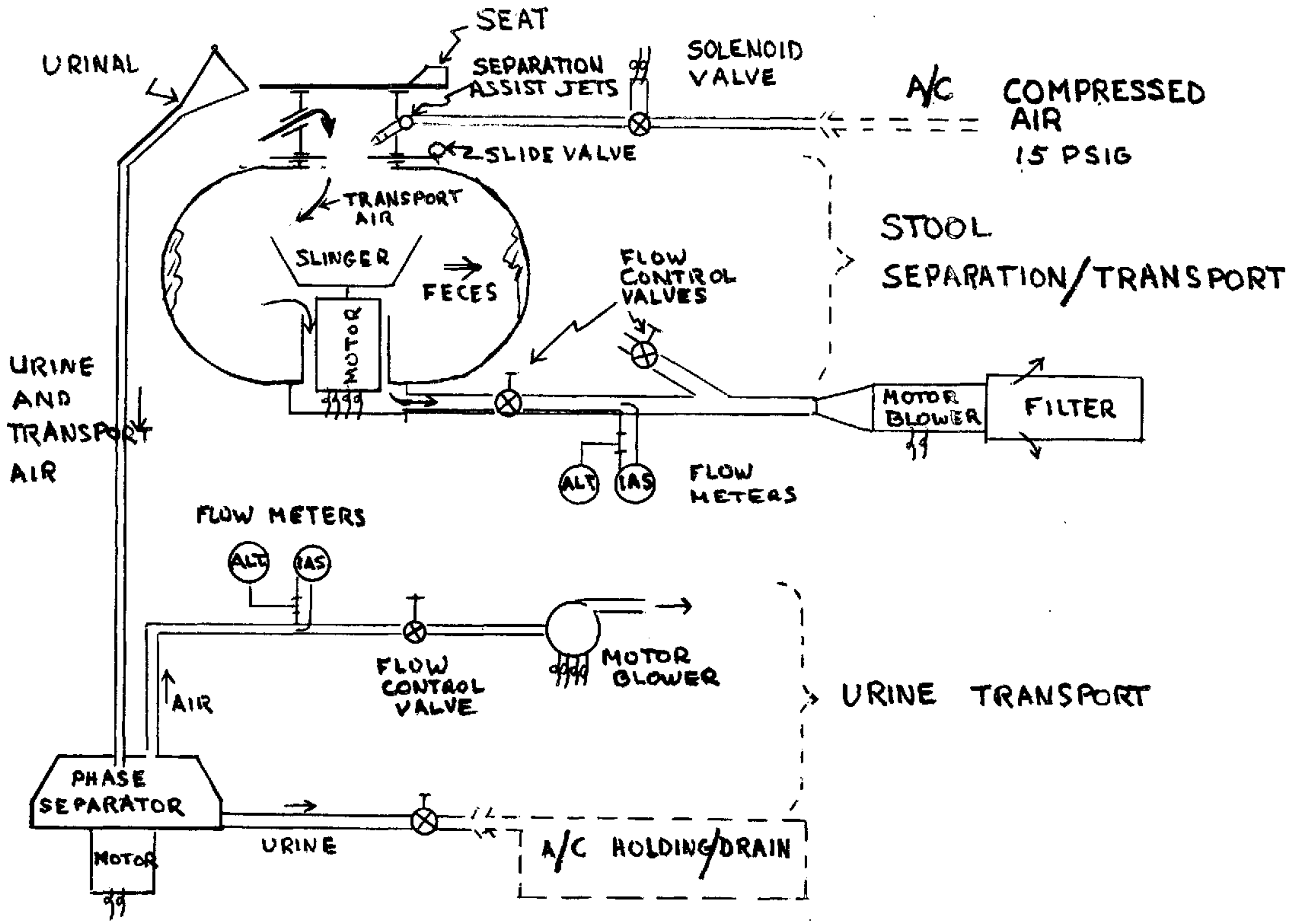

Figure 4.0-1 Functional Diagram - Advanced Waste Management System

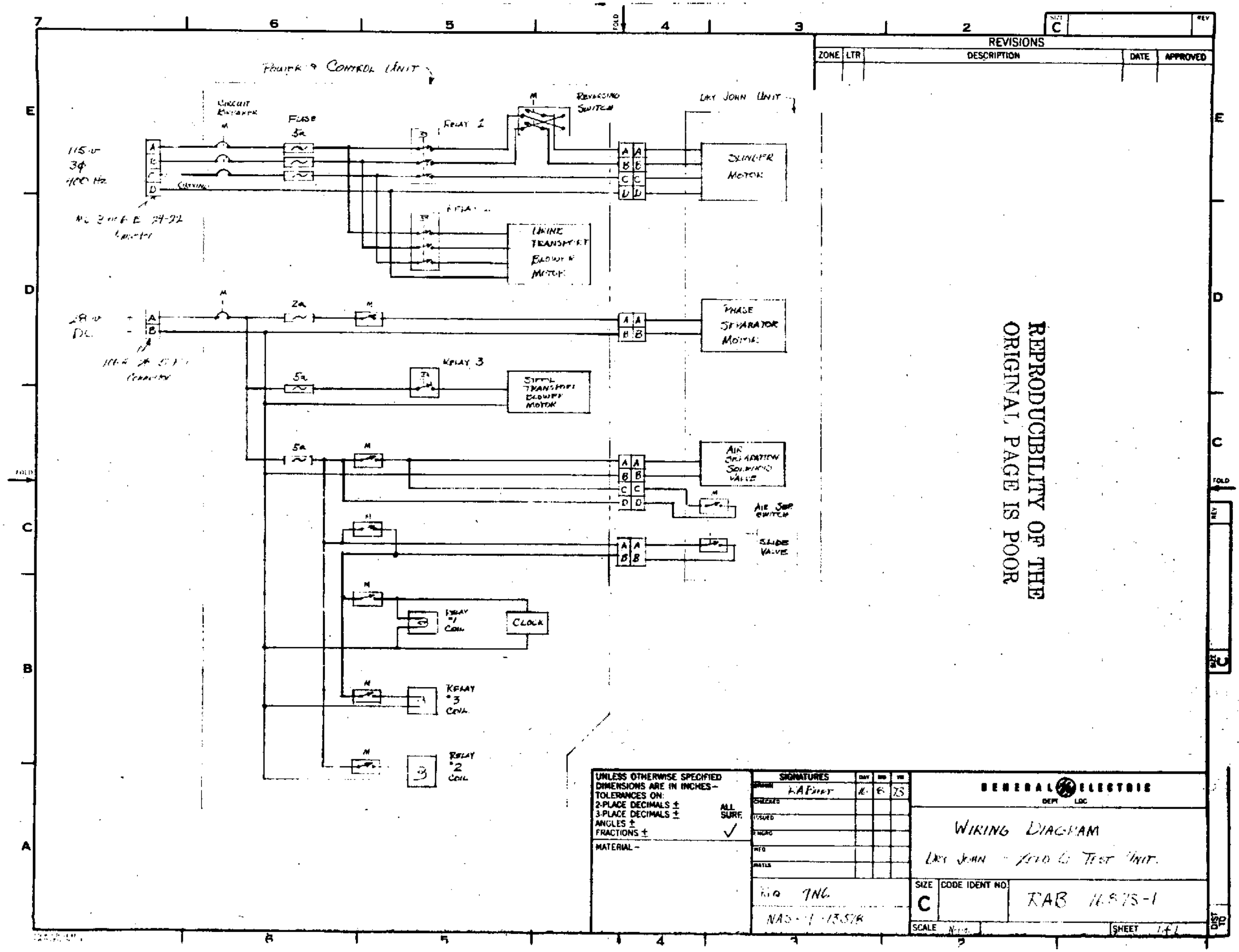

Figure 4.0-2 Schematic of Electrical System

The commode consisted of a seat, a slide valve, transport tube, a slinger and a storage container, together with a blower filter and air flow control valves .

The contoured seat of the commode assisted in positioning the user. Body and foot restraints secured the user to the seat during zero gravity operation. When properly seated, the user opened the slide valve closing a power switch which controlled power to both the slinger and blower. Transport air flow occurred concurrently with slide valve opening. This precluded any possible back flow from the feces storage container into the cabin ambient. During defecation, the stool was conveyed by the transport air flow through the transport tube into the storage container. The gas positioning jets were used to supplement the transport air flow to ensure disengagement of the feces from the anal area. Within the storage container, the feces impinged on the rotating slinger, where it was centrifugally accelerated through the slinger. This action, in addition to separating the transport air from the feces, shredded and then spread the feces in a thin layer over the internal surface. The resulting large surface area is of importance in the subsequent drying process. Used toilet tissue entered the storage container in a manner similar to that of the feces, the tissue being distributed by slinger action. Transport air was drawn through a bacteria filter and into the blower and filter assembly. After defecation was completed, the user closed the slide valve, and removed his position restraints. Closing the slide valve activated the interlocking switch which turns off the slinger motor and blower.

The commode storage container and transport tube were fabricated of clear plastic to provide photographic access to the fecal collection process. Air flow control valves and air flow instrumentation allowed setting predetermined air flow rates.

The fecal storage container of the commode was a closed bowl 50.8 cm (20 in) in diameter with the top half of transparent plastic. Located just below the seat was an air inlet ring having ten (10) 0.64 cm (1/4 in) inlet holes. The inside diameter of the inlet ring aligns with a clear plastic transport tube terminating about 12.7 cm (1/2 in) above the slinger tines. The 14.0 cm (5.5 in) diameter single row slinger was powered by a 400 Hz 7000 rpm motor. Slinger tines were 7.6 cm (3 in) long and mounted on a 0.5 radian (30°) half cone angle.

Transport air flow was provided by Vane-Axial Blower (Joy Mod AV 3.5-2.75 120D) rated at 1.7 m^3 (60 scfm). For air flow control, series and bypass valves were incorporated in the 5 cm (2 in) diameter air ducting. Flow measurement was by pitot-static connections which sensed total and static pressures in a section of the air ducting driving conventional aircraft air speed and altitude indicators.

The urine collection system included a urinal, urinal mounting device, phase separator, blower, air filters, air flow control and instrumentation.

The urinal was a conical device leading to a phase separator. The urinal position can be adjustable in position to suit the convenience of the user, male or female. The phase separator was a centrifugal device which dynamically separated the collected urine from the transport air flowing through the urinal and the connecting tube. The urine was pumped to a storage container while the air was recirculated by the blower and odor filter assembly.

Two types of urinal assemblies were constructed for the tests, one a female/male and the other a male design. Basic configuration of the male/female urinal was a receptacle approximately 5 cm (2 in) wide x 13 cm (5 in) long which was contoured to fit a periferal area surrounding the vulva. The urinal is shown in Figure 4.0-3. The structural connection element is interrupted to provide an inlet for transport air flow. Configuration and size of the inlets were intended to give a continuous in-flow of air around the full periphery directed parallel and in close proximity to local skin contour.

The male design was a simple conical device with 5 cm(2 in) diameter inlet. Both designs were fabricated out of transparent plastic to provide photographic access to the urine collection process.

The remaining elements of the urine collection system included a centrifugal phase separator to remove all liquid from the transport flow before the air stream proceeded to the blower and exited. Actual flow was controlled by an in-line butterfly valve and measured by pilot and static tubes in the exit of the phase separator.

To provide privacy to subjects using the Dry John, a simple modular enclosure was fabricated. Overall dimensions were 1.2 x 2.5 x 2m (4 ft. x 8 ft. x 6 1/2 ft.) high with the largest panel modules being 1.9 x .8m (6 ft. x 2 1/2 ft.). All panels were aluminum angle picture frame covered with an aluminum sheet except for one entry panel. For this, NASA-JSC provided a fire-proof curtain with velcro closures. Figure 4.0-4 shows the arrangement of Dry John within the privacy enclosure.

Equipment arrangements in the test aircraft are documented in three photographs. Figure 4.0-5 shows the power and control equipment as well as the phase separator mounted forward of the privacy enclosure. A curtained entrance was on the left side of the enclosure. Figure 4.0-6 displays the interior of the enclosure including the commode, restraints and camera equipment. Although

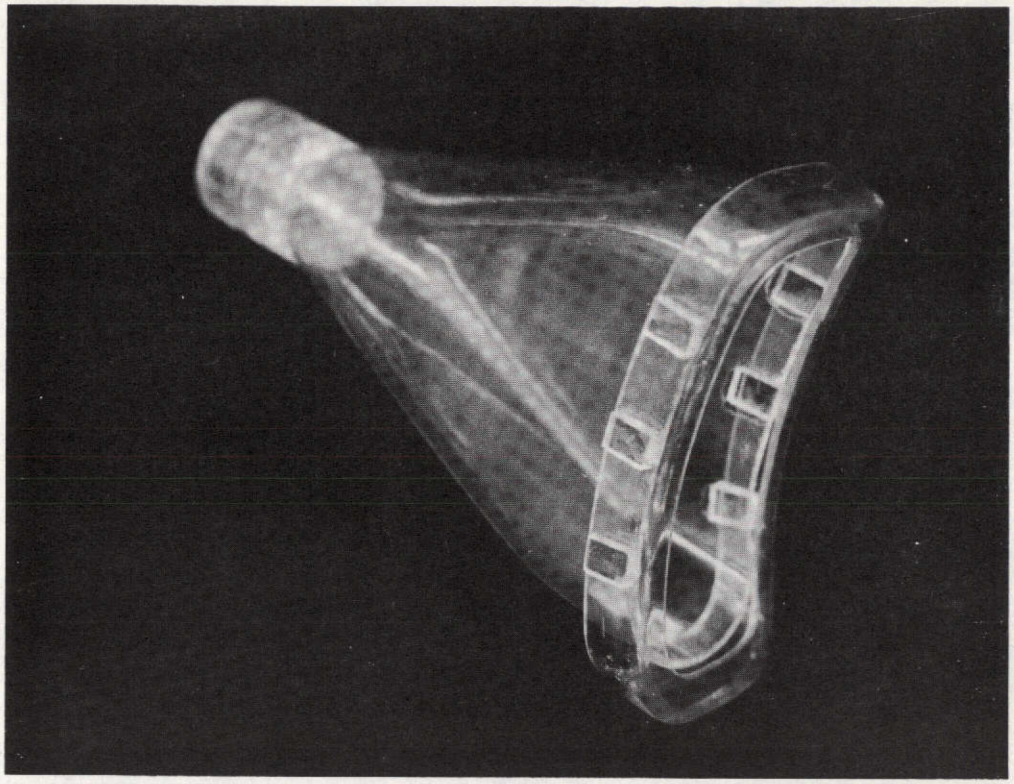

Figure 4.0-3 Male/Female Urine Receptacle

a urine receptacle is not in place, a new mounting mechanism is shown. Four (4) separate adjustments in this mechanism provided a wide range of adjustability to provide the capability to collect data regarding user positioning of the urinal. On each adjustment, a marked scale arrangement provided a position reference so that any urinal position could be reestablished, if required. For female usage, the support mechanism included a spring device to provide sealing forces of the urine receptacle against the subject's pubic area. When fully compressed, the spring excited a force of approximately 2.23 kg (5 lbs) on the female pubic area.

A dynamic phase separator was used during the zero "g" and ground testing to separate transport air from urine. Pictorial data by hand-held movie cameras

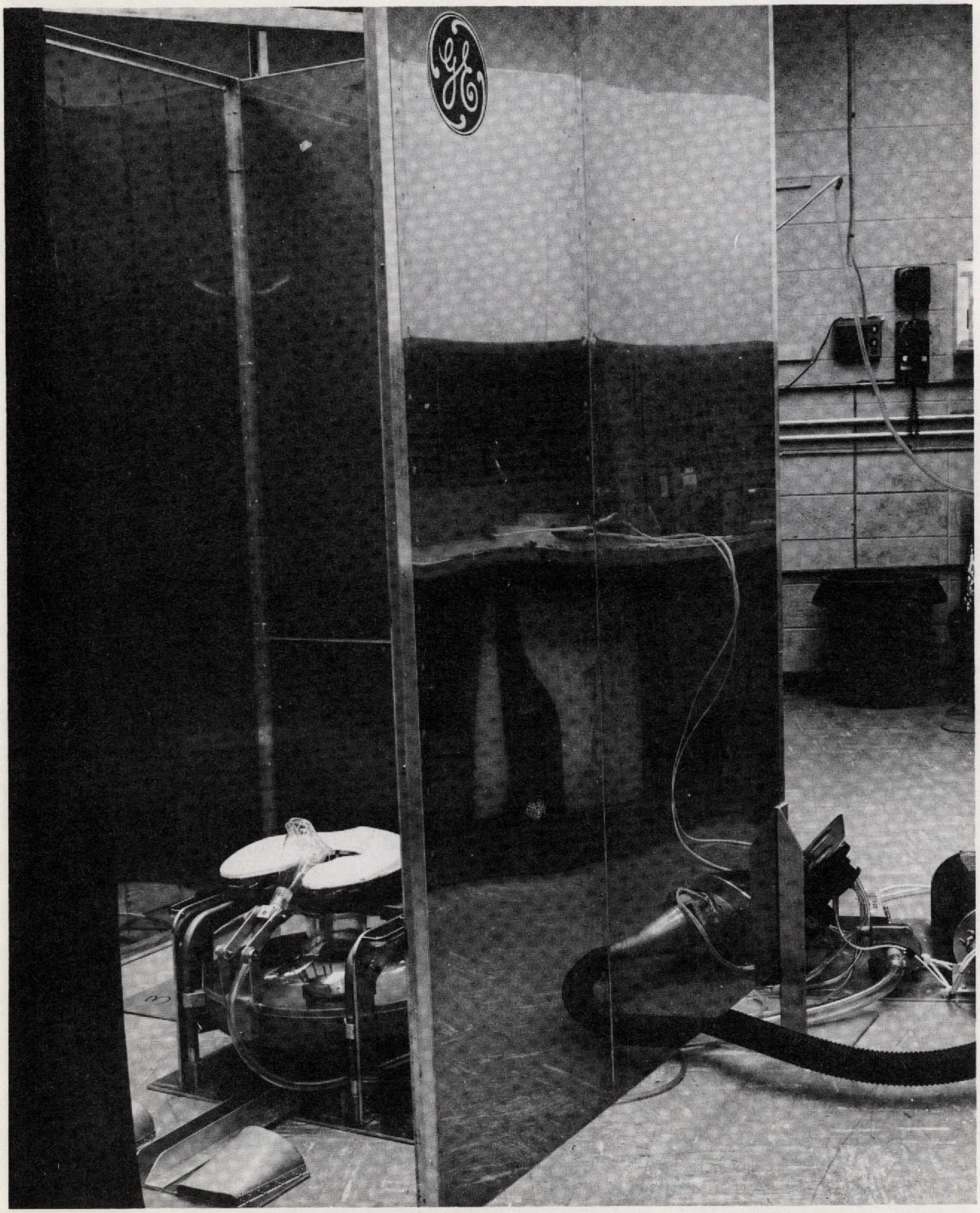

Figure 4.0-4 Dry John Zero "G" Test Unit With Privacy Enclosure

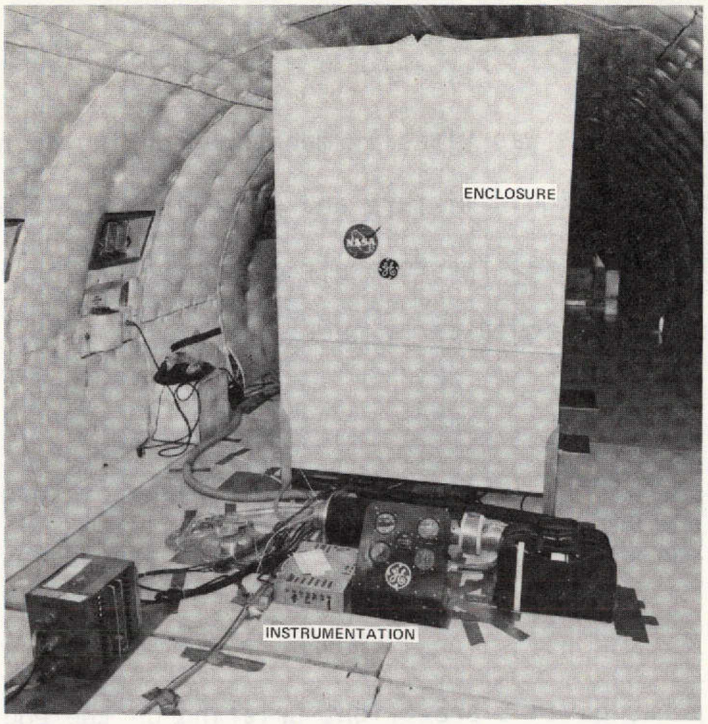

Figure 4.0-5 Power and Control Equipment, Phase Separator and Privacy Enclosure

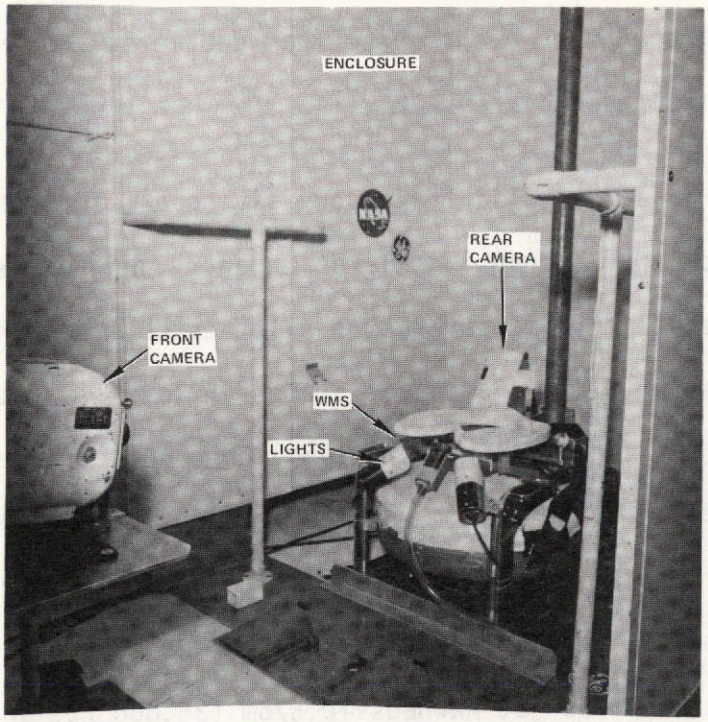

Figure 4.0-6 Interior of the Privacy Enclosure Showing Cameras, Restraints and Waste Management System

were taken and the performance was visually monitored during urine collections. Inlet line carrying the air/liquid mixture and exit lines for transport air and urine were transparent as was the top half of the separator itself to permit visual observation of liquid carry over.

5.0 PROCEDURES

Basic test procedures are found in Appendix B, Test Plan For Zero "G" Testing of General Electric's Waste Management Model. General procedures consisted of the following:

Each new subject group was given a pre-flight briefing on the equipment operation and test objectives and procedures. Then, a ground baseline test was run in which each subject used the system for a urine collection, becoming familiar with the adjustments necessary for obtaining a satisfactory urinal position. Following ground use, each subject was debriefed and asked to fill out a questionnaire (Appendix C).

The zero "g" maneuver is a parabolic trajectory giving a weightlessness period preceded and followed by high acceleration entry and recover (See Figure 5.0-1). To execute this maneuver, the pilot establishes an altitude of approximately 7625m (25,000 ft) and accelerates in level flight to Mach. 88 then pitches up at +2 G's to a 0.78 radian (45°) nose up attitude. Then a slight pitch down initiates the zero "g" period. The pilot continues pitch down rotation using a special accelerometer indicator to control vertical acceleration to essentially zero. This continues for up to 30 seconds while the aircraft goes "over the top" at perhaps 10,675m (35,000 ft) and comes comes back down. During this period, test procedures are conducted. At a 0.52 radian (30°) nose down pitch attitude, the experimenters get personnel into safe positions, and at 0.78 radian (45°) nose down pitch angle, recovery is started and 2 to 2 1/2 G's vertical acceleration is applied to bring the aircraft back into level flight and ready to repeat the maneuver.

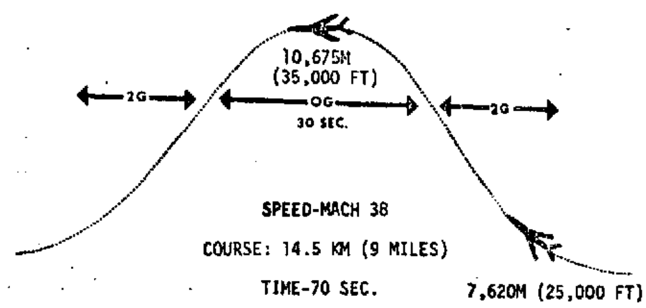

Figure 5.0-1 Illustration of the Trajectory Used in the KC-135 Aircraft to Produce the Zero "G" Condition

For each flight, the procedure was to use the "climbout" time to check out equipment functions and to organize the subject line-up. A clean urinal was installed and given a preliminary adjustment for each subject.

Before beginning the zero "g" maneuver a subject entered the enclosure, disrobed, sat down on the commode, engaged the restraints, adjusted the urinal position and signaled his readiness. Another subject ("Buddy") was stationed just outside the enclosure to be available if assistance or supplementary communication was needed. Normal communication was provided on a head set circuit between the subject, "Buddy", experiment conductors, and the flight deck.

Camera equipment and photo lights were controlled by the flight engineer and turned on only during the zero "g" part of the maneuver. Subjects attempted to time the start and stop of urination/defecation to occur only in the weightless period.

Normally each subject was scheduled for six parabolas, but the period was shortened or extended at the disposition of the subject. Straight and level flight was resumed for intervals when subjects were changed and then the same test procedure was repeated. After each usage, the subject filled out an appropriate questionnaire (Appendix C).

Following the flight when developed films were ready, a subject debriefing was held to elicit further comments and evaluations.

6.0 RESULTS

6.1 General Results

Results of the zero "g" tests were documented on 16 mm film and questionnaires. The user flight test phase was accomplished during November 1973 at the NASA Aircraft Operations Facility, Ellington AFB, Houston, Texas. In the course of ten flights, 242 parabolas were flown giving an available zero "g" test time approaching two hours. Nineteen subjects (12 female and 7 male) participated. The subjects were USAF Reserve Nurses or NASA and GE volunteers. As a result of the combined variabilities of subject availability and the test aircraft availability, there was a wide range of subject opportunity to become acclimated to the zero "g" maneuver environment and to make use of the Dry John equipment. Three of the nineteen subjects had only one opportunity while another three had from five to eight opportunities. From the total of fifty-four (54) subject opportunities, there were forty-five (45) urine collections and ten (10) fecal collections. However, because some of the urinations or defecations occurred at times of the Zero "G" Maneuver during which photo equipment was not functioning, those recorded on film were forty-two (42) urine and six (6) fecal collections. In addition, fifty-two (52) questionnaires were completed by the subjects (Appendix C). Table 6.1-1 tabulates the individual subject participation in user testing. For each flight, the usage opportunities are noted by the number of parabolic maneuvers used. Table 6.1-2 summarizes the performance, giving for each flight the number of urine and stool collections obtained.

6.2 Flight Chronology

In the following chronology, descriptive data on subject's performance, collection flow settings, and equipment are listed for each flight.

Flight 0 - Tuesday, November 6th, 1973

After one parabola and one subject voiding, the flight was aborted due to malfunctioning of the aircraft's cabin pressurization/conditioning system.

Flight 1 - Thursday AM, November 8th, 1973

Five subjects flew 17 maneuvers, and 4 urine collections were recorded. Flow rates used were 0.23 sm^3/min (8 scfm) and 0.68 sm^3/min (24 scfm) for urine collection and fecal collection system, respectively.

Subject	Initials	Parabolas	Collection
1	PF	4	Urine
2	MK	2	Urine
3	LB	3	Urine
4	MG	4	---
5	SF	4	Urine

Table 6.1-1 Subject Participation In User Tests

(By Number of Parabolas)

Subject	Ground Test	Flight Number										
		1	2	3	4	5	6	7	8	9	10	
Female												
LB	X	3	2	3	3							
PF	X	4		4	3							
GB	X			2			6					
SF	X	4		3		11	7	3	6	8	8	
MG	X	4			3							
MJK		2			2	6						
JM			2		3							
CS	X			2				3		4	2	
BS	X		2	3			6					
KOC											5	
PH										3	3	
LH										4	5	
MALE												
JN				6								
CR			3		3							
RB								4	5			
BP							9	9	6	5	6	
DA										4		
JH									3	4	6	
GS							5	7	3		4	
"Gynny"						(6)						
Total Participations		5	4	7	6	2	5	5	5	7	8	54
Total Parabolas		17	9	23	27	23	33	26	23	32	39	242

Table 6.1-2 Flight Test Subject Performance Summary

	No. Subjects			Urine Collections			Stool Collections		
Flight No.	Male	Female	Total	Recorded On Film	Not Recorded	Dry	Recorded	Not Recorded	Dry[1]
1	0	5	5	4		1			
2	1	3	4	4				NOT ATTEMPTED	
3	1	6	7	7					
4	1	5	6	6					
5		2	2	2				1	1
6	2	3	5	3		2	2	1	2
7	3	2	5	2		3	1		3
8	4	1	5	2	3		1		4
9	3	4	7	5		2		2	5
10	3	5	8	7		1	1		7
	18	36	54	42	3	9	5	4	22

1 Dry runs are those test runs where urination or defecation was not accomplished by the subject.

Flight 2 - Thursday PM, November 8th 1973

Four subjects flew 9 parabolas, and four successful urine collections were recorded. Air flow setting was 0.17 sm^3/min (6 scfm).

Subject	Initials	Parabolas	Collection
1	BS	2	Urine
2	LB	2	Urine
3	CR	3	Urine
4	JM	2	Urine

Flight 3 - Friday AM, November 9th, 1973

Seven subjects flew 23 parabolas. Seven successful urine collections were recorded. Air flow setting was 0.17 sm^3/min (6 scfm).

Subject	Initials	Parabolas	Collection
1	SF	3	Urine
2	CS	2	Urine
3	GB	2	Urine
4	PF	4	Urine
5	BS	3	Urine
6	LB	3	Urine
7	JM	6	Urine

Flight 4 - Friday PM, November 9th, 1973

Six subjects flew 17 parabolas and all had successful urine collections. Except for subject no. 2, the collection air flow was 0.17 sm^3/min (6 scfm). 0.23 sm^3/min (8 scfm) was used for subject no. 2 (L.B.). To compensate for difficulties in maintaining an adequate sealing contact with the urine receptacle throughout the zero "g" maneuvers, this subject of small ≈ 45.4 kg size (≈ 100 lbs) had to use the receptacle adjustment at one end of total range of the equipment.

Subject	Initials	Parabolas	Collection
1	MG	3	Urine
2	LB	3	Urine
3	JM	3	Urine
4	MK	2	Urine
5	PF	3	Urine
6	CR	3	Urine

Between Flights 4 and 5 while aircraft hydraulic system difficulties were being diagnosed, improvements were made in the front camera adjustments and lighting. Also discussions under the guidance of Dr. C. E. Ross, NASA Flight Surgeon, were held with the subjects on methods of obtaining defecations in flight. To aid subjects in defecating, Metamucil[2] was made available to subjects and flight schedules were advanced for earlier (7:30 AM) take-offs. The test aircraft availability, however, did not always conform with this planning.

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[2] Searle Laboratories

Flight 5 - Monday PM, November 19th, 1973

Two subjects flew 17 parabolas with two successful urine collections. One fecal collection occurred during the high G portion of a maneuver so it was not recorded by the cameras. In addition, the female mannequin "Gynny" was tested for 6 parabolas to explore the effect of large gaps $\approx$ 0.64 cm ($\approx$ 1/4 in) at the collection receptacle on collection efficiency. The latter was run at an airflow of 0.25 sm^3/min (9 scfm), and urine flow rates of 5 to 35 ml/sec with all simulated collections successful. Flow rates for the human subjects were 0.19 sm^3/min (7 scfm) and 0.62 sm^3/min (22 scfm).

Subject	Initials	Parabolas	Collection
1	SF	11	Urine - (Small Stool Not Recorded)
2	MJK	6	Urine
3	"Gynny"	6	Urine

Flight 6 - Tuesday AM, November 20

Five subjects flew 33 parabolas with five urine collections and three stool collections. One stool collection was recorded. Of the other two, one was not completed until after termination of the 25 second zero "g" period and record of the third was lost due to a camera malfunction. Air flows were 0.17 sm^3/min (6 scfm) for urine and initially 0.68 sm^3/min (24 scfm) for stool collection. This flow dropped down to 0.57 sm^3/min (20 scfm) after subject 1 and at the end of the mission was less than 0.42 sm^3/min (15 scfm) due to a blockage of the air outlet by excessive amounts of paper toweling and tissue.

Subject	Initials	Parabolas	Collection
1	GB	6	Urine & Fecal
2	BS	6	Urine
3	BP	9	Urine
4	GS	5	Fecal
5	SF	7	Urine & Fecal

Flight 7 - Wednesday AM, November 21

Five subjects flew 26 parabolas. Three urine and two stool collections resulted with one of the latter recorded on film. A modified slinger having bottom side tines was substituted for the original slinger to prevent paper blockage experienced on Flight 6. Airflows were set at 3.7 (8 scfm) and 0.85 sm^3/min (30 scfm) for urine and feces collection.

Subject	Initials	Parabolas	Collection
1	BS	7	Urine & Fecal
2	BP	9	Urine
3	SF	3	Fecal
4	CS	3	-
5	RB	4	Urine

Flight 8 - Wednesday AM, November 28

Five subjects flew 23 parabolas. Four urine collections and one fecal collection were made but film record on urinations of the first three subjects were lost due to film breakage in the camera. A new Apollo type urinal was used for male collections and a new stronger spring to get higher contact forces was used for the female collections. Collection air flows were 0.09 sm^3/min (7 scfm) and 0.85 sm^3/min (30 scfm) for urine and stool collection, respectively.

Subject	Initials	Parabolas	Collection
1	CS	3	*Urine & Defecation
2	JH	3	*Urine
3	BP	6	*Urine
4	SF	6	Urine
5	RB	5	Urine

*Film Record Unavailable

Flight 9 - Thursday AM, November 29

Seven subjects flew 32 parabolas. Three were novices from a new group of Air Force nurses. Five urine collections were made and recorded. Two defecations occurred but not during the zero "g" filming window so they were unrecorded. Air flow settings were 0.23 (8) and 0.85 sm^3/min (30 scfm).

Subject	Initials	Parabolas	Collection
1	JH	4	Urine & Defecation*
2	PH	3	Urine
3	LH	4	-
4	CS	4	Urine
5	SF	8	Defecation*
6	BP	5	Urine
7	DA	4	Urine

*Not Recorded

Flight 10 - Friday AM, November 30th

Eight subjects including one novice flew 39 parabolas with six urine and one stool collection recorded. Collection air flows were 0.23 (8) and 0.85 sm^3/min (30 scfm). Subject 1 had a very poor adjustment of seat restraint and urine receptacle with the result that a small amount of urine (estimated at 1/2 ml or less) entrained in the collection flow and escaped into the cabin ambient. This loss was not reported by the subject and no apparent contamination occurred to the subject. All other collections were completely successful.

Subject	Initials	Parabolas	Collection
1	KOC	5	Urine - (Poor Adjustment)
2	CS	2	Urine
3	JH	6	Urine & Defecation
4	BP	6	Urine
5	GS	4	Urine
6	LH	5	-
7	PH	3	Urine
8	SF	8	Urine

6.3 Phase Separator Operation

Data on and urinal observation of the phase separator indicated that at no time was there carry over of urine into the air exit. Occasionally a small band of condensation was observed on the first 10.2 cm (4 in) of air exit tube immediately after a urine collection. At an early stage in the testing there was indication that the impeller speed was erratic and slow during zero "g" maneuvers, and inspection of the separator cover indicated that the impeller was occasionally rubbing. Adjustments were made to give additional axial clearance of $\approx$ 0.08 cm ($\approx$ 1/32 in) which alleviated the problem.

7.0 ANALYSIS/DISCUSSION

7.1 Analysis of Urine Collection Films

A study of urine collection results included comparison with simulated collection tests, the range of performances obtained with the different subjects, and appraisal of the equipment performance.

Results of simulated female urine collections (Gynny) suggested that satisfactory collection was obtained at air flows above 0.08 sm^3/min (3 scfm) as long as approximately full sealing contact occurred between the urine receptacle and the mannequin. Also when a deliberate mis-seal of 0.32 cm (1/8 in) to 0.64 cm (1/4 in) was introduced collection was still satisfactory at the one air flow tested, 0.25 sm^3/min (9 scfm). For the user tests the collection air flow was set initially at 0.17 sm^3/min (6 scfm), and subsequently at 0.23 sm^3/min (8 scfm). Collections were satisfactory with all fluid retained within the system. The higher airflows were used when there were questions about how well the adjustment of the urinal could be made to give a proper seal. One of the subjects had a very small physique which the urinal adjustments, at their limit, found difficult to accommodate. For all the other subjects the adjustment range was adequate.

Wide ranges were noted in the rate of urine flow and direction of the stream. Very low urine flows were characterized by formation of large globules of liquid which would eventually be pinched off and entrained by the collection air flow. Very high urine flows were accompanied by splatter and some accumulation of urine in the receptacle throat. Considerable variability of stream direction was noted. In half of the collections the stream impinged on sidewalls of the urinal, and in 10% of the collections the lateral and elevation directions were such that the subject's limbs would probably have been contaminated were it not for the direct sealing presence of the collection receptacle. Flow cross-sections typically were coherant and circular. Only the very high flow rates had any breakup into splatter. There was very little residual urine left in the labia afterwards.

For male subjects the collection air flows of 0.17 - 0.23 sm^3/min (6-8 scfm) were more than adequate when the male type urinals were used. When the female receptacle was used, the urine on receptacle walls near the entrance was transported very slowly as a result of the relatively low air velocities. The principle difficulty encountered by males during the test was in maintaining a proper aim. Transitions from 2 "g" to zero "g" together with occasional turbulance required frequent attention and re-aiming. All of the male collections, none the less, were successful with all urine contained within the system.

7.2 Analysis of Stool Collection Films

A study of the stool collection films can be summarized by comments about the physical characteristics and dynamics observed. Of the six stools filmed, five were produced in time to go through the slinger during zero "g" while a 6th did not come in time to make the complete cycle. As for size and shape three were 20 cm (8 in) or longer and the rest about 10 cm (4 in). Also half had a decided curl which is probably unique to the zero gravity situation. The dynamics observed were generally that the long stools, whether curled or not came straight down the transport tube where as two shorter stools came down with initial tumbling and landed on the slinger disk crosswise. The transport velocities were estimated for three stools and compared with velocities predicted from the neutral bouyancy simulation results. The realized velocities observed with natural stools ranged from 20 to 40 cm/sec (8 to 16 in/sec) and were roughly 2/3 of the prediction.

One subject, Flight 6 - No. 1, reported a more than average amount of tissue was needed for wiping and cleanup after defecation. In the urine collection films for this subject there were indications of discontinuous contact with the seat as the subject appeared to "lift-off" during portions of the zero "g" maneuvers probably due to inappropriate use of the user restraint system. Also separation did not appear to occur cleanly at the anus leaving a short stool (1-2 cm long) adhering to the sphincter. Loss of the seal between buttocks and seat apparently interferred with normal clean separation. Contamination, however, was restricted to the anal area of the subject and cleaned off by use of a wiping tissue.

7.3 Analysis of Subjective Data and Questionnaires

The amount of data collected by questionnaires, debriefings and other comments of the test subjects was voluminous. In general, both the male and female users of the system were totally satisfied with system performance. There were no reports by the subjects of serious malfunction.

A wide variety of comments about system design and operation of a human factors nature were obtained. In many instances these comments were accommodated as the test proceeded.

Since the subject questionnaire data was varied in its content and should be interpreted essentially on an individual basis, no overall summarization of the questionnaires was attempted.

Questionnaire data collected during the study is provided in Section C of the Appendix.

8.0 CONCLUSIONS

The GE Dry John system functioned satisfactorily during the zero "g" tests. Both males and females were accommodated by the urine and fecal collection systems. User acceptance of the system was excellent. A number of suggestions regarding design features and operational procedures were obtained during the conduct of the study; many of these suggestions resulted in modifications and improvements to the equipment during the test.

Data from the study indicates that the design features of GE WCS should function entirely satisfactorily as a spacecraft system. The basic features and design of the current GE system tested in this program could be directly incorporated into a Shuttle Orbiter WCS without further testing in zero gravity.

SECTION 4

INVESTIGATION OF AIR DRYING OF FECAL WASTES AS AN ALTERNATIVE FOR THE SHUTTLE ORBITER WASTE MANAGEMENT SYSTEM

1.0 BACKGROUND

Air drying of feces offers a number of advantages over vacuum drying for a Shuttle Orbiter type spacecraft. First, the elimination of vacuum vents prevents the possible impairment of visibility, maneuvering capability, spectral sensor responses, photography ports, thermal control surfaces, and even telemetry, through a combination of plating-out (coating) and physical interference. Contrary to early predictions, contaminants form a "cloud" around the spacecraft as they are produced. Condensible gases coat the cold surfaces of the spacecraft while both the condensible and noncondensible gases are retained near the spacecraft by a number of factors; namely:

- Phase Equilibration.
- Hydrodynamic Coupling and Interaction with the Vehicle Flow Field.
- Induced Polarization.
- Electrostatic Field Effects.

Waste management systems have been a source of contamination both within the vehicle and in the immediate space environment when accumulated urine is jettisoned or through venting during vacuum drying of fecal waste.

Secondly, elimination of a vehicle penetration to space vacuum enhances the structural integrity of the spacecraft and therefore the safety of the crew.

