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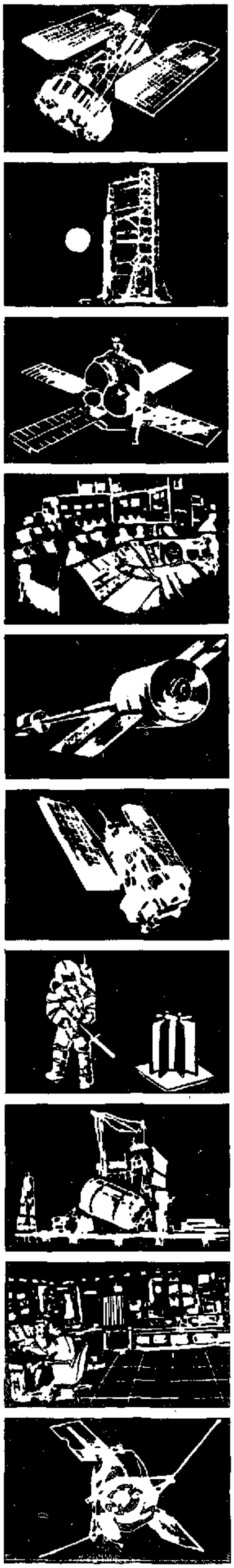
SPACE DIVISION



GE Report No. 74SD4215
April 1974

CR 134275

FINAL REPORT

ASTP
FLUID TRANSFER MEASUREMENT EXPERIMENT

CONTRACT NAS 9-13519

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

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GE Report No. 74SD4215
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FINAL REPORT

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FLUID TRANSFER MEASUREMENT EXPERIMENT

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Prepared By: G. L. Fogal
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FINAL REPORT
ASTP FLUID TRANSFER MEASUREMENT EXPERIMENT

1.0 SUMMARY

The ASTP Fluid Transfer Measurement Experiment flight system design concept was verified by the demonstration and test of a breadboard model. In addition to the breadboard effort, a conceptual design of the corresponding flight system was generated and a full scale mockup fabricated. A preliminary CEI specification for the flight system was also prepared.

2.0 BACKGROUND

The scope of the ASTP Fluid Transfer Measurement Experiment (FTME) program was twofold:

1. Verify the FTME flight system design concept for a potential ASTP mission application by demonstration and test of a Breadboard Model.
2. Generate a conceptual design of the corresponding flight system; prepare a preliminary CEI and fabricate a mockup of the flight system.

The basic objective of both the Breadboard Model and flight design was to demonstrate improved urine collection and urine volume measurement techniques. This was accomplished by combining the Geoscience Ltd. thermal flow sensor with the General Electric dynamic phase separator. The FTME Breadboard Model and flight mockup included the following design features:

1. A system concept which will give real-time measurement of micturition volume.
2. A system which will provide measurement of a liquid (urine) in a liquid - gas mixture and not require use of a personal contact device such as a roll-on cuff.

3. A system capable of measuring urine volume accurate to within ± 2%.
4. A system which has the potential capability for collecting inflight urine samples.

The development and fabrication of the thermal flow sensor was accomplished as a separate effort by Geoscience Ltd. under NASA contract NAS 9-13461. The thermal flow sensor and associated electronics were supplied as GFE hardware for incorporation into the Breadboard Model.

3.0 BREADBOARD MODEL

3.1 Description

The Breadboard Model is shown in Figure 3-1 and is consistant with the requirements noted in the Design Specification, Appendix Section 5.3. The breadboard block diagram is shown in Figure 3-2.

Operationally the Breadboard Model functions as follows:

> Urine plus transport air enters the system via the urinal assembly and flows thru the thermal flow sensor into the phase separator. The output of the thermal flow sensor is integrated and readout on the digital meter. The phase separator removes the transport air from the urine flow stream by centrifugal action and temporarily stores the total urine volume voided. The pressure sensor output, which is proportional to urine mass, is readout on the digital meter. The purpose of this auxiliary measurement is to supplement and confirm the thermal flow sensor output. When micturition is completed, the operator initiates the dump (or sample) mode which causes solenoid valve S1 to open allowing urine to flow from the phase separator via a small gear pump and a double end shut-off type quick disconnect coupling to space vacuum (or a sample container).

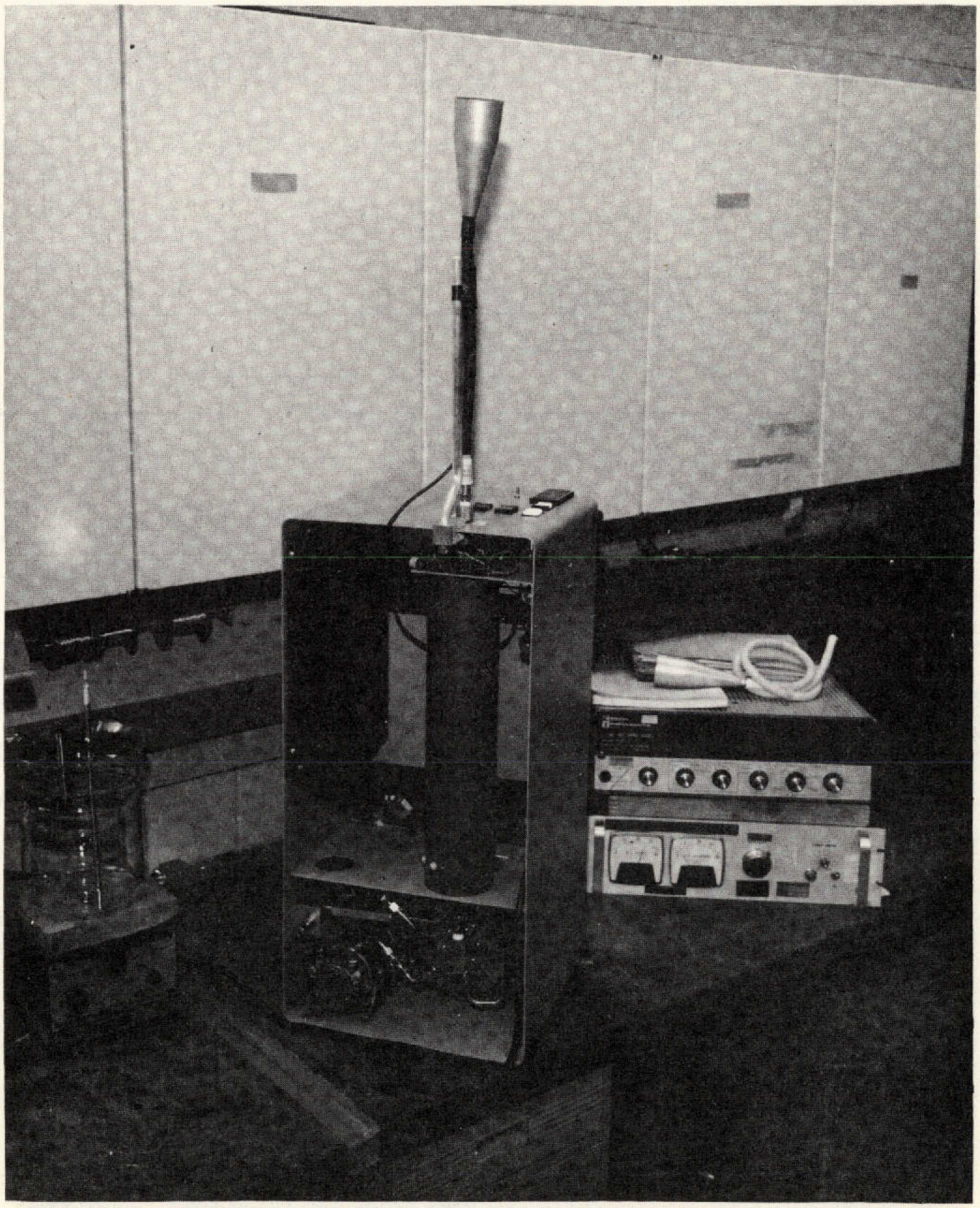


FIGURE 3-1. BREADBOARD MODEL

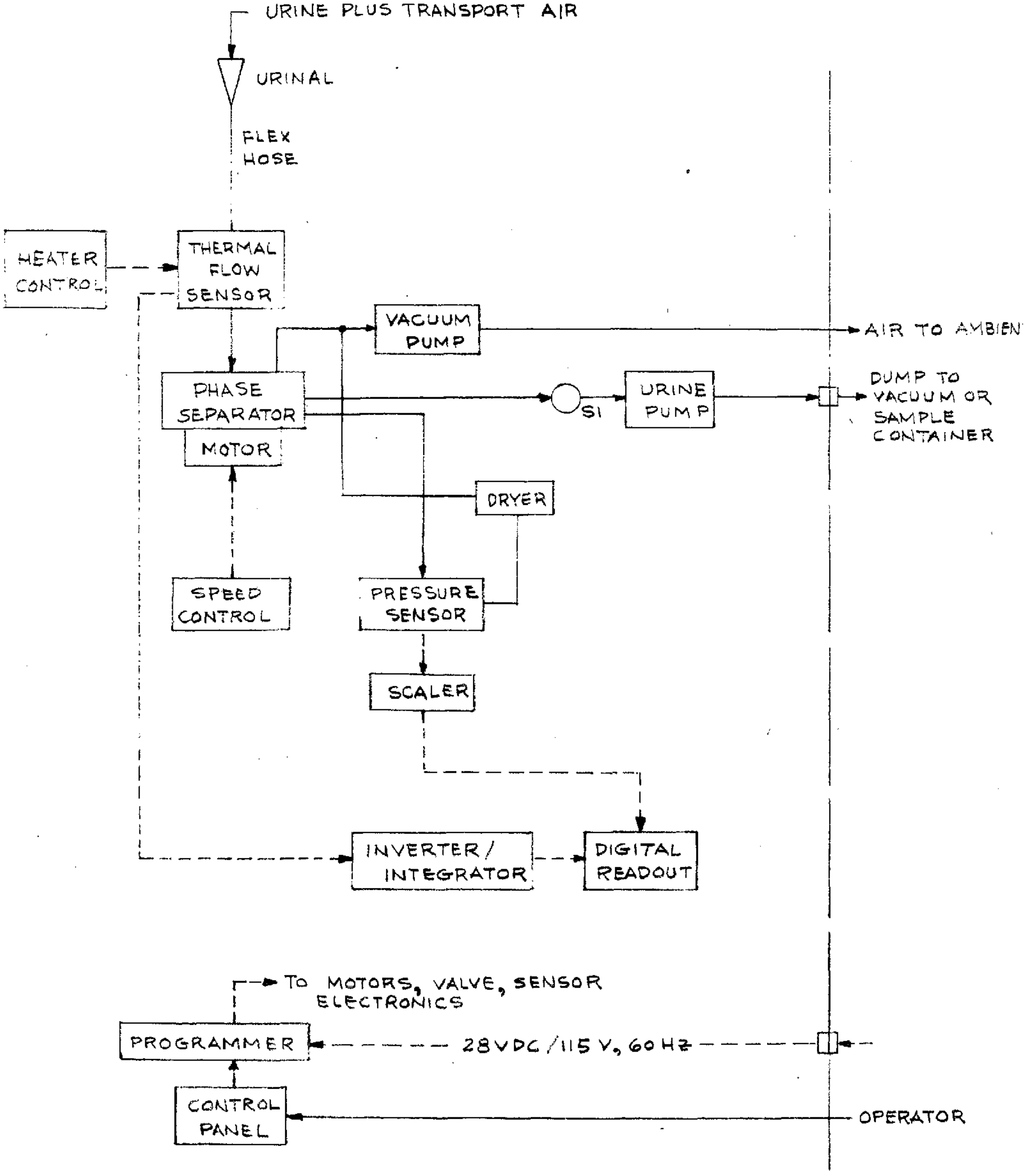


FIGURE 3-2 FTME B/B MODEL BLOCK DIAGRAM

Because of the relatively high pressure drop thru the thermal flow sensor (1 to 2 psi), a vacuum pump is used to provide the transport air flow required (to simulate space vacuum conditions).

Essentially the FTME Breadboard Model consists of two subsystems. The GFE thermal flow sensor hardware (from Geoscience Ltd.) was supplied as a complete operating assembly as shown in Figure 3-3. The GE provided subsystem, Figure 3-4, supports and complements the GFE hardware in two ways. The phase separator, blower, urine pump, etc. are needed to operate the GFE hardware in the context of an ASTP space experiment; the pressure transducer and associated electronics provide a second reading of urine volume to complement the thermal flow sensor.

It should be noted that the thermal flow sensor cannot function in the possible ASTP mission application without the phase separator. This is due to a limitation imposed by the Apollo CM. The flow sensor requires a minimum flow of air and/or liquid thru the sensor of at least 0.2 to 0.4 CFM. The existing Apollo CM overboard dump vent cannot accommodate this flow rate for liquid or air/liquid mixtures of high liquid content. Thus the phase separator temporarily stores the urine so that the minimum flow rate thru the flow sensor can be maintained during the volume measurement process. Also, depending on specific requirements, a phase separator may be necessary to accomplish satisfactory urine sampling.

3.2 Test Results

3.2.1 Thermal Flow Sensor

The thermal flow sensor equipments were designed and fabricated by Geoscience Ltd. under NASA contract NAS 9-13461 and supplied GFE to GE for incorporation

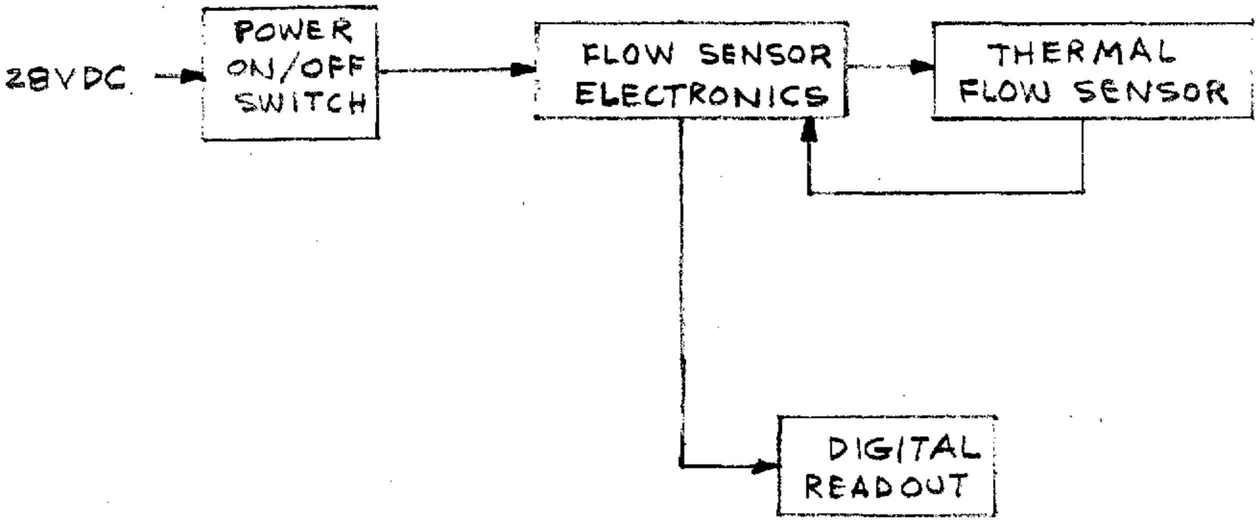
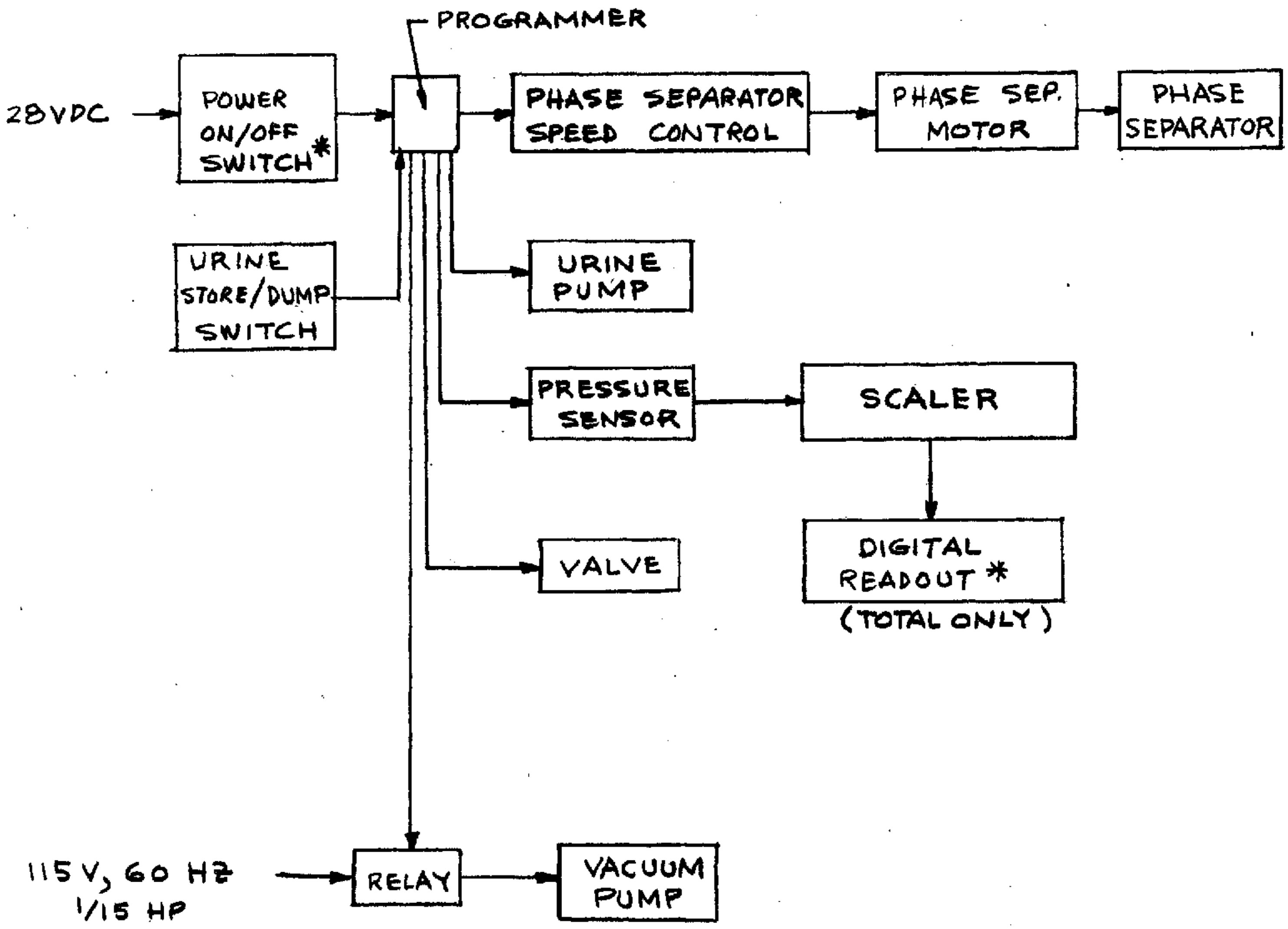


FIGURE 3-3 GFE SUBSYSTEM



* COMMON WITH GFE HDWR.