Thirdly, the basic simplicity of the Dry John design is retained, while reducing the number of control functions and minimizing redundancy requirements. As a consequence, rigorous valve and connecting line designs are eliminated and the overall result is a more cost effective approach to waste management.

2.0 INVESTIGATION PROGRAMS

2.1 General Approach

The investigation was conducted in three phases beginning with a trade study of drying air sources using the current Shuttle cabin ambient as a baseline. The second phase involved selected laboratory testing of critical areas. Finally, an actual user test checked the feasibility of air drying under simulated Shuttle usage conditions.

2.2 Trade-Off Study of Drying Air Sources Test Definition and Study Approaches

2.2.1 Objectives

The primary objectives for the air drying study were:

- Identify and define parametric constraints of air drying based on expected Shuttle cabin environment and ECLS system characteristics.
- Identify possible optimal situations which may offer more drying performance at less cost in weight, power, space, or interface complications.

2.2.2 Approach

The general approach used was to survey the available technical information on Shuttle cabin and environmental control--life support systems for data on potential sources, sinks and movers of drying air. These sources were then compared to the requirements, mediated through the biodynamics and crew size, in order to establish feasible limits of major test parameters including air-flow rates, temperatures and humidities.

2.2.3 Requirements

Functional requirements of an air drying method are drawn from data associated with rates of waste production, crew size and assumptions concerning the biodynamics of dried solid metabolic waste.

Data available on solid metabolic waste generation[1] indicates the following:

Rates Of Solid Metabolic Waste Generation

	Min.		Normal		Maximum		
Fecal Solids	18g	(0.04 lb)	31g	(0.07 lb)	68g	(0.15 lb)	/24 hrs
Fecal Water	58g	(0.13 lb)	91g	(0.20 lb)	200g	(0.44 lb)	/24 hrs
Total	77g	(0.17 lb)	122g	(0.27 lb)	267g	(0.59 lb)	/24 hrs

Crew Size Assumptions

Basic Crew 4 for nominal 7 day mission.

Maximum additional passengers 6 for short missions.

Biodynamic requirements stipulate that the waste management system shall be capable of accommodating the total 24 hour input within a period as short as 2 1/2 hours, with a concomitant reduction in moisture content. Pecoraro[2] indicates that reduction of fecal moisture to 50% by weight provides a bacterio-static condition for prolonged storage periods.

2.2.4 Data

Table 2.2.4-1 identifies and lists available data on potential sources of drying air and sinks into which "used" air could be discharged.

2.2.5 Air Flow Required for Drying

Two primary factors that determine the amount of air flow required to dry solid metabolic waste are: The rate of fecal water evaporation required, and the increment of absolute humidity change of air passing thru the commode.

1 North American Rockwell document, No. 50-72-SH0106.

2 Pecoraro, J. N., Bioastronautics Data Book, 1973

Table 2.2.4-1 Potential Sources of Drying Air

Location	Flow		Pressure		Temperature				Source	Sink
	sm³/min	(scfm)	atm.		t_d °C	(°F)	t_w °C	(°F)		
1. ARS - Downstream from Blowers	8.07	(285)	+0.014	(5.7 in. w.c.)	25.56°	(78°)	3.89°-16.11°	(39°-61°)	X	
2. ARS - Downstream from Cabin Heat Exchanger	8.07	(285)	<0.014	(5.7 in. w.c.)			3.89°-16.11°	(39°-61°)	X	
3. ARS - Downstream from Air Mixing Junction	8.07	(285)	<0.014	(5.7 in. w.c.)					X	
4. Cabin Ambient Air	0	0	0		21.11°	(70°)	10.00°	(50°)	X	X
5. Make-Up Gas Inlet to Cabin	0.002	(.08)	>2.04	(30 psi)			<<0°	(0°)	X	
6. ARS - Between Inlet and Filter	8.07	(285)			21.11°	(70°)	3.89°-16.11°	(39°-61°)		X
7. Avionics Bay	0.001	(.03)	-0.03	(0.4 psi)						X
<u>Air Movers</u>										
1. ARS - Blowers	8.12	(287)	0.014	(5.7 in. w.c.)						
2. WMS - Stool Collection	0.85	(30)	0.037	(15 in. w.c.)						

Fecal inputs are dependent on crew compliment and are noted in Figure 2.2.5-1. Not all of the fecal water must be evaporated. In order to obtain a moisture content, for example, of 50% from a stool that is initially 25% solids and 75% water, requires removal of 83% of the original water.

The fecal moisture contents, in turn, define the air flow requirement as shown in Figure 2.2.5-2. Absolute humidity change is an "important" variable with this air flow.

The amount of water that a given air stream can pick up is illustrated on Figure 2.2.5-3 which defines the range of Shuttle cabin conditions on a psychrometric chart.

The amount of moisture, that will be transferred from fecal matter into an adjoining air volume is dependent on a number of variables which include concentration gradients, diffusion coefficients, and boundary layer characteristics of the air. Accordingly the evaluation test phase was planned to get some overall measure of drying performance.

2.2.6 Air Drying Concepts and Interfaces

Two concepts differing in airflow and interface impact were chosen. The first concept, with minimal interface demands, makes use of the stool transport airflow, approximately 0.85 sm^3/min (30 scfm), for air drying. A timing function is added to keep a blower running for some period following each usage[1]. second concept uses a low continuous flow from the ARS tapped off just beyond the blowers and using the air moving capability of the ARS to maintain this flow. After passing thru the commode bowl and odor/bacterial filters, this air would also return to the cabin. Additional interfaces are the 2.54 to

[1] Air is drawn from and returned to the cabin.

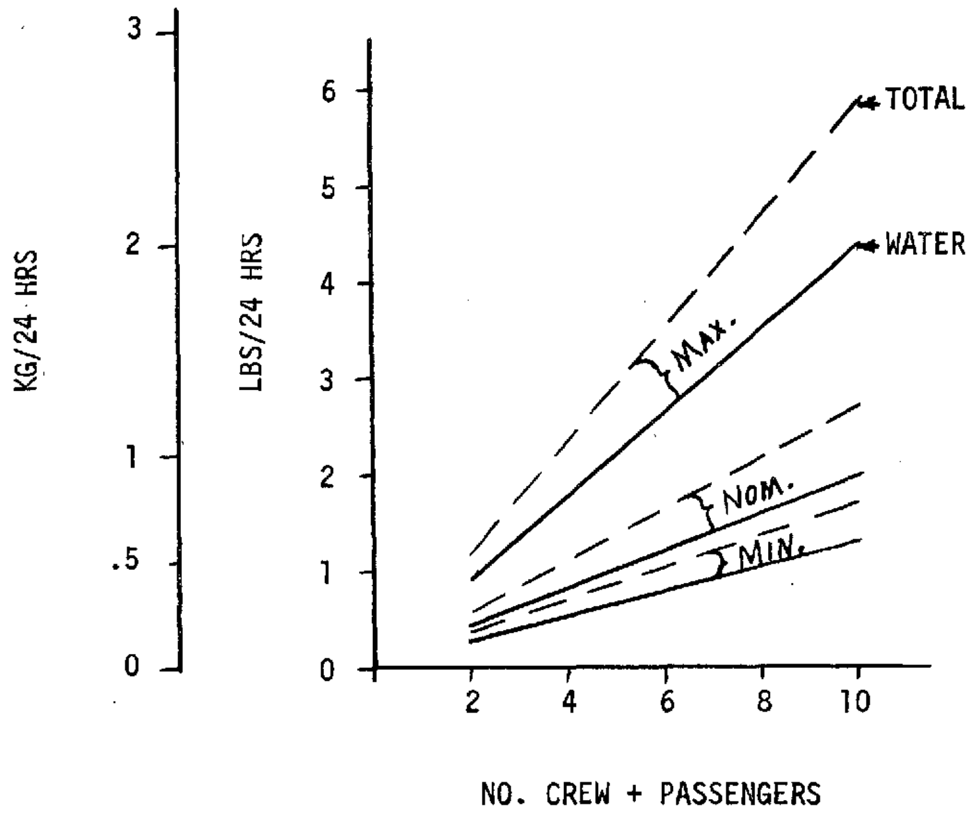

Figure 2.2.5-1 Fecal Input to Waste Management System

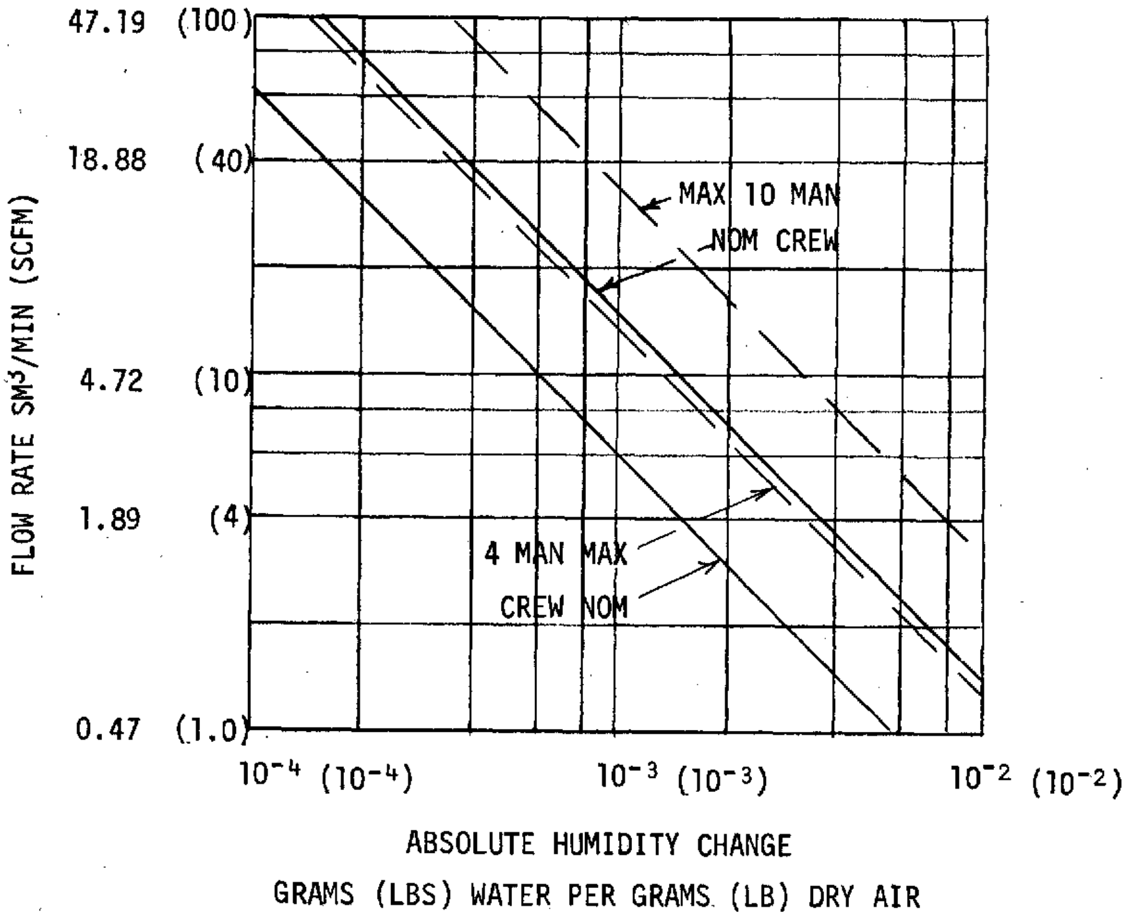

Figure 2.2.5-2 Drying Air Flow Requirement

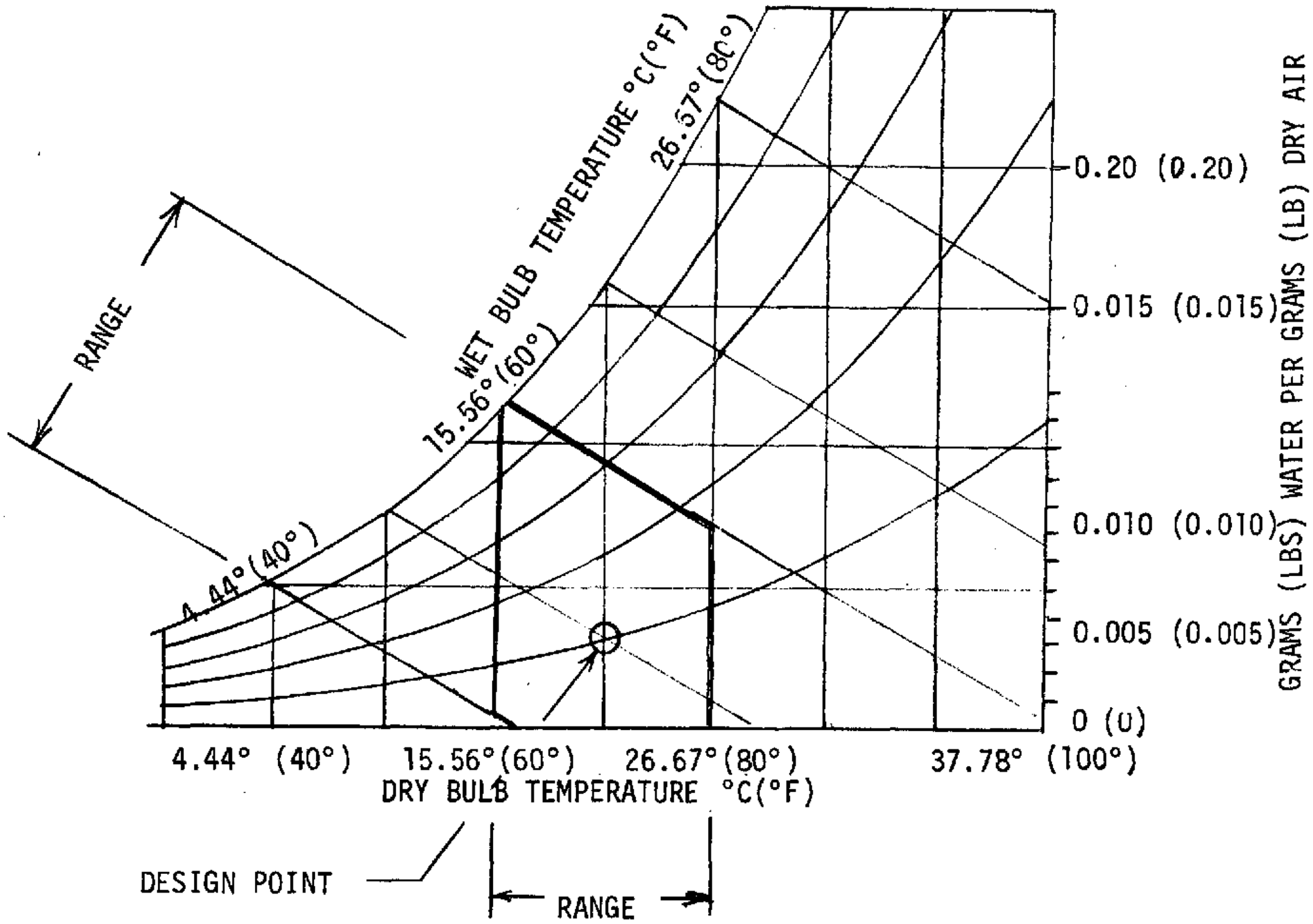

Figure 2.2.5-3 Cabin Atmosphere Characteristics

3.81 cm (1 to 1-1/2' in) air duct connection to the ARS blower chamber and the added duct run to the WMS unit.

2.3 Evaluation Test Program

2.3.1 Objectives

The Evaluation Test Program objectives were as follows:

- Develop data on drying characteristics and microbiological activity of slung fecal material,
- Evaluate the effectiveness of conceptual approaches, and
- Establish drying conditions for subsequent user testing.

2.3.2 Approach

Features of the approach to the evaluation program were the exploration of parameters affecting drying and the use of both simulated and natural fecal material. The apparatus capability for surface air velocity variation was explored, and measurements of drying performance as affected by airflow, humidity and velocity were made. Artificial fecal material was used initially to facilitate the experimental procedure, but subsequent runs with real fecal material were made.

2.3.3 Equipment

Equipment used for evaluation testing included the basic Dry John Bowl with an added inner basket in order to facilitate sampling and weighing collected feces. The external air circuit included means for humidity control.

Figure 2.3.3-1 shows the equipment, test rig equipment, and instrumentation. The Dry John Bowl assembly includes a 50.8 cm (20 in) bowl with a transparent

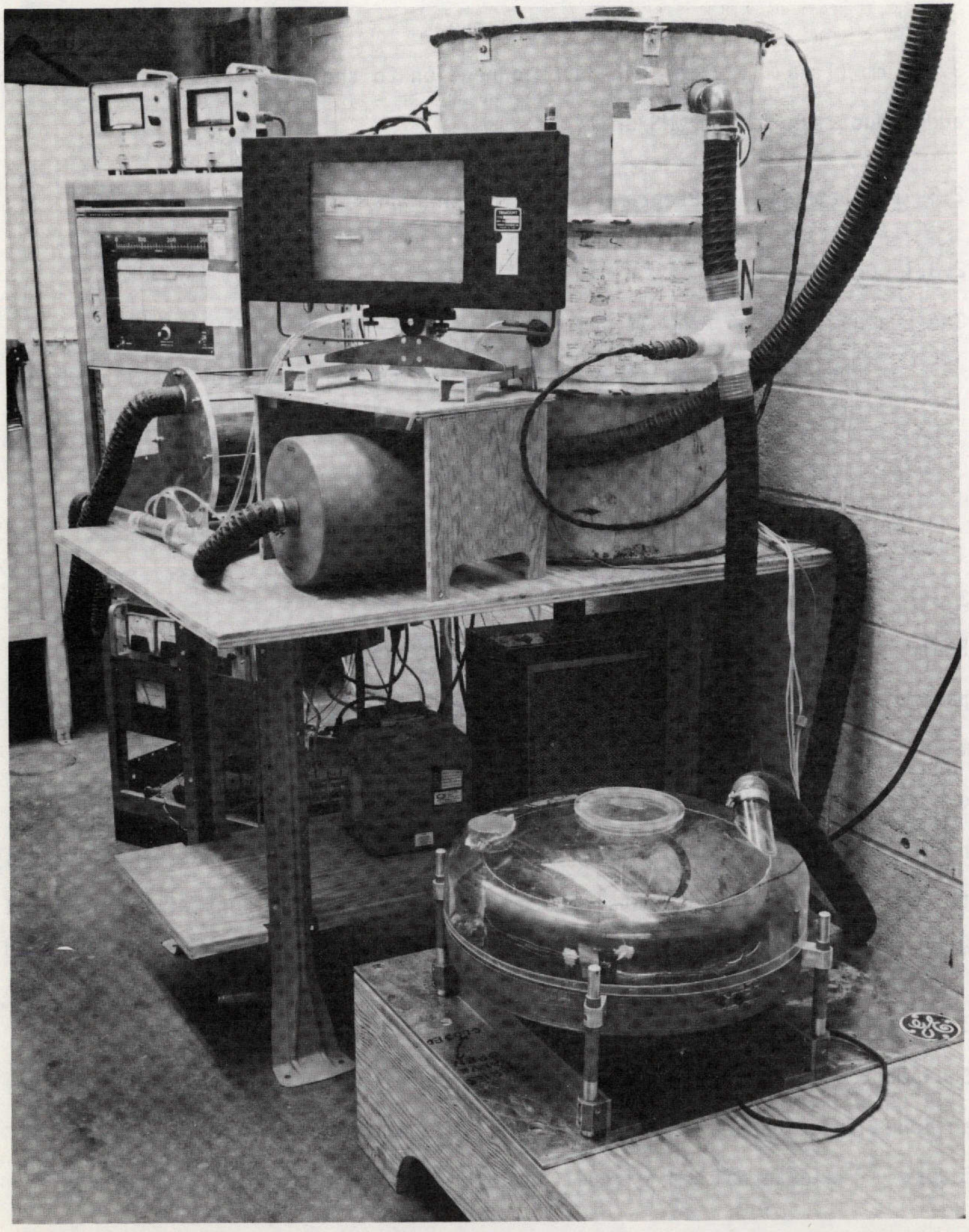

Figure 2.3.3-1 Equipment, Test Rig and Instrumentation for the Air Drying Investigation

top half. In the bottom half a slinger motor assembly and exit air ducting are mounted. Except for the motor the lower assembly is the same unit previously used on both simulated and user zero "g" flight testing. To drive the slinger, a 73.5 watt (1/10 H.P.) 60 Hz, 3.98 radians/sec (1550 rpm) shaded pole GE motor was used (Mod. No. GE-5KSP-11). The slinger had twelve 0.32 cm (1/8 in) diameter tines, 7.62 cm (3 in) long, at a 0.52 radian (30°) half cone angle.

A schematic of the system is shown on Figure 2.3.3-2. Inside the bowl a new "basket" insert was fitted so as to be quickly removable for weighing. The "basket" was a cylinderical surface 45.7 cm (18 in) diameter and 15.2 cm (6 in) high. Sample slides were installed at intervals along the inner bowl so that samples of slung material could be taken for biological assays. A new transparent bowl cover was fabricated with a 5.08 cm (2 in) diameter tangential air inlet, and an instrumentation access port for insertion of velocity probes.

Equipment for humidifying inlet air was assembled in a 227 liter (50 gallon) air-tempering chamber. Inside the chamber were water spray nozzles and a recirculation fan. In the outlet tube a humidity sensor (Wide Range Hygro Sensor Serial 4312 by Hygrodynamics, Inc.) measured humidity of air exiting to the bowl and provided, through a solenoid valve in the spray nozzel water-line, a simple control of relative humidity within the system.

For moving air within the system, a 115v 60 Hz "Windjammer" blower (Model No. 115603 by AMETEK/Lamb Electric) was used. A dual filter holder was fabricated to include both "Purafil" and activated charcoal materials in series. A Barneby-Cheney "Air Purifier Canister CHI" with activated charcoal was used

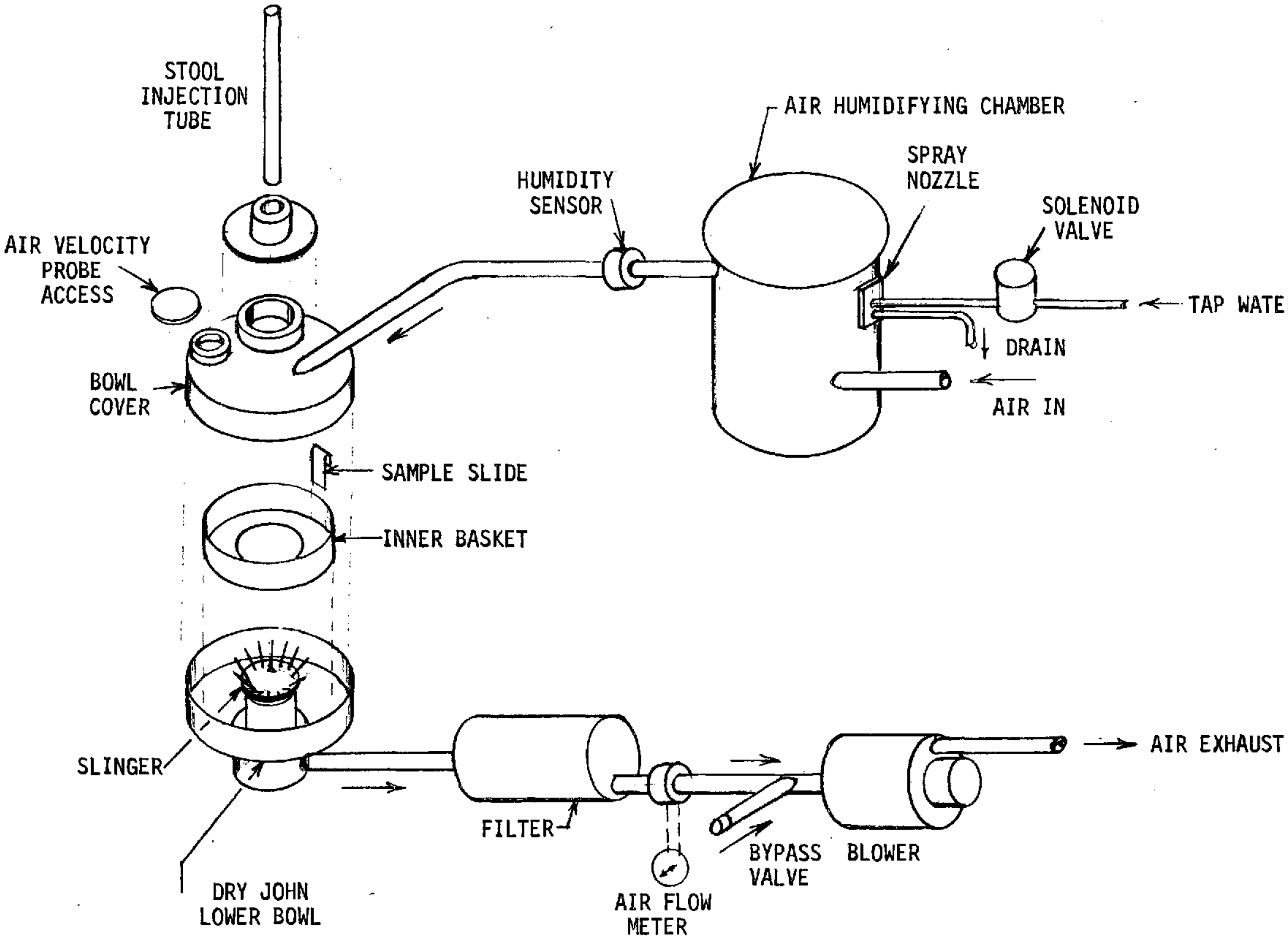

Figure 2.3.3-2 Schematic of Test Rig for Air Drying Investigation

as the container for 0.32 cm (1/8 in) alumina pellets, impregnated with potassium permanganate ($KMnO_4$), obtained as "Purafil" from H. E. Burroughs & Associates. Incoming air was distributed thru 45.7 cm (18 in) long 3.81 cm (1 1/2 in) diameter screen in the center of the assembly, passing first thru the Purafil filter and then the activated charcoal filter, and finally collected in a 25.4 cm (10 in) diameter housing at the exit.

Air velocity measurements within the bowl were made with a 0.32 cm (1/8 in) diameter Keil probe and a 2.54 cm (1.0 in) Inclined Water Manometer. Temperatures sensed by thermocouples, were recorded on a strip chart. Air flow measurements were made using a pitotstatic assembly built for the earlier zero "g" flight tests (See Appendix A for a more detailed description).

2.3.4 Procedures

Procedures developed for the preparation and injection of simulated fecal material were as follows:

Dog Food "Gains Burger Patty"	175g
Peanut Butter	20g
Water	70 to 680g
"Jello"	0 to 85g

"Jello" was added to the mixture in order to obtain a consistancy as close to actual human fecal material as possible. A chilled gel with a maximum water content of 70 to 75% would display acceptable characteristics. Tubes 2.54 cm (1 in) in diameter were used to "core out" slugs of the material and inject it into the Dry John Slinger. A normal load of 500 grams would be divided into four separate charges and injected into the transport tube opening at 1.57 radian (90°) points around the inlet.

Natural fecal material was collected in specially fabricated plastic bags with a small exit-neck. The material was squeezed into 2.54 cm (1 in) tubes and injected into the commode in the same way as the simulated fecal material.

Drying test runs were timed for a 22 hour cycle with the start of a test early in the morning. This allowed for more frequent readings early during the drying cycle with a long overnight period at the end of each run when drying changes were more stabilized.

Table 2.3.4-1 lists the test condition combinations used for the series of air drying tests.

2.3.5 Results

Initial tests established the relationship of surface air velocities to variable input flow and impeller activity. Drying tests with artificial fecal material provided data on the effects of airflow, time, relative humidity, sample moisture content, and sample mass on drying rates. Additional tests using natural fecal material were run under conditions chosen to simulate Shuttle applications.

Air velocity measurements were taken at the inner surface of the "basket" insert. The data plotted in Figure 2.3.5-1 and 2.3.5-2 show surface air velocity ranging with air flow thru the system; also, the velocity distribution at distances away from the wall as affected by slinger activity.

Air drying test results for runs with simulated feces were plotted. Moisture content as a function of drying time, for each of eight runs is depicted in Figure 2.3.5-3. The fecal drying rates are displayed in Figure 2.3.5-4.

Results of similar runs with natural fecal material are shown in Figure 2.3.5-5 and 2.3.5-6 which indicate moisture content and drying rates, respectively.

Table 2.3.4-1

Test Conditions

Evaluation Tests - Air Drying of Fecal Material

Test Run No.	Inlet Air: Flow sm^3/min	Inlet Air: Flow (scfm)	Inlet Air: R.H. %	Material Characteristics: Weight Grams	Material Characteristics: Moisture Content %	Material Characteristics: Type	Other Conditions
Phase I -1	1.08	38	35	238	41	Simulated	
Phase I -2	0.85	30	60	388	65	Simulated	
Phase I -3	0.42	15	60	252	65	Simulated	(C)
Phase I -4	0.85	30	60	414	65	Simulated	(C)
Phase I -5	0.85	30	60	500	75	Simulated	(C)
Phase I -6	0.14	5	43	500	75	Simulated	(A) (C)
Phase I -7	0.14	5	36	559	72	Simulated	(B) (C)
Phase I -8	0.14	5	37	202	75	Simulated	(B)
Phase II-1	0.14	5	50-55	584	81	Natural	(A)
Phase II-2	0.14	5	50-55	467	81	Natural	(B) Slinger Turned Back On At 21 Hours
Phase II-3	0.14	5	50-55	410	76	Natural	(A)
Phase II-4	0.14	5	50-55	208	71	Natural	(B-?)

NOTE: (A) - Slinger running for full drying period

(B) - Slinger running for first 4 hours of drying period

(C) - Wire mesh liner used on basket wall

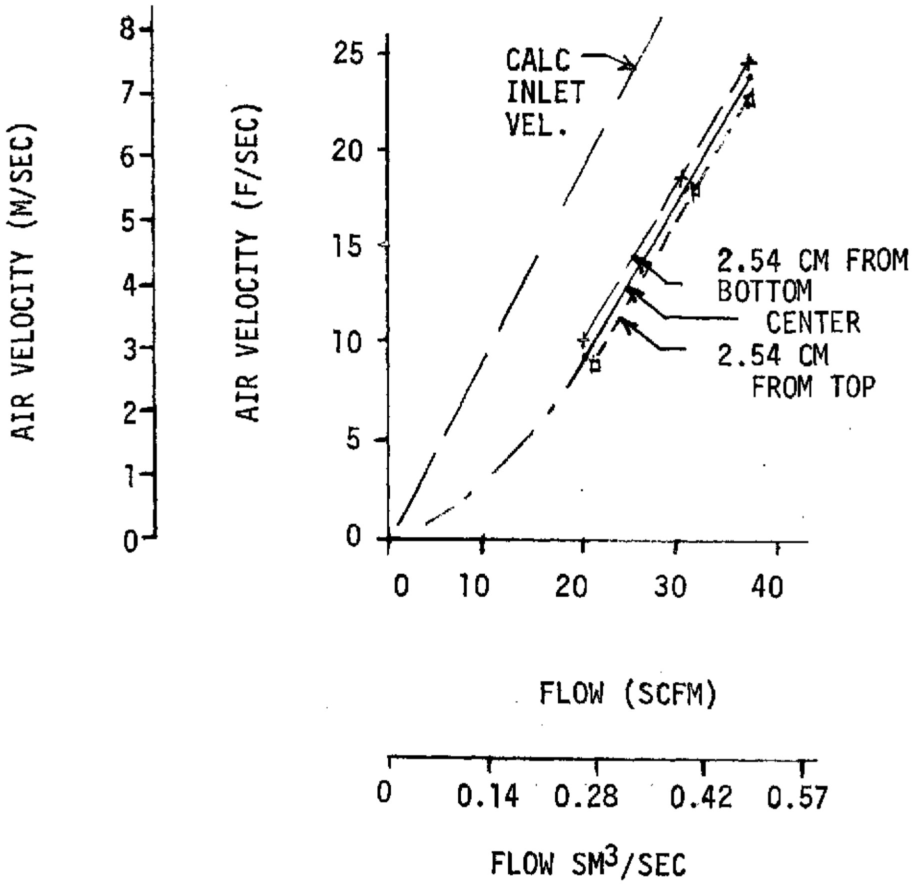

Figure 2.3.5-1 Surface Air Velocity as a Function of Air thru Flow

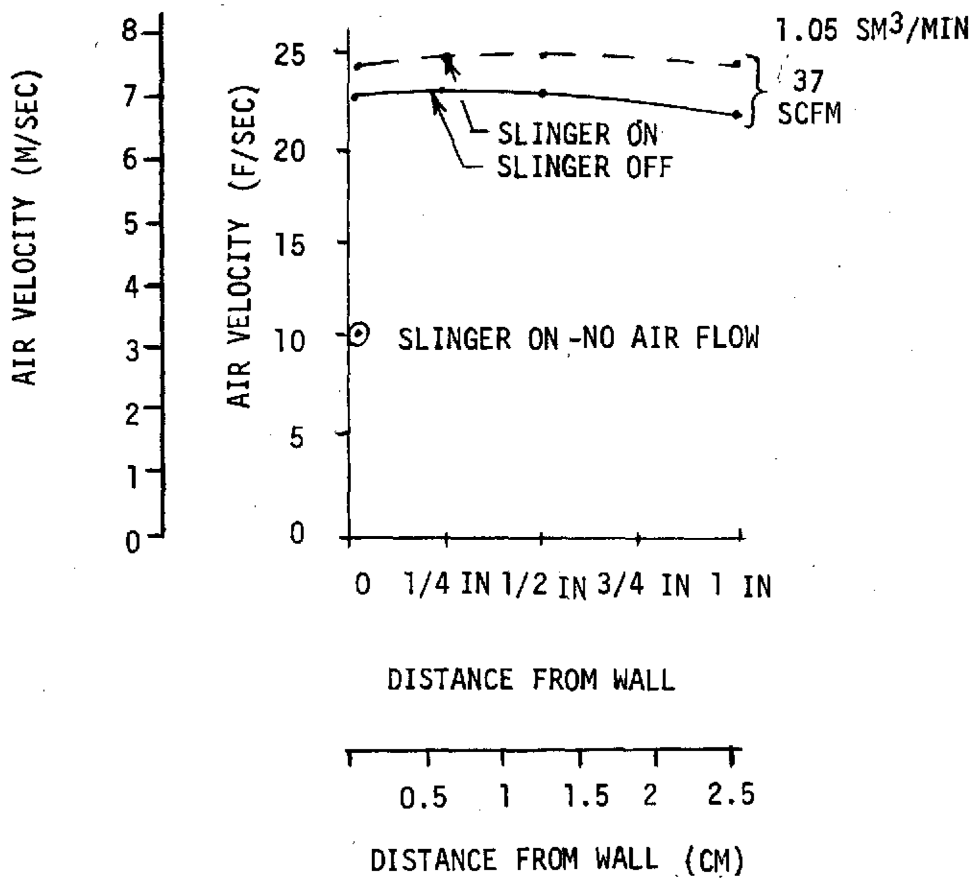

Figure 2.3.5-2 Air Velocity Distribution as a Function of Different Distances from Wall Surface

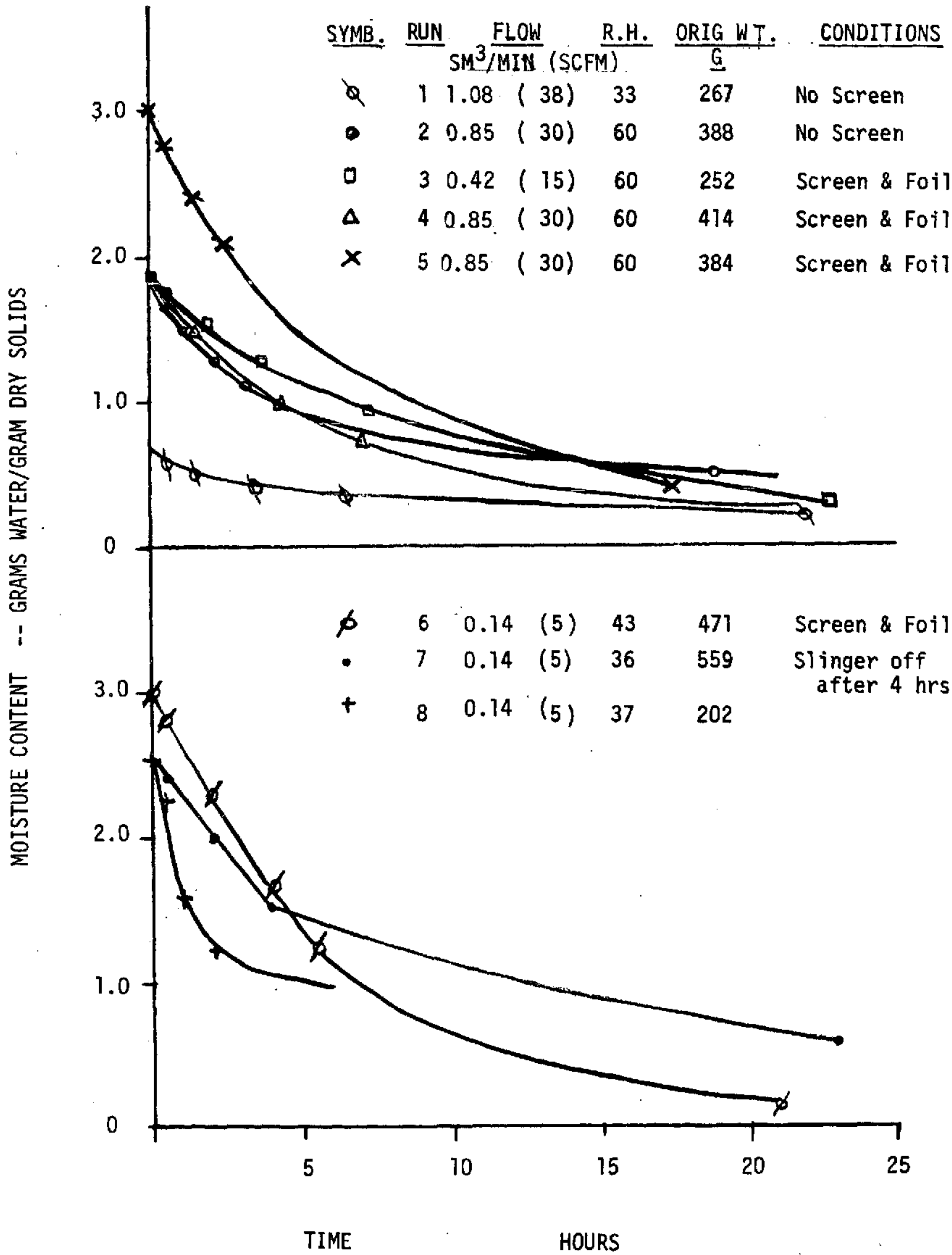

Figure 2.3.5-3 Moisture Content of Simulated Fecal Material

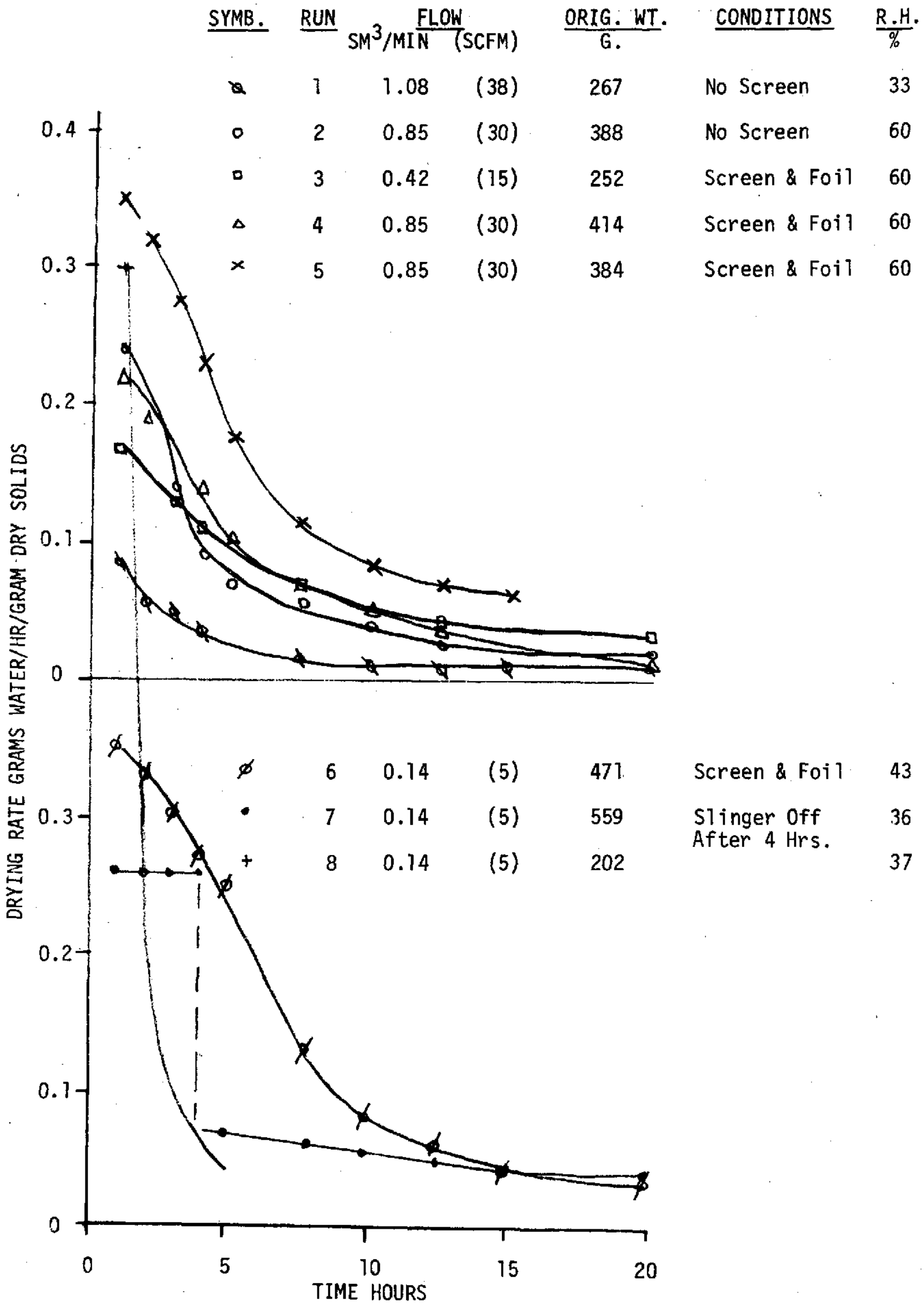

Figure 2.3.5-4 Rate of Drying of Simulated Fecal Materials

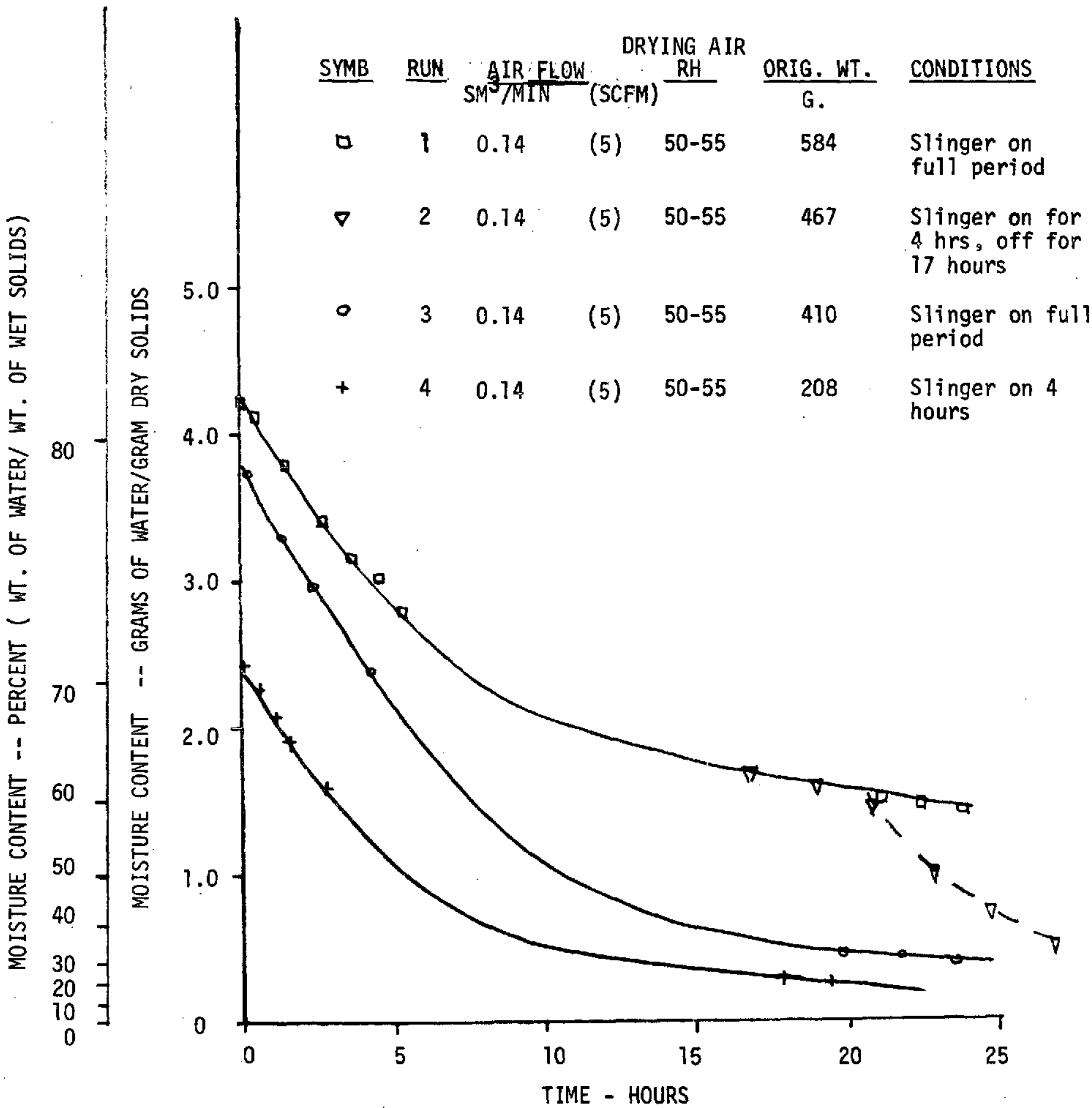

Figure 2.3.5-5 Moisture Content of Natural Feces

SYMB.	RUN	AIR FLOW SM^3/MIN	(SCFM)	DRYING AIR RH	ORIG. WT. G.	CONDITIONS
□	1	0.14	(5)	50-55	584	Slinger on full period
▽	2	0.14	(5)	50-55	467	Slinger on for 4 hrs, off for 17 hrs
○	3	0.14	(5)	50-55	410	Slinger on full period
+	4	0.14	(5)	50-55	208	Slinger on 4 hrs