FIGURE 3-4 GE SUPPORT SUBSYSTEM

into the Breadboard Model. Design details of the thermal flow sensor and test results are included in Geoscience Ltd. report GLR-124.

3.2.2 Calibrated Centrifuge

The phase separator, pressure transducer and associated electronics make up the calibrated centrifuge concept for determining fluid mass. The phase separator is a centrifugal type with a multi-bladed impellor rotating at constant speed within a stationary outer housing. As the air/liquid mix enters the phase separator, a rotating liquid vortex accumulates on the inner periphery of the stationary housing. The resulting vortex pressure on the housing wall is proportional to the mass of the fluid within the vortex (for a constant impellor rpm). This pressure is sensed by the pressure transducer and then electronically amplified (scaled) and readout on the digital meter as fluid mass in grams. Appendix Section 5.2 contains a brief analysis of the potential accuracy obtainable by this approach.

3.2.2.1 Accuracy/Linearity

Table 3-1 and Figures 3-5 and 3-6 show accuracy and linearity data obtained for the calibrated centrifuge. To eliminate the confounding effects of evaporation loss, see 3.2.2.4 below, the blower was not used during the test runs. As shown in Figure 3-5, some deviation from linearity exists for fluid input values below about 75 grams. This is confirmed by the corresponding pressure sensor output data of Figure 3-6. It should be noted that the centrifuge electronics were adjusted to achieve an approximate linear response over a fluid input range of 100 to 800 grams. The electronics are capable of a finer adjustment to achieve both a true linear response and a one to one ratio between input and meter reading. The data of Table 3-1 were used to calculate standard deviation values with results as shown. The data implies a 3 sigma error of less than 1% for fluid inputs greater than about 100 grams with larger errors for fluid inputs under 100 grams.

TABLE 3-1. ACCURACY*

Fluid Input**	50 grams	100 grams	200 grams	300 grams	400 grams	500 grams	600 grams	700 grams
Test No.	Meter Reading	Meter Reading	Meter Reading	Meter Reading	Meter Reading	Meter Reading	Meter Reading	Meter Reading
1	45	98	198	301	402	505	602	703
2	46	98	197	300	400	507	600	704
3	46	98	197	300	399	508	602	705
4	45	98	198	301	400	507	601	706
5	45	97	197	301	400	506	602	707
6	45	98	197	301	401	505	601	707
7	45	98	197	302	402	506	602	706
8	45	96	197	302	401	505	602	705
9	45	98	197	301	401	505	601	705
10	45	98	196	301	399	505	602	706
11	45	97	197	300	399	508	602	705
Average	45.2	97.7	197.1	300.9	400.4	506.1	601.6	705.4
One Std. Deviation grams %	 ± 0.57 ± 1.14	 ± 0.68 ± 0.68	 ± 0.54 ± 0.27	 ± 0.70 ± 0.23	 ± 1.12 ± 0.28	 ± 1.22 ± 0.24	 ± 0.83 ± 0.14	 ± 1.27 ± 0.18

* Includes meter, pressure sensor, phase separator rpm and residual and fluid input related errors.

** Room Temperature Water

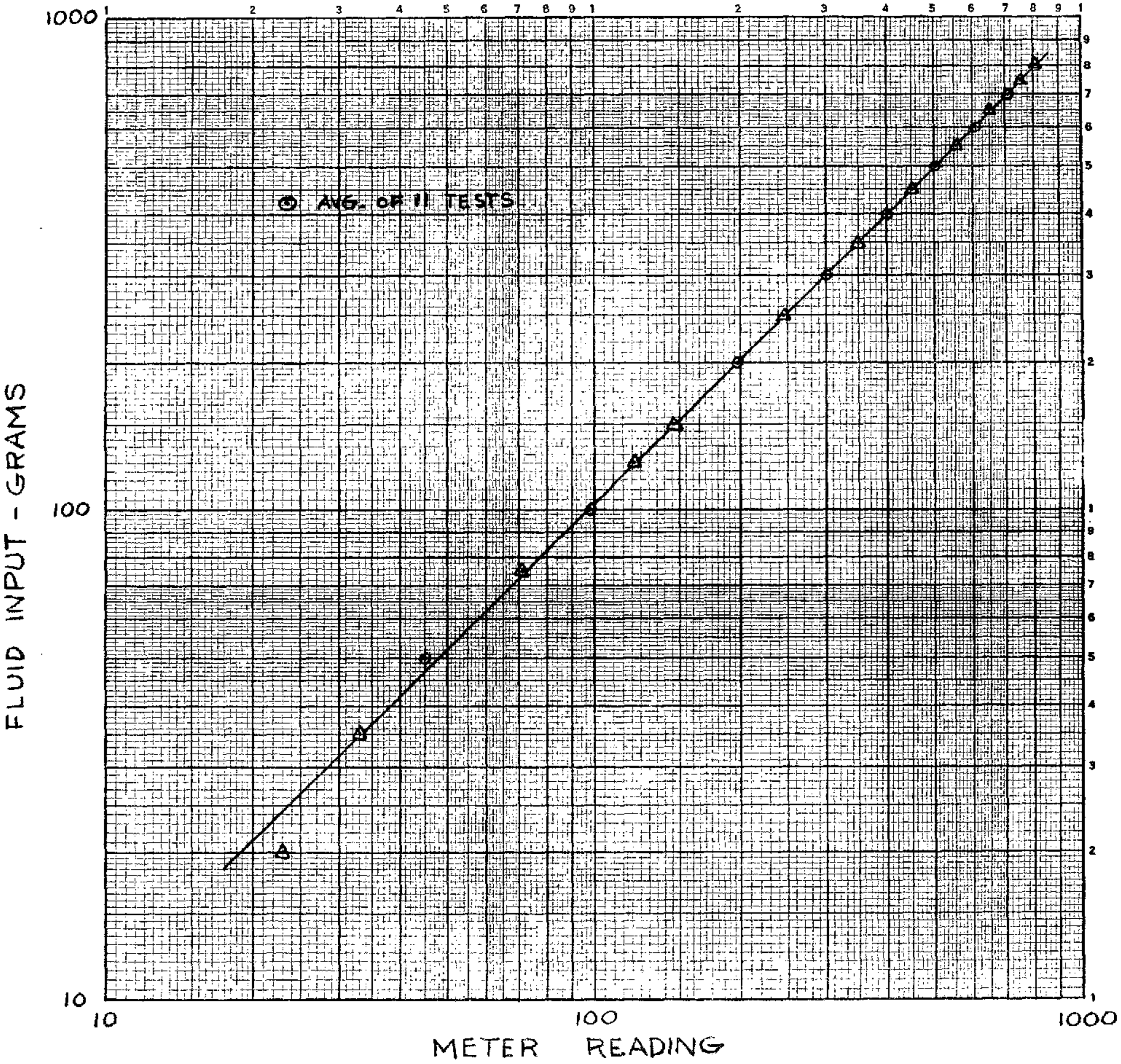


Figure 3-5. Meter Output as Function of Fluid Input

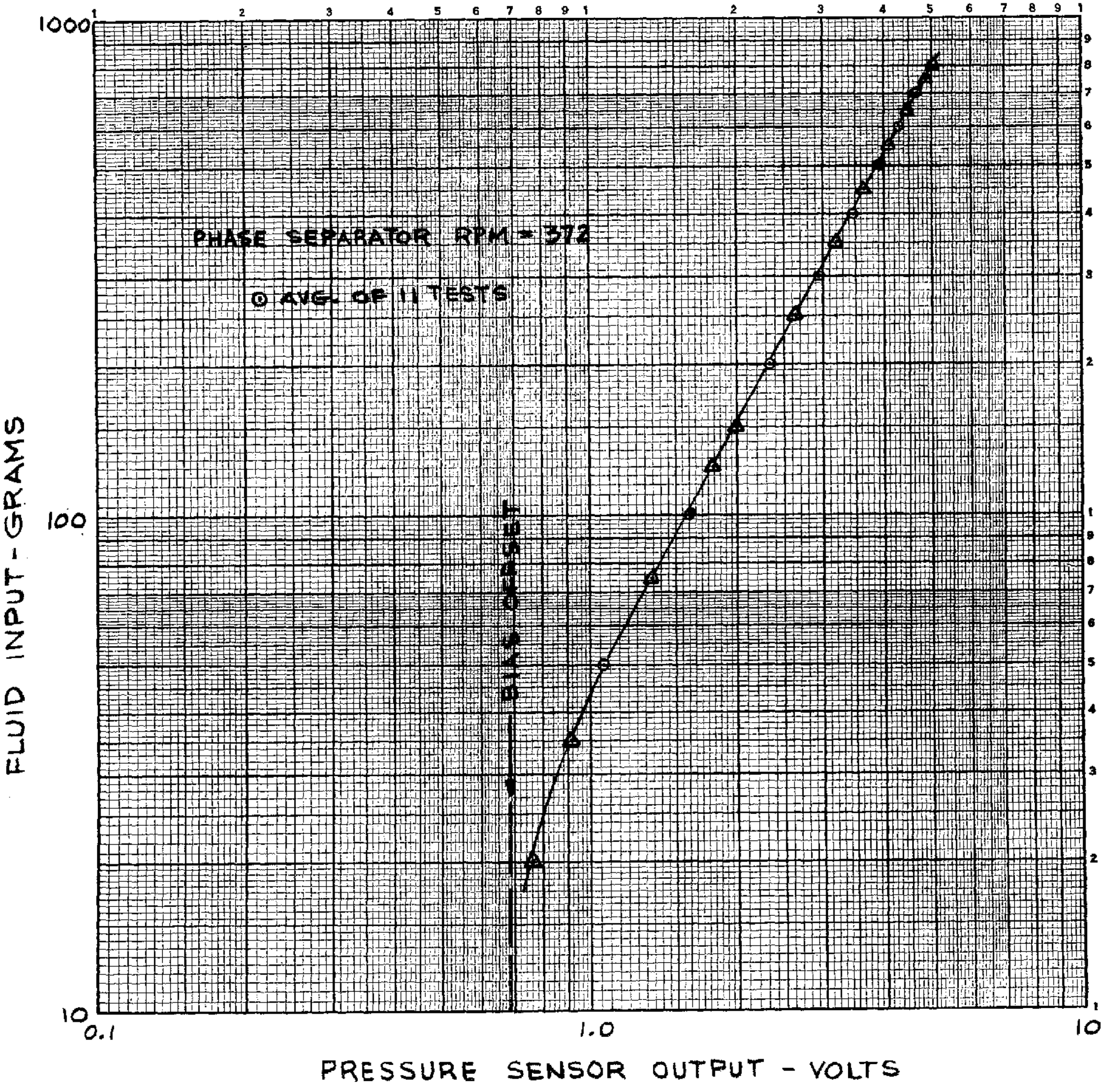


Figure 3-6. Pressure Sensor Output as Function of Fluid Input

3.2.2.2 Range

As shown in Figure 3-5, a range of 20 to 800 grams was obtained albeit with degraded accuracy at the low end. The upper value is limited by the physical capacity of the phase separator with the 800 gram value selected as suitable for the possible ASTP mission application. The lower limit of about 20 grams is a result of the method used to obtain a linear output from the pressure sensor. Linearity was accomplished by biasing the pressure sensor output so that at zero fluid input, a meter reading of 18 grams is obtained. If a lower threshold is necessary, an alternate method using additional electronic circuitry can be used.

3.2.2.3 Fluid Temperature

Initial tests using a Setra-Systems Model 237 pressure sensor produced erratic results due to thermal drift. Replacement with a model 240TC sensor resulted in a substantial improvement (the temperature compensating element is moved to the sensor per se from a position in the electronics assembly. However, for accurate measurement of urine mass, additional improvement is necessary. Table 3-2 shows results for a fluid temperature of 99°F with the centrifuge hardware initially at 76°F. A lower value of fluid mass input and a lower input flow rate will reduce the thermal lag. However, to realize the full potential of this measurement approach, thermal compensation needs to be improved.

The thermal compensation problem was discussed with Setra-Systems who note that thermal lag is proportional to the time required for the total pressure transducer temperature to equal that of the fluid. As tested, the bulk of the transducer is isolated from the fluid. Also the sensor is hard mounted to the phase separator housing, a relatively large mass. Both of these factors contribute to the lag shown in Table 3-2. Figure 3-7 shows a mounting

TABLE 3-2. FLUID TEMPERATURE

Hardware Temperature - 76°F

Input - 600 grams water @ 99°F

Input Rate - about 30 grams/second

Time	Meter Reading
0 Sec.	634 (Sample Injection Complete)
15	625
30	619
45	616
60	615
75	612 (2% Error)
90	610
120	609
150	608
180	607
240	606
300	605 (Water Temperature = 87°F)

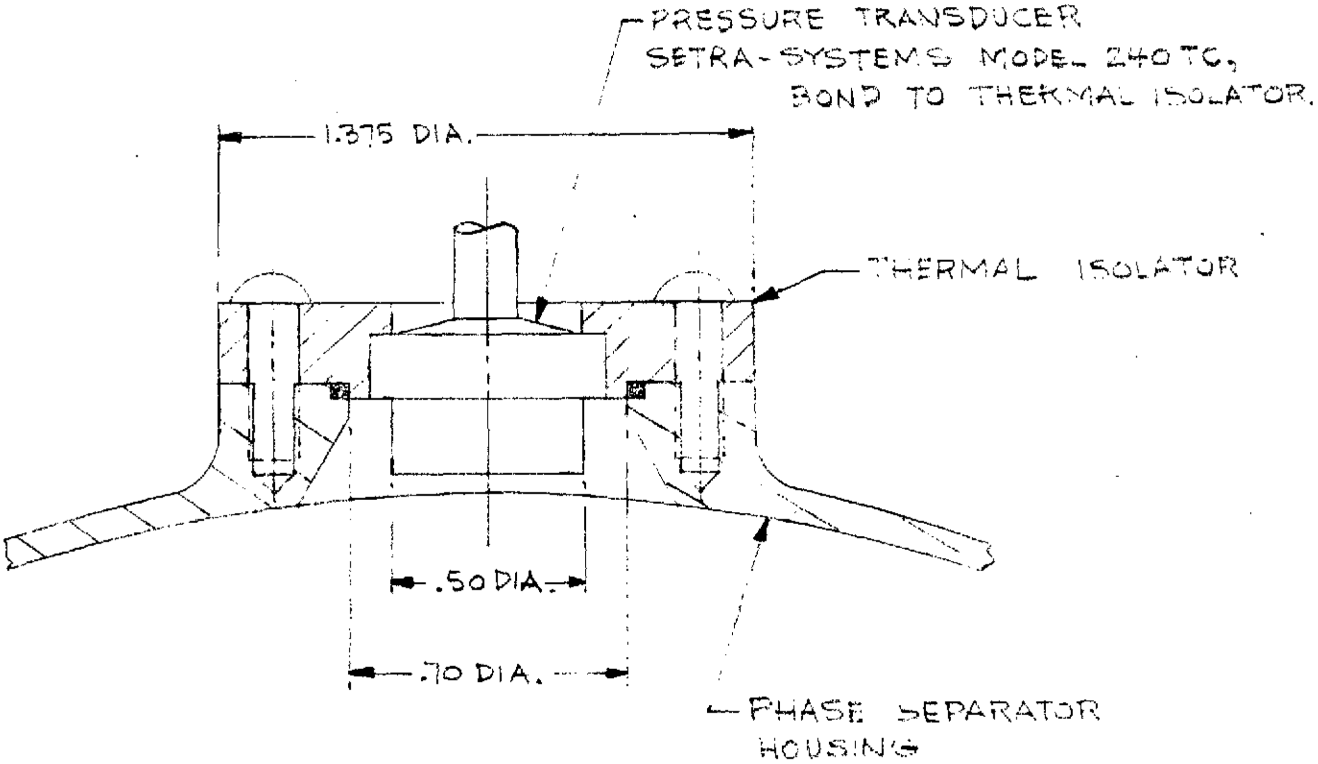


Figure 3-7. Pressure Transducer Mounting Detail

arrangement for the transducer which should alleviate the thermal lag. This is accomplished by opening up the cavity so that the sides as well as the end of the sensor are exposed to the fluid and by mounting the transducer in a thermal insulating material to prevent heat loss to the phase separator housing. Depending on micturition time, temperature compensation should then be effective within 15 to 30 seconds after completion of micturition.

3.2.2.4 Evaporation

Although not per se a part of the calibrated centrifuge hardware, the transport airflow does result in evaporation of the fluid within the phase separator and thus will result in a measurement error (in addition to Table 3-1 values). Several tests were performed to determine the magnitude of this evaporation error. Results indicate about a 0.3 to 0.5 gram/minute fluid evaporation for an airflow rate of 0.7 CFM with the rate seemingly independent of fluid mass in the phase separator. The above is roughly confirmed by calculations which indicate a loss of 0.6 grams/min. if the transport air were saturated leaving the phase separator. If desired, compensation of this relatively constant error would be easy to accomplish.

4.0 FLIGHT SYSTEM

Figure 4-1 shows a conceptual flight system in the form of a full scale mockup. The flight system was designed to meet the following general performance guidelines:

(a) Provide urine collection/disposal capability for individual micturitions.

(b) Measure volume of individual micturitions.

(c) Operation/design compatible with ASTP mission/interface constraints.

(d) Provide for semi-automatic operation.

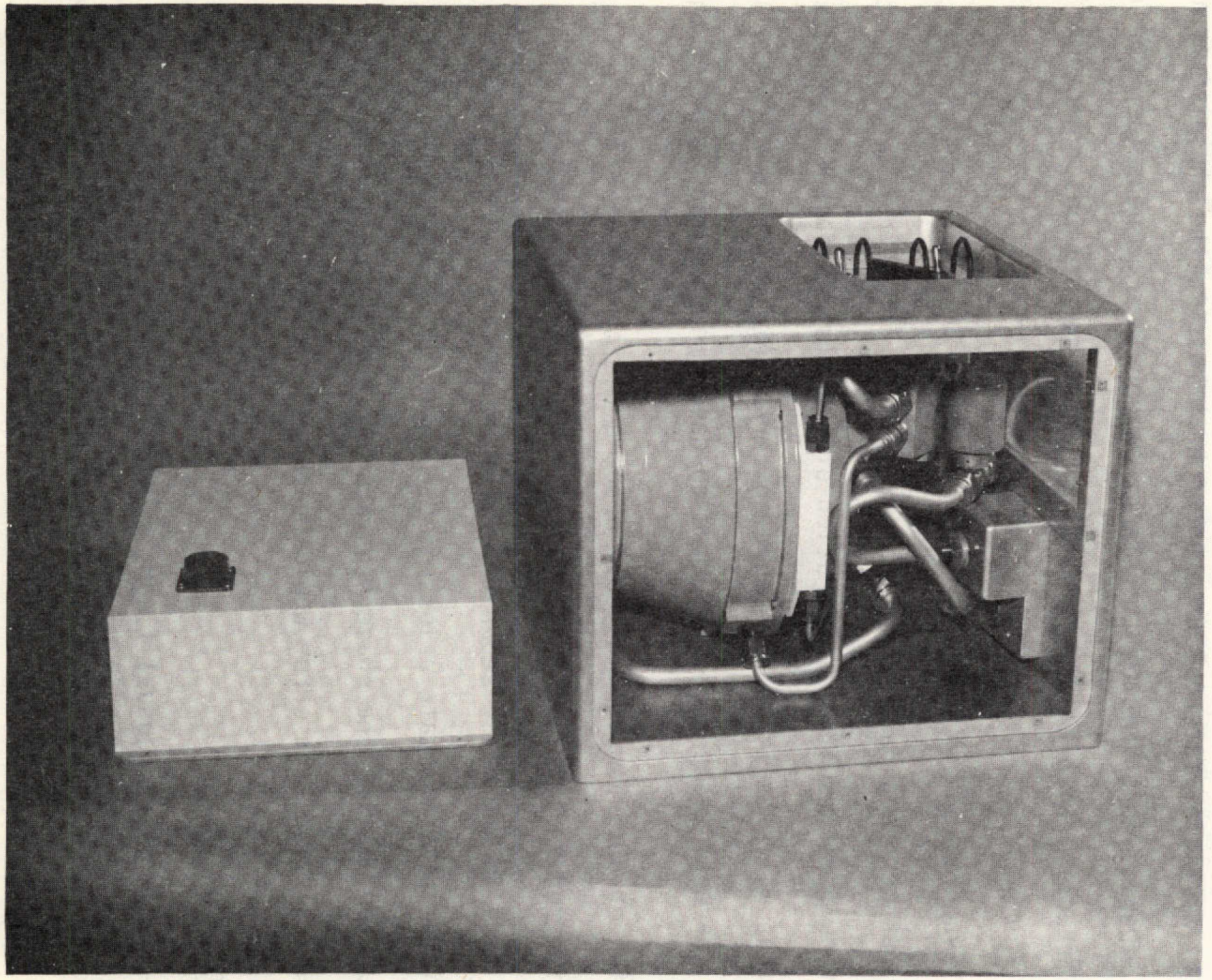


Figure 4-1. Flight Model Mockup (with electronics package shown removed on left)

The flight system block diagram is shown in Figure 4-2; Figure 4-3 illustrates the control/display panel layout. Table 4-1 summarizes the flight system operation sequence. Weight and power requirements were estimated for each component for a total overall weight of 28.5 lbs. and a peak power requirement (during volume measurement) of 65.7 watts, see Table 4-2.

In addition to the flight mockup, a preliminary CEI Specification, Part I, was prepared for the flight system, see Appendix Section 5.4.

5.0 APPENDIX

5.1 Drawing List

General Electric

GE Sk 56198-850	FTME Breadboard Model Assembly
GE Sk 56198-852	Inlet Fitting
GE Sk 56198-857	Dryer Assembly
GE Sk 56198-861	FTME Flight Mockup - Outboard Profile
GE Sk 56198-862	FTME Flight Mockup - Inboard Profile
GE Sk 56198-865	Electrical Schematic

Geoscience Ltd.

See Final Report on NASA Contract NAS 9-13461 (Report No. GLR-124).

5.2 Calibrated Centrifuge Analysis

GE PIR 1R62-73-127 (see copy attached).

5.3 Breadboard Model Specification

(See copy attached)

5.4 Flight System CEI Specification

Preliminary, Part I only (see copy attached).

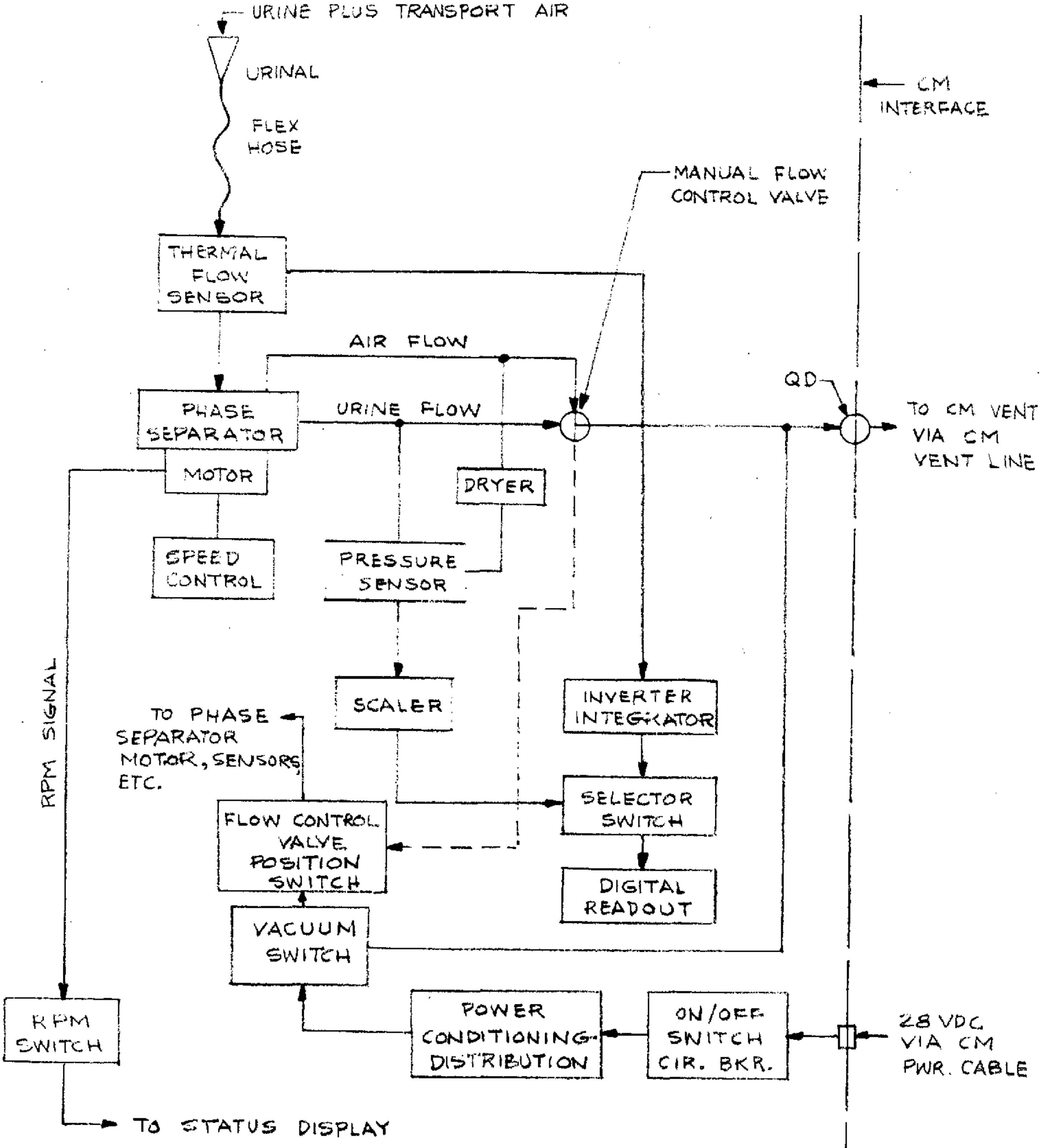
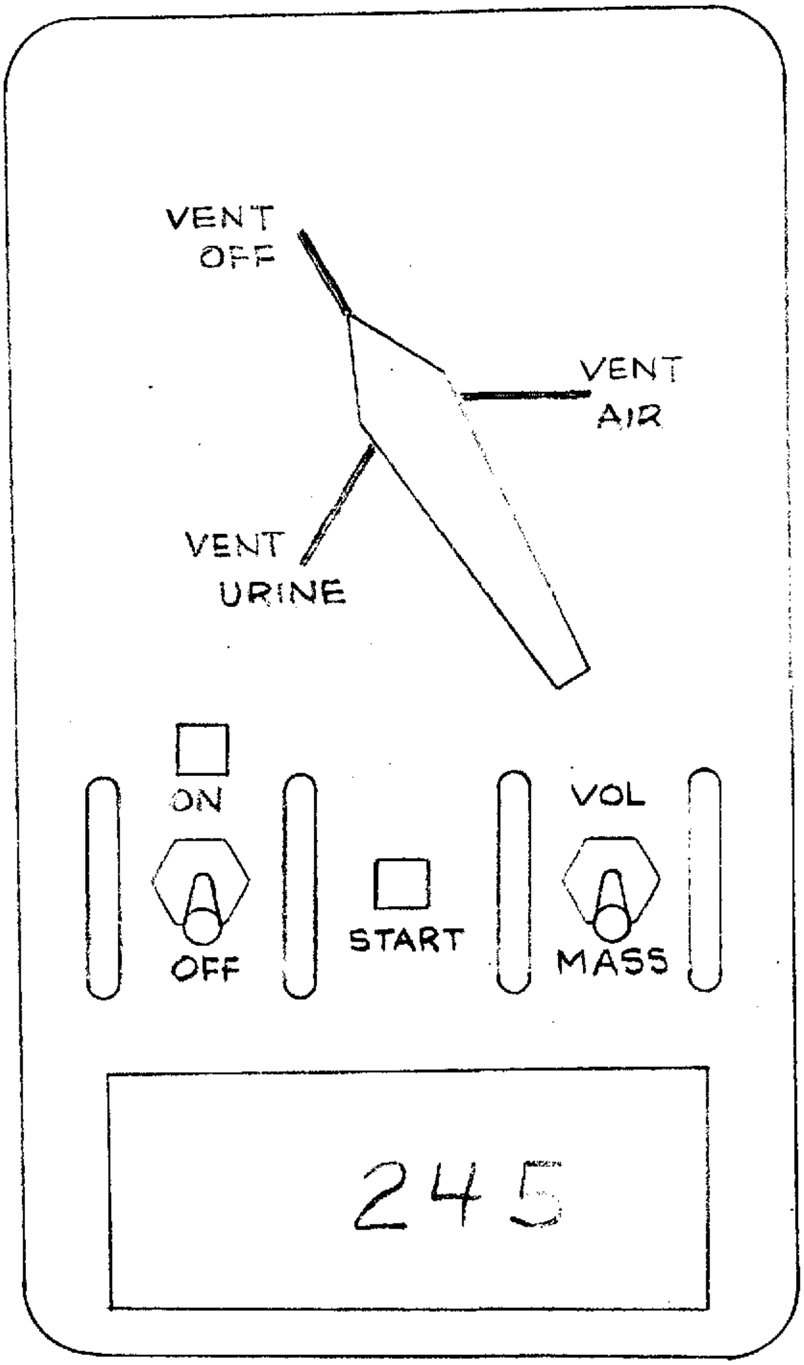


Figure 4-2. Flight System Block Diagram



- MANUAL VENT VALVE
- RECESSED PANEL / SWITCH GUARDS
- LED TYPE DIGITAL DISPLAY / INDICATOR LIGHTS

Figure 4-3. Control/Display Panel Layout (Preliminary)

TABLE 4-1. FLIGHT SYSTEM OPERATION SEQUENCE

1. OPERATOR ACTUATES POWER ON SWITCH.
2. POWER ON INDICATOR LIGHT ACTUATED AND POWER APPLIED TO SYSTEM ELECTRONICS.
3. OPERATOR SETS FLOW CONTROL VALVE TO VENT AIR POSITION.
4. WITH VACUUM PRESENT AND FLOW CONTROL VALVE IN VENT AIR POSITION, POWER APPLIED VIA FLOW CONTROL VALVE POSITION SWITCH TO PHASE SEPARATOR ASSEMBLY, THERMAL FLOW SENSOR HEATER, SENSOR ELECTRONICS AND SENSOR READOUT. IF FLEX VENT LINE NOT CONNECTED TO CM VENT OR VENT PLUGGED, VACUUM SWITCH WILL INHIBIT OPERATION.
5. WHEN PHASE SEPARATOR AT OPERATING RPM, START INDICATOR LIGHT ACTIVATED.
6. OPERATOR POSITIONS URINAL AND MICTURATES.
7. DURING MICTURITION, PHASE SEPARATOR REMOVES TRANSPORT AIR FROM INCOMING URINE STREAM AND STORES THE URINE (WITHIN THE PHASE SEPARATOR HOUSING).
8. AT COMPLETION OF MICTURITION, OPERATOR REPLACES URINAL AND RECORDS VOLUME AND MASS MEASUREMENT VALUES FROM DIGITAL READOUT VIA THE METER SELECTOR SWITCH.
9. OPERATOR RESETS FLOW CONTROL VALVE TO VENT URINE POSITION. FLOW CONTROL VALVE POSITION SWITCH STARTS TBD TIME DELAY AND TERMINATES POWER TO SENSORS AND ASSOCIATED ELECTRONICS.
10. URINE DUMPED TO CM VENT THRU FLOW CONTROL VALVE.
11. AT END OF TBD TIME DELAY, START INDICATOR LIGHT GOES TO FLASHING CONDITION.
12. OPERATOR RESETS FLOW CONTROL VALVE TO VENT OFF POSITION DEACTIVATING PHASE SEPARATOR.
13. SYSTEM READY FOR NEXT USER.