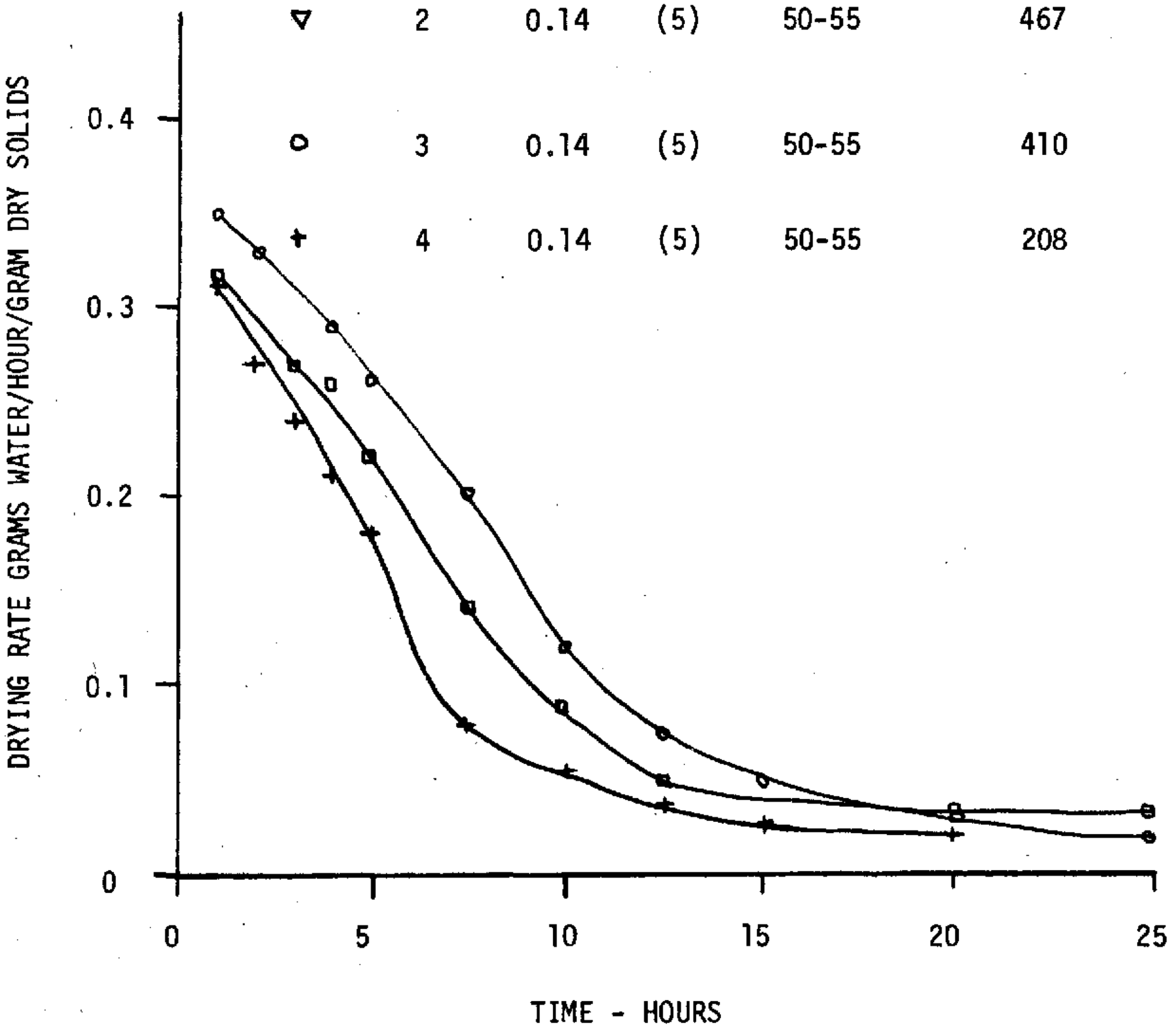

Figure 2.3.5-6 Rate of Drying of Natural Feces

2.3.6 Discussion

Three periods of an end-to-end fecal drying process have been identified as "Initial Warm Up", "Constant Rate" and "Falling Rate" periods. Early stages of the falling rate period are characterized by evaporation from the surface to partly wet and partly dry. Evaporation from the wet surfaces is controlled by vapor diffusion thru the boundary layer which is sensitive to air velocity and humidity gradients. For later stages, after the wet evaporation surfaces have all become dry, the overall process is controlled by transport of moisture thru the interior of the solid out to the surface. Diffusion coefficients of the material and lengths of diffusion paths then predominate.

With one expection, all of the runs displayed a "falling drying rate" which was characteristic right from the start. This was interpreted to mean that high air velocities along the drying surface would be less and less effective as time went on. Accordingly, test conditions used for natural material were narrowed to 0.14 sm^3/min (5 scfm) flow and 50% relative humidity with the principle variable being the weight of material used.

Earlier in-house test results were used together with these results to obtain a larger range of sample weights. The composite data which depicts percent moisture evaporated versus sample weight are shown on Figure 2.3.6-1. A definite relationship between original sample weight and the water evaporated at a specific time appears to be established. This relationship probably arises from the variation in thickness of the slung material deposited on the bowl walls.

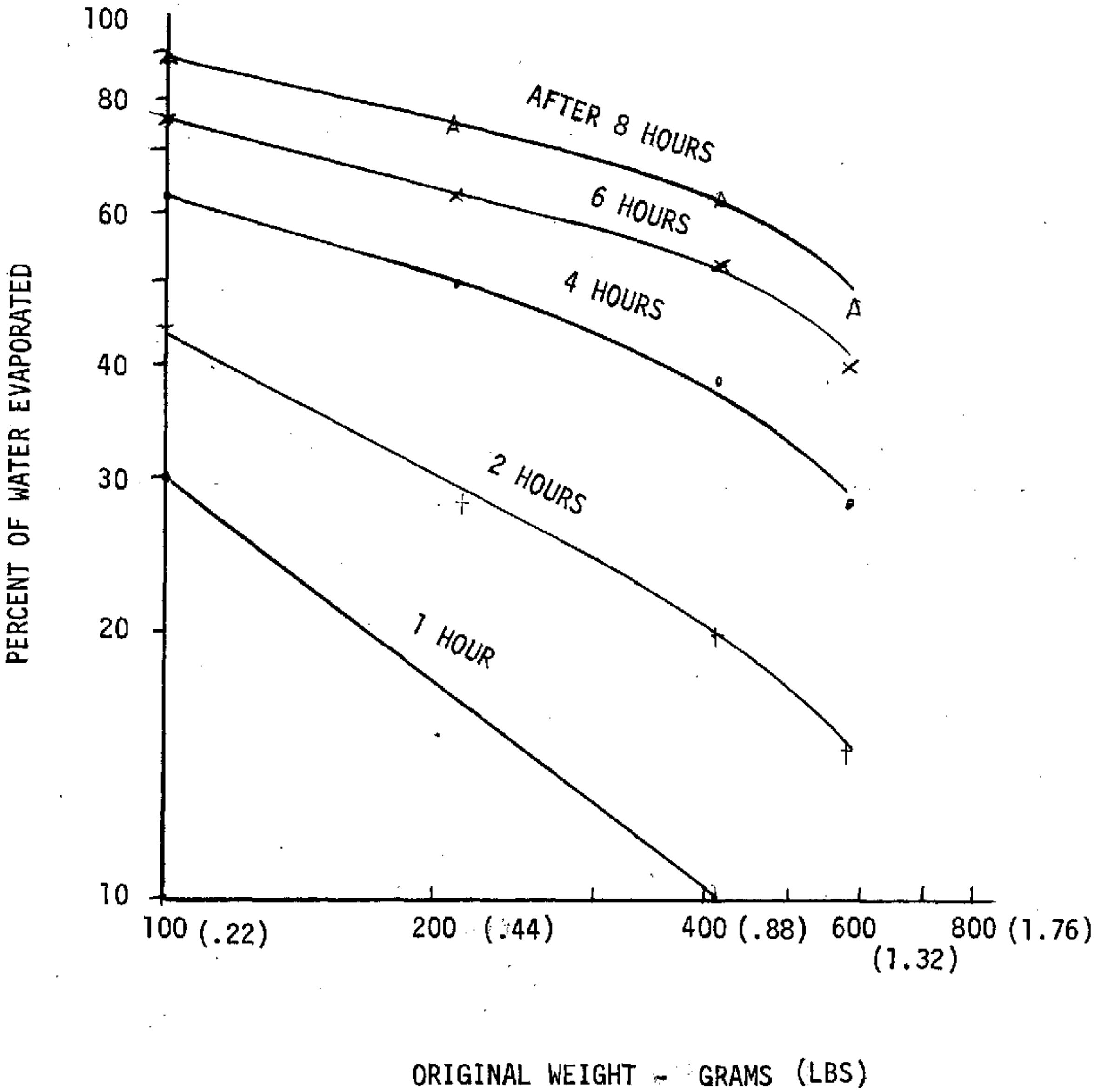

Figure 2.3.6-1 Composite Data Showing the Effect of Sample Weight on Drying

Drying times for falling rate period are typically given[1] as proportionate to depth of material such as

$$\theta_f = \frac{P_s\, L\, X}{h_t} \frac{(W_c - W_e)}{(t_a - t_s)} \ln \frac{(W_c - W_e)}{(W - W_e)}$$

or

$$\theta_f = \frac{4\, L^2}{D\, \pi^2} \ln \frac{(W_c - W_e)}{(W - W_e)}$$

θ_f = Drying Time for falling rate period - hrs

L = Depth of material - (ft)

W_o = Average Initial moisture content - (lbs/lb dry solid)

W_c = Average Critical moisture content - (lbs/lb dry solid)

W_e = Average Equilibrium moisture content - (lbs/lb dry solid)

W = Average Moisture content @ Time θ_t - (lbs/lb dry solid)

h_t = Average Overall heat transfer Co-eff - (BTU/(hr) (ft^2) (°F))

t_a = Air Temp - (°F)

t_s = Temp of Surface of material - (°F)

X = Latent Heat of Evap. 0 t_s - (BTU/lb)

P_s = Density of dry solid (lbs/ft^3)

D = Liquid Diffusivity - sq ft/hr

A challenging situation exists because the exponent of the depth factor that one would select by materials analogy would be towards the value of two (2) whereas the slopes of Figure 2.3.6-1 are 0.8 at one hour reducing to 0.25 at eight hours for the smaller sample weights. This suggests that considerable restraint must be used about assumptions of constant coefficients or the analogy between typical drying formulas and the specific situation here.

1 Chemical Engineers Handbook. Section 3, 1950

2.3.7 Conclusions

Slung fecal material in the amounts expected for Shuttle WMS can be dried to a moisture content approaching 50% (wet basis) in a 24 hour period.

High airflows are of no particular advantage.

A recommended approach for the user test would be - airflow 0.14 sm^3/min (5 scfm) with continuous operation of the slinger for 2-4 hours after each defecation.

2.4 User Test

2.4.1 Objective

The overall objective of this effort was to demonstrate the feasibility of the preferred approach (based on trade offs and evaluation testing) by actual user tests under conditions simulating a nominal Shuttle Mission. As a goal the study was to simulate a 4 man crew - 30 day mission or 120 usages in 30 days.

2.4.2 Approach

The general approach was to set up the equipment in a convenient private section of the laboratory and to make the set up relatively self sufficient and easy to use. Users were volunteers recruited from employees working in the immediate area.

2.4.3 Equipment

Equipment used in the earlier zero "g" testing[1] and user evaluation testing was assembled. The privacy enclosure, commode seat, bowl and urinal assembly

1 See Appendix, Section A and this report Section 2 for more detailed information.

were also from the same system. Blower, filter, humidity control and instrumentation from the evaluation tests were transferred to the user test rig. Equipment was added to provide an automatic switch-over from 0.71 sm^3/min (25 scfm) flow room air when the slide valve was open to 0.14 sm^3/min (5 scfm) of controlled humidity ($\approx$ 50% R.H.) air for all times when the slide valve of the commode was closed. Instrumentation was set up to measure airflow thru the bowl, temperatures of air and material in the bowl, and inlet air humidity. Temperatures and slide valve status were printed by a chart recorder. Figures 2.4.3-1 and 2.4.3-2 show the test set up.

2.4.4 Procedures

Each user would install a clean urinal, open the slide valve, perform his defecation/urination, close the slide valve, remove the urinal, rinse it in disinfectant solution, and replace it on the drying rack. In addition, the user would enter the date/time in the log book along with comments. Periodically the seat and inlet ring would be swabbed and cleaned with 1:200 Microquat solution; the urine drain system was flushed with tap water followed by a final Microquat flush.

Odors were monitored both in the vicinity of the commode and in the exit flow from the odor filter. Also on two occasions gas samples were drawn from the air stream above and below the air filter.

Over the week-ends, the unit was shut down with blowers, etc. turned off so that drying/moisture conditions remained essentially static for 2 2/3 days of each calendar week.

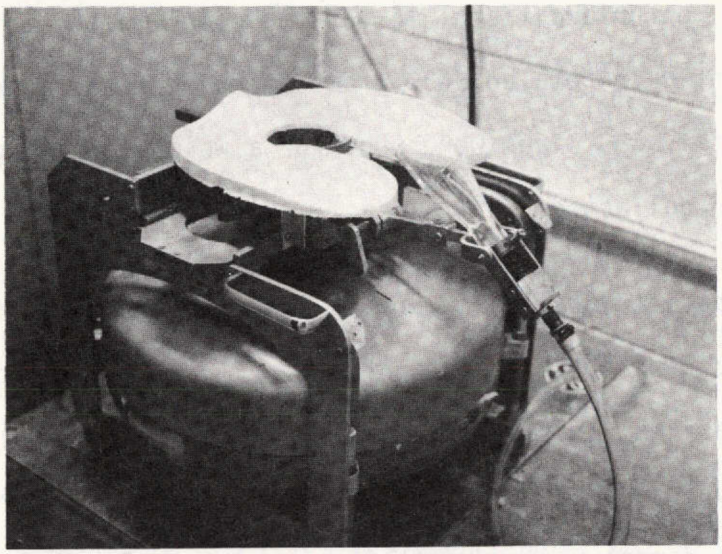

Figure 2.4.3-1 User Facility For Test Set-Up

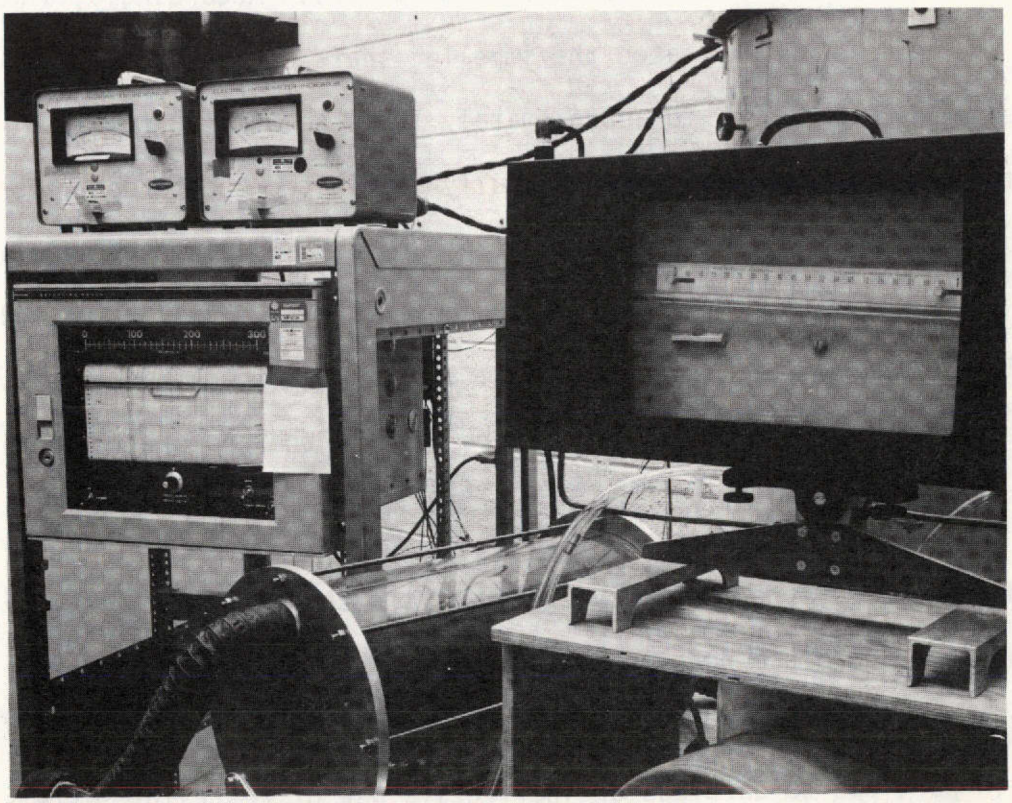

Figure 2.4.3-2 Test And Data Recording Equipment For Drying Test

2.4.5 Results

At the end of thirty days one hundred (100) usages had been recorded. The test was continued on an additional 15 days to complete the total of 120 usages. The weight gain totaled 3630 grams of dried fecal material and wipes. Approximately 680 wipes were used for a weight of 360 grams or 10% of the total waste collected.

At the end of 20 days a local build up of material surrounded the lower impeller tines and disk to the extent that normal transport flow was reduced by ≈ 12% with occasional interference to slinger operation. This situation was considered atypical because of the exceptionally narrow flow exit used in this unit. The normal unit, due to the insertion of a bacterial filter, would have an inlet area of ∼ 968 sq. cm (150 sq. in) while this particular test unit had an area of only 38.7 sq. cm (6 sq. in). Accordingly, a modification was made which increased the impeller shaft length by 4.13 cm (1 5/8 in), and increased the exit area to approximately 193.4 sq. cm (30 sq. in). Testing was resumed. This modification successfully eliminated the tendency for feces/wipes buildup at the airflow exit. A substantial volume of material remained at the conclusion of the test. Figure 2.4.5-1 shows the distribution of material at the end of testing. Visual estimates placed the capacity of the commode at approximately three quarters full by the end of the testing period.

Slight odors were detected in the vicinity of the commode after the week-end shut downs when there had been no airflow, and occasionally, when there had been some slight contamination above the slide valve. The contamination occurred in part due to careless or ineffective use of restraint systems which were critical to user positioning over the transport tube orifice. The

Figure 2.4.5-1 Distribution of Fecal Material and Wipes at the End of Testing

contamination that did occur was not significantly different or greater than would be encountered in a conventional toilet facility.

No odors were noted at the filter outlet.

2.4.6 Discussion

A significant difference between the evaluation tests and the user test results was the nature and amount of build-up of fecal material. The combination of tissue and thinly slung feces during the user test initially exhibited loose build-ups which rapidly converged toward the lower center part of the bowl. Large voids were left at the periphery of the bowl. Presumably, the inward directed flow of air was enough to cause this kind of accumulation. It can be speculated that after slinging was completed, some loose tissues, partly spread with thin feces, would be drawn back with the inward air flow to accumulate with others and dry into a "paper mache" like agglomeration. This tendency was substantially reduced when local air velocities were cut down.

Experience accumulated over the course of these tests (evaluation and user) indicated that the majority of the drying occurred during the first 24 hours following deposition of the fecal material (real or simulated). The general results show that the effect of the air drying after 30 days was probably not significantly different from a sample after only 24 hours of drying.

Test conditions for the user test differed from the actual Space Shuttle application in the continuity of usage. Every day usage, seven days per week was not feasible for this user test because of subject availability limitations. It was possible, however, to nearly match the application of drying air throughout to usage for the first three quarters of the program.

2.4.7 Conclusions

Air drying of fecal material in a Dry-John commode is a feasible alternative to vacuum drying. Sufficient moisture can be extracted from the slung material with very modest air flow and power costs. A continuous air flow of 0.14 sm^3/min (5 scfm) and running the slinger motor (20 watts) for 4 hours after each defecation are adequate. These costs can be traded-off against the cabin atmosphere dumpage, vacuum plumbing, and structural requirements as well as potential exterior contamination of the spacecraft which accompanys the vacuum drying approach.

2.4.8 Recommendation

It is recommended that a more extensive trade-off study of air drying versus vacuum drying be instituted for both specific application to Shuttle Orbiter baseline design and as a functional back-up system.

It is further suggested that the means for reducing size and weight of the bowl and vacuum plumbing assembly as well as prevention/reduction of debris build-up be explored.

2.5 Microbiological Laboratory Studies In Support Of Air Drying Approach To Stabilizing Human Fecal Material

2.5.1 Introduction

The metabolic activity of living microorganisms, primarily bacteria and to a lesser extent fungi and viruses in human fecal material, produce three potential problems for a closed environment:

- Generation of undesirable gaseous products.
- Build-up of microbial populations to significant levels of pathogenic microrganisms.
- "Aftergrowth" - the sudden, sharp increase in microbial populations in treated sewage.

Since these problems, potentially, represent a hazard to health, a means for treating or processing such material is required. Properly functioning waste disposal (and regenerative systems) should not contribute to environmental contamination.

One concept for controlling the microbial metabolic activity in the prospective Shuttle Orbiter Waste Management Subsystem proposes vacuum drying, together with odor filtration, to minimize these problems. This approach would utilize the vacuum of space with the potential for venting biological or chemical contaminants overboard. Such contaminants have been known to cause problems on external spacecraft surfaces (lenses, windows, etc.).

Another approach suggests drying the fecal material by flowing cabin atmosphere through the Waste Collection System and filtering out any particulates (including microbes) and chemicals (odors). This latter approach offers several engineering advantages over the vacuum drying process.

A brief survey of available technical information and literature uncovered little relevent information, particularly concerning the effect of drying on the microbial population. Preliminary studies were undertaken to establish the status of the microbial flora, and how it might be reflected as far as viability, levels of organisms, and odor production in human fecal material undergoing air drying.

From a practical point of view, all the variables discussed above would be evidenced in an actual commode in which fecal material was collected under the time and conditions desired.

The variables of importance were:

- Level of Contamination,
- Growth promoting properties of the material collected,
- Conditions of storage or treatment, primarily drying, and
- Effect on the microbial population.

It is known that bacterial growth can be effectively controlled by removal of sufficient moisture to bring about cessation of metabolic activity. In addition, it was assumed that a fairly accurate indicator of metabolic activity is the production of gas, and therefore, that sensitive determination of the evolution of gas would provide data indicative of the effectiveness of the air-drying procedure on microbial growth.

2.5.2 Objectives

Objectives in this study were to determine the relationship between the effect of air drying of fecal material, together with:

- Control of offensive odors arising from continuing bacterial metabolism of fecal waste products, and
- Control of the fecal collection unit as a potential source of microbial contamination/infection.

Limited pilot studies were performed utilizing respirometer monitoring of the gases produced by small samples, followed by assays of the microbial population to determine how the drying affected the metabolic activity, and hence, odor production from the fecal material.

Therefore, it was concluded that sensitive determination of the evolution of gas would provide data indicative of the effect of air-drying treatment on microbial control.

2.5.3 Approach

The activities deemed necessary for the study objectives included:

- Initial respiration studies with small samples of fresh human fecal material to establish the feasibility of the gas production monitoring technique for use in monitoring microbial metabolic activity.
- Follow-on testing of small samples of collected fecal material undergoing drying in the modified commode to include determination of gas generation, moisture and microbial levels.
- Retrieving and testing of small samples of freshly collected human fecal material from the modified commode onto which Betadine disinfectant had been sprayed.

The results obtained were analyzed to determine if any correlation exists between increasing dryness and microbial metabolic activity.

2.5.4 Specific Studies

2.5.4.1 Initial Respirometer Studies

In an attempt to assess the adequacy of a respirometer (manometric) technique as a metabolic indicator for microbial activity, preliminary studies were performed with fresh (wet) samples of human fecal material having a total bacterial level of 10^{10} organisms per gram. Replicate studies showed that gas production was immediately obvious by observation of the increase in pressure in the culture vessels as exhibited by the manometers. In fact, after 1 to 2 hours, the pressure had to be relieved to prevent escape of the indicator fluid. Such gas production was observed to continue for up to a week. No samples were monitored for longer than a week.

These initial experiments suggested that the manometric technique would be adequate. However, when human fecal samples, obtained at different degrees of dryness were tested, the technique proved less reliable. Results showed that after some intermediate drying had occurred ($\sim$ 20-50% moisture by weight) the aerobic (and probably anaerobic) bacteria levels decrease to $\sim 10^6$ organisms per gram (from 10^{10} per gram), and obvious proliferation of fungi, visible to the naked eye, occurred on the surface of the fecal material. With these conditions, more gas (probably oxygen) was used than produced. Thus, the analysis of the effect of air-drying by means of monitoring the gas(es) produced by small samples was complicated by the effect of fungal growth.

2.5.4.2 Bacterial Content

2.5.4.2.1 Introduction/Procedures

Since respirometer tests indicated that the monitoring of gas generation would be complicated by the effects of fungal contamination, total counts of the aerobic and total mesophiles were pursued to determine what level of viable microorganisms remained, if any, in samples of material dried to varying degrees. The dried material was obtained by extending the exposure to drying conditions for longer times. Duplicate broth cultures of the diluted samples (dilution to the point of extinction) were also run on each sample. Thioglycollate fluid medium was selected to recover as many of the organisms (both aerobe and anaerobe) as possible. This system was also used later in the program for tests with disinfectants or biocides. These tests were performed in conjunction with the series of engineering parameters being tested. Samples were taken throughout the engineering evaluation test and at stages during the 30-day usage test.

2.5.4.2.2 Results

A summary of the results of the residual microbiological levels versus drying time and the residual moisture content, along with a comment on the gas production is presented in Tables 2.5.4.2.2-1 and 2.5.4.2.2.-2.

The data presented indicate that large populations of microbes remain after protracted drying periods ($\sim 10^7$ organisms per gram), but that these populaations appear to be progressively less active with respect to gas production.

2.5.4.2.3 Discussion/Conclusions

Due to the declining total bacterial level and the relative decrease in the amount of gas produced from the drier samples, it can be reasonably concluded that bacterial proliferation had been arrested. The potential usefullness of the techniques as a simple monitor of the effectiveness of the WMS suggests that additional studies should be conducted to more closely define the drying time/air flow.

2.5.4.3 Investigation Of Betadine As A Biocide For Collected Fecal Material And Urine

2.5.4.3.1 Introduction

Although the air-drying treatment, discussed in the foregoing sections, appeared to accomplish all of the needed control of microbial activity, it was felt that inclusion of an anti-microbial agent might be necessary as an added safety factor, and as a reasonable back-up to air-drying. Therefore, an investigation of the effect of the anti-microbial agent Betadine[1] (a providone-iodine disinfectant) was performed.

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1 - Registered Tradename for the povidone-iodine product of Purdue-Frederick Company, Yonkers, New York

Table 2.5.4.2.2-1

Summary of Residual Moisture and Dry Condition

Identification During Engineering Evaluation Test

Test Run	Sample Number	Date Of Sample	Description Of Sample	Drying Exposure[2]	Percent Moisture (By Weight)[3] IR Balance	105°C Oven
I	1	1/9/74	Fresh Material	None	81%	NC
	2	1/9/74	#3 Strip[1]	2.67 Hours of Air Drying	55%	NC
	3	1/9/74	#10 Strip	5.3 Hours of Air Drying	47%	NC
	4	1/10/74	#4 Strip	22.3 Hours of Air Drying	9.7%	NC
II	5	1/10/74	Fresh Material	None	81%	NC
	6	1/10/74	Freshly Slung Material	Just Slinging	77%	NC
	7	1/11/74	#5 Strip	20.8 Hours of Air Drying	44%	39%
	8	1/15/74	#7 Strip	116 Hours of Air Drying	13.3%	9.3%
III	9	1/15/74	Fresh Material	None	78.7%	75.7%
	10	1/15/74	Sample Strip #B	2 Hours of Air Drying	73.9%	69.9%
	11	1/15/74	Sample Strip #A	4 Hours of Air Drying	41.6%	42.6%
	12	1/16/74	Sample Strip #10	24 Hours of Air Drying	23.9%	19.6%
IV	13	1/17/74	Sample Strip #6	Freshly Slung Material 10% Betadine Sol'n Sprayed On	71%	NC

NC = Not Completed

1. Strip refers to 6 x 1 in stainless steel strip inserted into liner for easy removal for sampling.

2. For particulars on the air-drying parameters refer to Section on Engineering Studies.

3. For specifics on methods for determing moisture content see Appendix, Section 4.

Table 2.5.4.2.2-2

Summary of the Levels of Microorganisms, Residual Moisture, and Gas Production Capability of Raw and Air Dried Human Fecal Material During Engineering Evaluation Test[1]

Sample#	Drying Time (Hours)	Percent Moisture (By Weight)		Level of Microbial Population			Gas Production (Relative)
		IR Balance	105°C Oven	Plate Count	TS Broth	THIO Broth	
9	None-a Freshly Collected Sample	78.7	75.7	$>3 \times 10^8$ $<8 \times 10^8$	$>2 \times 10^{10}$ $<2 \times 10^{12}$	$>2 \times 10^{10}$ $<2 \times 10^{12}$	Maximum
10	2 Hours of Air-Drying	73.9	69.9	$>2.6 \times 10^8$ $<3.0 \times 10^8$	$>2 \times 10^{10}$ $<2 \times 10^{12}$	$>2 \times 10^{10}$ $<2 \times 10^{12}$	Some
11	4 Hours of Air-Drying	41.6	42.6	$>3.0 \times 10^8$ $<4.8 \times 10^8$	$>2 \times 10^{10}$	$>2 \times 10^{10}$	Slight
12	24 Hours of Drying	23.9	19.6	$\geq 3.6 \times 10^8$	$>2 \times 10^{10}$	$>2 \times 10^{10}$	Very Slight
8	116 Hours of Air-Drying	13.3	9.3	$>1.1 \times 10^7$ $<3.0 \times 10^8$	$>2 \times 10^{10}$ $<2 \times 10^{12}$	$>2 \times 10^{10}$ $<2 \times 10^{12}$	Very Slight
13	None	71	NC	NC	NC	$>3.5 \times 10^8$ $<1 \times 10^{10}$	
-	>720 Hours of Air-Drying	8.4	7.4	$>1 \times 10^6$ $<1 \times 10^8$	--	--	Very Slight

1. For specifics, see respective test description in Engineering Section and text of report.

Betadine 10% solution (povidone-iodine), 1% available iodine, has been used on SKYLAB as the disinfectant of choice. It was also used for post-flight decontamination of the Apollo spacecraft and astronauts to preclude a potential microbiological hazard. It has been suggested for use, perhaps in a modified form, on the Space Shuttle. As such, it was natural to investigate its efficacy for use in the waste management system for control of the microbial population in the collected fecal material and wipes and/or for addition to the collected urine.

Assessment of the ability of the selected disinfectant to inhibit microbial metabolic activity in fecal material was initiated by addressing the following objectives with respect to Betadine:

- The concentration of the agent required to insure cessation of microbial metabolism
- The ability of the disinfectant to remain effective under the operational conditions of the system, i.e. with low air flows, deposition of additional layers of fecal material, and "sandwiching" of fecal material and paper, etc.
- The ability of the engineering hardware to disseminate the disinfectant effectively and
- The compatibility of the disinfectant and/or its byproducts with the proposed system hardware.

Since little specific information was available as to its efficacy in or on such material, other than general comments from the manufacturer, several preliminary experiments were devised to determine the efficacy of Betadine as a microbiocide. Thes are defined in the following sections.

2.5.4.3.2 Fresh Feces Studies

2.5.4.3.2.1 Investigation

The need to establish the efficacy of Betadine against the indigenous microbial population in freshly collected hum fecal material was investigated in the following study.

1. Equal volumes representing successive 10-fold serial dilutions of Betadine (10% providone-iodine or 1% available iodine), which represents a concentration gradient, were thoroughly mixed by means of a sterile glass rod with ∿ 1.0 gram samples of feces contained in sterile 100 ml beakers.
2. The mixtures were allowed to stand five minutes.
3. One half (approximately 0.5 ml) of the mixture was poured-off into sterile screw-capped test tubes. Subsequently, 0.1 ml samples were removed by means of a sterile pipette and placed in freshly prepared (deaerated and cooled) Thioglycollate Liquid Medium.
4. All culture samples were incubated at 35°C for 24 hours.
5. The beakers, containing the residual of each dilution (∿ 0.5 ml of Betadine/feces suspension) were refilled with ∿ 50 ml of each of the original concentrations of Betadine solutions (from the concentration gradient) and allowed to stand for 1 hour.
6. 10 ml of each mixture, defined above, were removed and placed in 90 ml sterile water blanks contained in screw capped milk dilution bottles. The bottles were shaken well and then 10 ml portions were pipetted aseptically into freshly prepared Thioglycollate Liquid Medium (35 ml in 25 x 160 mm screw-capped tubes). All tubes were incubated at 36°C for 24 hours.

7. The bottles (90 ml H_2O + 10 ml mixture of feces + Betadine) from #6 above were allowed to stand over the week-end (63-64 hours) and then re-assayed by pipetting 10 ml portions aseptically into freshly deaerated Thioglycollate Liquid Medium, as in 6 above.
8. Serial dilutions were also prepared for each of the six bottles in 6 and 7 above and 1 ml fractions were pipetted to 16 x 160 mm screw-capped tubes of fresh Thioglycollate Liquid Medium.

2.5.4.3.2.2 Results

All samples cultured from steps 4, 5 and 6 showed growth of organisms. Samples from step 7 did not show growth in the #1 and 2 tubes (highest concentrations of Betadine 10,000 ppm) but growth was evidenced in all other tubes.

Dilutions of samples, assayed as per step 8, showed no growth in any feces dilution, 10^{-2} thru 10^{-10}, for the highest concentration of Betadine (10,000 ppm), but growth at the 10^{-8} feces dilution for the next two Betadine concentrations of 1000 and 100 ppm respectively, was observed. All other samples (step 8) showed apparently uninhibted growth at less than 100 ppm Betadine.

2.5.4.3.2.3 Conclusions

The higher concentrations of Betadine, particularly >10,000 ppm, successfully inhibited growth of the microbial population in the fecal sample tested. Therefore, a concentration of 10,000 ppm was selected for application to the collected fecal material in the commode.

2.5.4.3.3 Studies on Fecal Material Collected in Waste Management System Commode

2.5.4.3.3.1 Introduction

An exploratory attempt was made to see how an aqueous suspension of Betadine would disperse within the waste collection commode.

Betadine (25 ml of straight 10% solution as received from the supplier) was poured slowly through the commode inlet tube, impacting the center of the spinning disc and tine device which disseminated the liquid to the sides of the commode. Examination of the pattern achieved, revealed that uniform dispersion (in a 1 G environment) could not be accomplished without extensive redesign of the hardware, or application of excessive volumes of the biocide. Since neither alternatiav was deemed practical, another approach was devised.

Accordingly, a spray application of the biocide was tested as an effective technique in controlling the microbial population in fecal material collected by the waste management subsystem commode.

2.5.4.3.3.2 Procedures

The study consisted of the following:

1. A cross-sectional sample was cut out of the material (feces and paper wipes) from the collection unit after the material had been slung and partially dried to approximately 16% moisture under typical conditions.
2. The sample was divided: One half (16 grams) was sprayed with Betadine and left exposed for 10 minutes; the other half (17 grams) remained untreated and served as the control.
3. The entire sample of each was assayed by homogenizing the material in 500 ml of sterile distilled water in a Waring blender for three minutes.
4. Serial dilutions were made and one ml aliquots were assayed as follows:
    a) Pour plates(9) for dilutions of $\sim 3 \times 10^{-2}$, 3×10^{-4}, 3×10^{-6} on through 3×10^{-14} on Plate Count Agar.[1]

[1] Difco Laboratories, Detroit, Michigan

b) Sterility tests in Thioglycollate Fluid Medium.

5. The plates and tubes were incubated at 35°C for 24 and 48 hours.
6. A second experiment was conducted, except that the exposure time between application of the Betadine, and the dilution, blending and culturing procedure was increased to one hour. The treated sample was exposed to flowing air in a chemical hood for one hour in an attempt to simulate the effects of drying which might occur in a waste collection system. The sample weighed 55 grams and 11 grams of Betadine (10% solution) was applied.

2.5.4.3.3.3 <u>Results</u>

The results of the trial assays are summarized in Table 2.5.4.3.3.3.-1. Assay techniques indicate approximately a 2-log reduction in the microbial level resulting from 10 minute treatment with full strength (10%) Betadine. The results with the sample treated for one hour indicate that the longer exposure time reduced the level of microbes detected by plate count by $\sim$ 3-4 logs.