TABLE 4-2. FLIGHT SYSTEM WEIGHT/POWER ESTIMATE

	WEIGHT *	PEAK POWER **
PHASE SEPARATOR	9.5 LBS.	-
PHASE SEPARATOR MOTOR	1.8 LBS.	30 WATTS
THERMAL FLOW SENSOR	1.0 LBS.	25 WATTS
PRESSURE SENSOR	0.1 LBS.	0.5 WATTS
DRYER	0.1 LBS.	-
FLOW CONTROL VALVE	0.9 LBS.	-
CONTROL SWITCHES	0.2 LBS.	-
DIGITAL READOUT	0.8 LBS.	0.2 WATTS
ELECTRONIC PACKAGE	5.5 LBS.	10 WATTS
WIRING HARNESS	0.6 LBS.	-
PLUMBING (LINES/FITTINGS)	1.1 LBS.	-
PRESSURE SWITCH	0.2 LBS.	-
URINAL ASSEMBLY	0.3 LBS.	-
STRUCTURE	6.4 LBS.	-
TOTAL	28.5 LBS.	65.7 WATTS

* FOR ASSUMED 9 x 11 x 11 (1089 IN^3) CONFIGURATION AND ASSUMING USE OF EXISTING CM POWER CABLE AND VENT LINE

** AVERAGE POWER 3.7 WATTS

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PROGRAM INFORMATION REQUEST / RELEASE

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DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
6-12-73		FTME Breadboard Model	

SUBJECT

MASS SENSING ACCURACY

INFORMATION REQUESTED/RELEASED

Figure 1 shows the calculated mass measurement error using the phase separator (in combination with pressure sensor and speed control) as a backup mass monitor. For estimating purposes, the total error was assumed to be the RMS sum of the pressure sensor error and the error resulting from speed variations of the phase separator. Phase separator rpm was assumed to be within ± 0.1% of the desired rpm, the accuracy obtained using the designated Inland motor speed controller. The error for a Setra-Systems Model 237 pressure sensor was assumed at ± 0.2% of full scale (based on discussion with Setra-Systems personnel). The measurement error was calculated as shown in Enclosure A.

Referring to Figure 1, it is apparent that the estimated accuracy using the phase separator as a calibrated centrifuge is well under the ± 2% specified requirement. Figure 2 shows the improvement obtained by using two pressure sensors, operating in a low-high range mode. Note that the above is based on the phase separator operating at 365 rpm which, as shown in Figure 3, results in an output of 0.5 psi for a 1000 gram loading of the phase separator (0.5 is a standard range for the pressure sensor).

cc: R. W. Murray
G. L. Fogal

PAGE NO. 1 OF 8

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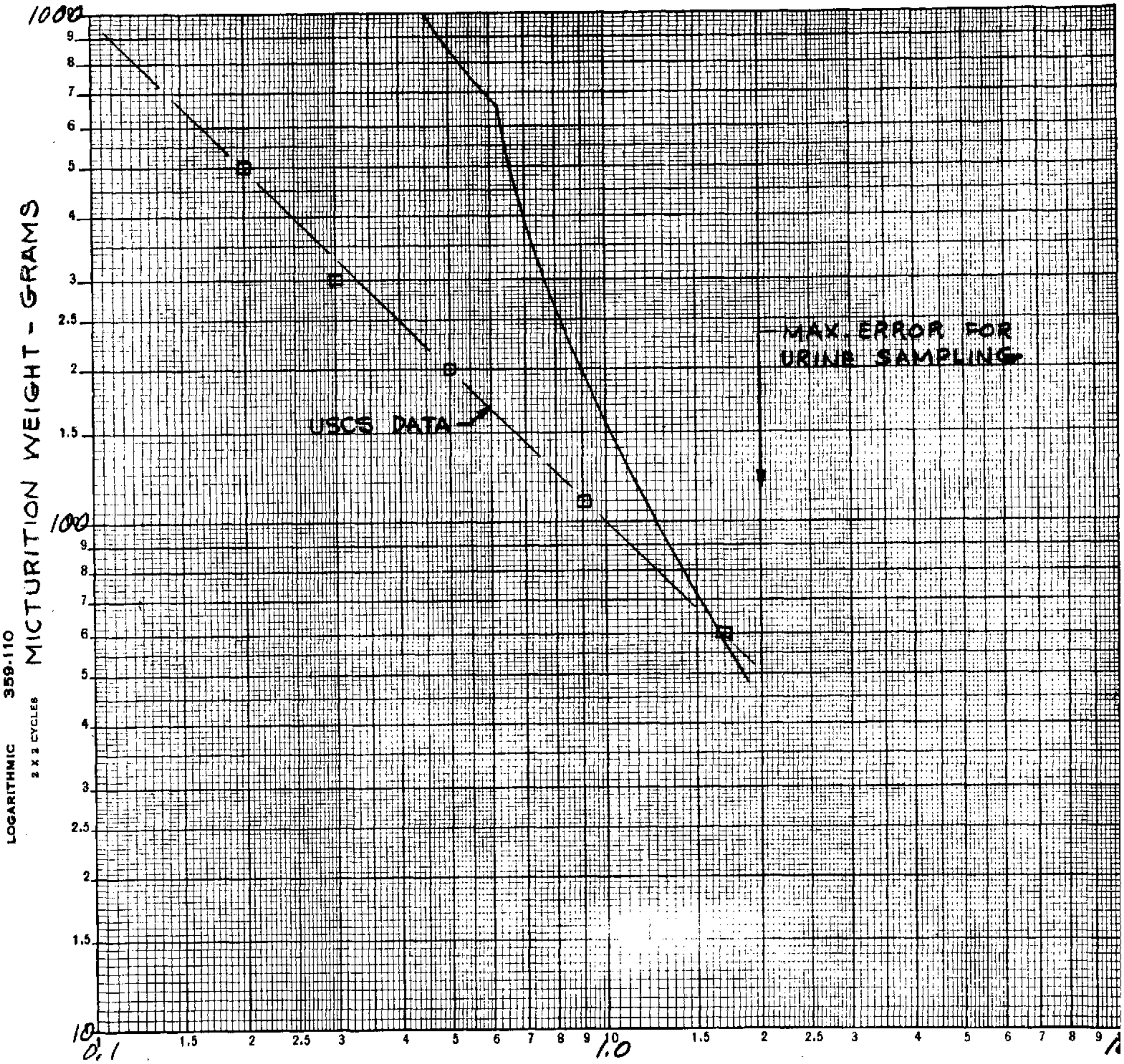


FIGURE 1 - CALIBRATED CENTRIFUGE MASS SENSING

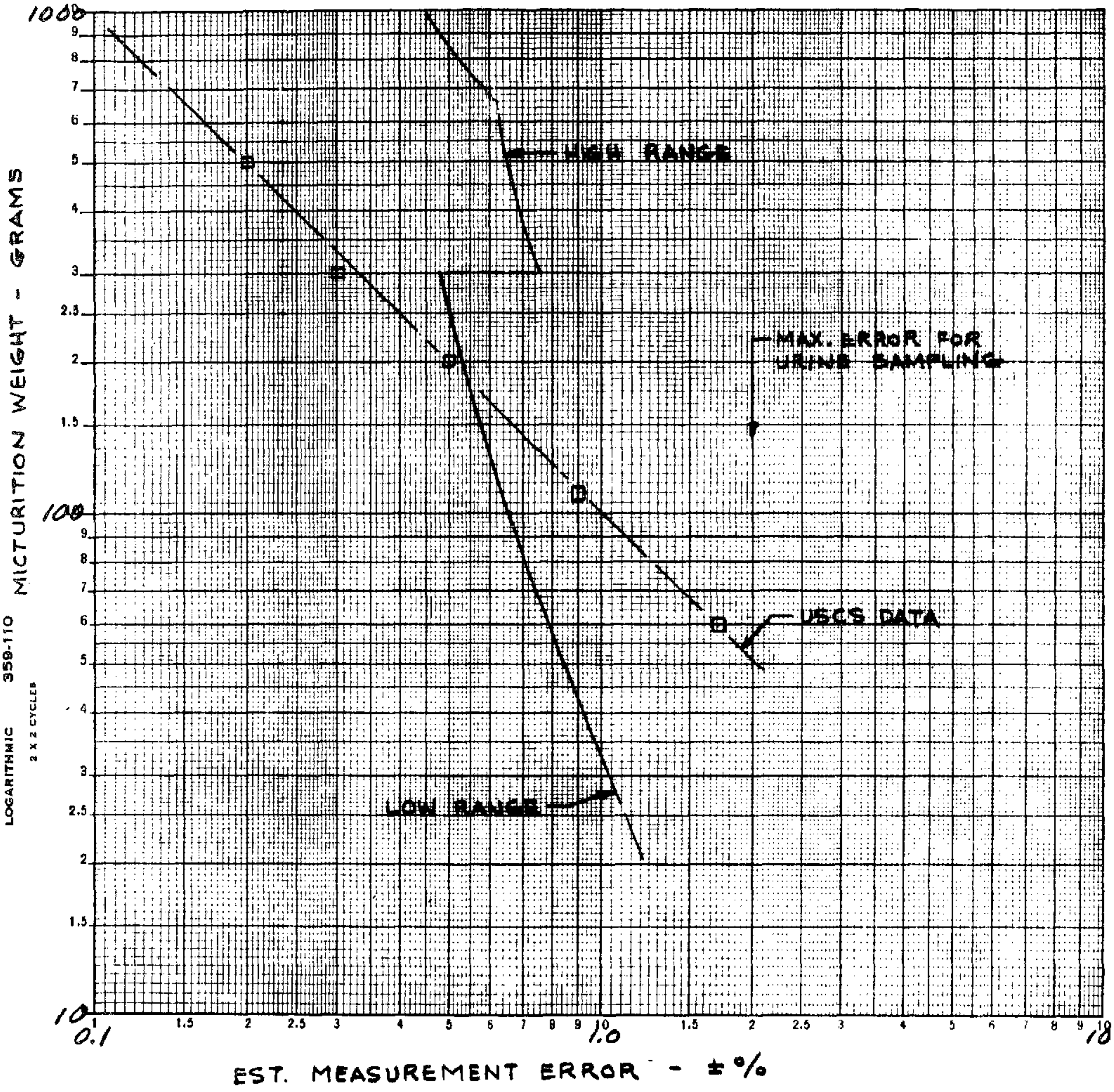
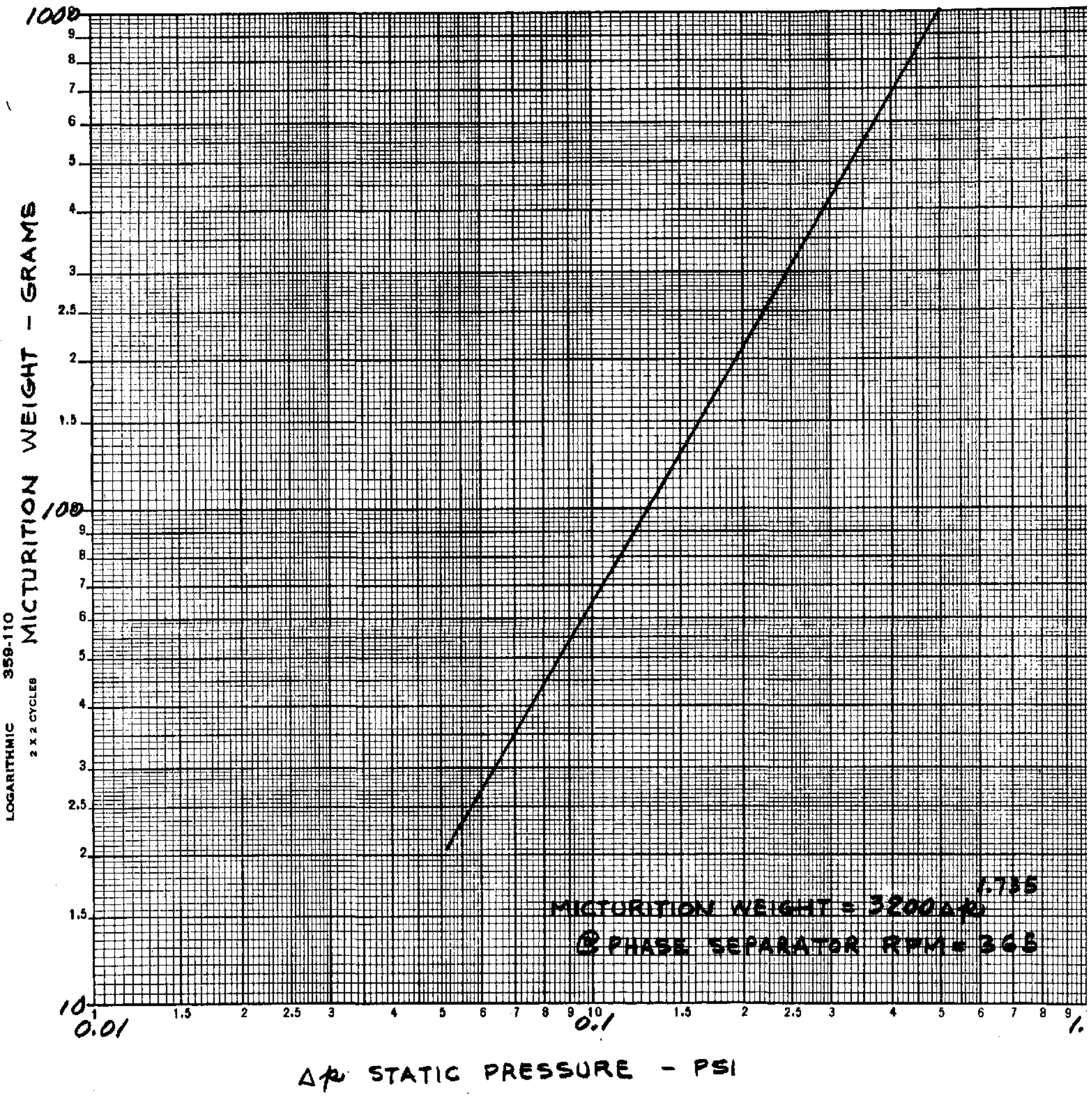


FIGURE 2 - CALIBRATED CENTRIFUGE MASS SENSING, DUAL RANGE



MICTURITION WEIGHT = $3200 \Delta p^{1.735}$

@ PHASE SEPARATOR RPM = 365

FIGURE 3 - PHASE SEPARATOR VORTEX STATIC PRESSURE

ENCLOSURE A - TYPICAL CALCULATION

GE USCS TYPE PHASE SEPARATOR (DWG. No. 47D225227)

STEP 1 : DETERMINE CENTRIFUGE RPM FOR 0.5 PSI PRESSURE SENSOR OUTPUT AT 1000 ML FLUID LEVEL.

$$p = \frac{\rho \omega^2}{2g}\left(r_0^2 - r^2\right) \qquad (1)$$

WHERE

p = FLUID STATIC PRESSURE AT r_0 (FOR ZERO GRAVITY CONDITION)

ρ = .0362 LBS/IN^3 (DENSITY OF WATER)

g = 386 IN/SEC^2

r_0 = 3.56 IN.

r = VORTEX INNER RADIUS AT 1000 ML LEVEL = 2.3 IN. (SEE FIGURE A-1)

ω = CENTRIFUGE RPM IN RAD/SEC.

THEN FROM EQ. (1),

$$\omega^2 = \frac{2(0.5)386}{.0362\left(3.56^2 - 2.3^2\right)}$$

ω = 38.3 RAD/SEC. = 365 RPM

STEP 2 : EST. PRESSURE CHANGE DUE TO VARIATIONS IN CENTRIFUGE RPM.

FROM EQ. (1),

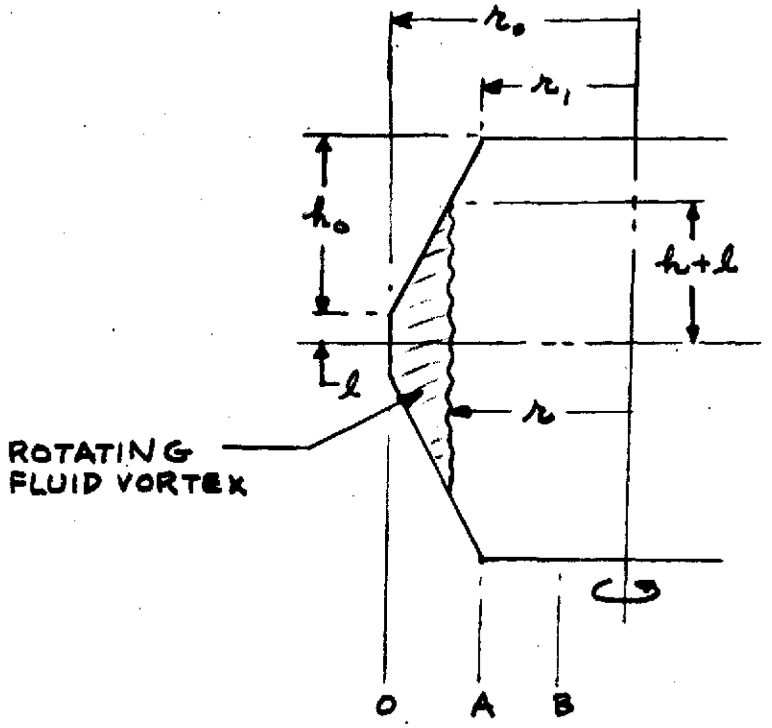
$$p + \Delta p = k\left(\omega + \Delta\omega\right)^2$$

$$p + \Delta p = k\left(\omega^2 + 2\omega\Delta\omega + \Delta\omega^2\right)$$

NEGLECTING $\Delta\omega^2$ AND SUB. FOR p FROM EQ. (1),

$$\Delta p = \frac{\rho}{g}\left(r_0^2 - r^2\right)\omega\Delta\omega \qquad (2)$$

$r_1 = 2.63$ IN.
$r_0 = 3.56$
$h_0 = 1.84$
$l = 0.25$



PHASE SEPARATOR CONFIG.

VOLUME (O TO A):

$$V = 2\left[\pi r_0^2 l + \frac{\pi}{4} h \left\{(r_0+r_1)^2 + \frac{1}{3}(r_0-r_1)^2\right\} - \pi r^2 (h+l)\right].$$

VOLUME (A TO B):

$$V = 2\left[\pi r_0^2 l + \frac{\pi}{4} h_0 \left\{(r_0+r_1)^2 + \frac{1}{3}(r_0-r_1)^2\right\} - \pi r^2 (h_0+l)\right].$$

r	V
2.3 IN.	1000 ml
2.49	800
2.63	655
2.9	382
3.1	218
3.3	94

FIGURE A-1 PHASE SEPARATOR VOLUME/RADIUS RELATIONSHIP

WHERE

$\Delta\omega$ = VARIATION IN CENTRIFUGE RPM = ±0.1%

$= .001\,(38.3) = 0.0383$ RAD/SEC.

STEP 3: EST. MIN. PRESSURE CHANGE DETECTION FOR PRESSURE SENSOR.

FOR SETRA-SYSTEMS MODEL 237, REPEATABILITY IS ± 10 MV OVER OUTPUT RANGE OF 5000 MV. THUS

$$\text{SENSOR ERROR} = \frac{0.5\,(10)}{5000} = \pm .001 \text{ PSI}$$

STEP 4: DETERMINE CENTRIFUGE DUE TO RPM VARIATION FROM EQ. (2) AT VARIOUS FLUID LEVELS IN CENTRIFUGE. THUS FOR 1000 ML,

$$\Delta p = \frac{.0362}{386}\,(3.56^2 - 2.3^2)\; 38.3\,(.0383) = .001 \text{ PSI}$$

STEP 5: DETERMINE RMS ERROR DUE TO PRESSURE SENSOR AND CENTRIFUGE. THUS FROM STEPS 3 AND 4,

$$\Delta p' = \text{RMS ERROR} = \sqrt{.001^2 + .001^2} = \pm .0014 \text{ PSI}$$

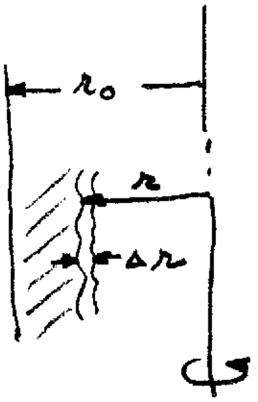
STEP 6: DETERMINE CHANGE IN FLUID LEVEL RADIUS TO PRODUCE $\Delta p'$. FROM EQ. (1),

$$p + \Delta p' = k\left[r_0^2 - (r - \Delta r)^2\right]$$

$$p + \Delta p' = k\,(r_0^2 - r^2 + 2r\Delta r + \Delta r^2)$$

NEGLECTING Δr^2

$$\Delta p' = k\,2r\Delta r = \frac{\rho}{g}\,\omega^2 r\Delta r$$



AND

$$\Delta r = \frac{g\,\Delta r'}{\rho\,\omega^2 r}$$

USING $\Delta r'$ FROM STEP 6,

$$\Delta r = \frac{386}{.0362}\,\frac{(.0014)}{38.3^2(2.3)} = .0045 \text{ IN.}$$

STEP 7: DETERMINE LIQUID MASS CHANGE EQUIVALENT TO Δr.

$$\Delta W = 2\pi r\,\Delta r\,\rho\,(h+l)$$

$$= 2\pi(2.3)(.0045).0362(2)2.09$$

$$= .0099 \text{ LBS.}$$

$$= 4.47 \text{ GRAMS}$$

STEP 8: DETERMINE EST. MEASUREMENT ERROR.

USING DATA FROM ABOVE FOR 1000 ML FLUID LOADING,

$$\text{EST. MEASUREMENT ERROR} = \frac{4.47 \times 100}{1000} = \pm .45\%$$

JULY 1973
Revision A

ASTP
FLUID TRANSFER MEASUREMENT EXPERIMENT
BREADBOARD MODEL

DESIGN
SPECIFICATION

CONTRACT NAS 9-13519

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

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FIGURES

ASTP
FLUID TRANSFER MEASUREMENT EXPERIMENT
BREADBOARD MODEL

Design Specification

1.0 SCOPE

This specification defines the performance and design requirements for the Fluid Transfer Measurement Experiment (FTME) Breadboard Model and establishes requirements for its design, development and test.

1.1 Purpose

The purpose of the FTME Breadboard Model shall be to provide verification and demonstration of the FTME concept.

2.0 APPLICABLE DOCUMENTS

Statement of Work, Contract NAS 9-13519.

3.0 REQUIREMENTS

3.1 Performance

3.1.1 Functional Requirements

3.1.1.1 Primary Performance Requirements

3.1.1.1.1 Collection

The FTME Breadboard Model shall collect the total quantity of urine voided by a human subject. Specific requirements are as follows:

a. The Breadboard Model shall accommodate individual micturitions ranging in volume up to a maximum of 800 ml.

b. The Breadboard Model shall be compatible with a maximum urine flow rate of 30 ml/second.

c. The Breadboard Model shall simulate pneumatic transport of urine into the system.

d. The Breadboard Model shall be sized to accommodate 21 man-days of use with an average of 7 micturitions per day per user.

e. The Breadboard Model shall not require use of an intimate contact device for urine collection.

3.1.1.1.2 Measurement

The FTME Breadboard Model shall provide real time measurement of the total quantity of urine voided. Specific requirements are as follows:

a. The primary measurement sensor for total volume shall be the thermal flowsensor concept developed by Geosciences Lts., under NASA contract NAS 9-11612. This sensor and supporting electronics will be supplied GFE for integration into the FTME Breadboard Model.

b. A secondary measurement sensor shall be provided to confirm and supplement the thermal flowsensor. This secondary sensor shall convert phase separator liquid pressure into equivalent total mass.

c. Each total micturition shall be measured within an accuracy of ± 2% error.

d. Provision shall be included for monitoring micturition rate.

3.1.1.1.3 Sampling

The FTME Breadboard Model shall be compatible with sample collection.

3.1.1.1.4 Equipment Requirements

The FTME Breadboard Model shall conform to the functional block diagram of Figure 3.1.1-1.

3.1.1.1.4.1 Displays

The Breadboard Model shall provide a digital readout for total micturition volume (or mass). A visual indication of operational status shall also be provided.

3.1.1.1.4.2 Power

The breadboard Model shall be designed to operate on 28 vdc and/or 115 v, 60 Hz.

3.1.1.1.4.3 Gravity Field

The Breadboard Model shall be designed for gravity independent operation. However, performance shall be demonstrated for normal earth gravity conditions only.

3.1.1.1.4.4 Configuration

The Breadboard Model shall be configured (within the constraints of equipment availability) to provide both a functional and attractive appearance representative of a possible flight configuration. The Breadboard Model need not be optimized for minimum size, weight or power input.

3.1.1.1.4.5 Operation

The Breadboard Model shall be designed for a high degree of automatic operation.

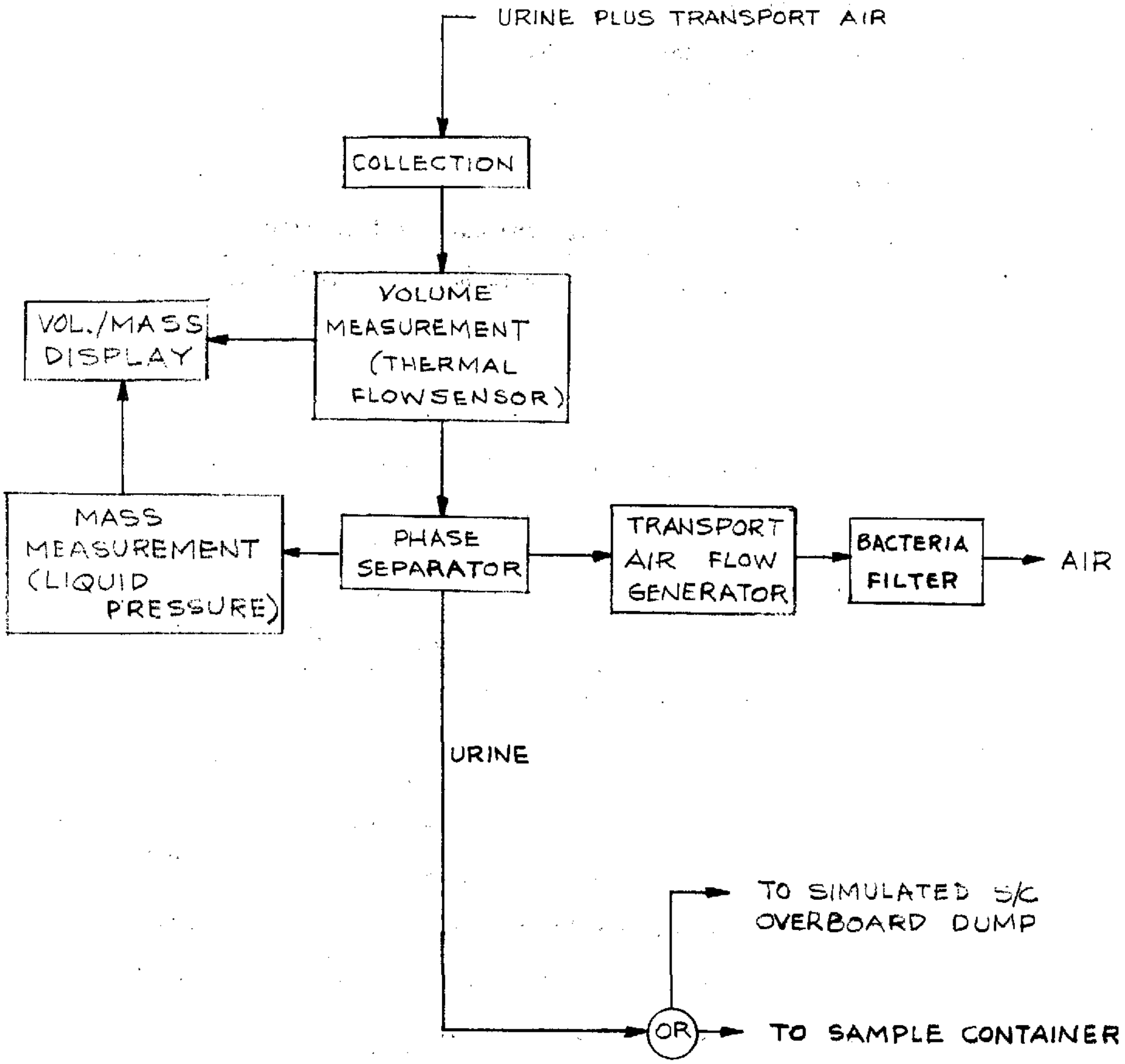


FIGURE 3.1.1-1 FTME B/B MODEL FUNCTIONAL BLOCK DIAGRAM

3.1.1.1.4.6 Maintenance

The Breadboard Model shall be designed to be easily maintainable including replacement of components.

3.1.1.2 Secondary Performance Requirements

The FTME Breadboard Model shall conform to the block diagram of Figure 3.1.2-1 and operating sequence diagram of Figure 3.1.2-2.

3.1.1.2.1 Size

The Breadboard Model shall be configured to fit within an envelope 11 inches high, 13 inches wide and 27 inches deep (except for urinal assembly).

3.1.1.2.2 Weight

The Breadboard Model shall not be weight constrained.

3.1.1.2.3 Component Description

3.1.1.2.3.1 Urinal Assembly

The urinal assembly serves as the urine collection agency for the Breadboard Model. Specific design requirements are as follows:

(Urinal Assembly Supplied GFE)

3.1.1.2.3.2 Thermal Flow Sensor

The function of the thermal flow sensor is to provide a real time measurement to urine volume for each micturition. Specific design requirements are as follows:

(Thermal Flow Sensor Supplied GFE)

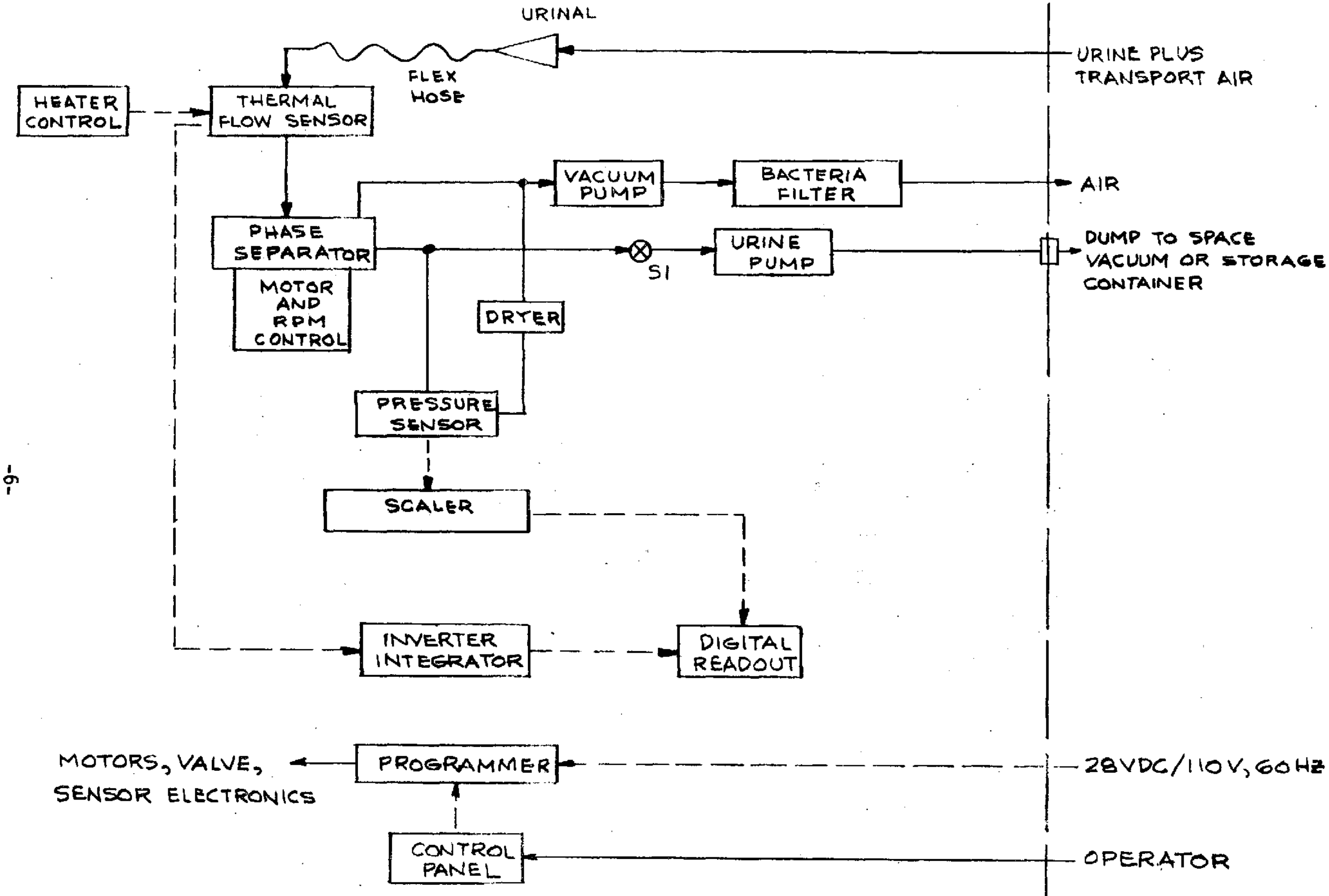
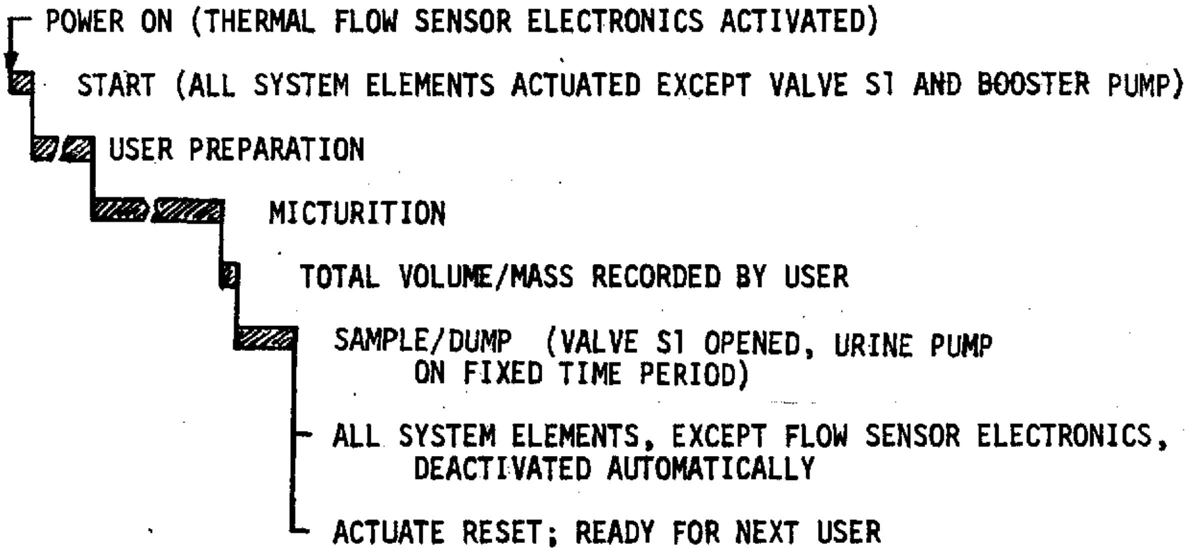


FIGURE 3.1.2-1 FTME B/B MODEL BLOCK DIAGRAM



COLLECTION/MEASUREMENT/STORAGE SEQUENCE

POWER ON (THERMAL FLOW SENSOR ELECTRONICS ACTIVATED)

START (ALL SYSTEM ELEMENTS ACTUATED EXCEPT VALVE S1 AND BOOSTER PUMP)

USER PREPARATION

MICTURITION

TOTAL VOLUME/MASS RECORDED BY USER

SAMPLE/DUMP (VALVE S1 OPENED, URINE PUMP ON FIXED TIME PERIOD)

ALL SYSTEM ELEMENTS, EXCEPT FLOW SENSOR ELECTRONICS, DEACTIVATED AUTOMATICALLY

ACTUATE RESET; READY FOR NEXT USER

FIGURE 3.1.2-2 OPERATING SEQUENCES

3.1.1.2.3.3 Phase Separator Assembly

The function of the phase separator assembly is to separate the urine from the transport air flow, to temporarily store the urine prior to sampling or storage and, in combination with the pressure sensor, used as a calibrated centrifuge to measure total urine mass for each micturition. Specific design requirements are as follows:

a. Positive dynamic phase separation featuring a rotating impellor within a fixed external housing shall be used.

b. The phase separator drive motor shall be capable of driving the impellor at a constant speed (± 0.5%).

c. External diameter of the assembly shall be limited to 8.0 inches. The height shall be sized (less motor) to accommodate a maximum 1000 ml urine load.

d. A static type exit port (rather than tangential) for sensing pressure shall be provided.

e. Flow passages shall be sized to be compatible with a 1 CFM transport air flow, an entering urine flow of 45 ml/second maximum and an exit urine flow of 1.25 ml/second maximum.

f. A debris filter shall be incorporated into the impellor.