2.5.4.3.3.4 <u>Conclusions</u>

Betadine was shown to be effective in reducing the viable microbial population in human fecal material as collected and processed by the current waste collection subsystem when used with air drying. It would appear that 10% Betadine solution applied at a rate of 1/5 to 1/2 by weight of the fecal material being treated will bring about a significant decrease in the microbial population. Other questions which also require investigation are:

- Better dispersion of the biocide within the bowl, and
- Effect of adding more biocide solution (moisture) on waste material undergoing drying, since the ostensible purposes of each would appear to be non-complimentary.

Table 2.5.4.3.3.3-1

Results of Comparison by Plate Count and Tube Dilution Culture of Betadine on Partially Dried[1] Fecal Material and Wipes

Sample	Plate Count[2]	Thioglycollate Broth[2]
I Untreated (Control)	2.4×10^9/g	$>10^8$ $<10^{10}$/g
II Treated with Betadine 10 Minute Exposure Prior to Culture[3]	6.4×10^6/g	$>10^6$ $<10^8$/g
III Treated with Betadine 1 Hour Exposure[3]	2.2×10^5/g	$>10^4$ $<10^6$/g

1 % Moisture content = 15%
Drying time = 1 week.

2 Adjusted for Sample Weight

3 Full Strength Betadine

2.5.5 Overall Conclusion of Microbiological Studies

Although the results of these preliminary studies, and the studies themselves may not be conclusive, they do point out the feasibilities. Confirmation, of course, would await the results of future testing.

The studies show that:

1. Air drying can be an effective process for reducing the moisture level; hence, air drying can be effective for the stabilization of the microbial population and their metabolic gas production capacity. The microbial population is also reduced by air drying.
2. A biocide such as Betadine could be used to back-up the air-drying treatment.

2.5.6 Recommendations

As a result of the completion of the experiments and the conclusions from assessments made on the waste collection and processing system studied during this effort, the following recommendations can be made and should be carried out to optimize a waste collection system prior to flight:

1. Further testing should be done in the following areas:
    - Use of other microbiological assays, including anaerobes, to correlate microbial levels with the amount and type of gases produced to simplify testing techniques.
    - Use of gas chromatography to analyze effluent gases from fecal material, particularly for the hydrogen sulfide, methane and indol components and, if possible, on the same columns of water vapor.
    - Optimization of the method for dispensing a liquid disinfectant and the volume ratios for various specific disinfecting agents.

- Assessment of the actual transmission of microorganisms from hardware to user, hardware to atmosphere, and build-up of contamination on accessible hardware parts by microbiological sampling techniques.
- Extended studies of air drying effectiveness for microbiological control to systems and simulated crew sizes of 8-12 individuals.

SECTION 5

QUALITY ASSURANCE, RELIABILITY AND SAFETY

1.0 QUALITY ASSURANCE

As noted in Section 1, the basic objective of the contract effort was directed towards obtaining data for evaluating and optimizing the GE Dry John concept for urine and feces collection.

To achieve this objective, breadboard type test hardware was used predominately in a laboratory setting under conditions not warranting a quality assurance program on the laboratory equipment devised for this work.

However, two of the three tasks are inherantly vital precursors to a sound quality program applicable to follow-on contracts. Both the stool separation/-transport study (Section 2 of this report) and the air drying study (Section 4 of this report) were for the purpose of defining and evaluating the parametric relationships of the major factors affecting these processes. This information will not only assist in establishing the baseline design values of such follow-on systems but also provide information about the sensivity of system performance into separate variation due to individual parameters. This information is vital to the establishment of reasonable cost effective approaches and quality specifications for future hardware items.

2.0 RELIABILITY

The basic investigation of obtaining design information included some efforts towards generating reliability information about the process in the neutral bouyancy testing. Several likely "off-design" conditions were tested to obtain some insight as to whether the "off-design" conditions were failure modes or what amount of deviation from design condition was necessary before system failure could be considered to occur. Two such conditions investigated were the effects of plugging fecal transport air inlet holes and also imperfect seal between buttocks and the seat. Data from these efforts is contained in Section 2 of this report.

Other areas contributing to reliability but less tangible in nature such as the zero "g" flight testing have generated insights about performance of the system under operational environments with a variety of users. Data and analyses related to these activities can be found in Section 3 of this report. These insights together with "off-design" data will provide some basis for future developments in the WCS, to identify and define realistic failure modes and effects as well as maintenanance provisions and levels needed to support system performance level objectives.

3.0 SAFETY

Although no formal safety program was required or conducted during the program, nominal and good practice safety and human engineering requirements and procedures were followed in the conduct of the program. In addition to these nominal safety efforts, significant safety data was developed during the study especially in the area of system design and user procedures related to protection from potential microbiological contaminants. A major portion of Section 4 of this report, the air drying investigation, details microbiological studies and recommendations generated from the study. Other areas of the program providing significant data relative to user safety are included in the Section 3 of this report, the zero "g" study, in which user tests were conducted. It is significant to note that the zero "g" user tests of the breadboard WCS were conducted without any safety incidents or problems. Further evaluation of the subjects' user questionnaires obtained during both normal gravity and zero "g" testing[1] generally indicated that the test subjects found the system to be satisfactory from a user's view point and did not reveal any safety-related system design or procedures problem.

1 See Appendix, Section C for subject questionnaires.

SECTION 6

SPACE SHUTTLE INTERFACE REQUIREMENTS

1.0 SPACE SHUTTLE INTERFACE REQUIREMENTS

The physical interfaces for the air dry approach are greatly simplified over the baseline vacuum drying approach in that the space vent line is eliminated. Otherwise the interfaces are approximately the same.

The air flow for the drying process can be supplied by a small 0.14 sm^3/min (5 scfm) bleed from the vehicle environmental control system or a small blower added to the system.

The estimated difference in physical parameters for a 210 man-day air drying system versus the baseline are:

Weight:	4.5 kg (10 pounds)
Power:	10×10^7 ergs (10 watts) average
Size:	No Change

Figure 1.0-1 shows a mockup of a proposed Waste Collection System for Shuttle Orbiter. Many features of the proposed system are directly taken from the breadboard waste collection system tested in both the ground and zero "g" tests conducted during portions of this contract. The mockup includes not only proposed or actual system environments but also modifications incorporated for improved ease of operation.

The interface requirements for a Shuttle Orbiter System are further detailed in a preliminary assembly drawing of a proposed waste collection system included in Figure 1.0-2.

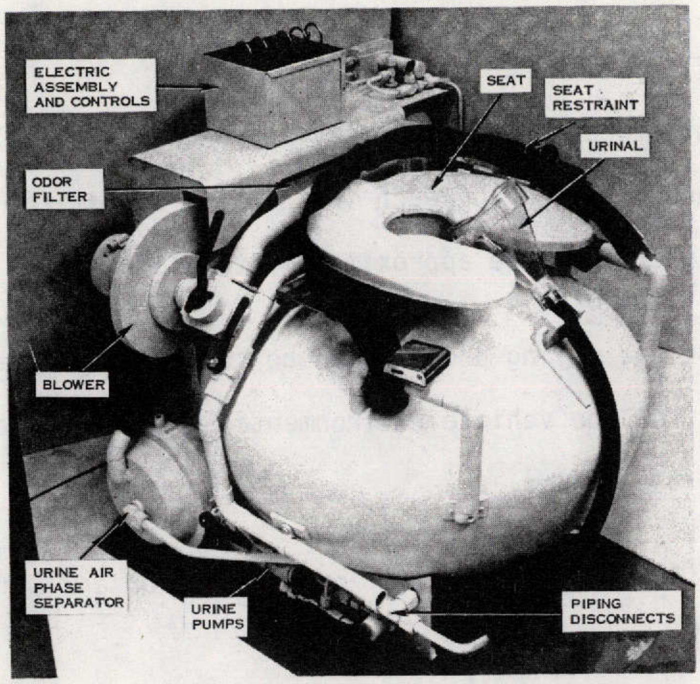

Figure 1.0-1 Mockup of One Version of a Proposed Waste Collection System

(Foot Restraint Not Shown)

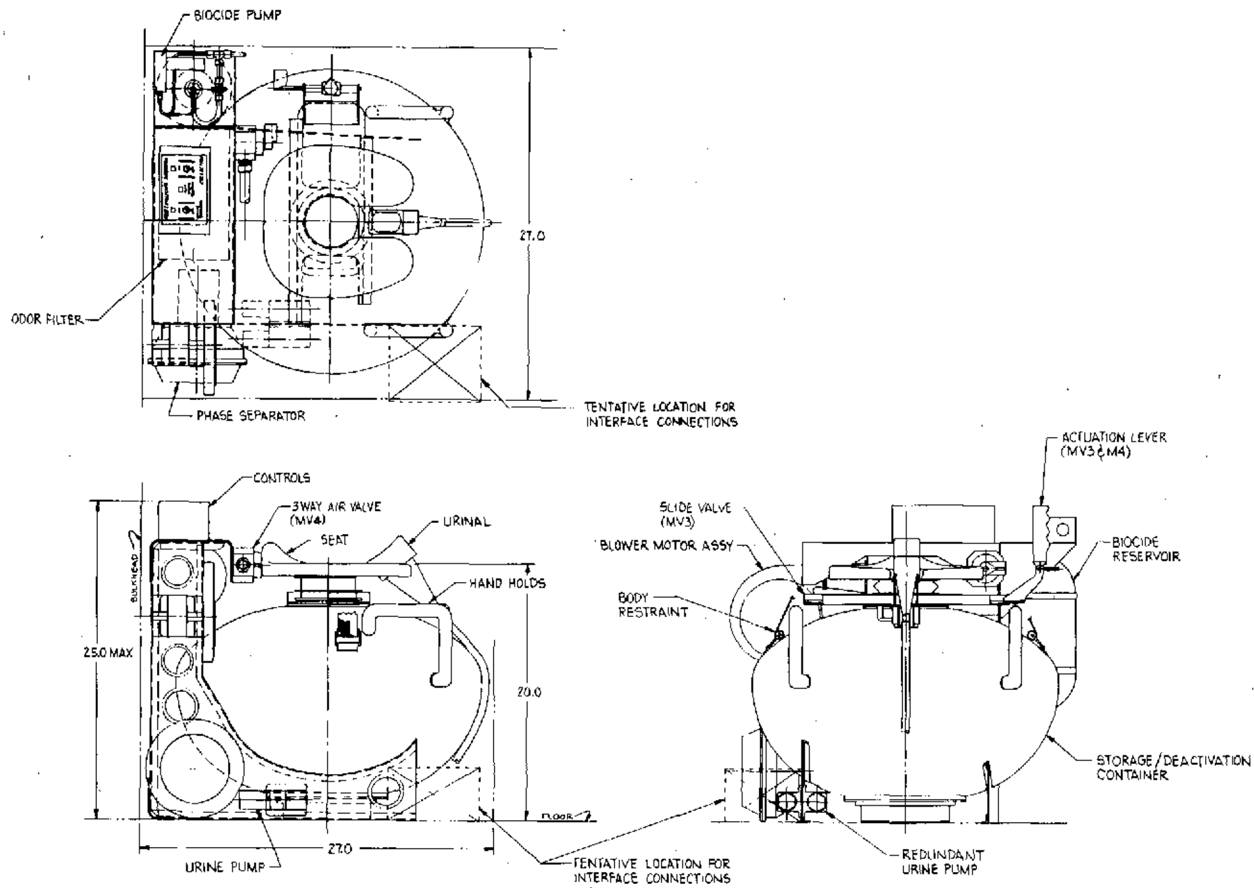

Figure 1.0-2 Preliminary Assembly Drawing of a Waste Collection System for Shuttle Orbiter

SECTION 7

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1.0 REFERENCES

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SECTION 8
APPENDIX

SECTION A

EVALUATION AND DESIGN OPTIMIZATION OF A WASTE MANAGEMENT SYSTEM FOR USE IN ZERO GRAVITY

GENERAL ELECTRIC TIS NO. 73SD233

TECHNICAL INFORMATION SERIES

NO. 73SD233

TITLE Evaluation and Design Optimization of a Waste Management System for Use in Zero Gravity

AUTHOR R.A. Burt & S.R. Hunt, Jr.

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AUTHOR	SUBJECT	NO.
R. A. Burt & S. R. Hunt, Jr.		73SD233
		DATE 8/10/73
TITLE Evaluation and Design Optimization of a Waste Management System for Use in Zero Gravity		G.E. CLASS 1
		GOVT. CLASS
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SUMMARY

The objective of this program was to prove the functional design of the GE Dry John for waste collection in the Zero Gravity environment expected for the Space Shuttle. The zero gravity and baseline tests of the GE Dry John Shuttle Orbiter Waste Management Subsystem (WMS) confirmed the soundness of the unique General Electric design approach and provided a high degree of confidence in future male/female user tests in zero gravity.

Specifically, the zero gravity tests established waste transport air flow rates of between 5.5 and 11 cfm for the female urinal. Three cfm was found to be adequate for male urinations, and approximately 30 cfm adequate for the commode operations. Urine droplets and diarrhetic type feces were transported at these flow rates. Also, the urinal as shown to be usable when repositioned for standing urinations in zero gravity and the liquid/gas separator accommodated all urine and air flow rates. There was no contamination of the "user" or aircraft environment during any phase of the test program; however, periodic cleaning of the internal commode transport tube may be required when diarrhetic or explosive stools are encountered. In most cases, the solid and liquid waste materials were collected, transported and stored in the 25-30 second time period of a single zero gravity aircraft test parabola.

The baseline tests confirmed that the WMS can accommodate male and female users and that the urinal could be used during the vertical launch attitude of the Shuttle Orbiter vehicle. Several specific advantages of the GE system, including the potential elimination of vaginal wipes, were observed during the tests. Female user acceptance has been excellent with a high degree of confidence in urine containment and urinal comfort.

KEY WORDS
Waste Management System, Zero Gravity Simulations, Life Support Equipment.

INFORMATION PREPARED FOR ______

TESTS MADE BY ______

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COMPONENT Environmental Engineering

APPROVED [signature]

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1.0 FOREWORD

The General Electric Company, Space Division, acknowledges the special coordination efforts and sponsorship of the National Aeronautics and Space Administration, Lyndon B. Johnson Space Center which permitted successful continuation of the company-funded development of a Shuttle Orbiter Waste Management Subsystem. Zero gravity and baseline user tests were successfully completed through the extra efforts of the Wright-Patterson Air Force Base personnel.

Special acknowledgements go to: A. Behrend, NASA-JSC for his help in sponsoring and coordinating these tests; Mr. D. Greggs, WPAFB Zero "G" test conductor; Mr. James Lackey, Assistant test conductor; MSGT R. Viramontez, cameraman, and to Col. Medwig, USAF/AFLC Medical Center, WPAFB who provided coordination for test volunteers for the user tests.

A special thanks is extended to the nurses of the medical staff at GE Valley Forge and the test volunteers from the USAF/AFLC Medical Center of Wright Patterson AFB without whose help this project would not have been successful. Thanks is also extended to other unnamed individuals who served as subjects for a variety of evaluations leading to design specifications for the test equipment.

General Electric personnel responsible for defining and conducting the program were R.A. Burt, Project Engineer, Environmental Engineering and Dr. S.R. Hunt, Jr., Biomedical Programs Manager, Environmental Engineering.

This report, together with a 16mm movie film, document the results of development and flight testing of a Shuttle Orbiter Waste Management System.

2.0 SUMMARY

The objective of this program was to prove the functional design of the GE Dry John for waste collection in the Zero Gravity environment expected for the Space Shuttle. The zero gravity and baseline tests of the GE Dry John Shuttle Orbiter Waste Management Subsystem (WMS) confirmed the soundness of the unique General Electric design approach and provided a high degree of confidence in future male/female user tests in zero gravity.

Specifically, the zero gravity tests established waste transport air flow rates of between 5.5 and 11 cfm for the female urinal. Three cfm was found to be adequate for male urinations, and approximately 30 cfm adequate for the commode operations. Urine droplets and diarrhetic type feces were transported at these flow rates. Also, the urinal as shown to be usable when repositioned for standing urinations in zero gravity and the liquid/gas separator accommodated all urine and air flow rates. There was no contamination of the "user" or aircraft environment during any phase of the test program; however, periodic cleaning of the internal commode transport tube may be required when diarrhetic or explosive stools are encountered. In most cases, the solid and liquid waste materials were collected, transported and stored in the 25-30 second time period of a single zero gravity aircraft test parabola.

The baseline tests confirmed that the WMS can accommodate male and female users and that the urinal could be used during the vertical launch attitude of the Shuttle Orbiter vehicle. Several specific advantages of the GE system, including the potential elimination of vaginal wipes, were observed during the tests. Female user acceptance has been excellent with a high degree of confidence in urine containment and urinal comfort.

3.0 BACKGROUND

The rewards of our manned space flight capability are improved earth resources determinations, weather forecasting, unique space manufacturing and pharmaceutical processes, basic research and astronomy to mention a few. As a consequence of these space activities, the astronaut's time is becoming more valuable so that mundane tasks must be eliminated while health and safety must continue to be of foremost concern.

There is probably no more mundane task than waste management and few that are more important or difficult to achieve in space. In the absence of gravity, liquids and solids are difficult to collect and store safely, especially if the liquid is urine which provides nutrients for microbial growth and the solids are highly contaminated and odorous excreta.

3.1 APOLLO

The APOLLO Waste Management System (WMS) was originally used on the GEMINI Program and is quite crude due to the vehicle limitations on equipment weight, power and volume. The urine is collected via a roll on cuff or funnel arrangement and jettisoned to space. The feces is collected in a plastic bag attached to the buttock. Stool separation is achieved by a gloved finger insert. Once collected, a biocide is added to the waste and the bag is stored. The APOLLO waste management system requires extensive training and from 45 to 60 minutes to perform and results in odor release and contamination of the cabin.

3.2 SKYLAB

The SKYLAB WMS is significantly more sophisticated than that of APOLLO since air flows are used to entrain and transport the urine and feces into separate collection areas. The air flows permit less user involvement and less odor release but requires more complicated equipment such as blowers, air filters and liquid/air separators.

The urinal is a funnel with air being drawn into it to capture the urine flow. The urine/air mixture is drawn into a centrifuge which dynamically separates the low mass air from the high mass urine. The air is drawn from the separator by a blower and is filtered and returned to cabin ambient. The urine is pumped by centrifugal force to a chilled bag for storage.

The feces collector also uses an air flow to entrain the stool and transport it into a porous collection bag. The bag retains any liquid and solid wastes while permitting passage of the transport air which is filtered and returned to the cabin ambient via a blower. After use, the bag is manually sealed and the wastes are vacuum dried and finally stored for return to earth.

Initial data from the SKYLAB program indicate that difficulties were encountered with stool separation during use of the current SKYLAB WMS. Other data regarding use of the SKYLAB system are just being evaluated and should be available in the near future.

3.3 SHUTTLE ORBITER

The SHUTTLE ORBITER will require innovations in waste management because all the crewmembers will not necessarily be specially trained astronauts and some may be female. Consequently, user procedures will need be simplified and more earth-like accommodations and a special urinal should be provided. All processing of the wastes will probably be automatic and all bags eliminated.

As in SKYLAB, air flows are used to entrain and transport the wastes; consequently, phase separators are required in the waste collectors to separate the air from the waste material.

The female urinal design impacts the selection of the separation technique because the two urinal designs under development require vastly different air flow rates. One design uses a collector built into the commode seat while the General Electric design uses a funnel-like device that can be positioned by the user. The integral urinal design requires a high air flow of approximately 60 cfm to assure urine entrainment while the GE funnel-type urinal positioned by the user requires significantly less air flow of approximately 6 cfm.

The feces collector commode uses the Dry John concept developed by General Electric in 1965. During defecation, the stool is conveyed by the transport air flow into the storage container. The gas positioning jets may be used to supplement the transport air flow to ensure disengagement of the feces from the anal area. Within the storage container, the feces impinge on the rotating slinger, where it is centrifugally accelerated through the slinger. This action, in addition to separating the transport air from the feces, shreds and then spreads the feces in a thin layer over the internal surface. The resulting large surface area is important in the subsequent drying process. Used toilet tissue enters the storage container in a manner similar to that of the feces, the tissue being distributed by slinger action.

After defecation, the user closes the seat valve and the interior of the feces storage container is exposed to space vacuum and the feces are vacuum dried. This arrangement for feces handling was successfully used in both the NASA 4 man-60day and a 4 man-90 day closed chamber tests.

The SHUTTLE ORBITER WMS must have design flexibility to provide for future requirements. Such features as biowaste sampling and non-venting may become necessary; consequently, the initial selection of design configurations must consider these possible additions.

4.0 OBJECTIVES

The program objective was to prove the functional design of the GE Dry John for Waste Collection in Zero Gravity environments expected for the "Space Shuttle." Within this overall objective, several more specific objectives related to making existing hardware more like the Shuttle requirements as well as incorporating performance improvements.

A more earth-like facility usable by both sexes with reductions in power, weight and size are objectives specific to the Shuttle. Also from recent experience on APOLLO, definite improvements in fecal separation and handling are needed.

4.1 PRIMARY OBJECTIVES

The objectives of the program were directed at attaining data to optimize the engineering design of GE Dry John to be used in Zero "G" environment and to evaluate and optimize the GE Dry John approach in terms of user acceptability.

The specific objectives of the study program were:

A. Obtain engineering data to determine minimal air flow requirements for the entrapment and transport of feces in a Dry John configuration.

B. Obtain engineering data on the slinger design to optimize dissemination of fecal and other waste material (e.g., tissue wipes).

C. Using the GE Dry John urinal collector configuration, obtain engineering data to determine minimal air flow requirements to collect, entrap and transport urine from both male and female users in a Zero "G" environment.

D. Determine the degree of user acceptance of the basic GE Dry John configuration for both male and female users.

4.2 SECONDARY OBJECTIVES

In developing the test program and designing the equipment for the study, several other objectives for design goals evolved and resulted in significant data or design modifications. Some of these objectives included:

A. An improved seat/urinal design for male and female use.

B. A design configuration similar to conventional "earth like" waste collection systems with a high degree of operational simplicity.

C. Developing restraint design requirements for Zero "G" conditions.

D. Developing a design philosophy and approach permitting ease of maintenance.

E. Developing a design philosophy and approach insuring the adequacy of both waste material and odor contamination control.

F. Using a cost-effective approach to develop the system design in such a manner as to promote a high degree of confidence of system reliability and user acceptance with minimal weight, power and volume requirement.

5.0 APPROACH

5.1 GENERAL APPROACH

The significant aspects of our approach included the use of Space Shuttle requirements as a focus for hardware/performance choices, quick look tests in flight of many factors but to a shallow depth and early use of simulations followed by later tests with subjects. Also, for Zero G environments, the use of aircraft Keplarian maneuvers and data taking by Hi-speed movies characterize the approach used.

The approach to hardware aspects of this program was to use an available "Dry John" functional mockup with some initial improvements. Initial ground tests were followed by flight tests using "stand in equipment" to generate simulated feces and urine. These tests were to explore the effects of varying major system parameters and establish a working optimum for subsequent testing. Finally ground and flight tests in a "Zero G Aircraft" using human subjects were planned to complete the demonstration of feasibility. The approach to operational aspects of the program was to initiate early contacts with NASA and the Zero "G" test facility to assure equipment and program compatibility as well as developing a pool of flight qualified subjects and GE test conductors/observers.

The next significant need for advanced Waste Management appears to be the Space Shuttle vehicle. Early requirements definitions for this program indicated significant advancements in the direction of a more earth-like system to accommodate less highly trained astronauts of both sexes. These requirements drove test equipment configuration choices and testing plans towards new urinal designs and additional urinal testing.

These new requirements also meant that relatively little Zero "G" equipment experience was available. So a "quick look" testing approach was used to gain some limited experience with each of a number of facets. Through this technique, any significant problems were then identified early in the program.

"Quick look" testing was initiated with simulations of human functions which later on would be done with human subjects. A simple fecal generator was devised to deliver selectable types of simulated feces in controllable amounts and times. Also, a female mannikin was used for initial testing of urine collection. These simulations made the early flight testing quicker and more controlled. Also, certain parameters such as urine flow rates could be varied systematically to find optimum settings of urine collection air flow to be used in subsequent tests with human subjects.

The Zero "G" testing environment was provided by an aircraft flying a parabolic maneuver which gives short periods of weightlessness and is for this application the closest approach to space flight available. Certain limited aspects can be tested in a Zero "G" environment produced by other methods. For example, there is a current program in which fecal separation and transport is being investigated in a neutral buoyancy facility. However, a much broader test spectrum including human usage could be done in an aircraft and a substantial capability was available at the USAF WPAFB Zero G facility.

5.2 ZERO "G" SIMULATION DESCRIPTION

Keplarian Trajectory Zero "G" Simulation was produced by executing a Keplarian Trajectory in a KC-135 Aircraft. To execute this maneuver, the pilot establishes an altitude of approximately 25,000 feet and accelerates in level flight to Mach .88 then pitches up at 266 to a 45° nose up attitude. Then a slight pitch down initiates the Zero "G" period. The pilot continues pitch down rotation using a special accelerometer indicator to control vertical acceleration to essentially zero. This continues for up to 30 seconds while the aircraft goes "over the top at perhaps 35,000 feet and comes back down. At a 30° nose down pitch attitude, the experimenters are notified by intercom to get personnel in safe positions and at 45° nose down pitch angle recovery is started and 2 to 2-1/2 G's vertical acceleration is pulled to bring the aircraft back into level flight and ready to repeat the maneuver.

5.3 GENERAL EQUIPMENT DESCRIPTION

Waste management is part of the Food, Water and Waste Subsystem for the Shuttle Orbiter spacecraft as shown in Figure 5.3-1. The waste collection, transportation and storage portion of the subsystem shown in Figure 5.3-1 was fabricated of clear plastic materials in critical areas and subjected to photographic examination during zero gravity tests in an aircraft and during normal gravity baseline tests.

5.3.1 Urine Management

The urinal can be used in the seated or standing position, separately or during defecation. Upon micturition, the urine is entrained in an air flow and conveyed to the liquid/gas separator. The dynamic liauid/gas separator pumps the urine to storage and permits the transport air to exit to the blower and odor filter prior to return to the cabin atmosphere. After use, or periodically, a small volume of liquid biocide is dispensed into the urinal and flushed with water. The unit continues to operate until the biocide and flush water are pumped to storage.

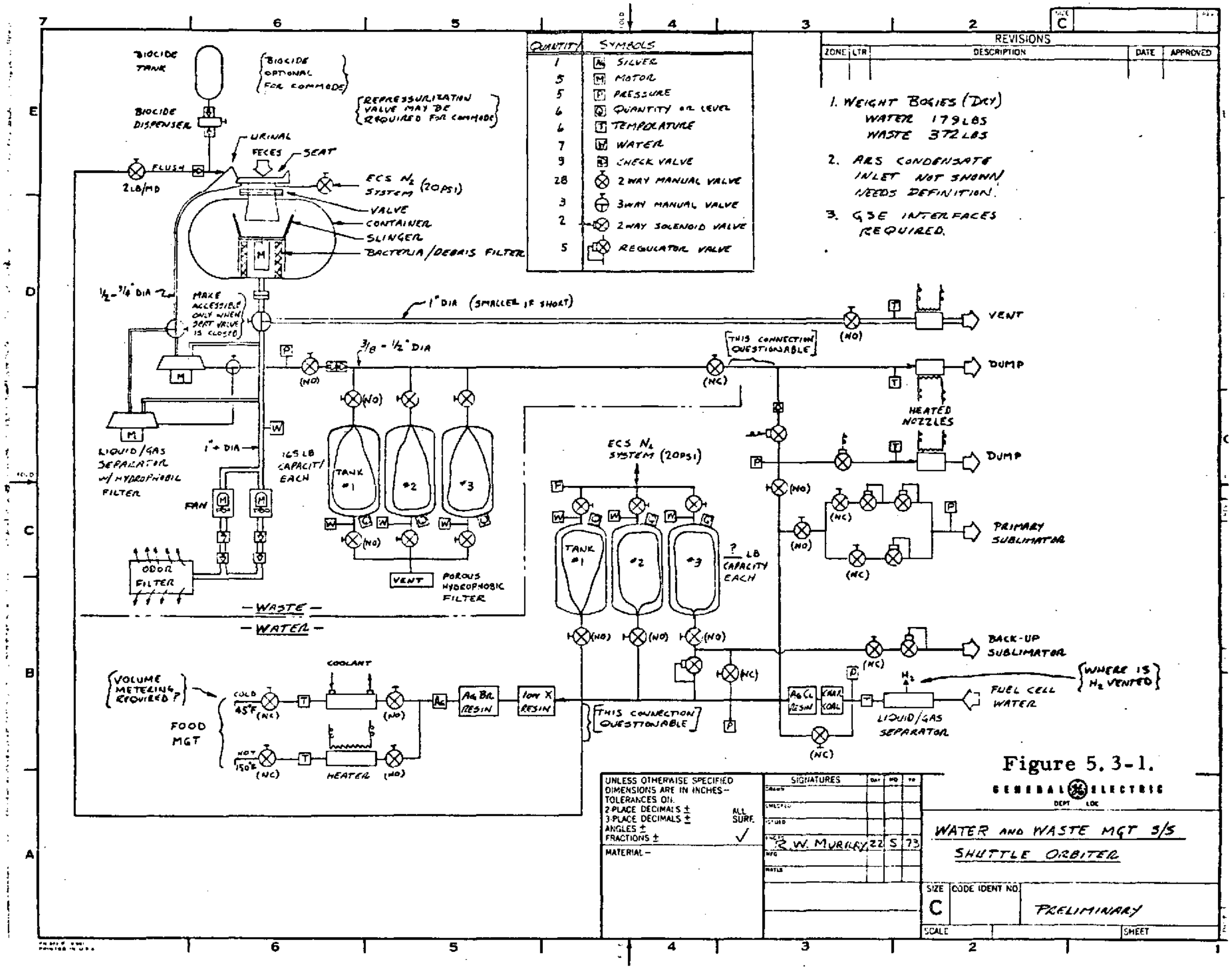

BIOCIDE TANK
BIOCIDE OPTIONAL FOR COMMODE
BIOCIDE DISPENSER
REPRESSURIZATION VALVE MAY BE REQUIRED FOR COMMODE
URINAL
FECES
SEAT
FLUSH
2LB/MD
ECS N2 SYSTEM (20PSI)
VALVE
CONTAINER
SLINGER
BACTERIA/DEBRIS FILTER
QUANTITY | SYMBOLS
1 SILVER
5 MOTOR
5 PRESSURE
6 QUANTITY OR LEVEL
6 TEMPERATURE
7 WATER
9 CHECK VALVE
28 2 WAY MANUAL VALVE
3 3WAY MANUAL VALVE
2 2WAY SOLENOID VALVE
5 REGULATOR VALVE
REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
1. WEIGHT BODIES (DRY) WATER 179 LBS WASTE 372 LBS
2. ARS CONDENSATE INLET NOT SHOWN NEEDS DEFINITION.
3. GSE INTERFACES REQUIRED.
1/2-3/4" DIA
MAKE ACCESSIBLE ONLY WHEN SEAT VALVE IS CLOSED
1" DIA (SMALLER IF SHORT)
VENT
3/8 - 1/2" DIA
THIS CONNECTION QUESTIONABLE
DUMP
HEATED NOZZLES
DUMP
LIQUID/GAS SEPARATOR w/ HYDROPHOBIC FILTER
1"+ DIA
165 LB CAPACITY EACH
TANK #1 #2 #3
ECS N2 SYSTEM (20PSI)
PRIMARY SUBLIMATOR
FAN
ODOR FILTER
VENT
POROUS HYDROPHOBIC FILTER
? LB CAPACITY EACH
TANK #1 #2 #3
— WASTE —
— WATER —
BACK-UP SUBLIMATOR
WHERE IS H2 VENTED
FUEL CELL WATER
LIQUID/GAS SEPARATOR
COOLANT
VOLUME METERING REQUIRED?
COLD 45°F
HOT 150°F
FOOD MGT
HEATER
Ag Br RESIN
ION X RESIN
THIS CONNECTION QUESTIONABLE
AgCl RESIN
CHAR COAL
(NO)
(NC)
GENERAL ELECTRIC
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES— TOLERANCES ON 2-PLACE DECIMALS ± 3-PLACE DECIMALS ± ANGLES ± FRACTIONS ±
ALL SURF.
MATERIAL—
SIGNATURES
R. W. MURRAY 22 5 73
WATER AND WASTE MGT S/S SHUTTLE ORBITER
SIZE C CODE IDENT NO.
PRELIMINARY
SCALE
SHEET

Figure 5.3-1.

5.3.2 Feces Management

The contoured seat of the commode assists in positioning the user. Body and foot restraints secure the user to the seat during zero gravity operation. When properly seated, the user places the system power switch to the on position and manually activates the vent valve, repressurization valve and the slide valve. The slide valve cannot be opened before repressurization of the container and power is applied to the slinger. Transport air flow occurs concurrent with slide valve opening. This precludes any possible back flow from the feces storage container into the Shuttle ambient. During defecation, the stool is conveyed by the transport air flow through the transport tube into the storage container. The gas positioning jets may be used to supplement the transport air flow to ensure disengagement of the feces from the anal area. Within the storage container, the feces impinges on the rotating slinger, where it is centrifugally accelerated through the slinger. This action, in addition to separating the transport air from the feces, shreds and then spreads the feces in a thin layer over the internal surface. The resulting large surface area is important in the subsequent drying process. Used toilet tissue enters the storage container in a manner similar to that of the feces, the tissue being distributed by slinger action. Transport air is drawn through a bacteria filter and into the blower and filter assembly. (Trash and vomit filled bags are handled in a similar manner). After defecation is completed, the user closes the slide valve, opens the vent valve and removes his position restraints. Closing the slide valve activates the interlocking switch which turns off the slinger motor and opening the vent valve permits the start of the fecal microorganism control process.

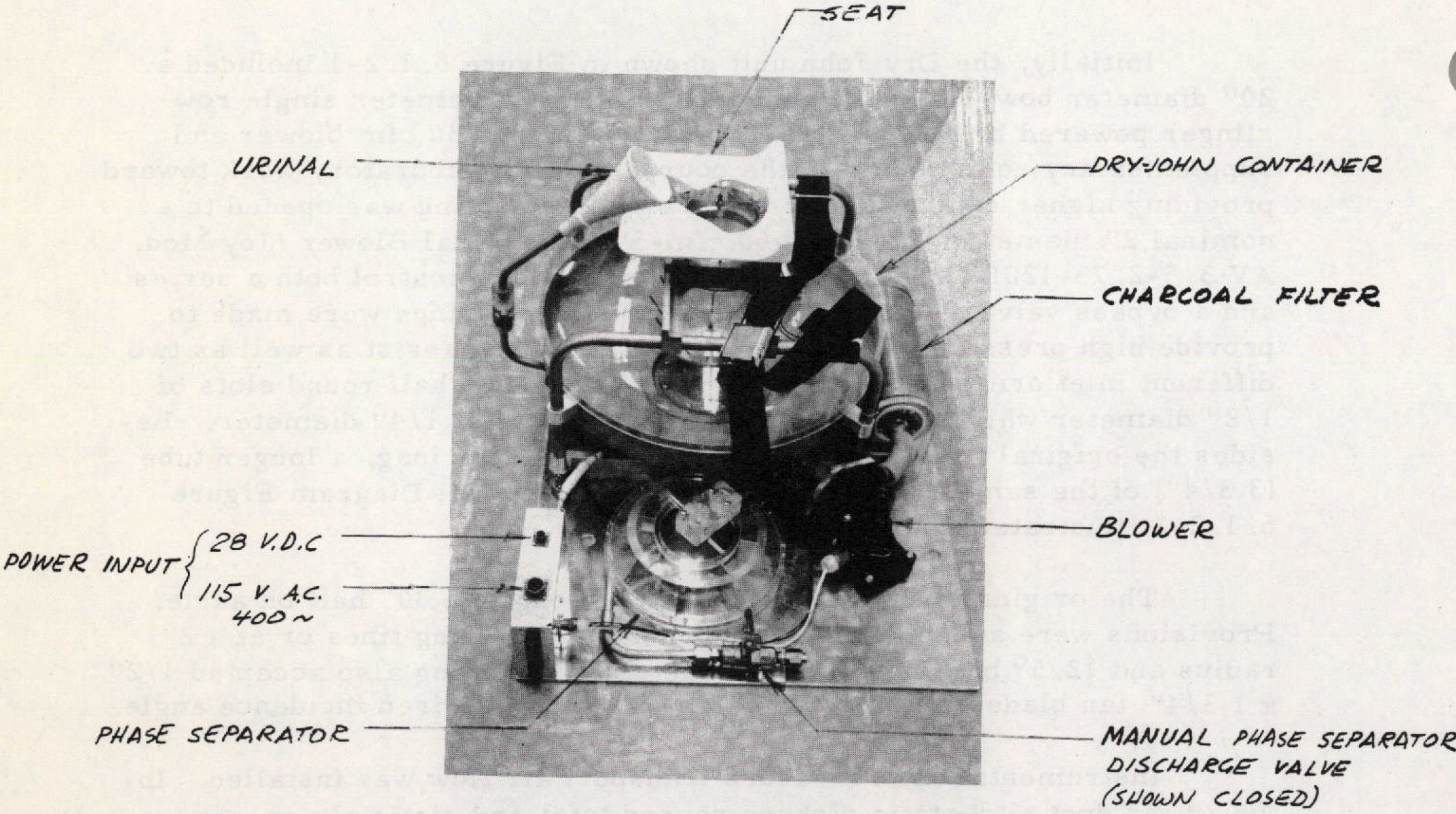
Opening the vent valve of the interior of the storage container results in drying of the thin layer of deposited feces either by freeze drying by vacuum or drying by circulating ambient air. The container surface remains at essentially room temperature throughout the process with sufficient heat being transoferred from the environment to permit complete drying.

Initially, the Dry John unit shown in Figure 6.1.2-1 included a 20" diameter bowl (top half transparent), 5 1/2" diameter single row slinger powered by a 400 Hz 2000 rpm motor, one 30 cfm blower and supplementary equipment. In the course of early laboratory work toward providing higher controlled air flow rates, all ducting was opened to a nominal 2" diameter and a new 60 cfm-5" Vane-Axial Blower (Joy Mod. AV 3.5-2.75-120D) substituted. Also for air flow control both a series and a bypass valve were incorporated. New inlet rings were made to provide high pressure air jets for fecal separation assist as well as two different inlet orifice arrays. One inlet had eleven half round slots of 1/2" diameter while the second had similar slots of 1/4" diameter. Besides the original transport tube, 4" bore by 2 1/2" long, a longer tube (3 3/4") of the same bore was also used. Functional Diagram Figure 6.1.2-2 illustrates this air flow system.

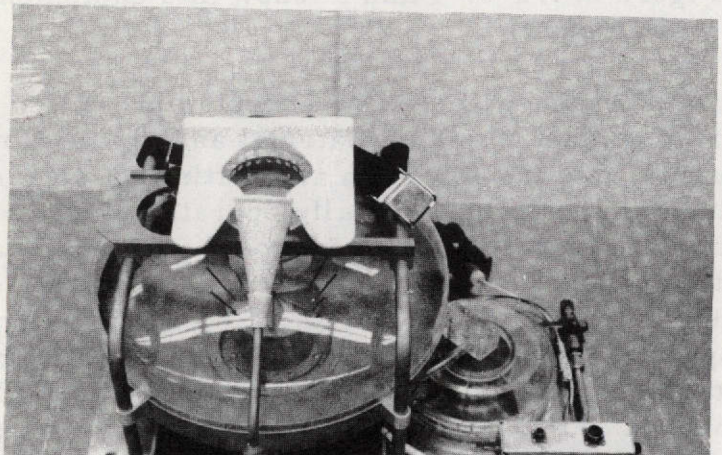
The original slinger had 12 tines 3" long at a 30° half on angle. Provisions were added to mount additional 1 3/4" long tines or at a 2" radius and 12.5° half cone angle. The same mounting also accepted 1/2" x 1 3/4" fan blades which could be preset to any desired incidence angle.

Instrumentation to measure transport air flow was installed. In the 2" air duct pitot-static pickups sensed total and static air pressures and drove standard aircraft air speed and altitude indicators. Two high-speed 16 mm movie cameras having orthogonal views of the Dry John bowl were used to record separation and transport occurrences during flight tests. Figure 6.1.2-3, 4 and 5 show this equipment installed in the Zero "G" test aircraft.

The simulated feces generator accepted pre-filled cartridges containing the varied consistencies of material and provided means for introducing the material into the Dry John and cutting off segments with an artificial sphincter. A simple manually operated plunger was used to extrude the simulated fecal material from the preloaded cartridge. A normal operation sequence would start with the sphincter closed and a loaded cartridge inserted into the loading tube. Manual rotation of the loading tube opens the sphincter and then using the plunger, a measured amount of material is pushed through the sphincter into inlet area of the Dry John. Rotation of the loading tube in the opposite direction applies closing forces on the sphincter. However, the soft compliant nature of the sphincter does not give immediate positive closing and cut off the fecal material, but rather a slower pinch-off action somewhat analagous to that of the natural sphincter operation. In addition, a limited axial freedom was provided in the device. When the sphincter was closed, a motion of 3/4" total could be obtained by manual forces along the loading tube axis. This provided a primitive capability to introduce axial acceleration (jounce) as a fecal separation assisting means. Figure 6.1.2-6 shows the sphincter end of the simulated stool generator installed in the seat and simulated anal configuration used in the fecal transport Zero "G" tests.