3.1.1.2.3.4 Urine Pump

The function of the urine pump is to provide the pressure head for conveying the urine from the phase separator to the sample/dump. Specific design requirements are as follows:

a. The urine pump shall be capable of 200 lbs/hour (25 grams/second) flow at a 2 psi pressure head.

b. The pump shall be a seal-less type.

3.1.1.2.3.5 Air Pump

The function of the air pump is to provide the transport air flow into the urinal and in turn thru the thermal flow sensor, phase separator and out through the filter assembly. Specific design requirements are as follows:

a. The air pump shall be capable of 1.0 CFM air flow at a 4.5 psi vacuum.

b. The air pump shall be an "oil-less" type.

3.1.1.2.3.6 Filter Assembly

The function of the filter is to trap bacteria prior to the return of the transport air to ambient. Specific design requirements are as follows:

a. The bacteria control media shall mechanically remove 98% of 0.04 micron size particles and 100% of 0.6 micron size (or larger) particles.

b. Pressure drop thru the filter assembly shall be less than 0.2 inches of water at 1 CFM air flow.

c. The filter assembly shall be sized for 21 man-days of mission operations.

3.1.1.2.3.7 Pressure Sensor

The output of the pressure sensor is proportional to fluid mass within the phase separator. Specific design requirement are as follows:

a. Pressure sensing range shall be 0 to 0.5 psia.

b. Sensor output shall be linear and directly proportional to the sensed pressure. An increasing pressure shall result in an increasing output.

c. Frequency response shall be flat to 100 Hz.

d. Performance shall not be degraded by exposure to urine.

3.1.1.2.3.8 Scaler

The function of the scaler is to convert the pressure sensor output to mass units and to condition the output for acceptance by the digital meter readout. Specific design requirements are as follows:

a. The relationship between mass and pressure sensor output shall conform to Figure 3.1.2-3.

3.1.1.2.3.9 Heater Controller

The function of the heater controller is to provide a controlled power input to the thermal flow sensor heater element. Specific design requirements are as follows:

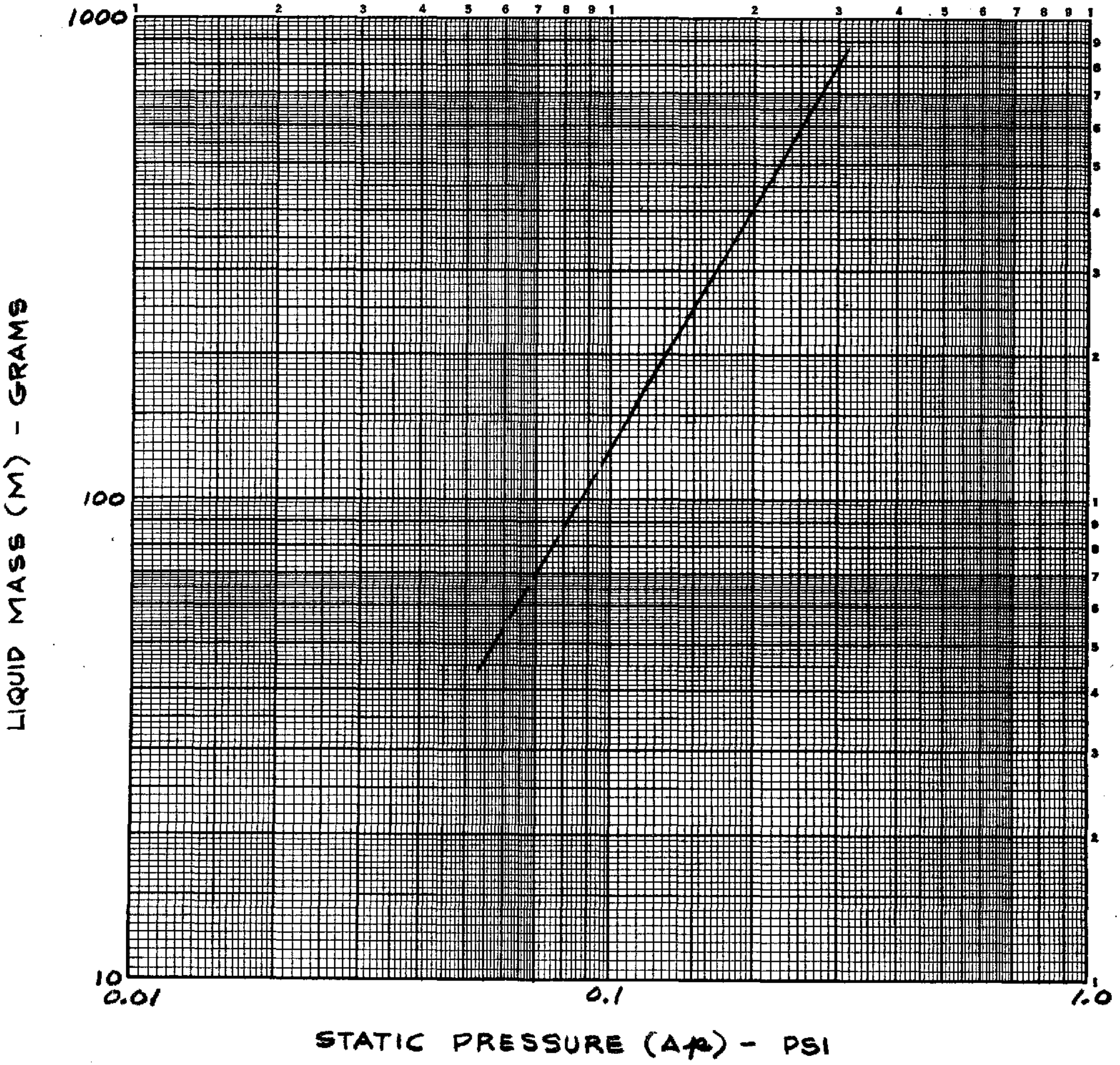
(Heater Controller Supplied GFE)

3.1.1.2.3.10 Inverter/Integrator

The inverter/integrator conditions and integrates the output of the thermal flowsensor. Specific design requirements are as follows:

(Inverter/Integrator Supplied GFE)

FIGURE 3.1.2-3 PRESSURE/MASS RELATIONSHIP



3.1.1.2.3.11 Digital Readout

The digital readout meter displays the thermal flow sensor or pressure sensor output. A selector switch shall be provided for selecting the desired sensor input. Specific requirements are as follows:

(Meter, Datascan Model 820, Supplied GFE)

3.1.1.2.3.12 Power Conditioning And Distribution

The power conditioning and distribution component shall condition and/or distribute external power as required by individual Breadboard Model components.

3.1.1.2.3.13 Control Panel

The control (and displays) panel shall conform to Figure 3.1.2-4.

3.1.1.2.3.14 Structure Assembly

A structure assembly shall be provided for mounting and supporting the Breadboard Model components. Specific design requirements are as follows:

a. The structure assembly with other equipments installed (except the urinal assembly) shall conform to the dimensions of 3.1.1.2.1. The urinal assembly may be located externally.

b. Specific equipment shall be located to minimize potential EMI problems and length of plumbing runs consistent with normal operating and maintenance requirements.

c. The control panel shall be top mounted (11 x 13 inch surface).

d. The structure assembly shall be designed to withstand normal laboratory use.

3.1.1.2.4 System Operation

The FTME Breadboard Model shall conform to the following operational sequence (Reference Figures 3.1.2-1, 3.1.2-2 and 3.1.2-4).

3.1.1.2.4.1 Power ON

a. Power ON switch actuated by user.

b. Power ON indicator light activated.

c. Thermal flow sensor electronics, digital meter activated.

d. Warm-up (approximately 2 hours required to stabilize thermal flow sensor and related electronics).

3.1.1.2.4.2 Collection And Measurement

a. START switch actuated by user.

b. START switch indicator light activated.

c. Phase Separator, air pump, pressure sensor and control electronics activated.

d. If required, user actuates RESET switch to zero digital meter.

e. Urinal removed by user.

f. Micturition by user.

g. Phase separation, i.e., removal of transport air, and volume/mass measurements occur simultaneously with micturition.

h. At completion of micturition, user replaces urinal and records volume and mass (as displayed on the digital meter).

3.1.1.2.4.3 Dump

a. SAMPLE/DUMP switch actuated by user.

b. SAMPLE/DUMP switch indicator light activated.

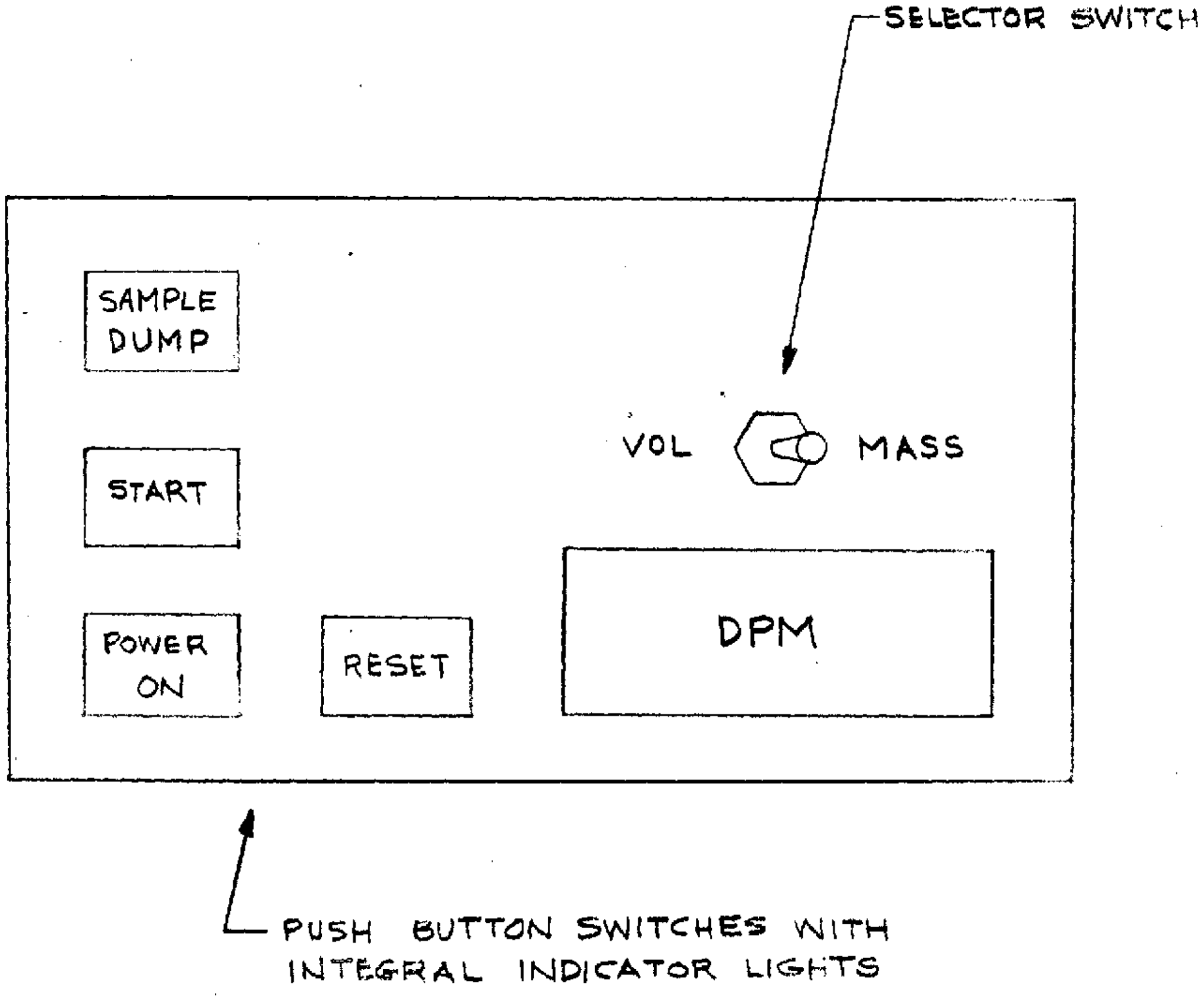


FIGURE 3.1.2-4 CONTROL PANEL LAYOUT (NOT TO SCALE)

c. Valve S1 activated (OPEN) and booster pump ON.

d. After 60 seconds, power OFF; all components except those of 3.1.1.2.4.1(c) deactivated.

e. Ready for next user.

3.1.2 Operability

3.1.2.1 Reliability

Breadboard Model reliability shall be achieved by reliance on maintenance procedures rather than redundancy.

3.1.2.2 Maintainability

The Breadboard Model shall be designed to provide component accessibility, replaceability and serviceability consistent with the intended use.

3.1.2.3 Useful Life

The Breadboard Model shall be designed for a useful laboratory life, with maintenance, consistent with the intended use.

3.1.2.4 Operating Environment

The Breadboard Model shall be designed to operate under conditions normally encountered in engineering or physiological test laboratories.

3.1.2.5 Human Engineering

Human Engineering factors shall be considered in the design and layout of the Breadboard Model.

3.1.2.6 Safety

3.1.2.6.1 User Safety

The Breadboard Model shall be designed to prevent hazardous conditions and inadvertent operation. Specifically,

a. Sharp edges, corners or equal shall be eliminated.

b. All electrical junction points shall be insulated or otherwise covered to prevent accidental contact.

c. All components shall be grounded to the structure with provisions on the structure for connecting to an external ground provided.

3.1.2.6.2 Equipment Safety

The Breadboard Model shall incorporate fail-safe features. Specifically, fault isolation protection shall be provided as required. Consideration shall also be given to protecting electrical circuits from inadvertent urine leakage.

3.2 Interface Requirements

3.2.1 Electrical

The Breadboard Model shall operate on nominal 28 volt DC or 115 volt, 60 Hz power from an external source.

3.2.2 Mechanical

The Breadboard Model shall be self-supporting (structurally).

3.2.3 Fluid

The Breadboard Model shall use ambient air as the transport fluid.

3.2.4 Dump

The Breadboard Model shall be compatible with a simulated spacecraft vacuum dump capability.

4.0 TEST REQUIREMENTS

4.1 Quality Assurance

A minimal quality assurance program shall be performed consistent with the design status of the FTME Breadboard Model. The intent of this effort shall be to provide valid background information for subsequent program phases. Specific requirements are as follows:

a. Maintain configuration control records, i.e., provide a good record of what was fabricated and tested.

b. Perform laboratory tests to compare actual performance with specification requirements.

c. Fabricate in accordance with good commercial practice.

4.2 Verification

The performance of the FTME Breadboard Model shall be determined under simulated ASTP environment and interface conditions and with specific development tests as follows:

a. Verify operating conditions/cycles, i.e.,

    (1) Power ON/OFF
    (2) START
    (3) SAMPLE/DUMP

b. Determine accuracy of volume and mass measurements.