- SIDE VIEW -



- FRONT VIEW -

Figure 6. 1. 2-1. Waste Management System Test Model

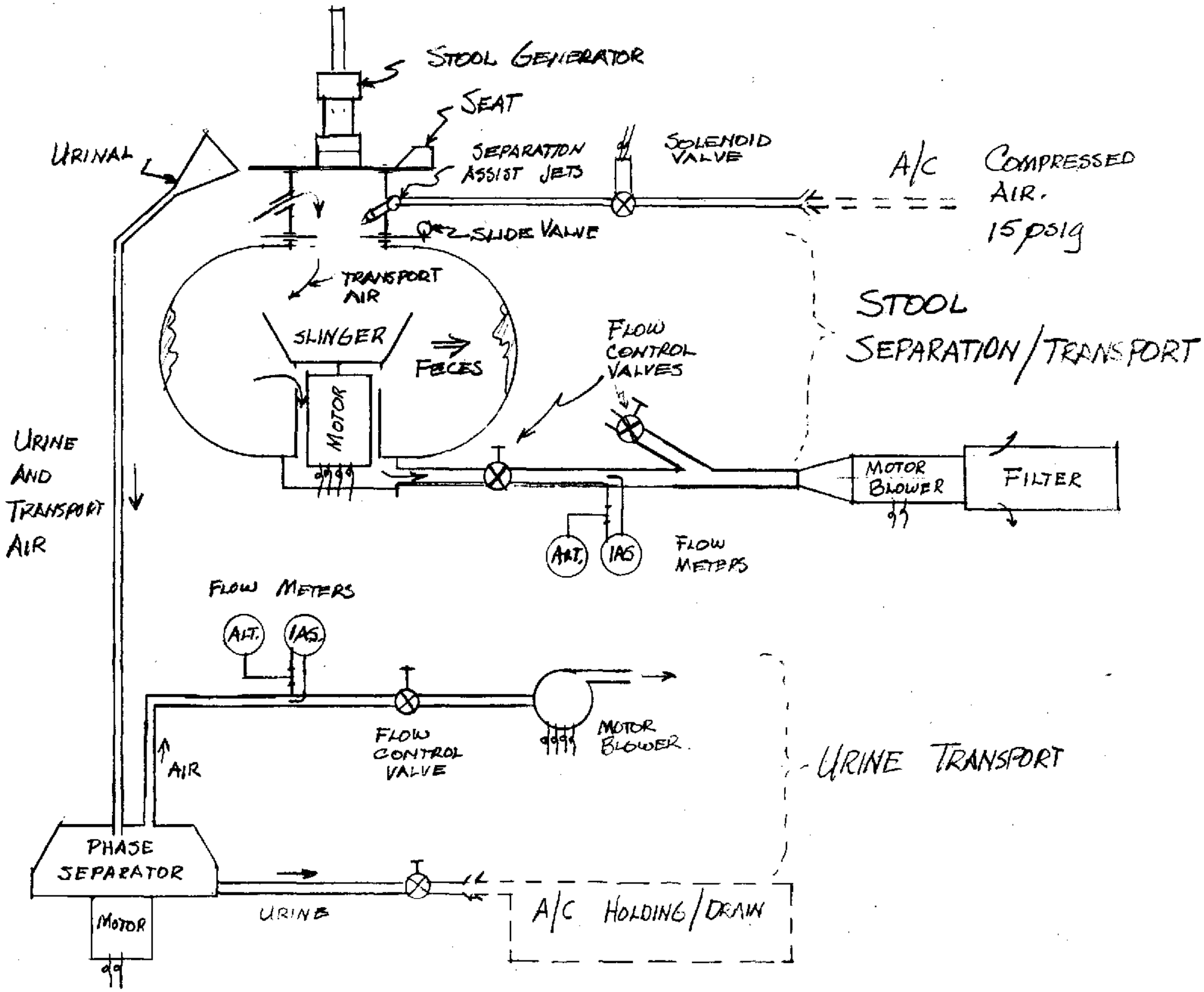


Figure 6.1.2-2. Functional Diagram - Advanced Waste Management System

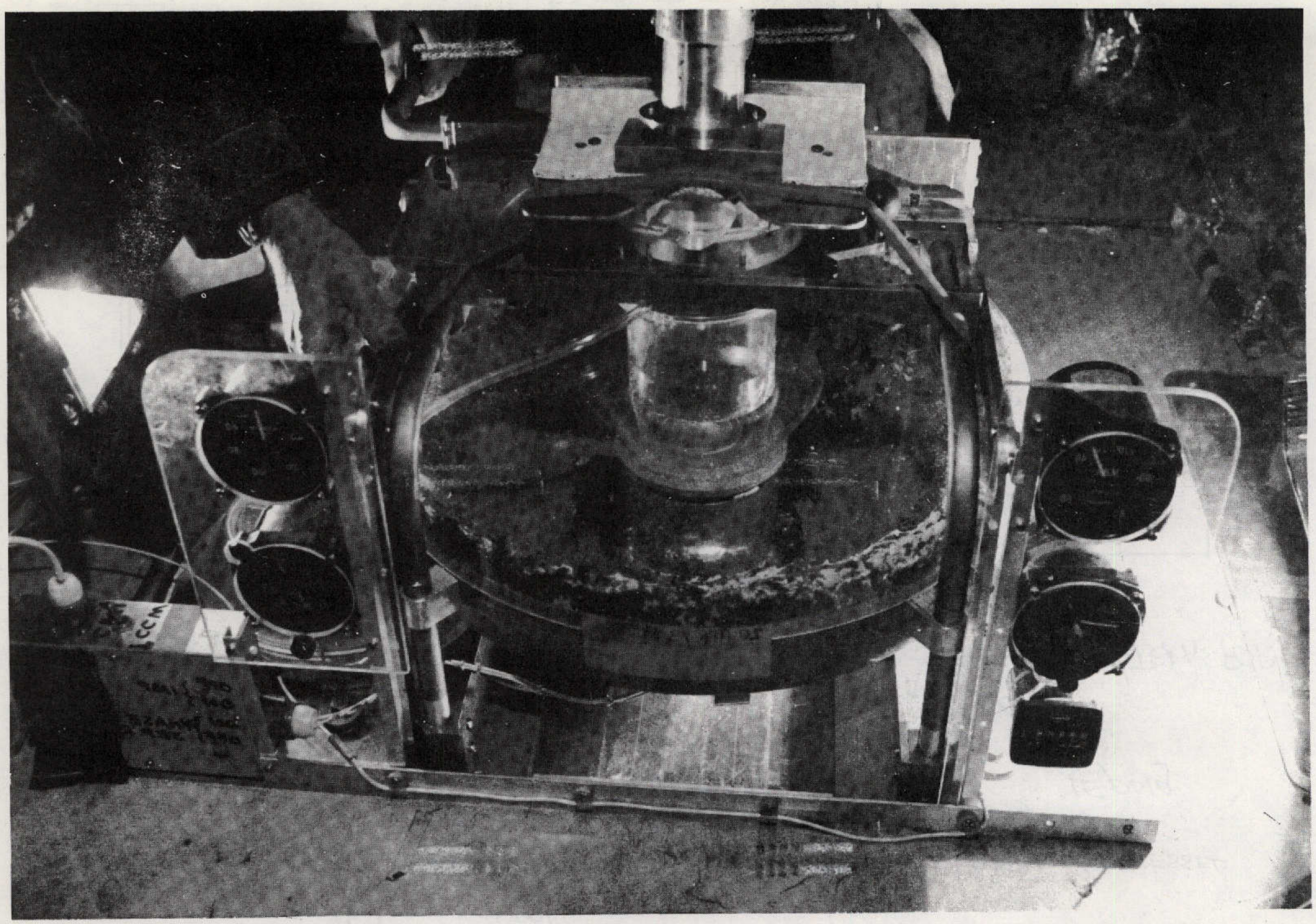
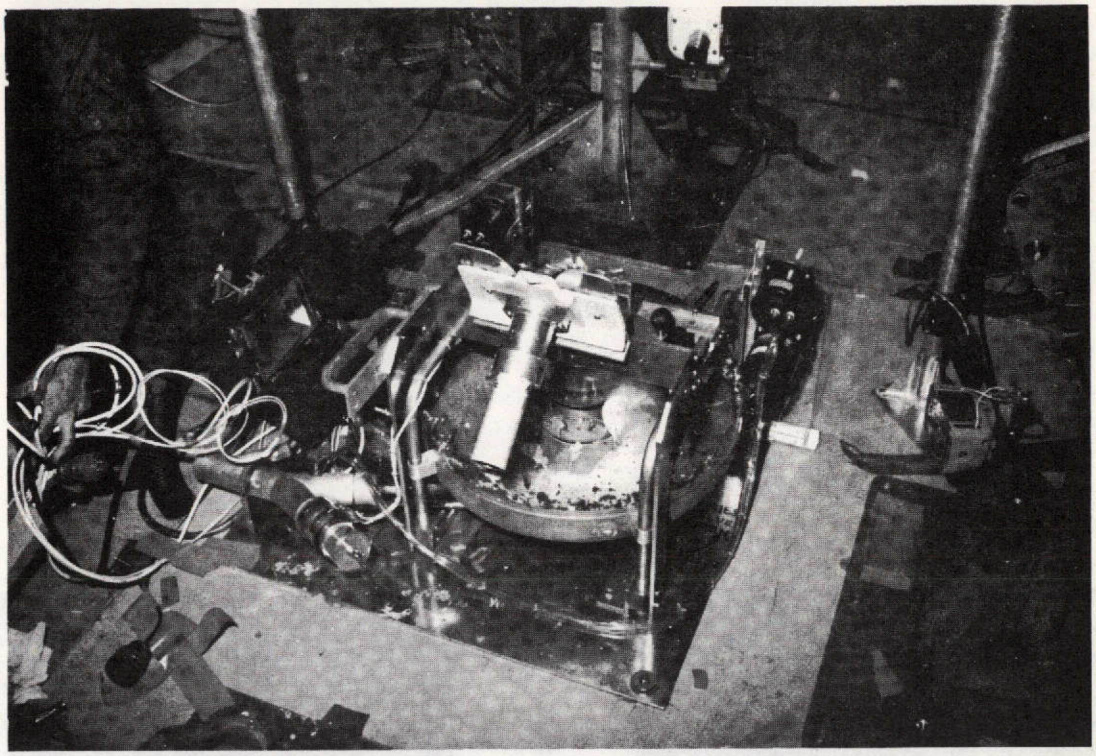
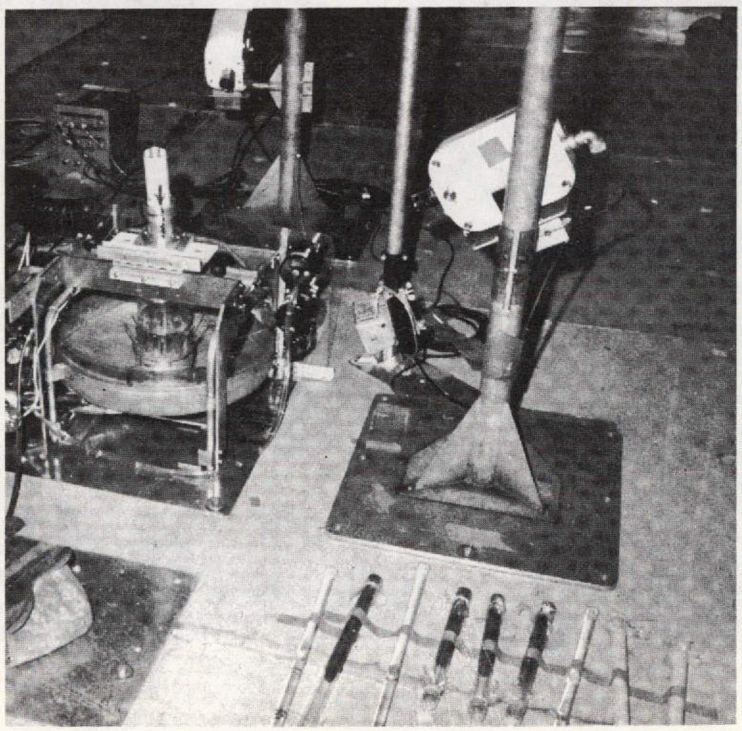


Figure 6.1.2-3. Equipment Installed in Aircraft





Figures 6. 1. 2-4 & 5. Equipment Installed in Aircraft

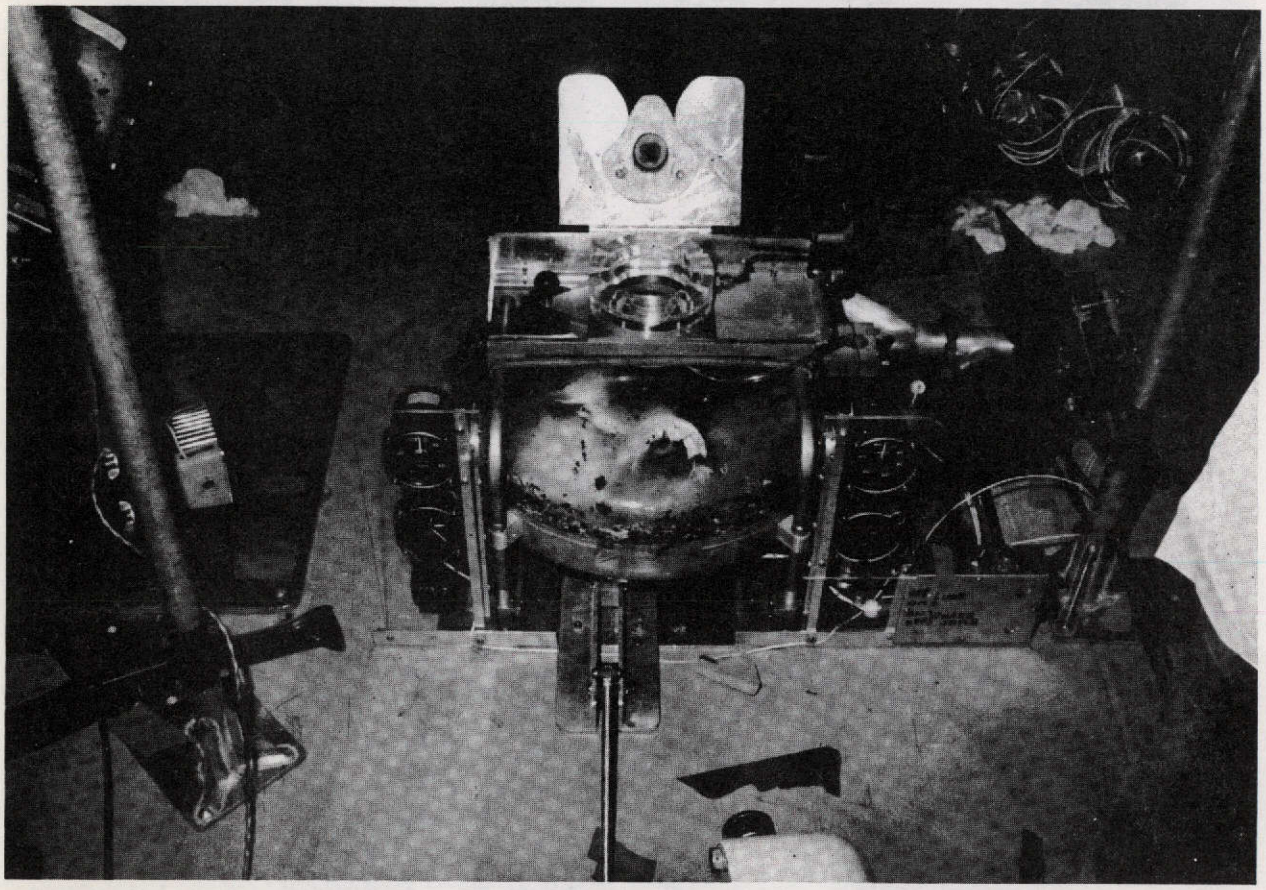


Figure 6.1.2-6. Equipment in the Aircraft Showing the Sphincter End of the Simulated Stool Generator

6.1.3 Procedures

Procedures used during Zero "G" flight testing of simulated fecal separation transport and storage resulted in a systematic variation and observation of the effects of nine different parameters. The following tabulation lists these parameters and their levels of variation.

	Parameter	Variations
1.	Inlet Ring	1/2" & 1/4" Inlet Slots
2.	Transport Tube	Short & Long
3.	Slinger Configuration	12 Round Tine 12 Round Tine Plus 12 Square Tines 12 Round Tine Plus 3 Square Tines 12 Round Tine Plus 12 Blades
4.	Slinger Rotation	CW & CCW
5.	Transport Air Flow	27 & 47 S.C.F.M.
6.	Simulated Feces	Consistency - Firm, medium, soft
7.	Simulated Feces	Length - 2", 3", 4", 5", 10", 12"
8.	Simulated Feces	Induction Angle 0^{o}, 12^{o}
9.	Separation Assist	Transport Air Only Air Jets Jounce

Of these parameters, seven could be varied while in flight but two,(2) transport tube and (3) slinger configuration were only changed on the ground between flights. The sequence for testing is outlined in Table 6.1.3-1 "GE Dry John Zero "G" Flight Test Conditions - Simulated Feces Separation and Transport."

Pre-flight preparations included making the several simulated fecal mixtures and loading into cartridges tubes. Both "firm and standard" formulas were in the proportion of (one) Gainesburger Dog Food Patty mixed with one teaspoon of peanut butter plus water; For a "firm" mixture, 30 ml while for "standard" 45 ml H_2O was used. The loose consistency was 110 ml H_2O to one packet of instant oatmeal cereal. For easy distinction between mixtures a blue food coloring was added to the "firm" mixture.

Table 6.1.3-1.
G.E. Dry John Zero G Flight Test Conditions
Simulated Feces Separation & Transport

Flt Date	Film Roll	Test	Inlet	Xport Tube	Slinger Config.	Slinger Rotat.	Xport Air Flow	Stool Char.	Stool Length	Stool Angle	Sep. Assist.
1) 20 Apr '73	1 & 3	1	1/2" slots	Long		CW	47 CFM	Firm	5"	12°	--
		2						"	4"		Air
		3						"	3"		Jounce
*		4						Med	10"		--
		5						"	"		A
		6						"	"		J
		7						Soft	6"		--
		8						Soft	6"		A
*	Front Roll #1 @ 64 frames/sec; Side Roll #3 @ 24 f/s	9	Feces Separation & Transport		Outer Row - 12 round tines; Inner Row - 12 square tines		47	"	12"		J
		11					27	Firm	5"		--
		12					CFM	"	4"		A
		13						"	3"		J
		14						Med	10"		--
*		15						"	"		A
		16						"	"		J
		17						Soft	6"		--
		18						"	6"		A
	1 & 3	19	1/2"	Long		CW	27	"	12"	12°	J

*Side only

Camera Speed

Front 64 frames per second
Side 24 normal
Except 25th and 26th runs

NOTE: Test conditions defined above are per the Test Plan. Actual conditions and test identification numbering sometimes did not conform to the plan. A review and analysis of films and tapes was used to reconcile these differences.

Simulated Feces Separ n & Transport (cont'd)

Flt Date	Film Roll	Test	Inlet	Xport Tube	Slinger Config.	Slinger Rotat.	Xport Air Flow	Stool Char.	Stool Length	Stool Angle	Sep. Assist.
1) cont'd 20 Apr '73	1 & 4	21 Feces Separation & Transport	1/4" slots	Long	Outer Row - 12 Round Tines Inner Row - 12 Square Tines	CW	50 CFM	Firm	5"	12°	--
		22						"	4"		Air
		23							3"		Jounce
		24						Med	10"		--
	2	25						"	"		A
		26						"	"		J
		27						Soft	6"		--
		28						"	6"		A
		29					50	"	12"		J
		33					27 CFM	Firm	5"		--
		34						"	4"		A
		35						"	3"		J
*		36						Med	10"		--
		37						"	"		A
		38						"	"		J
		39						Soft	6"		--
		40						"	6"		A
	2 & 4	41	1/4"	Long		CW	27	"	12"	12°	J
	Frames/sec.										
4) 25 Apr '73	64	1	1/4"	Short	Outer Row - (12) Round Inner Row - 12 blades @ 30°	CW	31	Med	(2) 2"	12°	Air
	200	2						"	(2) 2"		"
	200 Roll 2-Front 3-Side	3						Soft	12"		" @ +10 sec
	200	4						Med	10"		A&J
	64	5				CCW	31	"	10"		A&J
	64	6				CW	47	Med	(2) 2"		Air
	200	7						"	(2) 2"		"
	200	8						Soft	12"		--
*	500	9						"	"		Air @ +15 sec
*	200	10						Med	10"		A&J
	200	11	1/4"	Short		CCW	47	Firm	8"		A&J

Simulated Feces Separation & Transport (cont'd)

Flt Date	Film Roll f/s	Test	Inlet	Xport Tube	Slinger Config	Slinger Rotat.	Xport Air Flow	Stool Char.	Stool Length	Stool Angle	Sep. Assist.
5) 26 Apr. '73	200 Roll-1&3-Front, 2-Side ↓	*1	1/4" ↓	Long ↓	Outer Row - (12) Round (Only)	CW ↓	31	Med	(2) 2"	0° ↓	--
		*2					CFM ↓	"	(2) 2"		Air
		3						Loose	12"		" @ +10
		*4						"	"		--
		5					31	Med	10"		A&J
		6					47	Med	(2) 2"		--
		*7					CFM ↓	"	(2) 2"		Air
		8						Loose	12"		" @ +10
		9						"	"		--
		10	1/4"	Long		CW	47	Med	10"	0°	A&J

During the 2G portions of Keplarian maneuver, stool cartridges were loaded and any programmed adjustment of air flow made. At the beginning of the weightless period on signal from the flight deck, the cameras and lights were turned on and injection of the simulated fecal material started. Although not subject to rigorous temporal control, an attempt was made to inject the material smoothly over a 5 to 10 second period and have the sphincter closed between 10 to 15 seconds into the weightless period. The period from 15 to 20 seconds was used for applying whatever separation assist was specified for that test run.

Figure 6.1.3-1 shows the array of cartridges and plungers near the Dry John just prior to the first test run. Figure 6.1.3-2 taken during run 17 illustrates how these procedures were executed for the simulated fecal separation and transport studies.

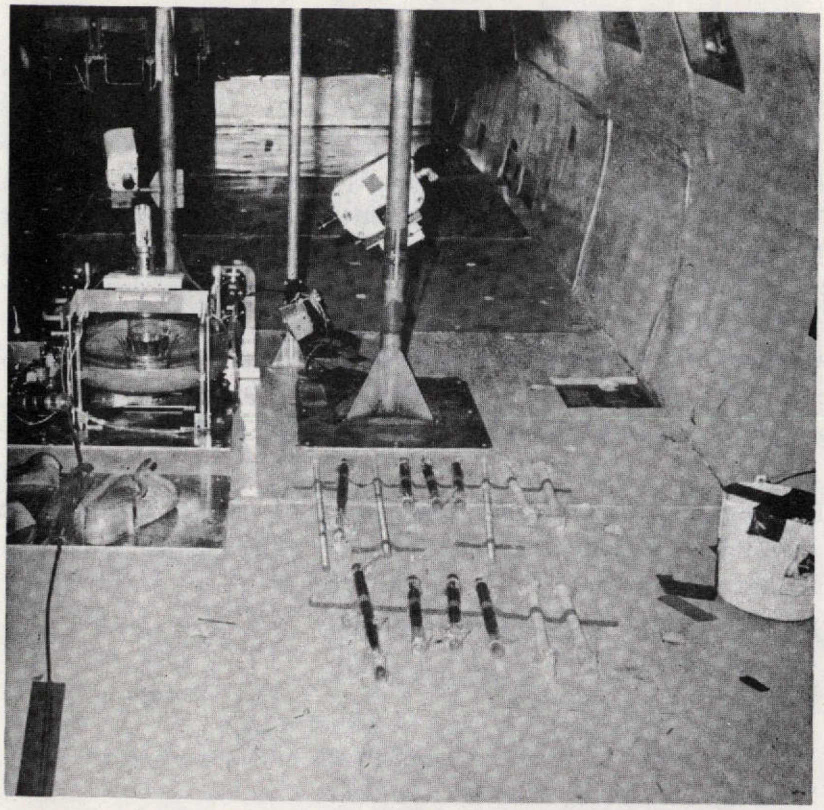


Figure 6.1.3-1. Cartridge and Plunger Assemblies in Aircraft Prior to Use

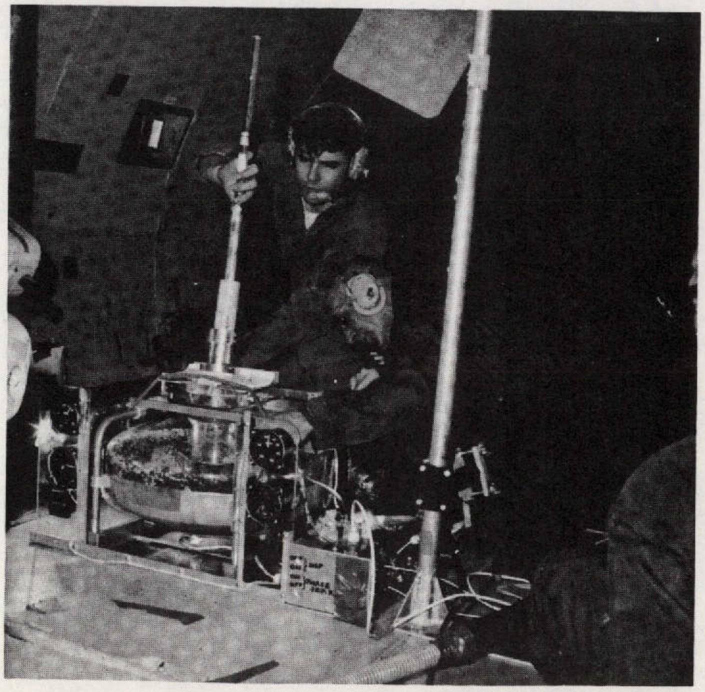


Figure 6.1.3-2. Illustration of Procedures for Simulated Fecal Separation and Transport Study

6.1.4 Results

Preliminary ground testing of the Dry John resulted in characterization of the transport air flow. Subsequent flight tests provided indications of the effects on simulated fecal separation and transport performance caused by varying a number of parameters under weightless conditions.

Transport air flow pattern was shown to be initially a radial inflow through eleven slots just under the Dry John seat and perpendicular to transport tube axis. As the separate jets come together in the center they merge and turn downward along the transport tube axis in a single high velocity core. Velocity traverses made along a major diameter of the tube located 1 1/4" below seat lower surface showed a high velocity core approximately 1 1/2" diameter in the center of transport tube. Maximum velocity at the core center was measured as 40 ft/sec. with the nominal 60 CFM blower and original 24 - 0.213" diameter hole inlet ring. A similar velocity profile was obtained with the original 25 CFM blower giving a maximum velocity of 16 ft/sec.

Besides velocity profiles, a static pressure traverse was taken on the center line axis of transfer tube. A local high pressure zone extending from the seat bottom to approximately two inches down the transport tube. Peak pressure rise noted was $\approx$ 1.2" water above the general pressure levels in the transport tube.

Flight test data on separation and transport of simulated feces was obtained during three flights with 56 test points run. For the second and third flights, some modification made to the test procedures resulted in an improved data yield.

Fecal separation performance was influenced by the basic properties of the simulated material and as well as by the type of separation assists used. Test runs with the "firm" material typically did not separate during the available time at Zero "G" for a run unless assisted. Of the two assist methods, the "jouncing" was judged to be somewhat more effective than high pressure air jets in obtaining separation.

Fecal transport performance was characterized in terms of velocity of the stool after separation and its trajectory. These performance indicators were affected when several of the operating parameters were varied. Transport velocities were higher at higher air flow rates and also had some sensitivity to the separation assist. Air jet separation gave higher stool velocities. Any sensitivity to inlet size was obscured. Fecal transport trajectories were crudely defined by whether or not the stool proceeded down the transport tube without touching or not. There was relatively little tumbling even with short stool lengths; most would proceed down the tube in a stable orientation until contact was first made with the slinger. Between the three types of material, there was more inclination of the soft to make contact with the transport tube and then to proceed much more slowly towards the slinger. There were, however, no marks indicating such contact until one inch or more below the seat.

6.2 FECAL SEPARATION, TRANSPORT AND SLINGER STUDIES - HUMAN SUBJECTS

6.2.1 Approach

Plans for the studies of fecal separation, transport and slinger studies using test volunteers during Zero "G" flights have not been finalized. Lack of availability of the KC-135 aircraft precluded the possibility of conducting these tests until a later time.

Basically, the first phase of this testing was to establish a "baseline" combination of variables as established from analysis of earlier tests. These established values will be used in subsequent tests with human subjects during Zero "G" flights. If necessary, adjustments of one or more of the baseline parameters could be made during Zero "G" runs, but the approach is to minimize equipment variability in favor of studying the overall performance with several different subjects. This test combines with the urine capture and transport tests. The basic equipment configuration will be essentially the same for human subjects as for simulated feces except that the artificial feces generator will be replaced by a seat and restraints appropriate for human usage in the Zero "G" test environment. Also, an enclosure will be used to provide privacy for the subjects.

6.2.2 Equipment

For human usage in the Zero "G" testing equipment will be substantially the same as that previously described in Section 6.1.1 for simulated fecal collection with the generator-seat assembly replaced by a new seat and appropriate restraints. Packaging of the power, control and instrumentation was changed and a privacy enclosure provided. A schematic of the electrical system is shown in Figure 6.2.2-1.

Figures 6.2.2-2 and 6.2.2-3 respectively, show the Dry John and the support equipment including blowers, odor filter, controls and flow instruments set up for ground checkout. The seat incorporated into the equipment was specially designed for both Zero "G", normal gravity, and if required 2 "G" use. The seat is a soft contoured unit providing support similar to that of a conventional commode. The contours on the seat

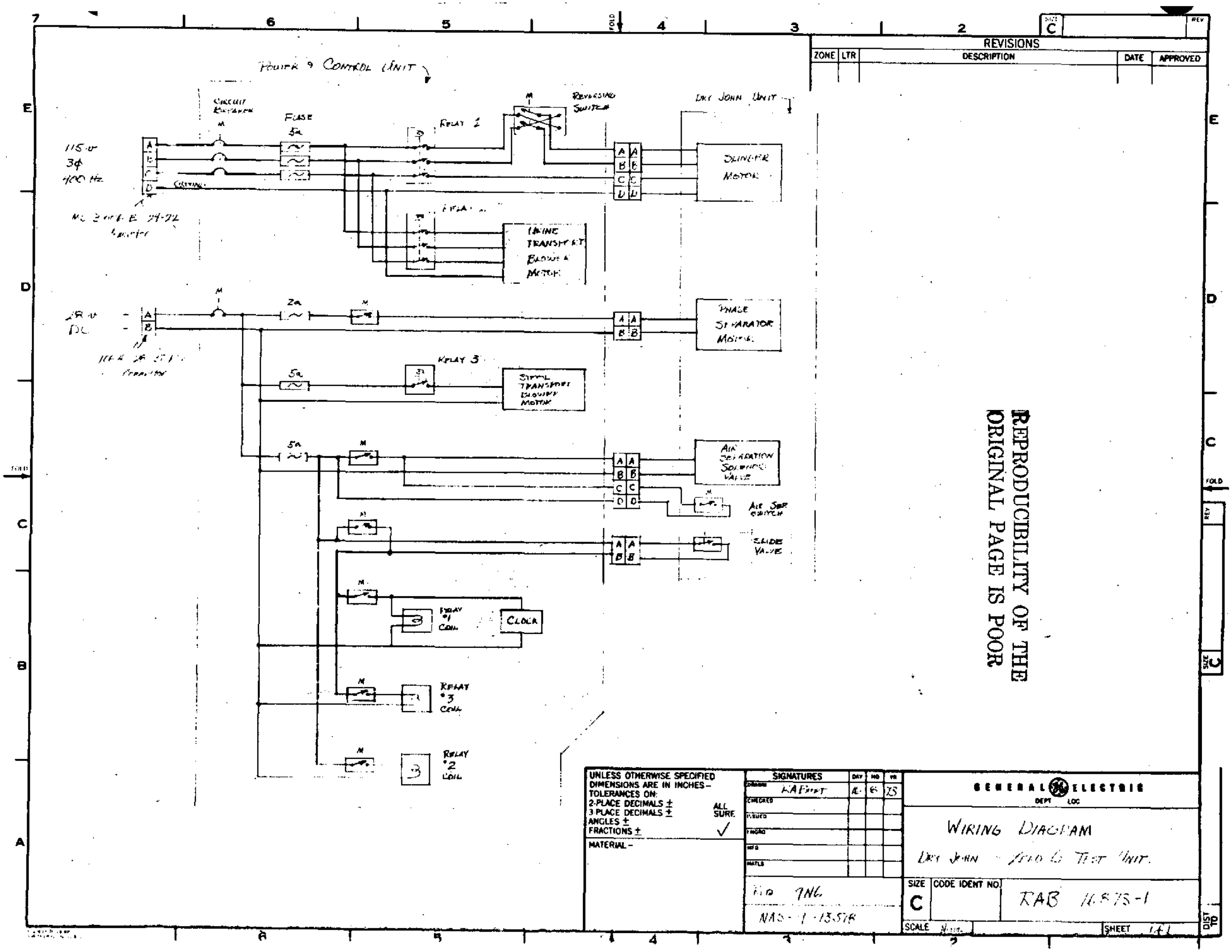


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Figure 6.2.2-1. Schematic of Electrical System

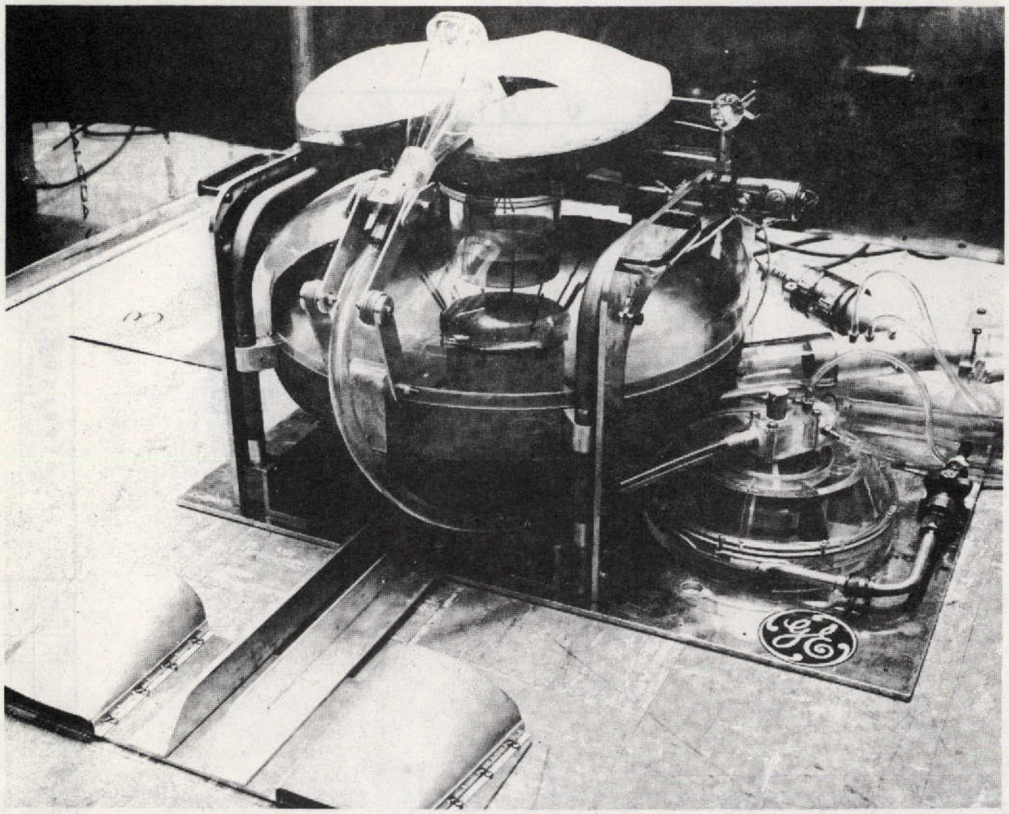

Figure 6.2.2-2. The Dry John Zero "G" Test Unit Assembled for Ground Check-out

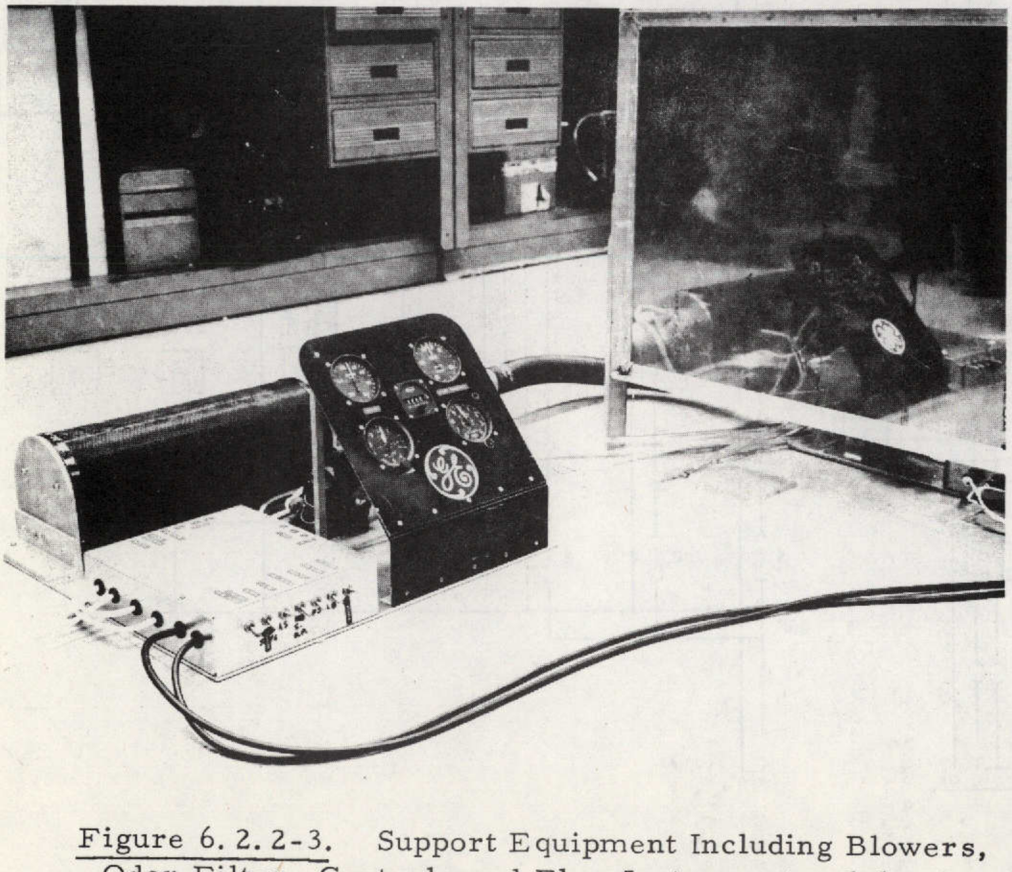

Figure 6.2.2-3. Support Equipment Including Blowers, Odor Filter, Controls and Flow Instruments of the Dry John Zero "G" Test Unit Assembled for Ground Checkout

provide sensory input to the seated or restrained user to aid in proper positioning for defecation. In addition, the seat is designed to provide flexible contour points for the ischial tuberosities to further insure proper user positioning. The compliance and contours of the seat also provides an air seal assuring proper air flow in the transport tube. Hand holds, foot restraints and a seat belt type restraint also have been provided.

To provide privacy to subjects using the Dry John, a simple modular enclosure was fabricated. Overall dimensions were 4 ft. x 8 ft. x 6 1/2 ft. high with the largest panel modules being 6 ft. x 2 1/2 ft. All panels were aluminum angle picture frame covered with an aluminum sheet except for one entry panel. For this, NASA-JSC provided a fire-proof curtain with velcro closures. Figure 6.2.2-4 shows the arrangement of Dry John within the privacy enclosure.

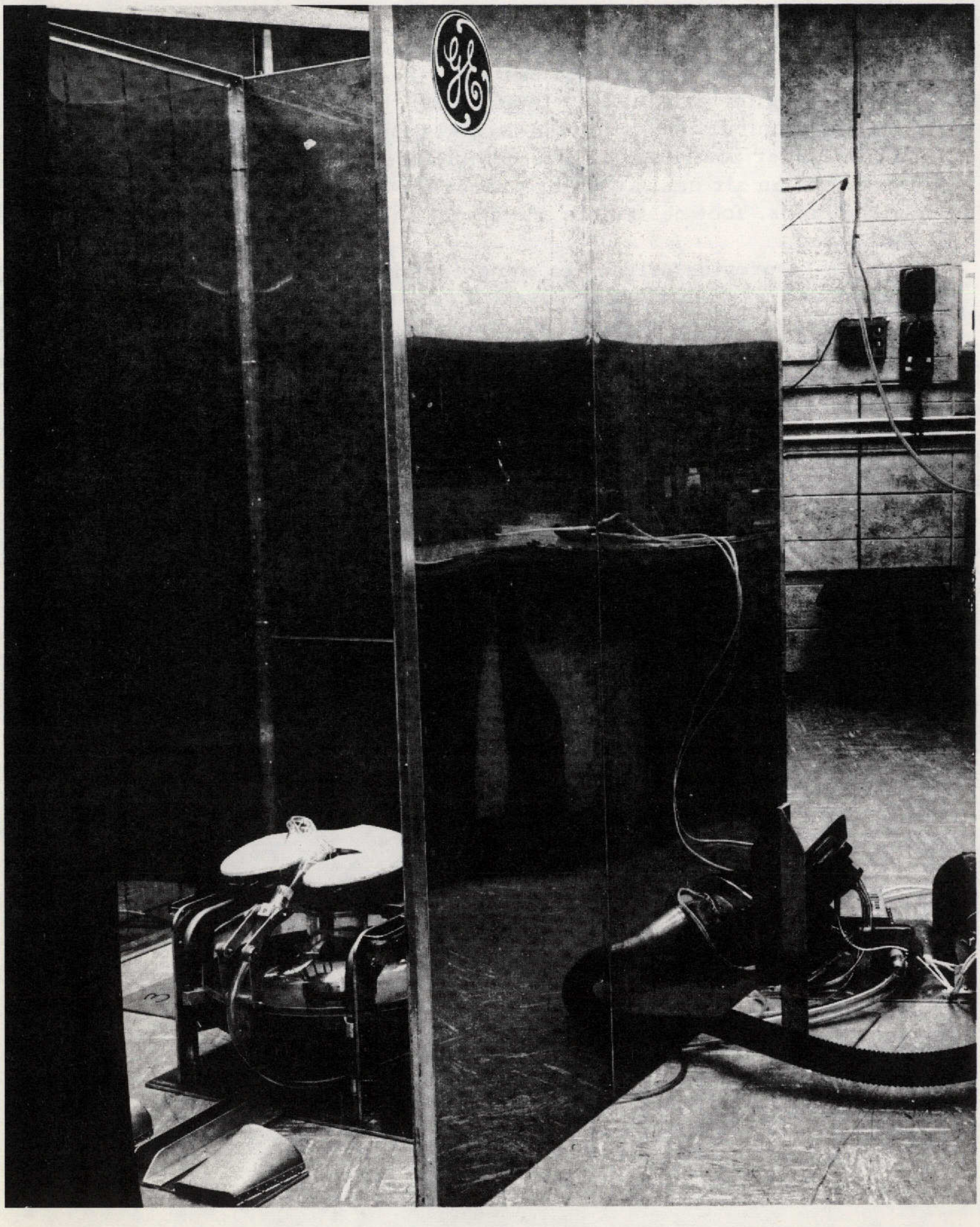

Figure 6.2.2-4. Dry John Zero "G" Test Unit With Privacy Enclosure

6.2.3 Procedures

Specific procedures for the fecal separation, transport and slinger studies have not been finalized. Additional Zero "G" tests using the Dry John equipment as updated from the simulated fecal transport tests are planned for the near future.

6.2.4 Results

T B D

6.3 URINE CAPTURE, CONTAINMENT AND TRANSPORT - SIMULATION STUDIES

6.3.1 Approach

The general approach to urine capture containment and transport studies was to concentrate on development of equipment for the female astronaut using first a ground testing and then a Zero "G" Flight testing environment.

Development of the urinal configuration included checks of fit and orientation to a female mannikin. Several systems for artificial urine flow and air transport were checked out and calibrated in ground tests.

For flight tests, the mannikin was mounted on the Dry John Unit. Test runs involved varying urine flow rates and transport air flow rates. This combination provided the performance envelope of satisfactory capture, containment and transport of simulated micturition using the female mannikin. Four levels of urine flow were used for each of the air flow rates. Data was gathered under Zero "G" flight conditions by high-speed movies.

6.3.2 Equipment

For initial studies of urine capture containment and transport under simulated conditions, the test equipment included a female mannikin, urinal assembly, phase separator and blower together with flow instrumentation and photographic data collection equipment.

The mannikin used for the tests was Gynny Pelvic Training Model obtained from the Ortho Pharmaceutical Corporation. The model was modified by the addition of a simulated urethra and an air pressurized system for providing a simulated urine flow. The quantity and flow rates of the simulated urine flow could be manually controlled. The basic elements of the system are shown in Figure 6.3.2-1.

Two types of urinal assemblies were constructed for the tests, but the main effort concentrated on the female urinal development as there already existed substantial space experiences with male urinal assemblies. Basic configuration of the male/female urinal was a receptacle approximately 2" wide x 5" long which is contoured to fit a periferical area surrounding the vulva. The urinal is shown in Figure 6.3.2-2. The structural connection element is interrupted to provide an inlet for transport air flow. Configuration and size of the inlets is intended to give a continuous in-flow of air around the full periphery directed parallel and in close proximity to local skin contour. A local air velocity of 20 ft/sec was expected to be adequate for capture and transport of urine droplets and splatter.

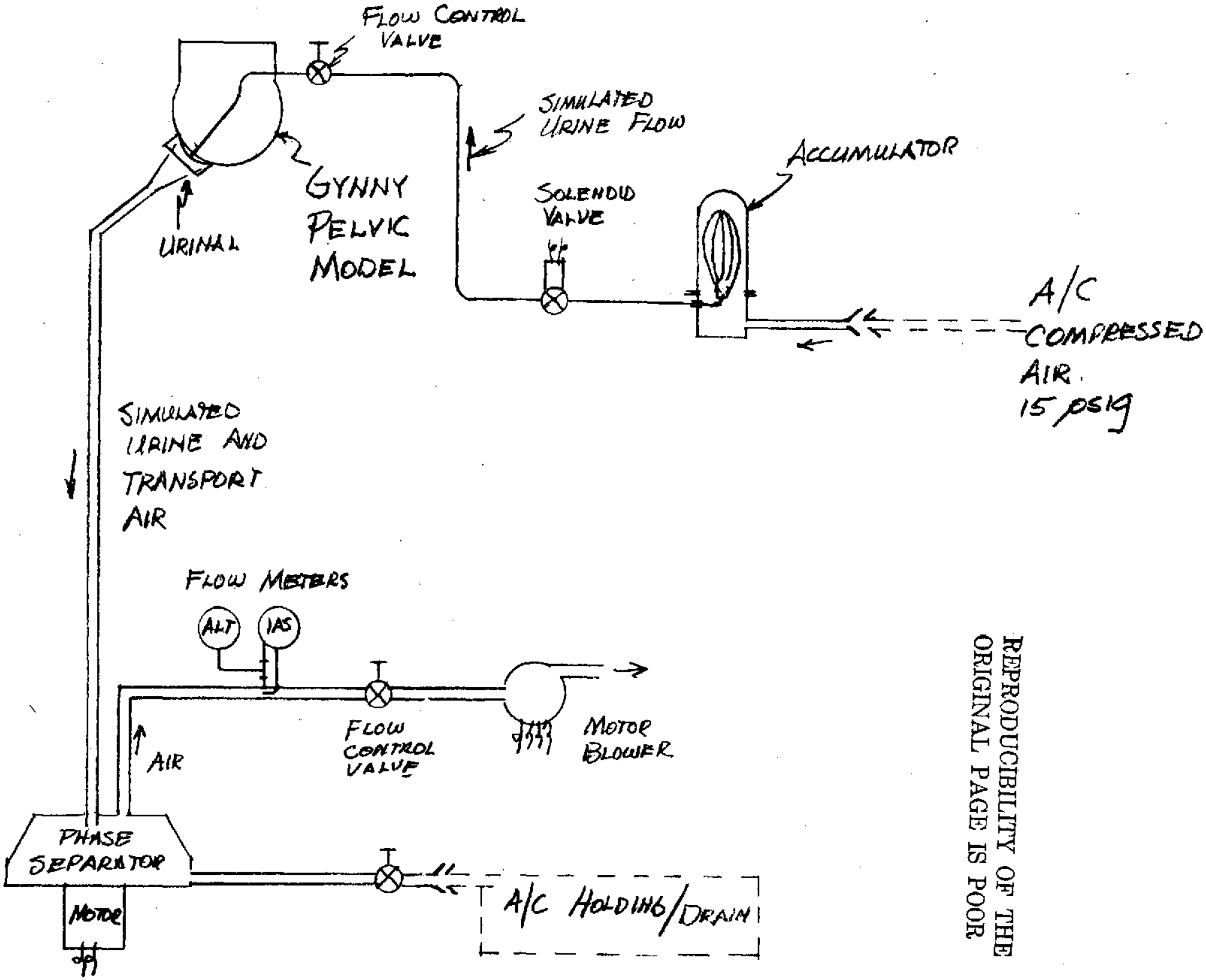

Figure 6.3.2-1. Elements of the System for Simulation of Female Micturition

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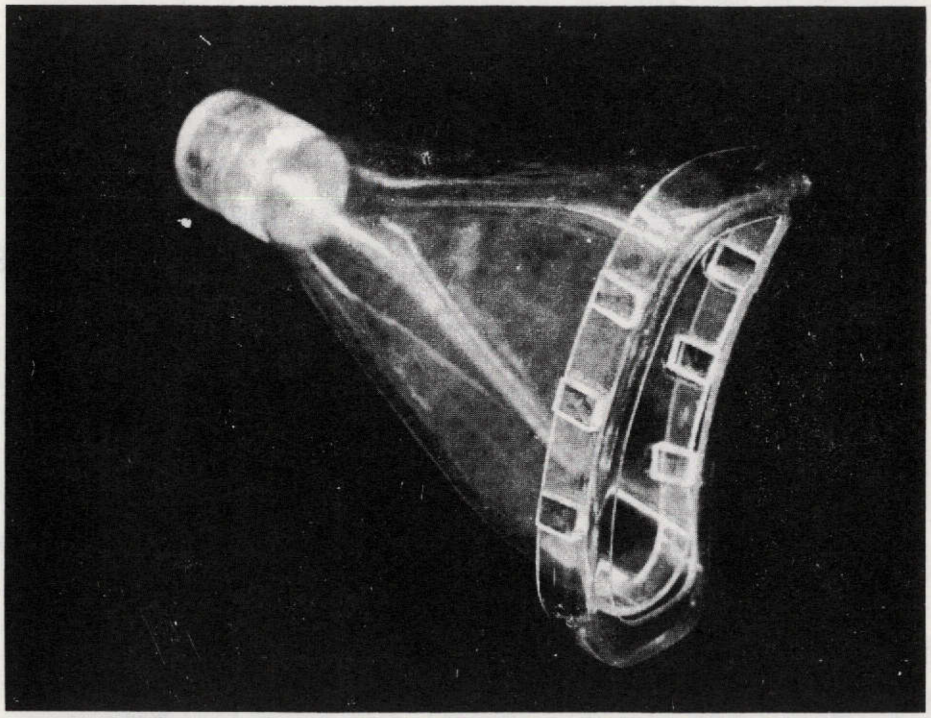


Figure 6.3.2-2. Male/Female Urine Receptacle

The remaining elements of the urine collection system included a centrifical phase separator to remove all liquid from the transport flow before the air stream proceeded to the blower and exited. The blower used was a 400 Hz ac motor driven centrifugal unit rated at 25 cfm @ 10" wc. Actual flow was controlled by an in-line butterfly valve and measured by pilot and static tubes in the exit of the phase separator.

6.3.3 Procedures

Procedures used for Zero "G" flight test of simulated urine capture containment and transport involved the simultaneous variation of two collection parameters and observing the results under weightless conditions.

The mannikin and urine collection system described in Section 6.3.2 together with a pressurized water supply and camera equipment were given ground calibration runs and then installed in the test aircraft. Colored water used to simulate urine was set at 14 psi pressure to match ground calibration runs of the flow control needle valve.

During the Zero "G" maneuvers, a test plan, shown in Table 6.3.3-1, was followed which called for four different "urine" flow rates at each of 3 different air flows--a total of 12 runs on each of two flights. The equivalent rates were urine flow 1 to 24 ml/sec and transport air flows of 1.5 to 11 SCFM. For each run, the flow rates were set up prior to entry into weightlessness. Upon signal that Zero "G" had been obtained, a solenoid valve controlling urine flow was opened for a planned time period. Results of testing were recorded by movie camera.

Table 6.3.3-1.
Simulated Urination (Gynny) Test Plan

Flt	Date	Film Roll	Test No.	Test Dsc.	Air Flow CFM	Water Flow ml/sec
2	23 Apr '73	1	*1	Gynny - Air Flow/Water Rate	11	2
		↓	2		↓	4
			*3			8
			4			1
			5		5.2	2
			6		↓	4
			*7			8
			8			1
			9		2.5	2
			10		↓	4
		1	11			8
		2	12			1
4	25 Apr '73		*1		2.8	1
		1&2	2		↓	3
			3			8
			*4			24
			*5		5.5	1
			6		↓	3
			7			8
			No Run			24
			9		1.6	1
			10		↓	3
			11			8
			No Run			24
			13		<1.5	0.5
			14			0.5

6.3.4 Results

Zero Gravity tests of simulated urine collection were satisfactory for air flows of 3 cfm or above. On two different flights and 26 test runs various combinations of transport air flow and simulated urine flow were tried. Air flows ranged from 1 to 11 SCFM and "urine" flows were from 1 to 24 ml/sec. Collection performance aspects observed were entrainment of the liquid by air flow, escape or leakage of liquids from the urinal, and any pooling or build-up of liquid either on the female mannikin or the urinal receptacle. The results showed that the collection performance was more sensitive to air flow than to "urine" flow rates. For airflows less than 3 SCFM*, there was a tendancy for urine to pool or build up either on and within labia of the mannikin, or on interior surfaces of the receptacle. This tendancy was more marked when "urine" flow rates were low or at the termination of a higher flow rate. No escape of urine or wetting of the model in areas outside the labial opening were noted and satisfactory transport was obtained whenever airflows of 3 SCFM or more were used regardless of the "urine" flow rate.

6.4 URINE FLUSH TESTS

6.4.1 Approach

To permit repeated use of a urinal assembly, periodic flushing with water and/or a biocide solution may be required. The objective of the urinal flush tests was to determine the feasibility of an open spray type flush. An open spray type flush simplifies the urinal assembly design by not requiring a "capped" urinal during flushing. Greater flexibility in locating the urinal during the flush cycle may also be possible.

An existing urinal design, an early male/female use version, was modified to include a directed spray capability. The general test approach was to evaluate the effects of transport air flow and flush water flow rate combinations. Results were recorded photographically and keyed to the various test conditions.

*For the receptacle design used, 3 SCFM corresponds to air velocity of 7 f/s at the air inlet nozzle throat.

6.4.2 Equipment Description

The basic equipment to be used was an early version of the male/female urinal as described in Section 6.3.2. An open spray type flush device which could be placed in the urinal was used. Figures 6.4.2-1 and 6.4.2-2 air drawings shows the nozzle plenum and general test set-up, respectively.

6.4.3 Procedures

The general test procedure was as follows:

1. Prior to Zero "G" flight condition:

   a. Pressurize flush water supply tank to predetermined valve.

   b. Adjust flow control valve to desired setting (pre-calibrated).

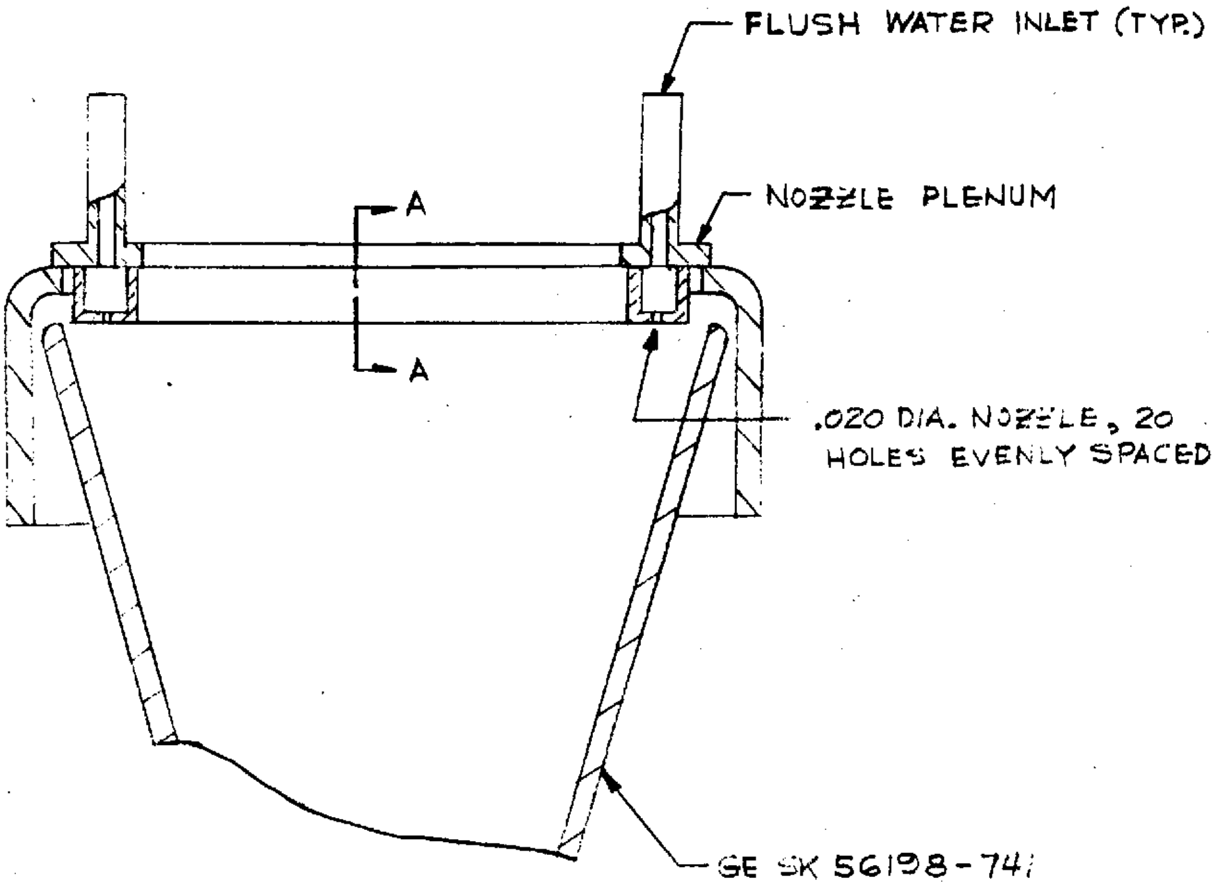
   c. Adjust transport air flow to desired setting (pre-calibrated).

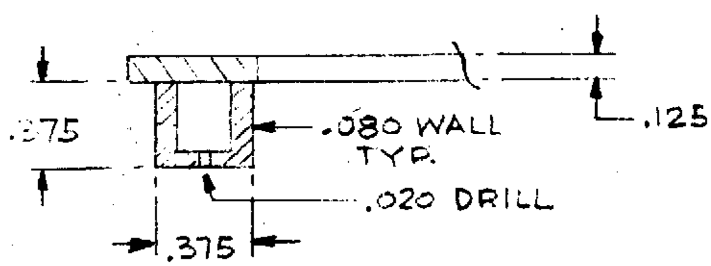
2. During Zero "G" flight condition:

   a. Camera (and camera lights) actuated by pilot.

   b. At camera ON signal, control switch actuated to open solenoid valve and start water flow.

   c. At end of approximately 3 to 5 seconds, flush water flow stopped by closing the solenoid valve. This rather short duration flush water flow period was used to assure sufficient time for the transport air to remove any accumulated fluid from the urinal.





SECTION A-A

Figure 6.4.2-1. Addition of Nozzle Plenum to Urinal Assembly (Not to Scale)

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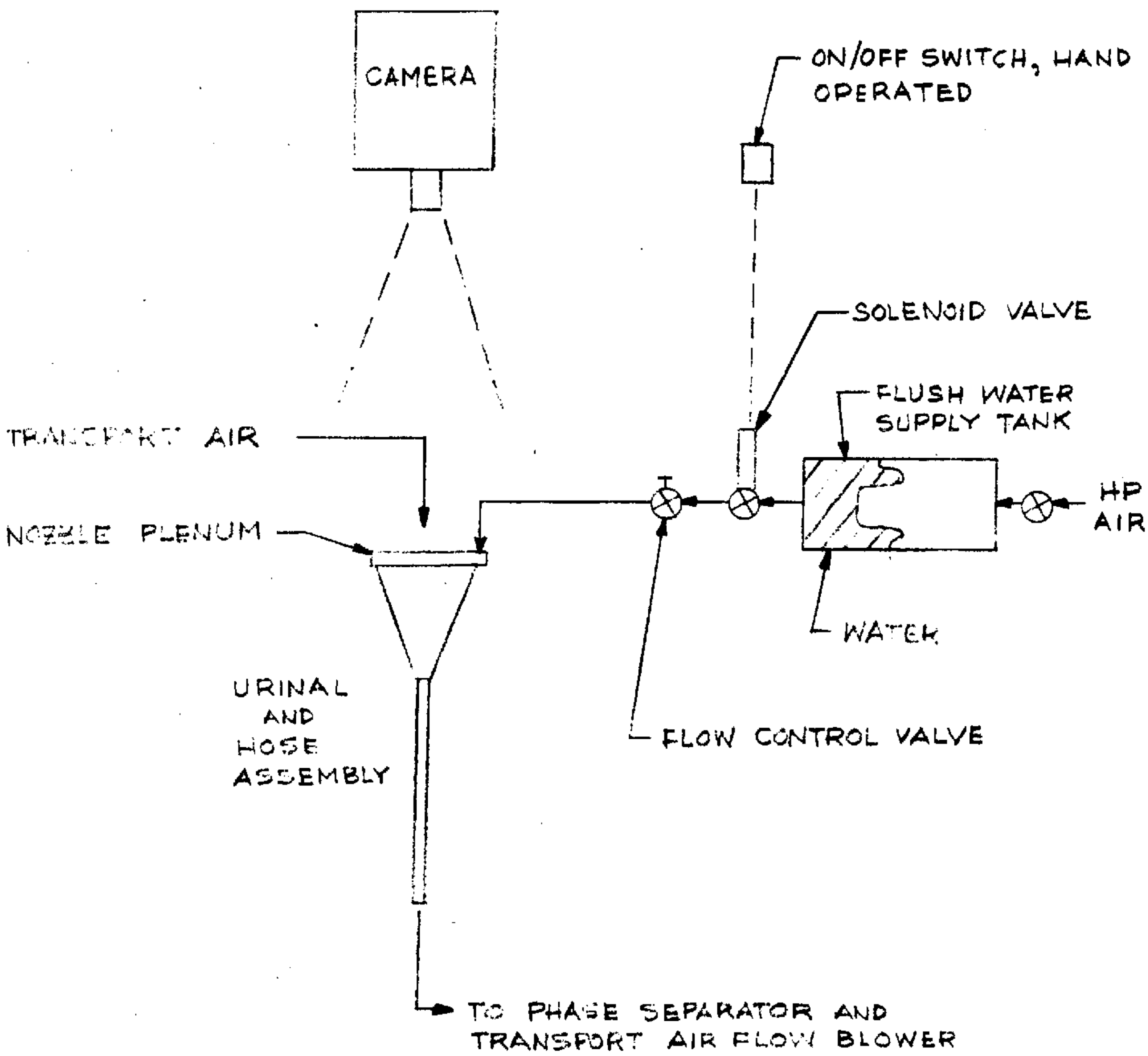

Figure 6.4.2-2. Test Set-Up

6.4.4 Results

Table 6.4.4-1 records the test conditions for the six tests planned and completed. Flush performance was satisfactory on all tests; i.e., flush water was confined to the urinal without loss to the surrounding ambient. Coverage, within the urinal, obtained by the multiple nozzle spray was comparable to that obtained under one "G" test conditions.

Table 6.4.4-1. Test Conditions for Urinal Flush Tests

Test	Transport Air Flow	Water Flush Flow	Water Flush Flow Duration
1	11.0 CFM	24 ml/sec	5 sec
2	5.5	24	5
3	2.8	24	5
4	11.0	36	3
5	5.5	36	3
6	2.8	36	3

6.5 URINE CAPTURE CONTAINMENT AND TRANSPORT - HUMAN SUBJECTS

6.5.1 Approach

Following the completion of the Zero "G" tests using the Gynny Pelvic Model for simulated female micturition, a series of tests using human subjects were planned to demonstrate the collection, containment and transport of urine in Zero "G" utilizing the GE Dry John. Using an optimum setting (or range of settings, if required) as established in the earlier Gynny Model simulation tests, ground baseline tests were run using three female subjects.* Subjects for the studies were briefed regarding equipment function and were debriefed both verbally and by questionnaire following use of the system. These ground baseline tests were used to: establish proper fit and adjustment of the urinal; orient and train the subjects; determine optimum camera angles for data collection; and obtain photographic data of female micturition in one "G" to demonstrate the feasibility of using the GE system in normal gravity as well as comparing one "G" and Zero "G" urine collection data. Subjects used for the baseline data collection were experienced subjects having previously used a urine waste management system during Zero "G" Keplarian flights; these same subjects are to be used in the Zero "G" Keplarian flight studies of the GE Dry John system. Through the use of the subjects in both one "G" ground baseline and Zero "G" studies, more adequate control of subject variables can be obtained. In addition, since the subjects had been used in other Zero "G" urine collection studies, comparison of the GE system with previously tested systems was possible at least on a subjective basis.

In addition, collection of urine in Zero "G" using the GE WMS concept has been accomplished. Over a series of parabolas, a complete micturition by a male subject was achieved.

*Air flows were basically optimized for female urine collection. Any values established for female micturition should be more than sufficient for male use.

Plans for the continuing Zero "G" portion of the test using additional male and female subjects are not yet finalized although the tests will be conducted as similarly as possible to the one "G" tests. In the Zero "G" tests, urine collection will be obtained from male and female subjects. In addition, male and female demonstration of operational usage of the waste management system including approach to the system, disrobing, engagement and use of restraints, system use and return to duty activities will be conducted as part of the Zero "G" testing.

The primary means of data collection for both the completed one "G" tests and future Zero "G" tests include motion pictures, questionnaires and debriefing of subjects.

6.5.2 Equipment Description

A close-up of the basic equipment used in the male urine collection Zero "G" study and the ground baseline data collection from female subjects is shown in Figure 6.5.2-1 and Figure 6.5.2-2. The equipment, with modifications by the addition of a seat (as described in Section 6.2.2) is basically the same as the equipment used in the simulated urine collection study, Section 6.3.2. A privacy enclosure was provided for the ground baseline studies and will be provided for the Zero "G" studies. Standard motion picture photography equipment were used for the ground baseline data studies and for the male urine collection study. Similar equipment will be used for future Zero "G" studies.

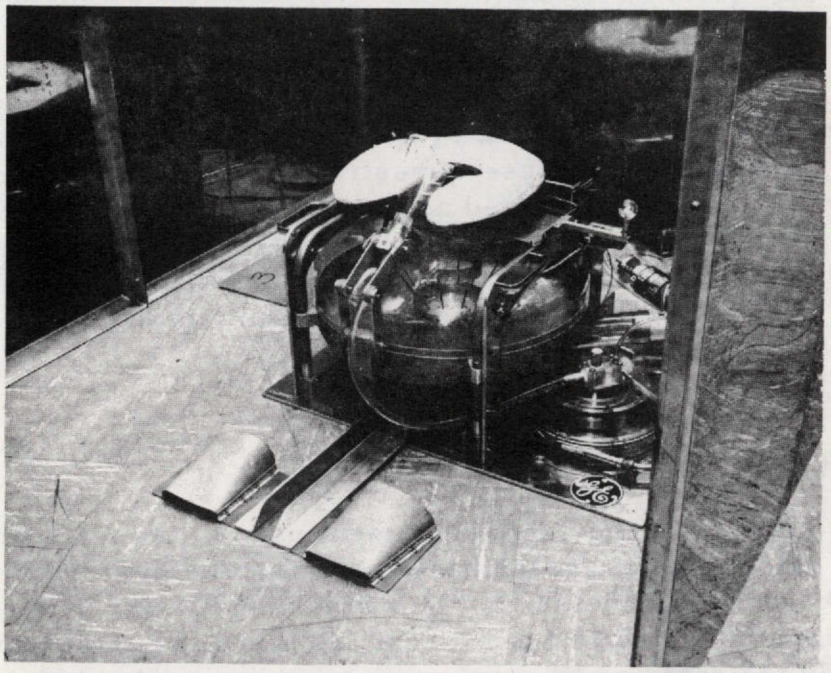

Figure 6.5.2-1. Urine and Fecal Collection System and Phase Separator for the Baseline and Zero "G" Studies

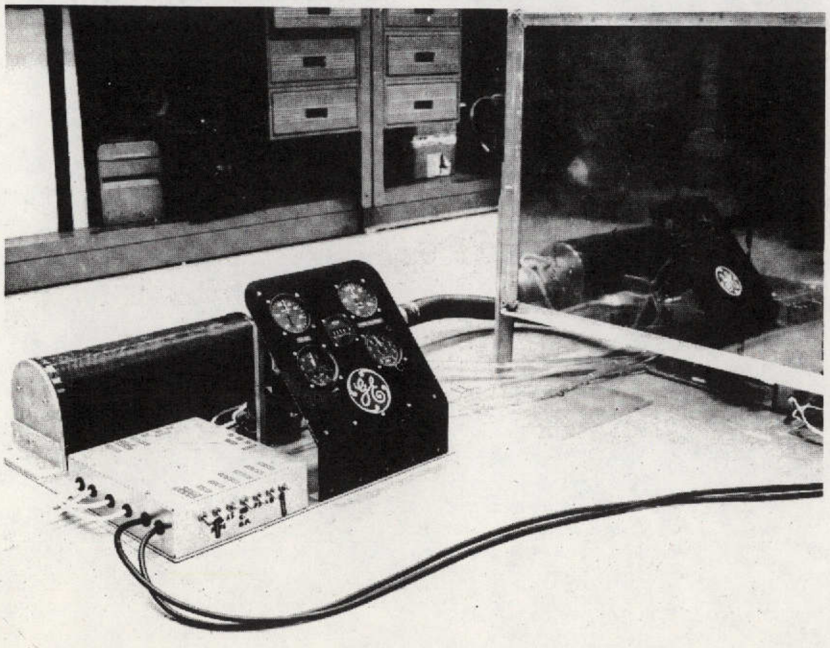

Figure 6.5.2-2. Blowers, Electronics, Odor Control Filter, Instrumentation and Controls for the Baseline and Zero "G" Studies

6.5.3 Procedures

6.5.3.1 Zero "G" Male Micturition

Urine collection using the male/female urine receptacle was accomplished by intermittent urine collection over a series of three parabolas. The test subject was in an "upright" position as opposed to a seated position to demonstrate the feasibility of using the male/female urine collector in a "standing" position. Air flow used in the urinal for the collection was 3 CFM. Recording of data was accomplished via motion picture photography.

6.5.3.2 Ground Baseline Data

Data on urine collection in one "G" was obtained from three female test volunteers. The subjects were first given a briefing describing overall function of the system and a demonstration of system functions was given. Each subject then used the system for a urine collection in the privacy of the enclosure. Air flow used in the urinal was 6 CFM. Motion picture photographic data of the micturition was taken for each subject. Following use of the system, each subject was individually debriefed and filled out a questionnaire. An example of the questionnaire can be found in the Appendix Section 10.2.

This entire process was repeated approximately 2 weeks later using the same subjects and test conditions. The equipment used for the second data collection was slightly different in that it was modified to give a larger range of position adjustment and spring loading to position and hold the urinal for the female urine collection. The questionnaires used for the second data collection session are provided in the Appendix Section 10.2.

6.5.4 Results

6.5.4.1 Zero "G" Male Micturition

Analysis of photographic data and subject comments indicate that the urine collection system for the Zero "G" male micturition were satisfactory. No difficulties were encountered with the use of the male/female device; entrapment, containment and transport of the urine at the 3 CFM flow were entirely satisfactory. During the urine collection and especially during the transition phase and two "G" phases of the urine collection, limited restraint of the subject, in addition to the Dutch Shoe Restraint, had to be provided. The need for the additional restraint was primarily created by the transition phase between the Zero and two "G" periods and the two "G" portion of the parabola. Dutch Shoes or a comparable restraint should be entirely satisfactory for true Zero "G" use.

6.5.4.2 Ground Baseline Data

All uses of the urine collection system in the one "G" baseline data tests by the three female users were completely satisfactory. Entrapment, containment and transport of the urine in the system were entirely adequate. Further, the subjects found the urinal, especially the spring loaded device used in the second session, to be very comfortable and in general provided a feeling of security during use in that the urine was effectively collected and contained. One significant advantage to the urinal design was that the subjects found that there was little if any need to wipe the vulva and labial area following micturition. This was due to the gentle "scrubbing" action of the air flow at the opening of the urinal in combination with the separation of the labia created by the lip of the urinal. The resulting effect was to remove any residual urine from the vulva.

The subjective evaluation of the system by the subjects was highly favorable. In general, the subjects preferred the system over previously tested systems. The seat/urinal combination was found to be comfortable and easy to use. All the questionnaire data obtained from the subjects for both data collection sessions can be found in the Appendix Section 10.

7.0 DISCUSSION

7.1 SIMULATION ACCURACY

The simulations used for this program are believed to be adequate to assess the parameters of interest evaluated in this study. However, it is felt that a discussion of the potential limitations of the simulations would be of benefit to those readers unfamiliar with the techniques used.

A substantial part of this study was based upon simulations, especially during the early phases. Later testing will have less simulation as the program passes into the human usage testing. Simulations of fecal material, stool generation, urine, and female genital configuration as well as the space environment, were used with varying degrees of accuracy.

The zero gravity environment of space as simulated by Keplerian maneuvers in an aircraft is unrealistic in several aspects. The duration of weightlessness is short and is preceded and followed by 2 to 2-1/2g periods; further, the acceleration is only approximately zero. Although the test runs were structured to be completed within 20 seconds, some results were still questionable. For example, fecal separation that did not occur within the 20-25 second weightlessness was reliably completed by the subsequent 2-1/2g acceleration of aircraft "Pull Out and Recovery." "Firm" fecal material was substantially affected while other consistencies separated without this difficulty. To some degree, the artificial sphincter of the feces generator was involved along with the fecal material and there is little firm basis for making a definite judgment as to the simulation accuracy of component functions of the overall separator process. Other than the "firm" feces separation, the human micturition was also affected by shorness of the Zero "G" periods relative to the overall cycle time of a normal micturition. However, the effect of this on a collection system was minimal and was in part accommodated by providing for higher maximum urine flow rates than those observed in this Zero "G" environment. Accuracy with which zero gravity was maintained during a maneuver depends upon tracking errors of the closed loop system including a sensing accelerometer, cockpit display instruments, pilot response and the aircraft pitch control dynamics over a wide speed range, together with disturbance effects from atmospheric turbulence. No quantitative accuracy data was available, but personal observation was that for the five flights to date, test run results have not been significantly affected by inaccuracies in maintaining the Zero "G" environment.

7.2 EQUIPMENT FUNCTION

Analysis of movie film data on the simulated fecal collection runs showed considerable dispersion in the velocity and separation performance results. Part of this has been subsequently attributed to random and occasional disruption of the air seal between seat and inlet ring. Attachment of the seat to the inlet ring is by a hinge plus somewhat resilient hold-downs. In turn, the feces generator mounts onto the seat. As the fecal generator is manually operated and the test personnel had minimal body restraints in flight, there were occasional extraneous torques on the feces generator as the test personnel steadied themselves during weightless periods. Torques above 25 in-lbs. about the seat hinge axis would cause variable leakage of air across the seat/inlet ring seal and confound test results. This was substantiated by occasional observations of erratic readings of bowl and duct altitude instruments. The probable effect of such leakage flow is to reduce the inlet velocities and distort the air flow distribution pattern. A result would be a lessening and distortion of the localized high pressure zone at the anal area. Weakening and eccentricity of the separation force would result with visible effect on separation, initial stool velocities and direction.

Data on performance of separation assists was primarily an average velocity of the stool over a short distance until contact was made with the slinger. With the long stools used on the first flight, the free travel distance was too short to get any velocity measurements. On successive flights having runs with shorter stool lengths, velocity data was taken on eleven runs. From these, there was enough information about three of the four separation conditions to draw some inferences. For example, for no separation assist (other than from the transport air always present), a characteristic velocity was 5"/sec. and with high pressure air jets, or air jets plus jounce, the velocity was typically 10-15"/sec. for the "jounce only" condition no usable velocity data came out.

A very interesting aspect of the observations of stool velocity is that essentially all of the velocity change appears to happen very soon after separation. As earlier measurements of transport air velocity gave a core velocity on the order of 40 ft/sec., this is not the probable controlling phenomena. A more likely cause would be an acceleration for limited distance defined by the local high pressure at the simulated anus. Transport air inlet velocity vector direction is turned from radially inward to downward along transport tube axis. This velocity change must be supported by a reaction force which probably results in a local high pressure zone located where the velocity change is taking place. By design, this zone is located just below the anal opening. Local high pressure in this zone operating on any differential area presented by the stool results in an impulsive acceleration of the stool away from the anal area. It can also be speculated that the local high pressure zone may be of some assistance to the sphincter in pinching off the fecal material to form a separated stool.

7.3 DESIGN IMPLICATIONS

7.3.1 User Acceptance

User acceptance is a key issue in the Shuttle Orbiter Waste Management Subsystem because it is likely that some of the crew will not be dedicated trained astronauts. Consequently, near earthlike procedures must be used to facilitate acceptance. In addition to the standard limitations of size, weight and power, and the system must also be clean, sanitary and not impact the spacecraft's environment; i.e., noise, microorganism or odor release.

The Zero "G" test unit offered several features to enhance user acceptance; i.e., hand holds, seat belt, foot restraints, spring loaded urinal pressure for females, and a cushion seat. The test unit also pointed out areas that need improvement.

7.3.1.1 Acceptance Improvement

It is recommended that several hardware design areas be improved prior to the next series of user tests:

A. Urinal - Methods to sanitize or replace the user interface needs definition and user tests.

B. Urinal Support - The mechanical urinal support requires refinement to permit positioning without "springback" and repositioning for standup usage. Also, the support and urinal should not interfere with seating, exiting or require inordinate disrobing.

C. Seat - The seat should be fabricated of a soft material for comfort and a smooth surface for easy cleaning. In addition, additional tactile information should be provided to further aid in user positioning.

7.3.2 Functional Hardware

The functional hardware design has seen several refinements and over 600 man-days of usage in normal gravity. However, the Zero "G" tests showed several areas requiring improvement.

It is recommended that several functional hardware designs be improved prior to the next series of tests:

A. Air Transport Jets - The air jets used to separate and transport the stool need further analyses to determine optimum configuration. Neutral buoyancy tests in the laboratory are being initiated for this purpose. As an example, the 30 CFM air flow required for the commode may be significantly reduced if supplemental high pressure jets are utilized for brief periods.

B. Transport Tube - Smearing of the transport tube with feces proved to be a problem during photographic analyses of stool transport. Periodic cleanup may be required during spaceflight and should be investigated.

C. Toilet Tissue - Single sheet tissue is recommended for deposit into the commode, because of the lower probability of clogging the slinger.

D. Urinal Flush - Wide slot orifices are recommended for the flush spray to better wet the urinal internal surface.

8.0 CONCLUSIONS

The tests and data analysis to date provide a high degree of confidence that the Shuttle Orbiter Waste Management Subsystem (WMS) will operate properly in zero gravity during actual usage. However, these users tests must be accomplished prior to commitment to this design for the flight vehicle.

One other observation is that the WMS is very tolerant to perturbations in test conditions. During the 115 test parabolas using a wide range of test conditions and gravity environments, at no time did the simulated and real waste material escape from the collecting devices to contaminate the user, test equipment or aircraft.

Summarization of the conclusions of the study are:

- Tests have confirmed the soundness of the GE Dry John approach to Shuttle WMS Requirements and give high degree of confidence that subsequent Zero "G" tests with human male and female users will be successful.
- Have established a baseline equipment configuration and adjustments for subsequent Zero "G" User Tests.
- Adequate female urine collection can be obtained with 5 to 10 CFM transport air flow when a small receptacle of design as depicted in Figure 6.3.2-2 is used.
- Males can use the same urine collection system, but more optimum conditions will be obtained with a modified configuration receptacle and lower transport air flow rates.
- Adequate fecal collection and transport can be obtained @ 30 CFM with the configuration used, involving seat, transport air inlet ring, valve, transport tube, slinger and storage bowl.
- Soft or diarrhetic feces can be separated and transported with contamination and soilage contained within the system (below Slide Valve).
- Tissue wipes of the single sheet can pass thru a properly designed slinger. Larger tissues in combination with bladed or more erect tines can lead to tissue hang-up in the impeller.

- Fecal separation under Zero "G" conditions can be assisted by forces from properly configured air jets and acceleration induced by the subject.

- Simulation such as the "Gynny" gynecological model and the stool generator are useful tools for the development and establishment of operating parameters of a metabolic waste collection system.

9.0 RECOMMENDATIONS

9.1 OVERALL RECOMMENDATIONS

The reported project has been a very successful test program in which the scope has been severely limited by availability of the zero gravity test aircraft and user personnel. Future investigations must be continued to provide a firmer basis of design and to compensate for expected anomalies in user physique, waste quantity and waste composition. Some of the areas recommended for continued and additional definition and investigation are:

1. Commode air flow rate and air inlet configuration
2. Stool separation techniques
3. Transport tube clean-up
4. Tissue wipe transport and storage
5. Slinger tine optimization for speed and configuration
6. User preparation, positioning and disengagement in zero gravity
7. Female use of urinal and commode in zero gravity (several subjects)
8. Male use of commode in zero gravity (several subjects)
9. Failure mode operation in zero gravity
10. Unit sanitation
11. Urinal configuration
12. Ground servicing
13. Vehicle integration

It is recommended that the above be accomplished using three methods; namely, laboratory tests, Zero "G" aircraft tests and of course analytic analysis.

9.2 ANALYTIC ANALYSIS

Analytic analysis is a prerequisite for all the tasks; however, at this early stage in the Shuttle Orbiter Waste Management Subsystem design, the vehicle integration task can only be accomplished analytically and with conceptual layouts. Such factors as weight, configuration, mounting, electrical power, monitoring electronics, pressurized gas sources, vent nozzles outlets, leakage rates and center of gravity change are of prime concern to the vehicle. However, of prime concern to the user will be appearance, ease of access and operation, privacy, operational efficiency (no mess or odors) and minimal noise (a SKYLAB problem).