SPECIFICATION NO. TBD
DATE: OCTOBER 1973

END-ITEM SPECIFICATION PART I

FLUID VOLUME MEASUREMENT SYSTEM

NASA CONTRACT NAS 9-13519

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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Specification No:
Date: October 1973

PRELIMINARY

FLUID VOLUME MEASUREMENT SYSTEM
END-ITEM SPECIFICATION PART I

1.0 SCOPE

This part of this specification establishes the requirements for the performance, design, test and qualification of one model Fluid Volume Measurement System (FVMS). This End-Item shall be used to demonstrate system performance and to accomplish the collection and real time measurement of individual micturition volumes under null gravity conditions. This End-Item is in criticality category 4.

1.1 Changes

All changes to Part I of the approved End-Item Specification shall be by approved Specification Change Notices (SCN).

2.0 APPLICABLE DOCUMENTS

The following documents, of exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between this specification and other documents herein, the requirements of this specification shall prevail.

2.1 NASA

MSC M8080	Manned Spacecraft Criteria and Standards
MSC-PA-D-67-13	Nonmetallic Materials Requirements Manual
NHB 5300.4(3A)	Requirements for Soldering Electrical Connectors
NHB 5300.4(1C)	TBD
KMI-1710.1A	General Safety Plan, Kennedy Space Center

2.2 Military

MIL-A-9067	Adhesive Bonding Process and Inspection Requirements; 16 March 1961.
MIL-B-5087B	Bonding, Electrical and Lightning Protection for Aerospace Systems; 15 October 1964.
MIL-STD-461	Electromagnetic Interface Characteristics Requirements for Equipment.
MIL-W-6858C	Welding, Resistance: Aluminum, Magnesium, Non-Hardening Steels or Alloys, Nickel Alloys, Heat-Resisting Alloys, and Titanium Alloys; Spot and Seam.
MS-33586	Metals, Definition of Dissimilar; 16 December 1958.
MIL-STD-470	Maintainability Program Requirements (For Systems and Equipments) 21 March 1966.
MIL-STD-1472A	Human Engineering Design Criteria for Military Systems, Equipment and Facilities 9 February 1968.
MIL-E-5400K	Electronic Equipment, Airborne General Specification for; 24 May 1968.
MIL-HDBK-217	Reliability, Stress & Failure Rate Data for Electronic Equipment
MIL-S-5002	Surface Treatment & Metallic Coatings for Metal Surface of Weapon Systems.
MIL-B-7883B	Brazing of Steels, Copper, Copper Alloys, Nickel Alloys, Aluminum and Aluminum Alloys. 20 February 1968.
MIL-STD-130C	Identification Marking of U.S. Military Property; 29 September 1967.
MIL-STD-810B	Environmental Test Methods
MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes.
MIL-STD-889	Dissimilar Metals
RADC-TR-67-108	RADC Reliability Notebook, Volume 2
MIL-STD-100A	Engineering Drawing Practices.

2.3 General Electric

GE-STD-S333802	Parts, Components, Assemblies and Sub-Assemblies; Surface Cleanliness for.

GE-STD-S33125	Penetrant Inspection of Nonmagnetic Metal Parts
GE-SPEC-171A83447	Acceptance Criteria for Tightness plus Cleanliness of Electronic Components.
GE-SPEC-171A4417	Cleanliness Requirements for Pneumatic System Components
GE-SPEC-146A9614	Fusion Welding
GE-SPEC-171A4420	Compound, Urethane - Flexible, for Potting and Conformal Coating.
GE-SPEC-171A4425	Bonding with Epoxy Series Adhesives
GE-SPEC-146A9026	Glass Fiber-Epoxy Resin, Low Pressure Laminates; Fabrication of
GE-SPEC-147A1845	AL Dip Brazing
GE-SPEC-118A1526	Identification and Marking
GE-SPEC-171A4287	Rivets, Installation of

3.0 REQUIREMENTS

3.1 Performance

3.1.1 Functional Requirements

The Fluid Volume Measurement System (FVMS) shall be comprised of those components required for the collection and volume measurement of individual micturitions under null gravity conditions.

3.1.1.1 Primary Performance Requirements

3.1.1.1.1 Collection

The FVMS shall collect the total quantity of urine voided by a human subject. Specific requirements are as follows:

a. The FVMS shall accommodate individual micturitions ranging in volume up to a maximum of 800 ml.

b. The FVMS shall be compatible with a maximum urine flow rate of 30 ml/second.

c. The FVMS shall utilize pneumatic transport of urine into the system.

d. The FVMS shall be designed to accommodate 21 man-days of use with an average of 7 micturitions per day per user.

e. The FVMS shall not require use of an itimate contact device for urine collection.

3.1.1.1.2 Measurement

The FVMS shall provide real time measurement of the total quantity of urine voided. Specific requirements are as follows:

a. The primary measurement sensor for total volume shall be a thermal type flowsensor.

b. A secondary measurement sensor shall be provided to confirm and supplement the thermal flowsensor. This secondary sensor shall convert dynamic phase separator liquid pressure into equivalent total mass.

c. Each total micturition shall be measured with an error of less than ± 2%.

d. An inflight measurement calibration check capability shall be provided.

3.1.1.1.3 Sampling

The FVMS design shall be compatible with the potential future addition of a sample collection capability.

3.1.1.1.4 Disposal

The FVMS shall be compatable with the Apollo CM overboard liquid dump capability for the disposal of collected urine. Loss of spacecraft ambient atmosphere shall be minimized during the disposal process.

3.1.1.1.5 Equipment Requirements

The FVMS shall conform to the functional block diagram of Figure 3.1.1-1.

3.1.1.1.5.1 Collection

3.1.1.1.5.1.1 Urinal Assembly

The SKYLAB urinal and flex hose designs shall be used for the FVMS.

3.1.1.1.5.1.2 Air Transport

Transport air flow required to pneumatically convey the urine into the FVMS shall be provided by connecting the FVMS to space vacuum via the Apollo CM overboard fluid dump vent. Maximum FVMS airflow requirements shall not exceed TBD CFM of ambient spacecraft atmosphere (nominal 5 psia).

3.1.1.1.5.2 Volume Measurement

The FVMS volume measurement capability shall be provided by the thermal flowmeter concept developed by Geoscience Ltd. under NASA contracts NAS 9-11612 and NAS 9-13461.

3.1.1.1.5.3 Phase Separation

Phase separation for the FVMS shall be accomplished by the dynamic type phase separator developed by General Electric under NASA contracts NAS 1-11443 and NAS 9-10741.

3.1.1.1.5.4 Mass Measurement

The phase separator, in combination with a pressure sensor, shall be used as a calibrated centrifuge to provide the FVMS mass measurement capability.

3.1.1.1.5.5 Calibration

Calibration containers shall be provided to inject a known volume/mass of fluid into the FVMS during flight operation to check FVMS measurement calibration.

3.1.1.1.5.6 Displays

The FVMS shall provide a digital readout for total micturition volume (or mass). A visual indication of operational status shall also be provided.

3.1.1.1.5.7 Operation

The FVMS shall be designed for semiautomatic operation. Manual control elements shall be easily accessible and positive acting.

3.1.1.1.5.8 Power Conditioning

The FVMS be designed to operate on 23 to 30 VDC (steady state limits) unregulated power from the CM. Maximum power required shall not exceed 70 watts.

3.1.1.1.5.9 Data Acquisition

Interfacing with the spacecraft telemetry system shall not be a requirement. Volume/mass data for each micturition shall be visually determined (from the digital display) and manually recorded.

3.1.1.1.5.10 Safety

3.1.1.1.5.10.1 Personnel Safety

The FVMS shall be designed to prevent the inadvertent release of collected urine into the ambient environment.

3.1.1.1.5.10.2 Equipment Safety

The FVMS shall incorporate fail-safe features to prevent equipment damage and personnel hazards.

3.1.1.1.5.11 Gravity Field Operation

The FVMS shall be designed to operate in either a zero gravity or normal gravity environment.

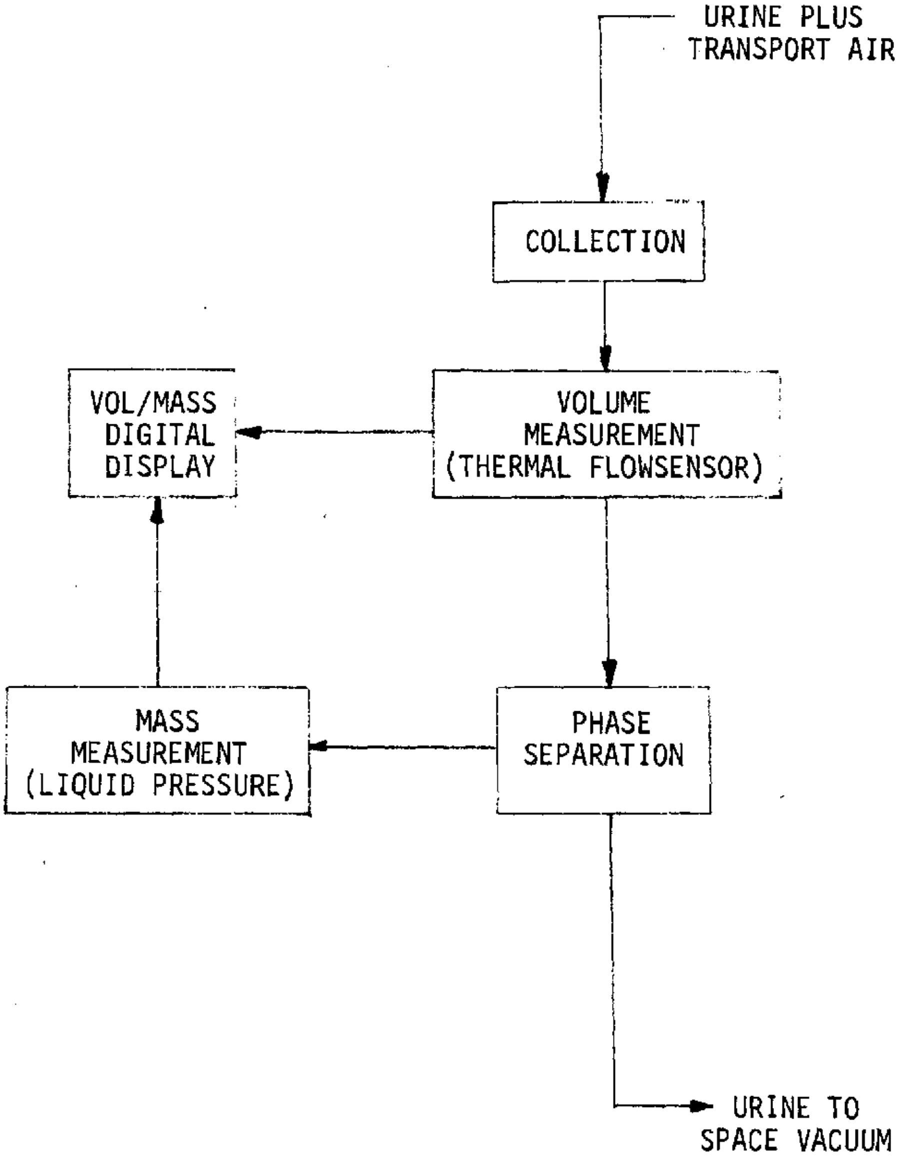


Figure 3.1.-1. FVMS Functional Block Diagram

3.1.1.1.5.12 Standardization

The FVMS design shall stress equipment physical modularity and commonality to enhance operating flexibility and maintainability.

3.1.2 OPERABILITY

3.1.2.1 Reliability Design Goals (Numerical)

The reliability design goals (numerical) specified in this section shall be used as guides in the design and development of the FVMS hardware. Verification through laboratory testing that the FVMS meets these goals will not be required. Numerical reliability tradeoff studies shall be accomplished for this purpose. Reliability design goals are as follows:

a. Safety of personnel and flight vehicle/module - Not applicable

b. Accomplishment of primary mission objectives and prevention of any effect on launch schedule as result of failure - Not applicable.

c. Accomplishment of DTO objectives - 0.99

3.1.2.2 Maintainability

3.1.2.2.1 General Requirements

The FVMS shall conform to the requirements of MIL-STD-470, paragraphs 2.0, 3.1, 5.4, and 5.5 as applicable. Specifically:

a. The FVMS hardware shall be designed to provide accessibility, replaceability, and serviceability consistent with efficient servicing; testing and maintenance requirements. Special consideration should be given to these criteria as they relate to unique requirements for late (on pad) installation, checkout, and servicing.

b. The principles of modular construction shall be employed in design of FVMS hardware to permit maintenance and replacement to be performed at the component level. Components expected to require servicing or maintenance shall be designed to be accessible without the removal of other components, wire bundles, or fluid lines.

c. Access covers of FVMS hardware not completely removable shall be self-supporting when open. Where access is required, the following practices shall be followed in order of preference:

   1. A hinged metal cover with captive quick-opening fasteners, capable of manual operation without the use of tools.
   2. Item (1) above, but requiring tools.
   3. An opening with no cover.
   4. Other.

d. The replacement, servicing or maintenance of any component of FVMS hardware shall require opening or removal of a minimum of covers or panels. Although desirable, if it is necessary to place one component behind another, the component requiring most frequent access shall be most readily accessible. Openings and work spaces provided for the adjustment and handling of components shall be ample to permit the required activity, and, where feasible, to permit direct viewing of the components being manipulated. Where components, connectors, and similar items must be inserted through a small access, external indication of the position for insertion shall be provided.

3.1.2.2.2 Additional Requirements for In-Flight Maintainability

No requirement.

3.1.2.3 Useful Life

The FVMS flight hardware shall have an operating life, during check out and inorbit, of 50 hours. The useful life of the flight hardware shall be sufficient for the total ASTP mission including ground storage.

3.1.2.4 Natural Environment

The FVMS hardware shall be capable of successfully performing the required function during or after, as applicable, being subjected to the natural environment conditions as specified in Table 3.1.2.4-1.

3.1.2.5 Induced Environment

The FVMS hardware shall be capable of successfully performing the required function while or after, as applicable, being subjected to the induced environmental conditions specified in Table 3.1.2.5-1.

Table 3.1.2.4-1. Natural Environment

Operational Phase Environment	Prelaunch	Launch	Ascent	Orbital Storage	Orbital Operational (1)
Ambient Temperature, °F	See induced	See induced	See induced	TBD	TBD
Humidity, % RH	See induced	See induced	See induced	See induced	See induced
Atmosphere Composition	See induced	See induced	See induced	See induced	See induced
Radiation, Rad/day	N/A	N/A	N/A	TBD	TBD

(1) FVMS located in CM; location in DM for all other operational phases.

Table 3.1.2.5-1. Induced Environment

Operational Phase / Environment	Prelaunch	Launch	Ascent	Orbital Storage	Orbital Operational(1)
Air Temperature, °F	70 ± 10	TBD	TBD	TBD	60 to 90
Humidity, % RH	0 to 10	0 to 100	0 to 100	0 to 100	TBD
Internal Pressure psia	14.7 to 26	TBD	16.2 max.	TBD	4.8 to 6.0
Atmosphere Composition, %	20% O_2, 80% N_2 to 60-65% O_2, 40-35% N_2	TBD	60-65% O_2, 40-35% N_2	See Table 3.1.2.5-4	100% O_2
Vibration	N/A	See Table 3.1.2.5-2	See Table 3.1.2.5-2	N/A	N/A
Shock	N/A	See Table 3.1.2.5-2	See Table 3.1.2.5-2	N/A	N/A
Acoustic Noise	N/A	See Table 3.1.2.5-3	See Table 3.1.2.5-3	N/A	N/A
Atmosphere Movement, ft./min.	N/A	N/A	N/A	N/A	TBD

(1) FVMS located in CM; location in DM for all other operational phases.

Table 3.1.2.5-2. Vibration/Shock(1)

Input to components mounted in DM section TBD.

1. Vehicle Dynamics Criteria

   TBD

2. Sinusoidal Evaluation Criteria

   TBD.

3. Lift-off Random Vibration Criteria

   TBD

4. Boost Random Vibration Criteria

   TBD

5. Shock Criteria

   TBD

---

(1) data from TBD .