9.3 LABORATORY TESTS

Neutral buoyancy offers a chance to test and refine designs in a controlled simulated space environment prior to the necessary final validation in zero gravity. Neutral buoyancy uses neutrally buoyant simulated stools in water to approximate the conditions of an actual stool being air transported in zero gravity. Optimization of commode air flow rate, air inlet configuration and stool separation techniques can best be evaluated and refined with this technique.

Laboratory test can also be used to define transport tube clean-up, tissue wipe transport and storage, unit sanitation, urinal configuration and ground servicing techniques.

9.4 AIRCRAFT TESTS

The final operational proof of system operation must be accomplished in Zero "G" aircraft tests prior to acceptance as a spacecraft design. The test protocol of controlled simulated waste discharges, baseline user tests and actual Zero "G" user tests used in this reported program is a very valid approach to the problem. Subject to aircraft and user availability, these tests should be continued.

SECTION 10 APPENDIX

10.1 ZERO "G" FILM NARRATIVE

To those unfamiliar with Zero "G" testing in a KC-135 aircraft, a brief introduction is given to show what the aircraft and crew must go through to simulate the null gravity of space.

After the aircraft climbs to about 24,000 feet with a speed of 520 miles per hour a series of parabolas are initiated which provide about 30 seconds of zero gravity per parabola.

As filmed from a ground based phototheodilite camera about 25 miles away, the parabolas are quite rigorous and produce 2 "g's" going into and coming out of the Zero "G" phase. The distance covered for each parabola is about 9 miles and the aircraft fuselage deflects about 1 foot during the maneuver.

The interior views show the "Gynny" female simulator mounted on the seat of a Dry John commode. Initial tests simulate female urinations at various air and urine flow rates. Note that camera lites are on during only zero "G" condition via pilot control.

The first scene shows urine pooling at a negligible air flow. Note that even though the urine pool collects near the model, none escapes from the urinal. This attests to the fail-safe character of the urinal design.

As the air flow is increased to 2.8 CFM, the high urine flow of 24 ml/sec is accommodated; however, there is some droplet collection on the urinal. Note how the air flow pinches off a urine droplet as it exits.

The major part of the splattering was controlled as the air flow was increased to 5.5 CFM. Also, droplet pinch off becomes quicker.

As the air flow was increased to 11 CFM, urine control is complete so that a flow of between the range of 5.5 and 11 CFM will provide urine collection for females. Note the trajectory of the urine droplets as they are emitted and drawn into the urinal outlet.

Ground baseline tests of the urinal with live subjects were very similar to the Zero "G" test. When positioned, the urinal opens the labium majus and labium minus to promote streamlined urine flow and minimize droplet formation. You can see how completely the labium was opened by the slight pressure on the mons pubis and labium. Note how the air flow vibrates the pubic hair and how thoroughly droplets are carried away. None of the gals had to use a wipe.

Going back to the Zero "G" tests, the liquid/gas separator operated successfully during all tests. Note the air/liquid mixture entering the separator and that there is no liquid in the air exit line. This is necessary to maximize downstream air filter efficiency.

The urinal design flexibility permits urine collection during the vertical vehicle launch position as well as while in Zero "G". Here the urinal was repositioned for upright male urination and tests were conducted during three parabolas using an air flow of 3 cfm. The user is standing in "Dutch Shoes" foot restraints and because of the violent 2 "G" period before and after the Zero "G" phase, the user was supported by two men and had to place his penis fully into the urinal to avoid potential spillage during the 2 "G" phase.

Another view of the aircraft interior shows the feces simulator mounted on the Dry-John seat. Several stool consistencies, sizes, air flows, separation techniques, air inlet configurations, transport tube configurations and air flow rates are shown next. Again, the slow motion films are 8 to 20 times longer than actual time.

This series taken by a side angle camera focused on the transport tube shows a firm stool color, coded blue, being air transported to the slinger, followed by a normal stool, coded red, and a diarrhetic stool, coded white. An artificial sphincter squeezes the stool into a small cross-sectional area and either the normal transport air, an air jet assist or a simulation of the normal anal canal movement is used to separate the stool. Note that the stool is angled forward to simulate actual stool exiting.

Next, a series of slinger and transport tube configurations are tested. But first, note the build-up of feces in red, white and blue layers over this test series and that the two 2 "G" environments encountered for each loop attest to the good feces adhesion to the wall.

Initially two row tine configurations were tested to observe stool shredding capability and ability to supplement the transport air flow, thereby reducing blower size. Both worked well on all feces consistencies but clogged on tissue wipes. The second configuration was photographed at 500 frames per second or 20 times the normal speed. Notice how stable the stool is in the transport tube. Note that with this slinger configuration, there is some feces hang-up on the inner tines. Also a piece of tissue is partially covered by the successive layers of feces illustrates the packing effect on the tissue. As previously shown, the feces adheres quite well to the walls even in 2 "G" conditions; however, a few pieces do not adhere and these will not dry as rapidly because of poor heat transfer to the feces. These particles or microorganisms cannot escape the container because of the inward air flow.

This configuration worked well with tissue when the slinger rotation was reversed.

On the third run, the simulated anal canal movement is best depicted. The anus normally moves approximately 1/2 inch during defecation and sphincter operation. This sequence is a little exaggerated.

This sequence shows the selected slinger configuration with a single row of tines. This arrangement operated successfully in over 600 man-days of testing.

Note that there is no feces retention in the slinger as disclosed in the previous configuration; however, some small feces did escape the shredder action necessitating a 1/2 inch increase in time length. The last run filmed at 20 times normal speed used no assist with a diarrhetic stool which contacted and adhered to the wall about 2-3 inches below the anus. This sequence was the worse case of several tests. Note that separation from the anus was achieved by the pinching action of the transport air flow. Also, the stool is eventually conveyed into the slinger in the total 25 second time period. It is evident that periodic cleaning of the transport tube may be required when diarrhetic or explosive stools are encountered. This obviously can be accomplished manually with a tissue/plunger combination with the tissue deposited into the commode. Other automatic means are being evaluated.

10.2 TEST SUBJECT QUESTIONNAIRES

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Waste Collection System Questionnaire

Part I

Normal Gravity Urine Collection

Test Subject No. 1

Date 11 May 73 Trial No. 1

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the urine collection? Yes ____ No X. If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No X If yes, please describe approximate area and quantity of urine. No "pooling - but "felt" as if the urine was spreading towards the rear. In reality it was not.

4) Was the urine collecting device in appropriate position during the micturition period? Yes X No ____ If any positioning difficulties were encountered, please explain or describe. I could not [illegible] the ischial "spots" - I tilted somewhat forward to get a fit.

5) The air flow in the urine collecting device can best be described as: Unnoticeable ✓ Comfortable ____ Uncomfortable ____
If you wish, further describe or explain. Although it was probably the air flow that made me feel as if I were "wet" (#3)

6) What restraint/positioning devices were used during the urine collection? Foot ________ Hand ________ Seat Belt ________. Were these restraint/positioning devices effective? Yes ________ No ________ Please describe or provide additional comments.

N/A

7) Was the seat/restraint combination comfortable during urine collection? Yes ________ No ________. Please describe or provide additional comments.

N/A

8) Please provide any additional comments on the performance of the urine collecting system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part I

Normal Gravity Urine Collection

Test Subject No. 2

Date 11 May 73 Trial No. 1

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the urine collection? Yes ____ No ✓. If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓ If yes, please describe approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the micturition period? Yes ✓ No ____ If any positioning difficulties were encountered, please explain or describe.

5) The air flow in the urine collecting device can best be described as: Unnoticeable ____ Comfortable ✓ Uncomfortable ____ If you wish, further describe or explain.

6) What restraint/positioning devices were used during the urine collection? Foot ________ Hand ________ Seat Belt ________. Were these restraint/positioning devices effective? Yes ________ No ________ Please describe or provide additional comments.

na

7) Was the seat/restraint combination comfortable during urine collection? Yes ________ No ________. Please describe or provide additional comments.

na -

8) Please provide any additional comments on the performance of the urine collecting system.

There was no backflow or leakage because I felt that I was getting wet -

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Waste Collection System Questionnaire

Part I

Normal Gravity Urine Collection

Test Subject No. 3

Date 11 May 73 Trial No. 1

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the urine collection? Yes ____ No ✓. If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓ If yes, please describe approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the micturition period? Yes ✓ No ____ If any positioning difficulties were encountered, please explain or describe.

But I did need to hold it against the vulva to make a tighter seal.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ____ Comfortable ✓ Uncomfortable ____
If you wish, further describe or explain.

Very much so - it was almost unnoticeable. And the temperature of the air flow I felt aided in the start of micturation.

6) What restraint/positioning devices were used during the urine collection? Foot __________ Hand __________ Seat Belt __________. Were these restraint/positioning devices effective? Yes __________ No __________ Please describe or provide additional comments.

Does not apply

7) Was the seat/restraint combination comfortable during urine collection? Yes __________ No __________. Please describe or provide additional comments.

Does not apply

8) Please provide any additional comments on the performance of the urine collecting system.

I like the idea of the collecting system fitting the way it does. I felt completely confident over the sealage of the unit. The air flow was so comfortable, I hardly knew there was one. The seat is very comfortable also. When I finished I felt completely dry & much relieved.

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GENERAL ELECTRIC

Waste Collection System Questionnaire

Part I

Normal Gravity Urine Collection

Test Subject No. 1

Date [illegible]   Trial No. 2

1) Was micturition achieved? Yes X No ____

2) Was there any backsplash or leakage onto yourself or the seat during the urine collection? Yes ____ No X . If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No X If yes, please describe approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the micturition period? Yes X No ____ If any positioning difficulties were encountered, please explain or describe. With the Jensen device (1) greater ease in positioning correctly — (2) no feeling of "becoming wet" as in previous test. (3) Very comfortable (no excess pressure) (4) no need to manually apply pressure

5) The air flow in the urine collecting device can best be described as: Unnoticeable X Comfortable ____ Uncomfortable ____ If you wish, further describe or explain.

(1) No feeling of airflow at all
(2) Had no sensation of voiding at all (checked visually to see if and finished)
(3) Did not have to use "wipe".

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6) What restraint/positioning devices were used during the urine collection? Foot __X__ Hand ______ Seat Belt ______. Were these restraint/positioning devices effective? Yes __X__ No ______
Please describe or provide additional comments.

If I were to have to use these foot restraint routinely, I would position them closer together - For purpose of the test ~~and~~ to accommodate photography they were comfortable, however

7) Was the seat/restraint combination comfortable during urine collection? Yes __X__ No ______. Please describe or provide additional comments.

~~No restraint used~~ ~~Foot~~
Seat restraint not used

8) Please provide any additional comments on the performance of the urine collecting system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part I

Normal Gravity Urine Collection

Test Subject No. 2

Date 5-23-73 Trial No. 2

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the urine collection? Yes ____ No ✓. If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓ If yes, please describe approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the micturition period? Yes ✓ No ____ If any positioning difficulties were encountered, please explain or describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ____ Comfortable ✓ Uncomfortable ____
If you wish, further describe or explain.

6) What restraint/positioning devices were used during the urine collection? Foot ________ Hand ________ Seat Belt ________. Were these restraint/positioning devices effective? Yes ________ No ________ Please describe or provide additional comments.

na

7) Was the seat/restraint combination comfortable during urine collection? Yes ________ No ________. Please describe or provide additional comments.

na

8) Please provide any additional comments on the performance of the urine collecting system.

Comfortable

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part I

Normal Gravity Urine Collection

Test Subject No. 3

Date 23 May 73 Trial No. 2

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the urine collection? Yes ____ No ✓. If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓ If yes, please describe approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the micturition period? Yes ✓ No ____ If any positioning difficulties were encountered, please explain or describe.
Spring tension wires worked great in holding it in place with no adjustment needed during micturition at all.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ✓ Comfortable ✓ Uncomfortable ____
If you wish, further describe or explain.

6) What restraint/positioning devices were used during the urine collection? Foot ✓ Hand ________ Seat Belt ________. Were these restraint/positioning devices effective? Yes ✓ No ________ Please describe or provide additional comments.

They allow you keep flexion + separation of legs at the right position + lessing pressure on the buttocks.

7) Was the seat/restraint combination comfortable during urine collection? Yes ✓ No ________. Please describe or provide additional comments.

8) Please provide any additional comments on the performance of the urine collecting system.

My previous information speaks for itself. It's a great system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Design Optimization

Test Subject No. 1

Date 5-23-77 Trial No. 2

1) a. Did the current GE system perform adequately for urine collection in normal gravity? yes - no backsplash or leakage; airflow unnoticeable - no paper "wipe" needed.

b. Did the urinal positioning system function appropriately? Yes X No ____. Please comment. Tension device provided comfortable 'seal' of the collector with no need to manually accommodate - Ease in positioning on the ischeal 'points' of the seat

c. Was the pressure excited by the urinal positioning mechanism adequate to result in a proper seal for micturition? Yes X No ____ Please comment.
no backsplash, etc. - no feeling of becoming "wet".

d. Was the pressure applied by the urine collector: Comfortable X; Uncomfortable ____; Essentially unnoticeable ____.
Comfort is not synon. with security - But I felt more secure in the position - and no discomfort

2) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No X. If yes, please describe the approximate area and quantity of urine.
no pooling or accumulation -

3) The air flow in the urine collecting device can best be described as: Unnoticeable X; Comfortable ____ Uncomfortable ____
If you wish, further describe or explain.
(1) No feeling of airflow at all
(2) Had no sensation of voiding at all (check visually to insure had finished)
(3) No paper "wipe" needed -

4) Based upon your experience with the GE system, what features do you like best about it? What features do you dislike?

like
1. Compact, i.e. fits over the "essentials" so no danger of splash onto thighs or other perineal portions
2. less noisey
3. Airflow unnoticeable but more than adequate —
4. Comfortable seat —

5) Based upon your experience of using a urine collection system in zero gravity, are there any improvements that you would recommend for the GE system for the planned zero gravity test flights or the actual zero gravity conditions of space flight? 1. Make sure you incorporate that tension device! I would need to use handholds or seat restraint in 0 G.

6) Although you have not yet had an opportunity to use the GE system in zero gravity, please compare the general concept of the GE low air flow type urine collection system with the general concept of a urine collecting system using an open urine collector with a higher air flow. Please consider all aspects of the system, but be sure to consider such areas as: confidence of urine containment; general user acceptance and user comfort. In addition, in what ways do you think that the two different concepts of urine collection are superior or inferior to each other?

GE ① more confidence of containment — less area exposed — and pressure of collecting device gives feeling of security
② greater user acceptance (for myself anyway)
③ greater comfort — no noticeable airflow, less noise, no need to use "wipe"; seat is very comfortable and ischial landmarks provide facility in positioning.

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GENERAL ELECTRIC

Waste Collection System Questionnaire

Design Optimization

Test Subject No. 2

Date 5-23-73 Trial No. 2

1) a. Did the current GE system perform adequately for urine collection in normal gravity?

b. Did the urinal positioning system function appropriately? Yes ✓ No ____. Please comment.

c. Was the pressure excited by the urinal positioning mechanism adequate to result in a proper seal for micturition? Yes ✓ No ____ Please comment.

d. Was the pressure applied by the urine collector: Comfortable ✓; Uncomfortable ____; Essentially unnoticeable ____.

2) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓. If yes, please describe the approximate area and quantity of urine.

3) The air flow in the urine collecting device can best be described as: Unnoticeable ____; Comfortable ✓ Uncomfortable ____ If you wish, further describe or explain.

4) Based upon your experience with the GE system, what features do you like best about it? What features do you dislike?

I do not dislike any of the features -
I like the low flow type urine
collection best.

5) Based upon your experience of using a urine collection system in zero gravity, are there any improvements that you would recommend for the GE system for the planned zero gravity test flights or the actual zero gravity conditions of space flight?

None -

6) Although you have not yet had an opportunity to use the GE system in zero gravity, please compare the general concept of the GE low air flow type urine collection system with the general concept of a urine collecting system using an open urine collector with a higher air flow. Please consider all aspects of the system, but be sure to consider such areas as: confidence of urine containment; general user acceptance and user comfort. In addition, in what ways do you think that the two different concepts of urine collection are superior or inferior to each other?

The modification of the urine collection device
is more comfortable - and gives me a better
feeling of security -
I think the low flow type urine collection
system is superior to the open urine collector
with a higher air flow -
The urine does not appear to bubble or
pool as it did with the high
air flow - and this is more comfortable
for me -

GENERAL ELECTRIC

Waste Collection System Questionnaire

Design Optimization

Test Subject No. 3

Date 23 May 73 Trial No. 2

1) a. Did the current GE system perform adequately for urine collection in normal gravity? Yes

b. Did the urinal positioning system function appropriately? Yes ✓ No ____. Please comment.

With the spring tension set up, it stayed exactly were it was placed

c. Was the pressure excited by the urinal positioning mechanism adequate to result in a proper seal for micturition? Yes ✓ No ____ Please comment.

d. Was the pressure applied by the urine collector: Comfortable ✓; Uncomfortable ____; Essentially unnoticeable ✓.

2) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓. If yes, please describe the approximate area and quantity of urine.

3) The air flow in the urine collecting device can best be described as: Unnoticeable ✓; Comfortable ✓ Uncomfortable ____ If you wish, further describe or explain.

4) Based upon your experience with the GE system, what features do you like best about it? What features do you dislike? None as for at Ground gravity

Liked: Comfortable seat; warm air flow around the top of the collection unit. the sealage it creates; and the fact that it comes up & fits up against & around the vulva; it's disposibility of the units used.

5) Based upon your experience of using a urine collection system in zero gravity, are there any improvements that you would recommend for the GE system for the planned zero gravity test flights or the actual zero gravity conditions of space flight? No, not at this particular time since we have not flown the apparatus at Zero G.

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6) Although you have not yet had an opportunity to use the GE system in zero gravity, please compare the general concept of the GE low air flow type urine collection system with the general concept of a urine collecting system using an open urine collector with a higher air flow. Please consider all aspects of the system, but be sure to consider such areas as: confidence of urine containment; general user acceptance and user comfort. In addition, in what ways do you think that the two different concepts of urine collection are superior or inferior to each other?

With the GE system, the urine collection is much more comfortable in that lower air flow is not felt as easily as high air flow so its almost unnoticible. I feel completely confident in that it seals around the ~~vaginal~~ vulva area and one is not spilling into mid-air which is what happens in Zero G.

Comfort of the seat is basically the same in that GE indentations on the seat provide softness to ischeal tuberosities but the open urine system had a softer seat altogether.

GE system is very compact & looks very much like a regular laboratory which should aide in acceptance & allay fear to use it among regular people of any type.

SECTION B

TEST PLAN FOR ZERO "G" TESTING

OF

GENERAL ELECTRIC WASTE MANAGEMENT MODEL

1 October 1973

TEST PLAN

FOR

ZERO "G" TESTING

OF

GENERAL ELECTRIC WASTE MANAGEMENT MODEL

PROGRAM TITLE: SOLID METABOLIC WASTE TRANSPORT AND STOWAGE INVESTIGATION

CONTRACT NUMBER: NAS 9-13518

Prepared For

National Aeronautics and Space Administration

Lyndon B. Johnson Spacecraft Center

Houston, Texas 77058

General Electric Company
Space Division
Valley Forge Space Center
P. O. Box 8555
Philadelphia, Pennsylvania 19101

TEST PLAN

1.0 STUDY SCOPE

This study will consist of the operational testing of a GE Waste Management System test model during the zero "g" portion of Keplarian trajectories. The tests will include both male and female system users. One "G" ground based data on use of the system will also be collected as a demonstration of the capability of the system to operate in normal gravity and for comparison purposes with the zero "G" data.

2.0 PURPOSE/OBJECTIVES

The purpose of the test program as planned is to demonstrate that the GE Waste Management Concept is capable of effective operation in a zero "g" environment as required for future manned space flight applications. The tests shall be conducted to verify proper separation and transport of feces and the entrapment, containment and transport of urine in Keplarian trajectory zero gravity condition. Slinger and urine separator performance of the system will be demonstrated. Human factors operational conditions and design features will also be demonstrated.

3.0 EQUIPMENT

The equipment is shown in Figure 3-1 and 3-2. It consists of a Dry-John functional model with urinal, phase separator, blower, filter and urine reservoir. A system block diagram and the electrical controls are shown in Figure 3-3 and 3-4 respectively.

The Dry-John consists of a seal, a slide valve, a slinger, a storage container, and transport tube. The seat is a self-positioning support device that permits relative good alignment for the use of the equipment. The valve

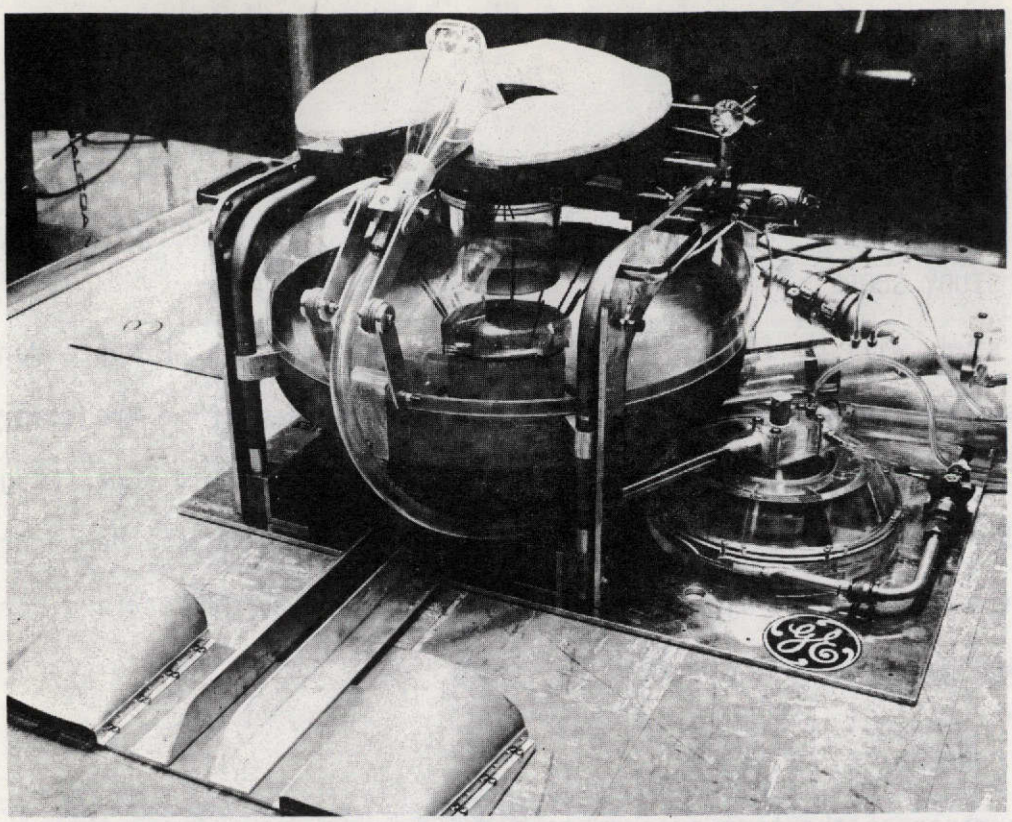

Figure 3-1. The Dry John Zero "G" Test Unit Assembled for Ground Check-out

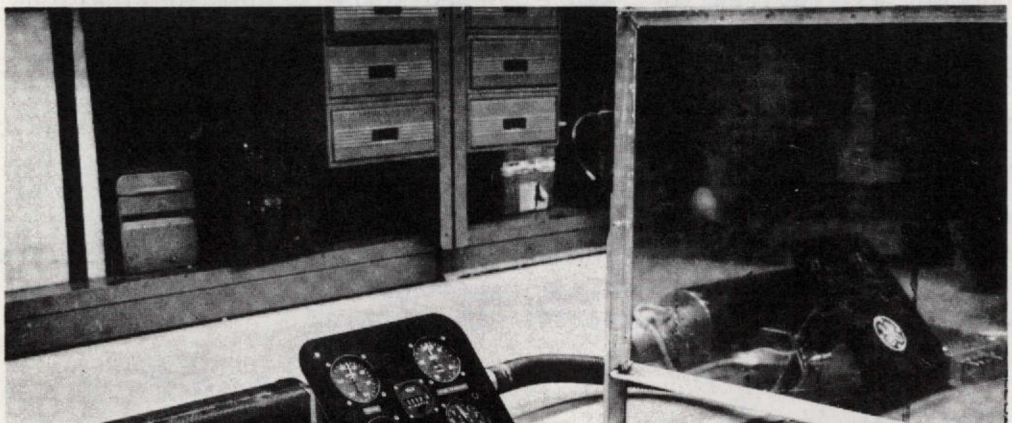

Figure 3-2. Support Equipment Including Blowers, Odor Filter, Controls and Flow Instruments of the Dry John Zero "G" Test Unit Assembled for Ground Checkout

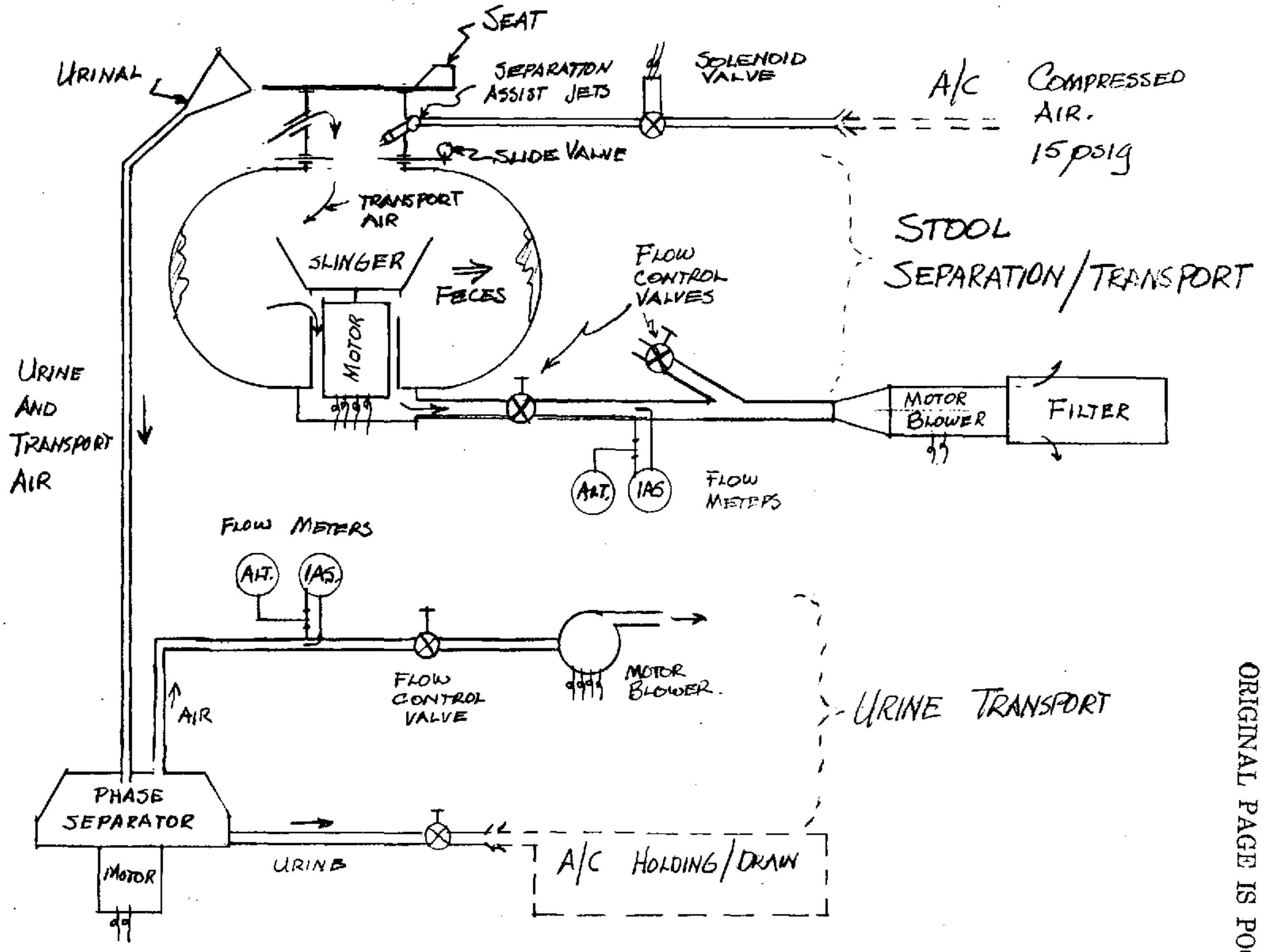

Figure 3-3. Functional Diagram - Advanced Waste Management System

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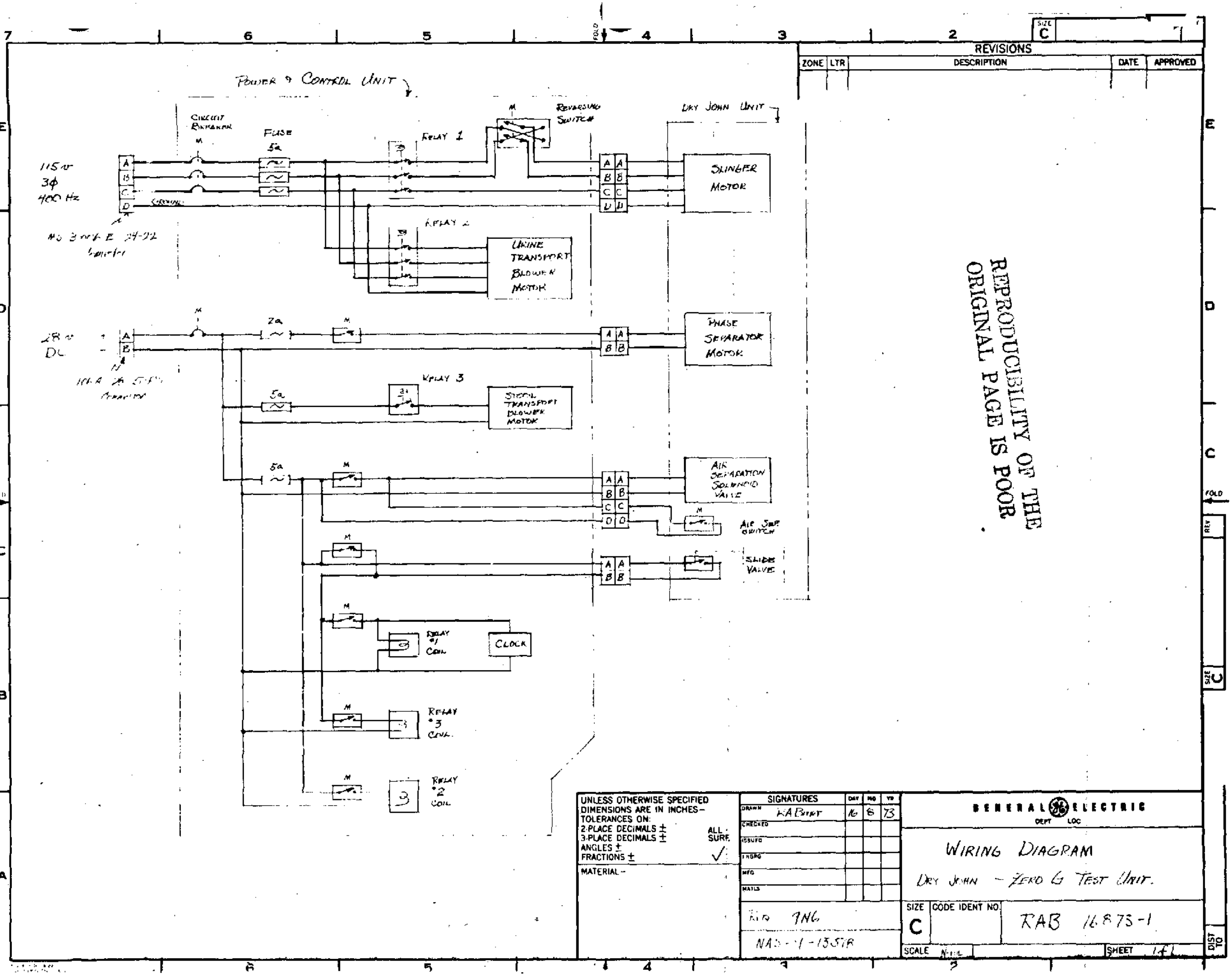

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Figure 3-4. Schematic of Electrical System is a manually operated sliding plate with "O" rings which keep the storage container sealed from ambient when the equipment is not in direct use. The storage container is designed for the collection and drying of the feces for a period in excess of 180 uses.

The slinger is a plate with canted tines turning at a speed of approximately 2,000 RPM. Air flows from openings under the seat to the slinger and from below and around the slinger to the blower and odor filter. The urinal is a conical device leading to a phase separator. The urinal position can be adjusted to suit the convenience of the user, male or female. The phase separator is a centrifugal device which dynamically separates the collected urine from the transport air flowing through the urinal and the connecting tube. The urine is pumped to a storage container while the air is recirculated by the blower and odor filter assembly. An enclosure to provide user privacy and zero "g" restraint and movement aids encloses the system.

The equipment being submitted for test duplicates the functional features of the proposed General Electric design which has been extensively and successfully operated in previous laboratory ground tests. Obvious modifications such as the use of Plexiglas have been made for visual and photographic coverage without impairing the safety or the performance of the equipment for this particular test.

4.0 OPERATING INSTRUCTIONS

4.1 The normal user operation of the system is as follows:

a. Prepare or remove clothing to the extent required for system use and subject positions himself/herself on seat engaging hand and/or foot restraints.

b. Adjust urinal to male or female configuration and perform final urinal positional adjustments if required.

c. Open slide valve for combined fecal/urine collection. This automatically energizes the blower, the slinger motor and the urine separator (Urine collection can be accomplished without an opened slide valve. This condition might be used during a stand-up male urine collection, for example.). The fecal collection is similar to normal ground type commode except for the optional use of an air jet separator assist system to aid in separation of the stool. The air assist is activated by the user by a push button control at the side of the support for the seat. After separation, the feces are transported by the downward air flow into the slinger where they are shredded by the high speed slinger and thrown against the container wall.

5.0 TEST DESCRIPTION

5.1 Ground Based Test

The Dry John equipment and enclosure will be assembled for 1 "G" ground tests. Photographic capability for collecting motion picture data on both fecal and urine collection will be provided. This configuration will be as similar to the zero "g" aircraft configuration as possible.

5.1.1 Equipment Preparation

5.1.1.1 Set up Waste Management system and privacy enclosure.

5.1.1.2 Install and adjust cameras and lighting equipment.

5.1.1.3 Checkout equipment operation and adjust air flows to 30 CFM stool transport and 6 CFM urine transport.

5.1.2 Subject Orientation and Training

Subjects will be briefed on previous data collection procedures of both simulated and ground based subject data collections. A film of previous data collection will be shown including zero "g" aircraft data collection. The basic function and operations of the Dry John equipment including zero "g" restraints will be demonstrated. Specific procedures will be demonstrated and all subjects will be trained in procedures required for use of the system. Optimal urinal adjustment positions and body positioning on the seat will be established for subsequent use in both ground based tests and zero "g" tests.

5.1.3 Ground Based Data Collection

Fecal and urine collection data will be collected on an ad lib basis. Photographic data will be attained for each usage of the system. Following each use of the system, a questionnaire covering the subjective use of the system will be completed by each subject. Figure 5.1.3-1 is an example of the questionnaire. The total number of subjects to be utilized is TBD. Repeat trials may be conducted if dictated by test conditions.

5.2 Flight Test

5.2.1 Equipment Preparation

5.2.1.1 Install waste management system and privacy enclosure in aircraft.

Figure 5.1.3-1

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part I

Normal Gravity Urine Collection

Test Subject No. ________

Date ____________________ Trial No. ______________

1) Was micturition achieved? Yes ________ No ________

2) Was there any backsplash or leakage onto yourself or the seat during the urine collection? Yes ________ No ________. If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ________ No ________ If yes, please describe approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the micturition period? Yes ________ No ________ If any positioning difficulties were encountered, please explain or describe.

5) The air flow in the urine collecting device can best be described as: Unnoticeable ________ Comfortable ________ Uncomfortable ________ If you wish, further describe or explain.

6) What restraint/positioning devices were used during the urine collection? Foot ________ Hand ________ Seat Belt ________. Were these restraint/positioning devices effective? Yes ________ No ______ Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during urine collection? Yes ________ No ________. Please describe or provide additional comments.

8) Please provide any additional comments on the performance of the urine collecting system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Normal Gravity Fecal Collection

Test Subject No. ____________________

Date ______________________________ Trial No. ______________

1) Was defecation achieved? Yes ________ No __________.

2) Was there any contamination of the seat or yourself during the defecation and fecal collection? Yes _______ No _______. If yes, please describe and comment.

3) Do you feel that you were positioned appropriately for the use of the system? Yes _______ No _______. If no, please explain.

4) What restraint/positioning devices were used during the fecal collection? Foot _______ Hand _________Seat Belt _______. Were these devices effective? Yes _______ No _______. Please describe or provide additional comments.

5) Was the seat/restraint combination comfortable? Yes _______ No _______. Please describe or provide additional comments.

6) The air flow in the fecal collecting device can best be described as: Noticeable _______ Comfortable _______ Uncomfortable _______. If you wish, further describe or explain.

7) Please provide any additional comments on the performance of the system.

5.2.1.2 Install lighting and camera equipment in aircraft.

5.2.1.3 Checkout equipment operation and adjust air flows to values as used in ground tests.

5.2.2 Zero "G" Familiarization

Subject familiarization with the zero "g" conditions as produced in the Keplarian trajectories will be conducted as required. These familiarization trials will be directed by the aircraft test conductor as appropriate.

5.2.3 Flight Tests

5.2.3.1 Preparation

During one "G" portion of flight pre-usage positioning of urinal and seat positioning aids will be accomplished. The subject will enter the enclosure and prepare for use of the system including engagement of restraints as required. After preparation is complete and system is in operation the subject will indicate that he/she is ready.

5.2.3.2 Keplarian Trajectories

During the zero portion the subject will defecate and or urinate when and as possible. It is anticipated that a total of 6 parabolas will be flown for each subject "sitting", but this number may be varied depending upon subject aircraft and other test conditions. Photographic data will be collected similar to the 1 "G" trials.

Following use of the system during zero "g" or after termination of the trial for any other reasons the aircraft commander will be requested to hold a one "G" flight condition while subject disengages restraints and prepares for egress from the enclosure. Appropriate communications between subject, test conductor and aircraft commander will be provided as required throughtout the test procedure. Following completion of a test period, the subject will complete the questionnaire shown in Figure 5.2.3.2-1 as appropriate.

These test procedures will be repeated for each subject on a flexible schedule as determined by the subjects and test conductor.

6.0 DATA REQUIREMENTS

6.1 Pre-Flight

Record results of checkout testing and urinal position setups for each subject photo coverage will be obtained for Urine collection only.

6.2 During Flight

The following will be required as part of each individual test:

a. Camera coverage, color, 24 fps.

b. Operator and/or subject observations and comments recorded via tape recorder (spontaneous).

c. Individual test identification.

6.3 Post Flight

Record results of equipment inspection.

7.0 GROUND AND AIRCRAFT INTERFACE REQUIREMENTS

7.1 Three - Fixed High Speed Movie Cameras 24 fps 16 mm Color
One - Fixed/Hand Held Movie Camera 24 fps 16 mm Color

7.2 Lighting - Camera lights - TBD

7.3 Power - 115v 4/00 Hz
- 28v DC

7.4 - Compressed air 15 psig $\approxeq$ 20 ft^3 STP

Figure 5.2.3.2-1

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. ________________

Date ________________________ Trial No. ______________

1) Was micturition achieved? Yes _________ No _____________

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes __________ No _________
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes __________ No __________. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ___________ No ____________.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable _______ Comfortable ________ Uncomfortable ________
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ________ Hand ___________ Seat Belt _____________. Were these restraint devices effective in maintaining your position during zero gravity? Yes _________ No __________. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ________ No ________. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes __________ No _________. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

Waste Collection System Questionnaire

Part II A

Zero Gravity Fecal Collection

Test Subject No. ____________________

Date ______________________________ Trial No. ____________

1) Was defecation achieved? Yes _______ No _______.

2) Was there any contamination of the seat or yourself during the defecation and fecal collection? Yes _______ No _______. If there was contaminati did it occur during the zero "G" portion of the parabola? Yes _______ No _______. Please provide additional comments.

3) Do you feel that you were positioned appropriately for the use of the system? Yes _______ No _______. If no, please explain.

4) What restraints/positioning devices were used during the fecal collection? Foot _______ Hand _______ Seat Belt _______. Were the devices effecti during the zero "G" portion of the parabola? Yes _______ No _______. Please provide additional comments.

5) Was the seat/restraint combination comfortable during the zero "G" portion of the parabola? Yes _______ No _______. Was the combination comfortable during the two "G" portion of the parabola? Yes _______ No _______ Please describe or provide additional comments.

6) The air flow in the fecal collecting device can be best described as: Noticeable _______ Comfortable _______ Uncomfortable _______. If you wish, further describe or explain.

7) Please provide any additional comments on the performance of the system.

7) Please provide any additional comments on the performance of the system.

7.5 - Drain or holding provsion for 2 qts liquid

7.6 Weight of Test Hardware 150 lbs.

7.7 Size - Privacy Enclosure - 4' x 7' x 6-1/2' high
Dry John Unit - 2-1/2 x 3-1/2 included with in enclosure
Power & Control Unit - 14" x 2' x 2'

7.8 Mounting holes pattern on 20" square

7.9 Mounting holes size 0.75" diameter

8.0 CAMERA COVERAGE (Anticipated)

8.1 Frontal View of Urinal on Commode LOS Horizontal or TBD

8.2 Side or rear view of Commode Bowl - LOS 45° Down

8.3 Top View of phase separator and air transparent outlet line

SECTION C

SUBJECT QUESTIONNAIRES

FLIGHT 0

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part I

Normal Gravity Urine Collection

Test Subject No. 2

Date 26 Oct 73 Trial No. ______

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the urine collection? Yes ______ No ✓. If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No ✓ If yes, please describe approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the micturition period? Yes ✓ No ______ If any positioning difficulties were encountered, please explain or describe.

5) The air flow in the urine collecting device can best be described as: Unnoticeable ______ Comfortable ✓ Uncomfortable ______ If you wish, further describe or explain.

6) **What restraint/positioning devices were used during the urine collection? Foot** ✓ **Hand** ________ **Seat Belt** ________. **Were these restraint/positioning devices effective? Yes** ✓ **No** ________ **Please describe or provide additional comments.**

7) **Was the seat/restraint combination comfortable during urine collection? Yes** ________ **No** ________. **Please describe or provide additional comments.** NA.

8) **Please provide any additional comments on the performance of the urine collecting system.** –

None at this time —

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part I

Normal Gravity Urine Collection

Test Subject No. 5

Date 20 Oct 73 Trial No. 1

1) Was micturition achieved? Yes X No ____

2) Was there any backsplash or leakage onto yourself or the seat during the urine collection? Yes ____ No X. If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No X If yes, please describe approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the micturition period? Yes X No ____ If any positioning difficulties were encountered, please explain or describe.

5) The air flow in the urine collecting device can best be described as: Unnoticeable X Comfortable ____ Uncomfortable ____ If you wish, further describe or explain.

6) What restraint/positioning devices were used during the urine collection? Foot X_______ Hand _______ Seat Belt _______. Were these restraint/positioning devices effective? Yes X_______ No _______ Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during urine collection? Yes _______ No _______. Please describe or provide additional comments.

8) Please provide any additional comments on the performance of the urine collecting system.

61-1
B.S.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part I

Normal Gravity Urine Collection

Test Subject No. 1

Date 7 NOV 73 Trial No. 1

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the urine collection? Yes ✓? No ____. If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of urine. I felt there was some wetting of the skin towards the ~~...~~ Right rear area covered by the urinal however the area seemed to be dry after the test & there was no evidence of any residual urine. Perhaps this was only air flow & not actually urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No X If yes, please describe approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the micturition period? Yes X No ____ If any positioning difficulties were encountered, please explain or describe.

5) The air flow in the urine collecting device can best be described as: Unnoticeable ____ Comfortable X Uncomfortable ____ If you wish, further describe or explain.

tickles - also see #2

at any rate, the airflow was not a problem.

6) What restraint/positioning devices were used during the urine collection? Foot ✓ Hand ______ Seat Belt ✓. Were these restraint/positioning devices effective? Yes ✓ No ______ Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Please provide any additional comments on the performance of the urine collecting system.

I had a tendency to try to lean against the back positioning pad which, in turn, gave way & folded down. I was not aware that it would do this but it should not be a problem on the next test.

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61-2
C.S.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part I

Normal Gravity Urine Collection

Test Subject No. 2

Date 7 Nov 73. Trial No. 1

1) Was micturition achieved? Yes X No ____

2) Was there any backsplash or leakage onto yourself or the seat during the urine collection? Yes ____ No X. If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No X If yes, please describe approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the micturition period? Yes X No ____ If any positioning difficulties were encountered, please explain or describe.

5) The air flow in the urine collecting device can best be described as: Unnoticeable X Comfortable ____ Uncomfortable ____ If you wish, further describe or explain.

6) What restraint/positioning devices were used during the urine collection? Foot ___X___ Hand ___X___ Seat Belt ________. Were these restraint/positioning devices effective? Yes ___X___ No ________ Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during urine collection? Yes ___X___ No ________. Please describe or provide additional comments.

8) Please provide any additional comments on the performance of the urine collecting system.

Moisture remained after system shut off

61 - 4
6B

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part I

Normal Gravity Urine Collection

Test Subject No. 4

Date 7 NOV 73 Trial No. ____________

1) Was micturition achieved? Yes X No ________

2) Was there any backsplash or leakage onto yourself or the seat during the urine collection? Yes X No ________. If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of urine.

LEAKAGE ON POSTERIOR PORTION OF URINE COLLECTOR POSSIBLY DUE TO INPROPER POSITIONING.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ________ No X If yes, please describe approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the micturition period? Yes ? No ________ If any positioning difficulties were encountered, please explain or describe.

See #2

5) The air flow in the urine collecting device can best be described as: Unnoticeable X Comfortable ________ Uncomfortable ________ If you wish, further describe or explain.

6) What restraint/positioning devices were used during the urine collection? Foot ___X___ Hand ________ Seat Belt ___X___. Were these restraint/positioning devices effective? Yes ___X___ No ________ Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during urine collection? Yes ___X___ No ________. Please describe or provide additional comments.

8) Please provide any additional comments on the performance of the urine collecting system.

WOULD A DEVICE WITH LESS ADJUSTMENT AREAS BE MORE ADVANTAGEOUS, SUCH AS AN OMNI-DIRECTIONAL BALL BEARING TYPE ADJUSTMENT WHICH YOU COULD ROTATE INTO POSITION QUICKLY.

REPRODUCIBILITY OF THE
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61-5
5F ... BF

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part I

Normal Gravity Urine Collection

(Last of forward ... Following #4 #)

Test Subject No. 10

Date 7 Nov 73 Trial No. 6

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the urine collection? Yes ____ No ✓. If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓ If yes, please describe approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the micturition period? Yes ✓ No ____ If any positioning difficulties were encountered, please explain or describe.

5) The air flow in the urine collecting device can best be described as: Unnoticeable ____ Comfortable ✓ Uncomfortable ____
If you wish, further describe or explain.

6) What restraint/positioning devices were used during the urine collection? Foot ✓ Hand ______ Seat Belt ✓. Were these restraint/positioning devices effective? Yes ✓ No ______ Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Please provide any additional comments on the performance of the urine collecting system.

FLIGHT 1

FD-1
LB

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 1-LB

Date 6 Nov 73 Trial No. 1

1) Was micturition achieved? Yes X No ____

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ____ No X
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No X. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ____ No X.
If any positioning difficulties were encountered, please describe.
I should have adjusted the device for a closer fit - I may not have been seated properly

5) The air flow in the urine collecting device can best be described as:
Unnoticeable X Comfortable ____ Uncomfortable ____
If you wish, further describe or explain.

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6) What restraint/positioning devices were used during zero gravity urine collection? Foot X Hand X Seat Belt X.
Were these restraint devices effective in maintaining your position during zero gravity? Yes X No ______. Please describe or provide additional comments.

The seat belt is most helpful to keep the buttocks "seated" – gives a feeling of security.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes X No ______. Please describe or provide additional comments.

It does not "get in the way".

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes X No ______. Please describe and provide additional comments.

no "binding" etc.

9) Please provide any additional comments on the performance of the system.

Needed to use wipe – (perhaps because of improper fit this test.

FLIGHT 1

F1-1
P.F.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 1

Date 8 Nov 73 Trial No. (AM) JB

1) Was micturition achieved? Yes X No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No X
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No X. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes X No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable X Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot __X__ Hand ______ Seat Belt __X______.
Were these restraint devices effective in maintaining your position during zero gravity? Yes __X__ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes __X__ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes __X__ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

I felt as tho I was pulled away from the urine collecting in Zero G but there was no spillage.

FL-3
LB

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 3-LB

Date 8 Nov 73 (AM) Trial No. 1

1) Was micturition achieved? Yes X No ____

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ____ No X
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No X. If yes, please describe the approximate area and quantity of urine.

~~During 2G~~ When slowing and stopping the urine flow during 2G, I did feel that the urine was "flowing back" onto the perineum

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes X No ____.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable X Comfortable ____ Uncomfortable ____
If you wish, further describe or explain.

Absolutely unnoticeable —

would feel "more" relaxed for me. full extension when arms are in using presently place hand holds.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ________ Hand ✓ ________ Seat Belt ✓ ________.
Were these restraint devices effective in maintaining your position during zero gravity? Yes X ________ No ________. Please describe or provide additional comments.

Short 5'2" person

Comfortable - if the hand restraints were positioned slightly back I think there might be greater comfort -

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes X ________ No ________. Please describe or provide additional comments.

did not feel it pulling back

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes X ________ No ________. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

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F1-4
MG.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 4

Date 8 Nov 73 (AM) Trial No. 1

1) Was micturition achieved? Yes not sure No ____

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes I think so No ____
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.
I felt there was a back lash a small amt to the peri-anal area

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ____ No ✓.
If any positioning difficulties were encountered, please describe.
I think it could have been closer

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ____ Comfortable ✓ Uncomfortable ____
If you wish, further describe or explain. noticeable!

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ______ No x. Please describe or provide additional comments.

could have been higher around me

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

F1-5

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 5

Date 8 Nov. 73 Trial No. 1 (AM)

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ____ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ____.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ____ Comfortable ✓ Uncomfortable ____
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

I had to wipe but thinks it was very habit, cause I really wasn't wet.

FLIGHT 2

F2-1

BS?

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 1

Date 8 Nov 73   Trial No. (PM)? (2)

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ____ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ____.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ____ Comfortable ✓ Uncomfortable ____
If you wish, further describe or explain.

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6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ______ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

I felt like I was contaminating myself - However I wasn't -

F2-2
LB

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 2-LB

Date 8 Nov (PM) Trial No. 3

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No X
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No X. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes X No ______.
If any positioning difficulties were encountered, please describe.
no - and tension at 0 G did not differ than @ 1 G or 2 G

5) The air flow in the urine collecting device can best be described as:
Unnoticeable X Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓.
Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

~~The~~ The seat belt is particularly good —

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes X No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes X No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

F2-3
W.R.
(M)

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. G.E. Ross #3

Date 8 Nov. 73 Trial No. 1 PM

1) Was micturition achieved? Yes ______ No ✓ not during zero G

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ✓ Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

With several trials probably would learn to use foot restraints as only restraint mechanism really necessary.

FZ-4
J/HMc

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 4 JMc

Date 8 Nov 73 (PM) Trial No. 1

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ______ Comfortable ✓ Uncomfortable ______
If you wish, further describe or explain.

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6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

FLIGHT 3

Fl 3-1
SF

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. ___/___

Date ___9 Nov. 73 AM___ Trial No. ___/___

1) Was micturition achieved? Yes ___✓___ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ___✓___
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No ___✓___. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ___✓___ No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ______ Comfortable ___✓___ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

adjustments seem a little complicated

F3-2
C.S.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 2 (PM) ?

Date 9 Nov 73 (AM) Trial No. ______

1) Was micturition achieved? Yes X No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No X
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No X. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes X No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable X Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ___X___ Hand ___X___ Seat Belt ___X___. Were these restraint devices effective in maintaining your position during zero gravity? Yes ___X___ No ________. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ___X___ No ________. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ___X___ No ________. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

F3 -3
G.B.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 3

Date 9 NOV 73 AM Trial No. ______

1) Was micturition achieved? Yes X No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No X
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No X. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes X No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable X Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ___X___ Hand ___X___ Seat Belt ___X___. Were these restraint devices effective in maintaining your position during zero gravity? Yes ___X___ No ________. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ___X___ No ________. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ___X___ No ________. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

F 3-4
PF

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 4

Date 9 Nov 73 (AM) Trial No. 2

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ____ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ____.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ____ Comfortable ✓ Uncomfortable ____
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ______ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

I was Comfortable during the Test.

F3-5
D.S.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 5

Date 9 Nov 73 (AM) Trial No. ______

1) Was micturition achieved? Yes X No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No X
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes X No ______. If yes, please describe the approximate area and quantity of urine. voided twice — once dur each O.G & felt wet at the start of each until there was approx 30 cc voided — I then observed this float down & get sucked away. Until then was this much I could feel it sticking to my skin rearward

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ______ No X.
If any positioning difficulties were encountered, please describe.
I felt that I floated away from it & that the seal was then not tight enough

5) The air flow in the urine collecting device can best be described as:
Unnoticeable X Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot __X__ Hand __X__ Seat Belt __X__. Were these restraint devices effective in maintaining your position during zero gravity? Yes __X__ No ______. Please describe or provide additional comments.

had to hang on c̄ my hands & pull myself down altho I had the lap belt tight — this may not be a valid test because it was my 1st & I was not acclimated to Zero G

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes __X__ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes __X__ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

I think that spring on the urinal could be stronger so that it maintains a greater pressure during Zero G.

F3-6
LB

GENERAL ELECTRIC

4-6

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 0-LB

Date 9 Nov 73 Trial No. 4

1) Was micturition achieved? Yes X No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No X
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

Comment: when stream is "slow" I feel that the urine tends to flow back along the perineum (I don't know that it really is) - when stream is strong - this sensation does not exist

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No X. If yes, please describe the approximate area and quantity of urine.

no pooling etc - but when stream is slow I believe the urine is running down the "back-side".

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes X No ______.
If any positioning difficulties were encountered, please describe.

Positioning is very easy in this apparatus - I think the large, soft ischial spots on the seat are very helpful - (and they are easy to find).

5) The air flow in the urine collecting device can best be described as:
Unnoticeable X Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

dries fairly well - but not completely in a short time.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot __X__ Hand __X__ Seat Belt ______.
Were these restraint devices effective in maintaining your position during zero gravity? Yes __X__ No ______. Please describe or provide additional comments.

Did not use seat belt this trip - feel that I stayed pretty well planted during 0 G

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ______ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ______ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

(1) Performance seems adequate - not difficult to use

(2) Spring tension device is excellent - I think the urinal "stays with" the user well - pressure against the area is not uncomfortable.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

F 3-7
JM (17)

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 7 JPC

Date 11-9-73 AM   Trial No. ______

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ✓ No ______. If yes, please describe the approximate area and quantity of urine.
I started very slow - in blobs. They did move along and caused no problems

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes X No ______.
If any positioning difficulties were encountered, please describe.
Due to an apparent spring torque the receiver rotated around the flow axis some - Undesireable.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ✓ Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

wall mounted

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓.
Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.
a little awkward getting in due to interference between collection hose and pants with feet restrained

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.
I rested my forearms on the hand restraints and was quite comfortable
(wall mounted)

FLIGHT 4

FL 4-1
M.G.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 1

Date 9 Nov 73 PM Trial No. 2

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable / @ 04 Comfortable ✓ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt —. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ____. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ____. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ____. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

system worked well this time - spring could be a little tighter for more "secure" feeling @ "0" G - but as it was, it did not inhibit micturation

I felt hand grips below may have helped me bear down & tried to use these but felt more @ ease using the ones along the wall

?

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 2

Date Nov 19, 1973 [redacted] Trial No. ________

1) Was micturition achieved? Yes ✓ No ________

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ________ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ________ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ________.
If any positioning difficulties were encountered, please describe.
Not at all - very little adjusting needed.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ________ Comfortable ✓ Uncomfortable ________
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ______ Seat Belt ✓.
Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.
Hand rails held - all other devices were comfortable and secure.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.
Seemed easy and fine

F 4-2
LB
AIR FLOW
80 IA.H.

GENERAL ELECTRIC

5-2

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 3. LB

Date 9 Nov 73 Trial No. 5

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ____ No X
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes X No ____.
If any positioning difficulties were encountered, please describe.
We had readjusted the device so that the back part was tighter against the perineum - believe this was a better fit - no discomfort -

5) The air flow in the urine collecting device can best be described as:
Unnoticeable X Comfortable ____ Uncomfortable ____
If you wish, further describe or explain.
Still used wipe -

Had turned flow up

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓.
Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ________. Please describe or provide additional comments.

Tried device without hand holds on one parabola - found hand-holds nec. to keep buttocks down during 0 G

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes X No ________. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes X No ________. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

Fl 4-3
JM

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. #1 Jole

Date 9 Nov. 73 PM Trial No. (2)

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes Slight No ______. If yes, please describe the approximate area and quantity of urine.

THERE WAS A SENSATION OF SOME SLIGHT ACCUMULATION AROUND THE VAGINA — PERHAPS BECAUSE THE DEVICE WAS TILTED BACKWARDS INSTEAD OF MORE FOREWARD.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ______ No ______.
If any positioning difficulties were encountered, please describe.

IT COULD HAVE BEEN TILTED MORE FOREWARD. THERE APPARENTLY WAS CONTACT ALL AROUND.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ______ Comfortable ✓ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

F4-4
MJK

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 4

Date Nov 9, 1973 PM Trial No. ______

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ✓ No ______. If yes, please describe the approximate area and quantity of urine.
Small am't in upper area near perineum
Occurred at end of 0 G

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ______ Comfortable ✓ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ______ Seat Belt ✓.
Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

Very secure

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

No real problem - Comfortable

C-14

FLIGHT 5

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 1

Date 19 March 73 Trial No. 1

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ____ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ____.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ____ Comfortable ✓ Uncomfortable ____
If you wish, further describe or explain.

6) **What restraint/positioning devices were used during zero gravity urine collection? Foot ___✓___ Hand ________ Seat Belt ________. Were these restraint devices effective in maintaining your position during zero gravity? Yes ___✓___ No ________. Please describe or provide additional comments.**

7) **Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ________ No ________. Please describe or provide additional comments.**

8) **Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ___✓___ No ________. Please describe and provide additional comments.**

9) **Please provide any additional comments on the performance of the system.**

125-1 , SKS

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II A

Zero Gravity Fecal Collection

Test Subject No. 1

Date 19 Nov 73 Trial No. ____________

1) Was defecation achieved? Yes ✓ No _______.

2) Was there any contamination of the seat or yourself during the defecation and fecal collection? Yes ✓ No _______. If there was contamination did it occur during the zero "G" portion of the parabola? Yes _______ No _______. Please provide additional comments. ?

defecation was very small + it stuck to the back of the seat just inside

3) Do you feel that you were positioned appropriately for the use of the system? Yes ✓ No _______. If no, please explain.

4) What restraints/positioning devices were used during the fecal collection? Foot ✓ Hand ✓ Seat Belt ✓. Were the devices effective during the zero "G" portion of the parabola? Yes ✓ No _______. Please provide additional comments.

I used the side rails + I did come off the seat some. will try the hand restraints on the seat next time

5) Was the seat/restraint combination comfortable during the zero "G" portion of the parabola? Yes ✓ No _______. Was the combination comfortable during the two "G" portion of the parabola? Yes _______ No _______. Please describe or provide additional comments.

6) The air flow in the fecal collecting device can be best described as: Noticeable _______ Comfortable ✓ Uncomfortable _______. If you wish, further describe or explain.

GENERAL ELECTRIC

7) Please provide any additional comments on the performance of the system.

to achieve defecation it requires a lot of straining & I was exhusted I think lifting up caused the contamination of the seat.

AS-2 MJK

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 2

Date 11/19/73 Trial No. ______

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ✓ No ______. If yes, please describe the approximate area and quantity of urine.
upper portion of collector

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ______ Comfortable ✓ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ________ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ________. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ________. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ________. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

Urine Collecting Device seemed uncomfortable during attempted defecation

FLIGHT 6

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. ___/___

Date ___20 Nov 73___ Trial No. ______

1) Was micturition achieved? Yes ___X___ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ___X___
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No ___X___. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ___X___ No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ___X___ Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ___X___ Hand ___X___ Seat Belt ___X___.
Were these restraint devices effective in maintaining your position during zero gravity? Yes ___X___ No _______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ___X___ No _______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ___X___ No _______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

Familiarity c̄ the device has made it quite easy to adjust quickly. Urine collection device is quite comfortable & when more pressure (ie, stronger spring) is used when placing it in contact c̄ body it is comfortable and assuring as to being in correct positioning.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II A

Zero Gravity Fecal Collection

Test Subject No. 1

Date 20 NOV 73 Trial No. ________

1) Was defecation achieved? Yes X No ________.

2) Was there any contamination of the seat or yourself during the defecation and fecal collection? Yes X No ________. If there was contamination did it occur during the zero "G" portion of the parabola? Yes X No ________. Please provide additional comments.

Feces adhered to posterior rectal area. Needed much cleansing following defecation

3) Do you feel that you were positioned appropriately for the use of the system? Yes X No ________. If no, please explain.

4) What restraints/positioning devices were used during the fecal collection? Foot X Hand X Seat Belt X. Were the devices effective during the zero "G" portion of the parabola? Yes X No ________. Please provide additional comments.

devices were effective but much downward pull on hand positioning device was required. Hand device could be slightly lower.

5) Was the seat/restraint combination comfortable during the zero "G" portion of the parabola? Yes X No ________. Was the combination comfortable during the two "G" portion of the parabola? Yes X No ________. Please describe or provide additional comments.

6) The air flow in the fecal collecting device can be best described as: Noticeable ________ Comfortable X Uncomfortable ________. If you wish, further describe or explain.

GENERAL ELECTRIC

7) Please provide any additional comments on the performance of the system.

Positioning was fairly easy c̄ air flow – you could feel the flow on rectal area + adjust somewhat using this flow as a reference point.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 2

Date 20 Nov 73 Trial No. ________

1) Was micturition achieved? Yes ✓ No ________

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ________ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ________ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ________.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ✓ Comfortable ________ Uncomfortable ________
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

maybe a second set of hand restraints about 2-3 inches lower would take care of those of us with long arms. This would be helpful for me while I was trying to strain down for defecation — also maybe a little padding on those hand restraints - I was really pulling on them!

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GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. III

Date 11-20-73 Trial No. ____________

1) Was micturition achieved? Yes ✓ No ____________

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ____________ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____________ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ____________ No ✓.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ✓ Comfortable ____________ Uncomfortable ____________
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓.
Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.
Collection system seamed to function very well. I was surprised that the air flow was not noticable. the hose clamp can be improved.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II A

Zero Gravity Fecal Collection

Test Subject No. III

Date 11-20-73 Trial No. ________

1) Was defecation achieved? Yes ________ No X.

2) Was there any contamination of the seat or yourself during the defecation and fecal collection? Yes ________ No ________. If there was contamination did it occur during the zero "G" portion of the parabola? Yes ________ No ________. Please provide additional comments.

3) Do you feel that you were positioned appropriately for the use of the system? Yes X No ________. If no, please explain.

4) What restraints/positioning devices were used during the fecal collection? Foot X Hand X Seat Belt X. Were the devices effective during the zero "G" portion of the parabola? Yes X No ________. Please provide additional comments.

5) Was the seat/restraint combination comfortable during the zero "G" portion of the parabola? Yes X No ________. Was the combination comfortable during the two "G" portion of the parabola? Yes X No ________. Please describe or provide additional comments.

6) The air flow in the fecal collecting device can be best described as: Noticeable ________ Comfortable X Uncomfortable ________. If you wish, further describe or explain.

after a few minutes the flow can be described as unnoticeable

7) Please provide any additional comments on the performance of the system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 4 G.[illegible]

Date 27 Nov. 73 Trial No. ____________

1) Was micturition achieved? Yes ✓ No ____________

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ____________ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ✓ No ____________. If yes, please describe the approximate area and quantity of urine.

Top and bottom of the cone. Very small droplets

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ____________.
If any positioning difficulties were encountered, please describe.

~~[illegible]~~ Tubing interfered with flight suit

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ________ Comfortable ✓ Uncomfortable ________
If you wish, further describe or explain.

Very cold air flow but not uncomfortable

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ________. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ________. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ________. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ________. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II A

Zero Gravity Fecal Collection

Test Subject No. 4 (GS)

Date 30 Nov 73 Trial No. ________

1) Was defecation achieved? Yes ✓ No ________.

2) Was there any contamination of the seat or yourself during the defecation and fecal collection? Yes ________ No ✓. If there was contamination did it occur during the zero "G" portion of the parabola? Yes ________ No ________. Please provide additional comments.

3) Do you feel that you were positioned appropriately for the use of the system? Yes ✓ No ________. If no, please explain.

4) What restraints/positioning devices were used during the fecal collection? Foot ✓ Hand ✓ Seat Belt ✓. Were the devices effective during the zero "G" portion of the parabola? Yes ✓ No ________. Please provide additional comments.

5) Was the seat/restraint combination comfortable during the zero "G" portion of the parabola? Yes ________ No ________. Was the combination comfortable during the two "G" portion of the parabola? Yes ✓ No ________. Please describe or provide additional comments.

6) The air flow in the fecal collecting device can be best described as: Noticeable ________ Comfortable ✓ Uncomfortable ________. If you wish, further describe or explain.

GENERAL ELECTRIC

7) Please provide any additional comments on the performance of the system.

~~~~ Stoll did ~~not~~ seperate from ~~[illegible]~~ rectum until the high G portion of the flight.
~~~~

SF
FL-6-5 B

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 5

Date 20 Nov. 73   Trial No. ______

1) Was micturition achieved? Yes ✓ No ______ not sure its on if camera

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

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3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ______ No ✓.
If any positioning difficulties were encountered, please describe.
But had no difficulties

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ✓ Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

I was concentration on fecal did not have collection device positioned correctly as I did not intend to void - I did (maybe not on camera) But even though container was not flush to pubic area no leaking or wetting

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ________.
Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ________. Please describe or provid additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ________. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ________. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II A

Zero Gravity Fecal Collection

Test Subject No. ___5___

Date ___20 Nov 73___ Trial No. ________

1) Was defecation achieved? Yes ___✓___ No ________.

2) Was there any contamination of the seat or yourself during the defecation and fecal collection? Yes ________ No ___✓___. If there was contamination did it occur during the zero "G" portion of the parabola? Yes ________ No ________. Please provide additional comments.

3) Do you feel that you were positioned appropriately for the use of the system? Yes ___✓___ No ________. If no, please explain.

4) What restraints/positioning devices were used during the fecal collection? Foot ___✓___ Hand ___✓___ Seat Belt ___✓___. Were the devices effective during the zero "G" portion of the parabola? Yes ___✓___ No ________. Please provide additional comments.

5) Was the seat/restraint combination comfortable during the zero "G" portion of the parabola? Yes ___✓___ No ________. Was the combination comfortable during the two "G" portion of the parabola? Yes ___✓___ No ________. Please describe or provide additional comments.

6) The air flow in the fecal collecting device can be best described as: Noticeable ________ Comfortable ___✓___ Uncomfortable ________. If you wish, further describe or explain.

GENERAL ELECTRIC

7) Please provide any additional comments on the performance of the system.

I used the hand restraints on the seat + it was much better. I did not lift up!

FLIGHT 7
(DATA INCOMPLETE)

FLIGHT 8

G.S.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II A

Zero Gravity Fecal Collection

Test Subject No. #1

Date 3 Nov 73 Trial No. ________

1) Was defecation achieved? Yes ✓ No ________.

2) Was there any contamination of the seat or yourself during the defecation and fecal collection? Yes ________ No ✓. If there was contamination did it occur during the zero "G" portion of the parabola? Yes ________ No ________. Please provide additional comments.

3) Do you feel that you were positioned appropriately for the use of the system? Yes ✓ No ________. If no, please explain.

4) What restraints/positioning devices were used during the fecal collection? Foot ✓ Hand ✓ Seat Belt ________. Were the devices effective during the zero "G" portion of the parabola? Yes ✓ No ________. Please provide additional comments.

Seat belt must be extremely tight almost to the point of being uncomfortable.

5) Was the seat/restraint combination comfortable during the zero "G" portion of the parabola? Yes ✓ No ________. Was the combination comfortable during the two "G" portion of the parabola? Yes ✓ No ________. Please describe or provide additional comments.

6) The air flow in the fecal collecting device can be best described as: Noticeable ✓ Comfortable ________ Uncomfortable ________. If you wish, further describe or explain.

A little cold

7) Please provide any additional comments on the performance of the system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 2

Date 23 Nov 73 Trial No. ____________

1) Was micturition achieved? Yes ________ No X

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ________ No ________
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ________ No X. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes X No ________.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable X Comfortable ________ Uncomfortable ________
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot __X__ Hand ______ Seat Belt __X__.
Were these restraint devices effective in maintaining your position during zero gravity? Yes __X__ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes __X__ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes __X__ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

3-3
B.P.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 3

Date 11-28-73 Trial No. ______

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ______ No ✓.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ✓ Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ______. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

System worked well.

Nov 67

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 4

Date 28 Nov 73 Trial No. 4

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ✓ Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

urination seem like normal. I felt dry + no need to use tissue. No problems.

8-5
R.B.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 5

Date 11-28-73 Trial No. 2

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ✓ No ______. If yes, please describe the approximate area and quantity of urine.
Small isolated globules on urinal inner surface for brief moments but soon carried away by air flow

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ______ Comfortable ✓ Uncomfortable ______
If you wish, further describe or explain.
The flow was noticably cool. (Cabin temperature rather low this flight - Needed flight jacket when coveralls dropped.)

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

Used new special 2" ɸ male urinal.

Some A/C bumpiness lead to need for shifting position & relocating to maintain registration with the urinal.

FLIGHT 9

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II A

Zero Gravity Fecal Collection

Test Subject No. 1

Date 29 NOV 73 Trial No. ______

1) Was defecation achieved? Yes X No ______.

2) Was there any contamination of the seat or yourself during the defecation and fecal collection? Yes ______ No X. If there was contamination did it occur during the zero "G" portion of the parabola? Yes ______ No ______. Please provide additional comments.

3) Do you feel that you were positioned appropriately for the use of the system? Yes X No ______. If no, please explain.

4) What restraints/positioning devices were used during the fecal collection? Foot X Hand ______ Seat Belt X. Were the devices effective during the zero "G" portion of the parabola? Yes X No ______. Please provide additional comments.

5) Was the seat/restraint combination comfortable during the zero "G" portion of the parabola? Yes X No ______. Was the combination comfortable during the two "G" portion of the parabola? Yes X No ______. Please describe or provide additional comments.

6) The air flow in the fecal collecting device can be best described as: Noticeable X Comfortable X Uncomfortable ______. If you wish, further describe or explain.

GENERAL ELECTRIC

7) Please provide any additional comments on the performance of the system.

AIR ~~ASSIST~~ USED for SEPERATION ASSIST DID NOT APPEAR to work PROPERLY

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 2

Date 29 November 73 Trial No. ______

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ______ Comfortable ✓ Uncomfortable ______
If you wish, further describe or explain. Cold

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓.
Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

(Hand rests were uncomfortable - needed padding) #7

Had to really hold on to hand devices, but able to maintain position.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

see #6 ( )

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

Not really aware of devices.

9) Please provide any additional comments on the performance of the system.

FLT-5 (F) SF
29 Nov

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II A

Zero Gravity Fecal Collection

Test Subject No. 5

Date 29 Nov 73 Trial No. ____________

1) Was defecation achieved? Yes ✓ No ________.

2) Was there any contamination of the seat or yourself during the defecation and fecal collection? Yes ________ No ✓. If there was contamination did it occur during the zero "G" portion of the parabola? Yes ________ No ________. Please provide additional comments.

3) Do you feel that you were positioned appropriately for the use of the system? Yes ✓ No ________. If no, please explain.

4) What restraints/positioning devices were used during the fecal collection? Foot ✓ Hand ✓ Seat Belt ✓. Were the devices effective during the zero "G" portion of the parabola? Yes ✓ No ________. Please provide additional comments.

5) Was the seat/restraint combination comfortable during the zero "G" portion of the parabola? Yes ✓ No ________. Was the combination comfortable during the two "G" portion of the parabola? Yes ✓ No ________. Please describe or provide additional comments.

6) The air flow in the fecal collecting device can be best described as: Noticeable ________ Comfortable ✓ Uncomfortable ________. If you wish, further describe or explain.

very little, fecal material - separation was so complete I was not even sure that I went until I looked in the container afterward
But not sure it was mine

7) Please provide any additional comments on the performance of the system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 6

Date 11-29-73 Trial No. ____

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ✓ No ____
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓. If yes, please describe the approximate area and quantity of urine.
Slight pooling

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ____.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ✓ Comfortable ____ Uncomfortable ____
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ______ Seat Belt ______. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 7

Date 29 nov 73 Trial No. 1

1) Was micturition achieved? Yes ______ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ✓ No ______
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No no. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ______ No no.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ✓ Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ ~~No~~ ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 4

Date 29 NOV 73 Trial No. ________

1) Was micturition achieved? Yes X No ________

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ________ No X
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ________ No X. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes X No ________.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable X Comfortable ________ Uncomfortable ________
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ___X___ Hand ___X___ Seat Belt ___X___. Were these restraint devices effective in maintaining your position during zero gravity? Yes ___X___ No ________. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ___X___ No ___[scribbled out]___. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ___X___ No ________. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

FLIGHT 10

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 1

Date 30 Nov 73 Trial No. 1

1) Was micturition achieved? Yes ✓ No ____

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ✓ No ____
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.
I think I just didn't have urinal in tight enough

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No ✓. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ____ No ✓.
If any positioning difficulties were encountered, please describe.
I just did not tighten it enough

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ✓ Comfortable ____ Uncomfortable ____
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓.
Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

It was very comfortable and I think it is easy to use.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 2

Date 30 Nov 73 Trial No. ____

1) Was micturition achieved? Yes X No ____

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ____ No X
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____ No X. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes X No ____.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable X Comfortable ____ Uncomfortable ____
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot __X__ Hand __X__ Seat Belt __X__.
Were these restraint devices effective in maintaining your position during zero gravity? Yes __X__ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes __X__ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes __X__ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 3

Date 30 NOV 73 Trial No. ______

1) Was micturition achieved? Yes X No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes X No ______
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.
SMALL DROPS CAME UP INTO THE MOUTH OF THE COLLECTION DEVISE

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes X No ______. If yes, please describe the approximate area and quantity of urine.
SEE ABOVE

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes X No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable X Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ___X___ Hand __________ Seat Belt ___X___.
Were these restraint devices effective in maintaining your position during zero gravity? Yes ___X___ No __________. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ___X___ No __________. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ___X___ No __________. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II A

Zero Gravity Fecal Collection

Test Subject No. 3

Date 30 NOV 73 Trial No. ____________

1) Was defecation achieved? Yes X No ________.

2) Was there any contamination of the seat or yourself during the defecation and fecal collection? Yes X No ________. If there was contamination did it occur during the zero "G" portion of the parabola? Yes X No ________. Please provide additional comments.
WAS NOT POSITION CORRECTLY

3) Do you feel that you were positioned appropriately for the use of the system? Yes ________ No X. If no, please explain.
WAS TOO FAR BACK

4) What restraints/positioning devices were used during the fecal collection? Foot X Hand ________ Seat Belt X. Were the devices effective during the zero "G" portion of the parabola? Yes X No ________. Please provide additional comments.

5) Was the seat/restraint combination comfortable during the zero "G" portion of the parabola? Yes X No ________. Was the combination comfortable during the two "G" portion of the parabola? Yes X No ________. Please describe or provide additional comments.

6) The air flow in the fecal collecting device can be best described as: Noticeable X Comfortable X Uncomfortable ________. If you wish, further describe or explain.

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7) Please provide any additional comments on the performance of the system.

HAD ~~[illegible]~~ SOME Difficulty GETTING POSITION correctly The "Holes" in the SEAT DID NOT SEEM TO fit

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 4

Date 11-30-73 Trial No. ______

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No ✓. If yes, please describe the approximate area and quantity of urine.
Pooling of several drops of urine

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ✓ Comfortable ______ Uncomfortable ______
If you wish, further describe or explain.
Air flow appeared to be less than on previous runs.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 3

Date 11-30-73 Trial No. ____________

1) Was micturition achieved? Yes ✓ No ____________

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ____________ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ✓ No ____________. If yes, please describe the approximate area and quantity of urine.
Upper rims of the collection device
small amt.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ____________.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ________ Comfortable ________ Uncomfortable ________
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 6

Date 30 Nov 73 Trial No. 6

1) Was micturition achieved? Yes ______ No ✓

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ______
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ______ No ______. If yes, please describe the approximate area and quantity of urine.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ______ Comfortable ______ Uncomfortable ______
If you wish, further describe or explain. was noticeable but not uncomfortable

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ____. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ____. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ____. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

unusual possibly distracting.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. 7

Date 30 November 73 Trial No. ______

1) Was micturition achieved? Yes ✓ No ______

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ______ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ✓ No ______. If yes, please describe the approximate area and quantity of urine.
Anterior and large amt. at beginning.

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ______.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ______ Comfortable ✓ Uncomfortable ______
If you wish, further describe or explain.

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6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓. Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ________. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ________. Please describe or provide additional comments.

Hand holds cold & sharp edges

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ________. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

GENERAL ELECTRIC

Waste Collection System Questionnaire

Part II

Zero Gravity Urine Collection

Test Subject No. ____________

Date 20 Nov 73 Trial No. ____________

1) Was micturition achieved? Yes — very little No ____________

2) Was there any backsplash or leakage onto yourself or the seat during the zero gravity urine collection? Yes ____________ No ✓
If yes, please describe the backsplash or leakage indicating the general location and approximate quantity of the urine.

3) Were you aware of any pooling or accumulation of urine in the collecting device? Yes ____________ No ✓. If yes, please describe the approximate area and quantity of urine.
although I didn't feel it, it looked like for a sec or so urine stayed at top of device

4) Was the urine collecting device in appropriate position during the zero gravity micturition period? Yes ✓ No ____________.
If any positioning difficulties were encountered, please describe.

5) The air flow in the urine collecting device can best be described as:
Unnoticeable ✓ Comfortable ____________ Uncomfortable ____________
If you wish, further describe or explain.

6) What restraint/positioning devices were used during zero gravity urine collection? Foot ✓ Hand ✓ Seat Belt ✓ ______.
Were these restraint devices effective in maintaining your position during zero gravity? Yes ✓ No ______. Please describe or provide additional comments.

7) Was the seat/restraint combination comfortable during zero gravity urine collection? Yes ✓ No ______. Please describe or provide additional comments.

8) Was the seat and restraint combination comfortable during the high gravity portion of the flight? Yes ✓ No ______. Please describe and provide additional comments.

9) Please provide any additional comments on the performance of the system.

SECTION D

MICROBIOLOGICAL PROCEDURES - DETECTION OF BACTERIAL GAS GENERATION

MICROBIOLOGICAL PROCEDURES

Procedures

1. Detection Of Bacterial Gas Generation

An excellent method of monitoring bacterial growth or metabolism, which is responsible for the noxious odor produced in fecal material, is the assessment of gas produced by manometric techniques. The most convenient instrument for performing this is the Warburg respirometer, utilizing a culture flask in combination with a manometer. The gas produced will increase the pressure and be evidenced by movement of the column of fluid in the manometer. Warburg manometers are quite sensitive to the slightest changes in the gaseous environment from small amounts of microorganisms.

Therefore, the objective was to investigate the feasibility for utilizing this apparatus for monitoring the residual viable microbial ability to produce gas from cored-out samples of the human fecal material at different progressive stages of drying, noting the point at which cessation of gas production occurred.

Small samples (~0.5-1.0g) of collected fecal material, were taken from the larger (25g) samples of material, cored from the fecal material collected in commode, and placed in Warburg reaction vessels. The reaction vessels were immediately attached and sealed to the manometers and the pressure in each side equilibrated and the vessel with manometer sealed off. The Warburg respirometer units were held at room temperature similar to that being practiced in the WCS. The difference in pressure, noted by displacement from equilibrium of the liquid in the manometer arms was monitored at 5-15 minute intervals and longer.

Of course, changes in gas production could be the result of action of microbial enzymes, even though the organisms are inhibited. Therefore, one reason for performing the feasibility study was to determine whether this method would be adequate to reflect the biological stability of human fecal material as it is progressively dried.

If it appeared to be adequate, then the amount of gas produced could be monitored precisely and quantitatively by standardizing and calibrating the respirometers.

2. Determination Of Moisture Content Of Human Fecal Material

Initially, the method of choice for determining the moisture content of the human fecal material was to use the Ohaus Infra-Red Moisture Balance. In order to verify the moisture levels it was decided to dry samples in a forced circulation hot air oven and determine the weight loss gravimetrically.

a. Infra-Red Moisture Balance. This technique consists of the following procedural steps and calculation:

1. Place from 1-2g of the sample of fecal material onto a dry (tared to zero) aluminum disposable weighing dish by means of a metal spatula (for drier samples, forceps). The material was spread as thin as possible on the weighing dish.
2. The weighing dish was placed on the pan of the Ohaus Moisture Balance (Model 6010). The moisture balance was located in a chemical fume hood.
3. The weight of the sample was noted and recorded.

The term "Moisture content" here would also include the weight of any other volatile chemicals also present in the fecal material and reflects the weight loss as compared to the original weight of the wet material.

4. The best lamp position setting was 1-1/2 inches above the sample and the wattage setting selected was 20 watts. These conditions and settings were used throughout the study.
5. The lamp was turned-on by setting the Timer to 15 minutes.
6. Readings of the residual weight were taken at intervals of 15 minutes until the sample showed no further decrease in weight. Most samples showed no further weight loss after 30 minutes of drying. Some were dried for up to 16 hours. Generally, the drying was considered to be complete when two consecutive readings 15 minute apart showed no further weight loss at the second decimal (0.01g) place.
7. The percent moisture was then calculated according to the following formula using weight in grams:

$$\frac{\text{Original Weight - Final Weight}}{\text{Original Weight}} \times 100 = \%\ \text{Moisture}$$

b. Hot Air Oven Method:

Samples of the material were placed either on drying pans, dried aluminum foil, the raw material spread as thin as possible, or on the original sampling strip as retrieved from the commode. These samples were weighed on a Mettler analytical balance (Model H6T)[1]. The sample carrier had either been tared prior to use or upon completion of the test after it was cleaned.

The samples were placed in a preheated forced circulation hot air oven[2] at 105°C.

1. Mettler Instrument Corporation, Hightstown, New Jersey
2. Blue M Constant Temperature Cabinet, Model OV-586A-1, Blue M Electric Company, Blue Island, Illinois

The samples were removed at successive 30 minute intervals and re-weighed on the analytical balance. They were returned to the oven and dried until two consecutive weighings were constant.

The percent moisture was then calculated in a manner similar to the other procedure, taking into account the tared weight of the sample carrier.