Table 3.1.2.5-3. Acoustic Environment(1)

1/3 Octave Band Center Frequency Hz	DM External Noise Spectra (1/3 Octave Band Sound Pressure Level - dB re 0.0002 - Bar)	
	Lift-off (t = 0 seconds)	Mach 1 (t = 60 seconds)
20	108	105
25	115 115	112
31.5	120	114
40	125	116
50	127	116
63	130	117
80	133	117
100	134	118
125	133	118
160	132	118
200	129	120
315	127	121
400	124	122
500	122	119
630	119	119
800	118	118
1000	117	113
1250	116	110
1600	115	109
2000	112	109
2500	111	108
3150	110	107
4000	109	105
5000	108	104
6300	107	103
8000	106	102
Overall	141	129

(1) Data from SD-72-CS-0055A

Table 3.1.2.5-4. DM Atmosphere Composition(1)

	Partial Pressure (mmHg)	Percent By Volume
1. DM before hatches opened to CM, after integrity check		
Constituent Gas		
Oxygen	0.0 - 178.0	0.0 - 65.0
Nitrogen	274.0 - 85.0	100.0 - 35.0
Carbon Dioxide	0.0 - 0.0	0.0 - 0.0
Water Vapor	0.0 - 0.0	0.0 - 0.0
2. DM-CM after hatches opened, following integrity check.		
Constituent Gas		
Oxygen	160.0 - 225.0	58.4 - 91.83
Nitrogen	107.3 - 0.0	39.3 - 0.0
Carbon Dioxide	0.6 - 6.0	0.2 - 2.46
Water Vapor	5.6 - 14.0	2.1 - 5.71
3. DM before hatch opened to Soyuz.		
Constituent Gas		
Oxygen	160.0 - 225.0	32.7 - 45.9
Nitrogen	320.0 - 225.0	65.3 - 45.9
Carbon Dioxide	1.0 - 14.0	0.2 - 2.9
Water Vapor	9.0 - 26.0	1.8 - 5.3
4. DM-Soyuz after hatches opened.		
Constituent Gas		
Oxygen	142.0 - 216.0	28.3 - 39.9
Nitrogen	352.0 - 298.0	70.1 - 55.0
Carbon Dioxide	0.2 - 11.0	0.0 - 2.0
Water Vapor	7.8 - 17.0	1.6 - 3.1
5. DM before hatches opened to CM, return transfer.		
Constituent Gas		
Oxygen	162.0 - 188.0	55.9 - 64.8
Nitrogen	122.0 - 78.0	42.1 - 26.9
Carbon Dioxide	1.0 - 9.0	0.3 - 3.1
Water Vapor	5.0 - 15.0	1.7 - 5.2
6. DM-CM after hatches opened, following return transfer		
Constituent Gas		
Oxygen	160.0 - 215.0	57.5 - 82.3
Nitrogen	110.0 - 20.0	39.6 - 7.7
Carbon Dioxide	1.0 - 8.0	0.4 - 3.1
Water Vapor	7.0 - 18.0	2.5 - 6.9
7. DM-CM after Joint Operations completed.		
Constituent Gas		
Oxygen	160.0 - 311.0	*
Nitrogen	0.0 - 110.0	*
Carbon Dioxide	1.0 - 8.0	*
Water Vapor	8.0 - 19.0	*

(1) Data from SD-72-CS-0055A.

3.1.2.6 Transportability

Where required, special packaging and/or transportation methods shall be used to provide adequate protection and/or control (particularly with respect to freezing temperature conditions).

a. Shipment of FVMS hardware that is sensitive to shock or acceleration shall include instrument(s) that record peak acceleration along three orthogonal axes with respect to time. The instrument(s) shall be used to verify that design acceleration limits have not been exceeded during shipment.

b. A temperature indicator shall be provided to verify that design temperature limits have not been exceeded during shipment.

3.1.2.7 Human Engineering

FVMS hardware shall be designed to permit efficient use of the capabilities of ground and flight personnel in the applicable natural and induced environments, unsuited. Controls shall be readily accessible, suitably arranged, properly identified, and of such size and construction as to permit convenience and ease of operation. Controlled characteristics, such as sensitivity, volume, and voltage shall increase with clockwise rotation of the control as seen from the operating position. The flow rate in fluid systems controlled by hand operated valves shall increase with counter-clockwise rotation of the control as seen from the operating position. The opening of doors, lens covers, and the like shall, when effected by rotation of a control, increase with counter-clockwise rotation of that control. The position of the device (doors, lens covers, and the like) shall be displayed either directly or indirectly to the flight personnel. The setting, position, or adjustment of the controls shall not be affected by vibration, shock, or other service conditions. All controls shall operate freely, smoothly, and easily without excessive binding, play, or back lash. Switches, levers, and other controls that are manipulated during operation of the equipment shall be of such rugged design and construction that they will not be damaged when repeatedly operated. When stops are used, they shall be sufficiently rugged to prevent damage to the mechanism. Flight hardware shall comply with the design criteria of MIL-STD-1472A.

3.1.2.8 Safety

a. The safety of the flight and ground personnel shall be a prime consideration in the design of FVMS hardware. Sharp edges, burrs, corners, and protuberances are not permitted. Hardware shall be designed to prevent personal contact with high temperature surfaces (105°F) and hazardous electrical points.

b. FVMS hardware shall have adequate safeguards to prevent hazardous conditions and inadvertent operation; and normal operations, component replacement, the act of replacing components, malfunctions, or failures shall not disable other equipment, personnel, or the flight vehicle.

c. Hardware shall be designed to meet the requirements of KMI 1710.1A Attachment A, Sections 1 through 7.

d. FVMS hardware that may expose astronauts to ionizing radiation shall comply with requirements furnished by NASA. Hardware that emits ionizing radiation shall be handled, packaged, and shipped in accordance with applicable federal, state, and local regulations.

e. Components, such as relays, switches and motors with commutators, which in normal operation produce or are likely to produce, sparking or arcing shall be hermetically sealed or of explosion-proof construction.

3.2 Interface Requirements

3.2.1 Flight Hardware

3.2.1.1 Flight Vehicle Interfaces

3.2.1.1.1 Location, Envelope, Weight, and Center of Gravity

a. Stowed and/or Mounted for Launch:

The FVMS hardware assembly shall be designed to be stored in the DM (locker D5). The envelope, weight and center of gravity shall not exceed the values shown on Figure 3.2.1-1.

b. Stowed and/or Mounted for Flight Operation:

The FVMS hardware shall be designed to be mounted in the CM, area A7, during operational use. Envelope and weight shall not exceed the values shown on Figure 3.2.1-1.

c. Stowed and/or Mounted for Flight While Not In Use:

The FVMS hardware shall be mounted as for flight operation.

d. Stowed and/or Mounted for Return and Recovery:

Only the calibration containers (3 maximum) shall be returnable for subsequent content weight check.

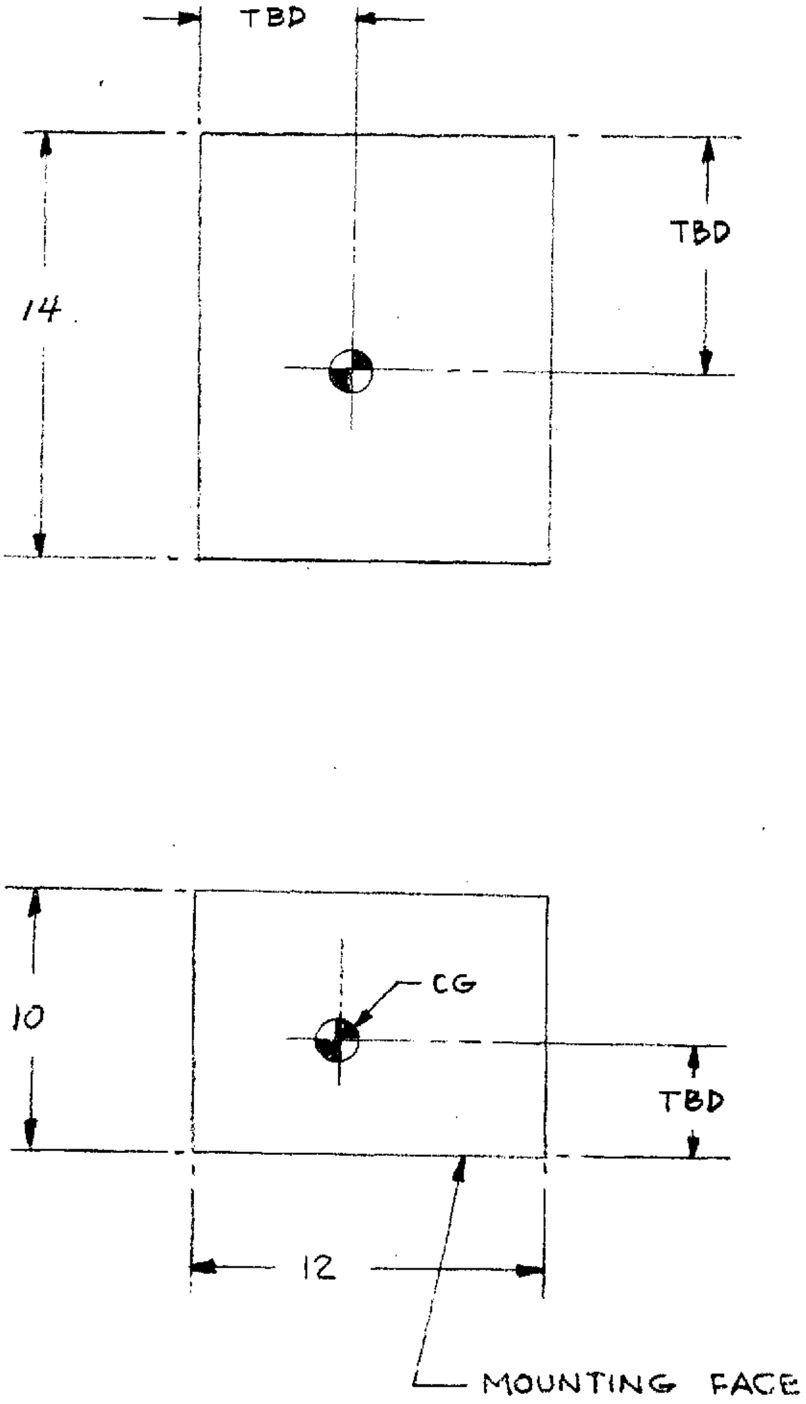
Individual containers shall be stowable in the CM at location TBD. Envelope and weight shall not exceed the values shown on Figure 3.2.1-2.

3.2.1.1.2 Structural

Stowage and mounted shall be as specified in 3.2.1.1.1, a thru d.

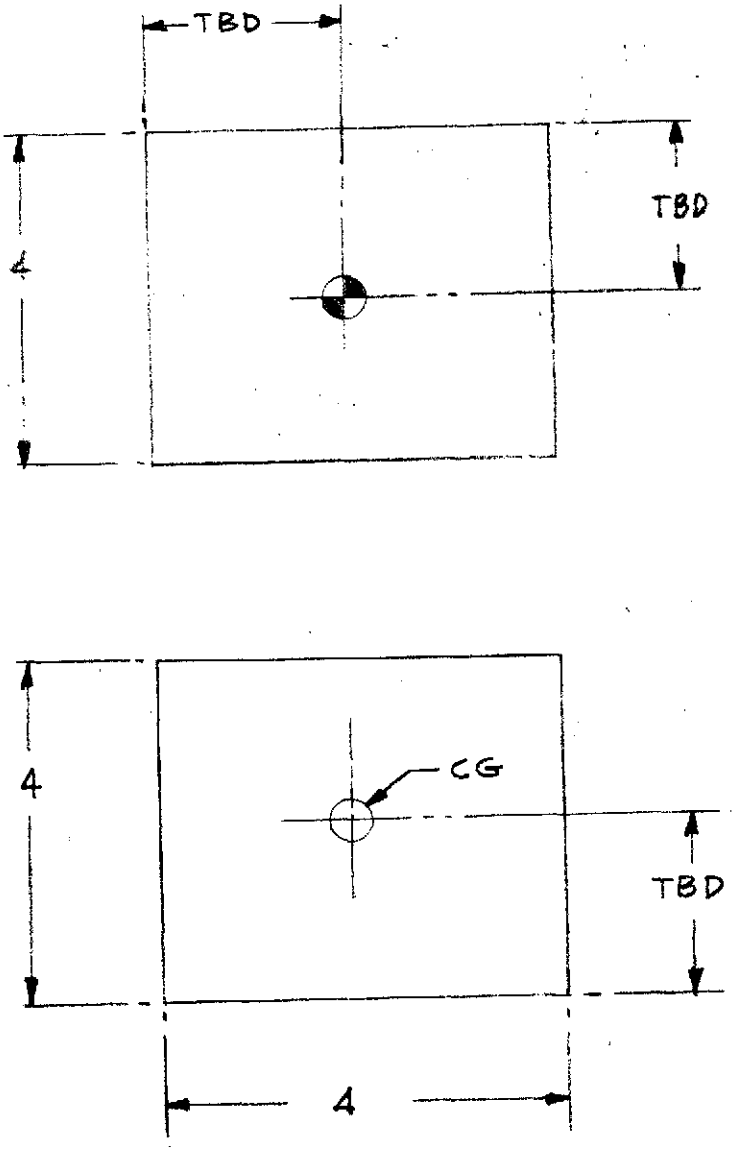
3.2.1.1.3 Fluid

No requirement.



MAX. WEIGHT = 33 LBS. INCLUDING CALIBRATION CONTAINERS

Figure 3.2.1-1. FVMS Configuration Limits for Launch and Flight Operations



TOTAL WEIGHT = 1.0 LBS (WITH FLUID); TBD LBS. AFTER USE.

Figure 3.2.1-2. FVMS Calibration Container Configuration Limits for Return and Recovery

3.2.1.1.4 Electrical

Power shall be supplied to the FVMS from power outlets on CM panel TBD. The FVMS mission power profile shall not exceed the following:

	Mission Phase	Phase Req'd	Operation Time
a.	Launch	0 watts	N/A
b.	Flight Ops., FVMS stowed	0	N/A
c.	Flight Ops., FVMS operation	see Figure 3.2.1-3	

3.2.1.1.5 Communications and Instrumentation

a. Command - Input and/or Output

No requirement.

b. Instrumentation Data - Input and/or Output

No requirement.

c. Time Identification - Input and/or Output

No requirement.

d. Voice - Intercom and/or Recording

Record volume/mass measurement data.

e. Photographic

No requirement.

3.2.1.1.6 Environmental Control

a. Stowed and/or mounted for launch:

Not applicable.

b. Stowed and/or mounted for flight operation:

Thermal - FVMS hardware assembly generated heat, not to exceed 70 watts equivalent, shall be dissipated to the ambient atmosphere.

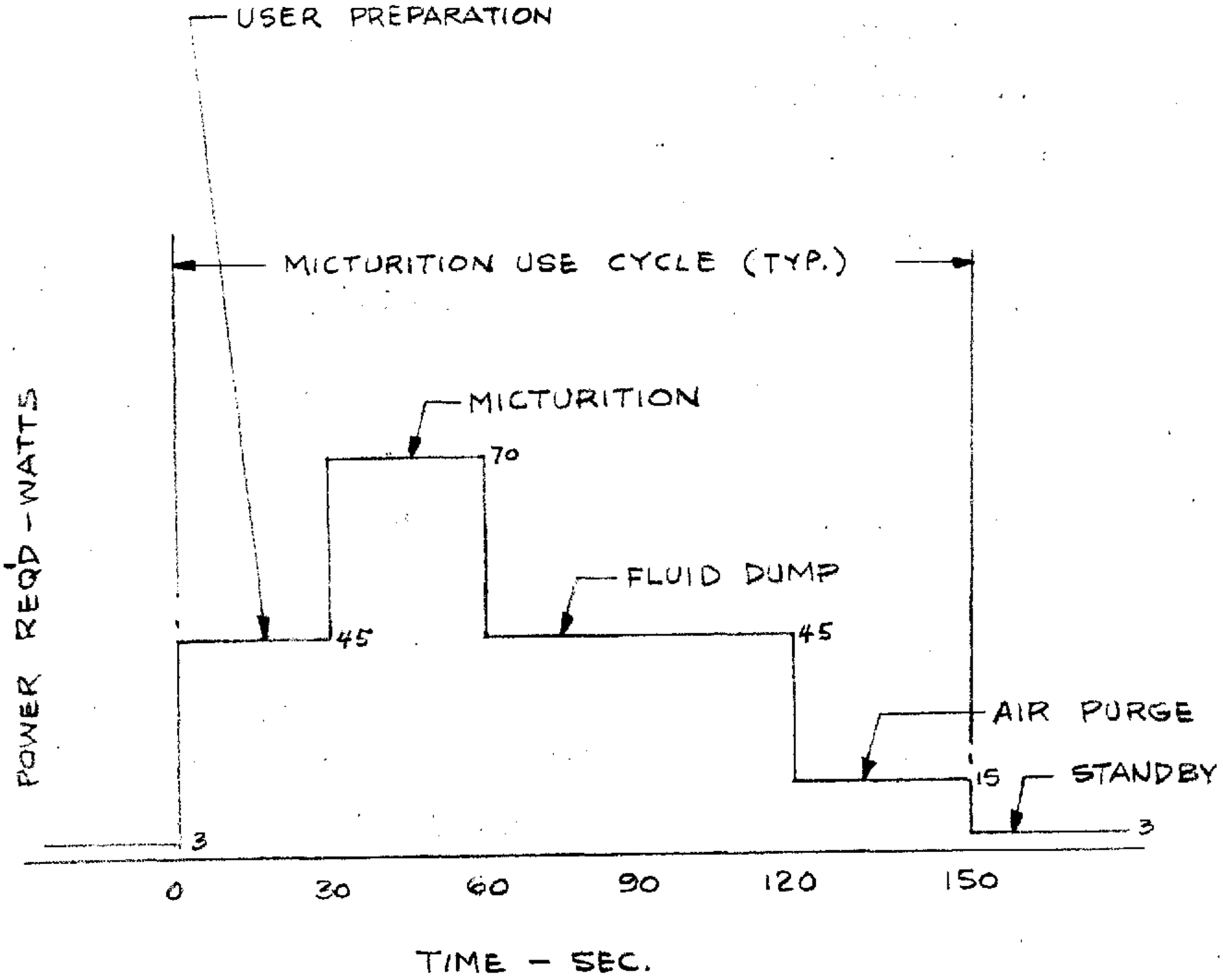


Figure 3.2.1-3. FVMS Power Profile Limits

c. Stowed and/or mounted for flight while not in use:

Not applicable.

d. Stowed for return and recovery:

Not applicable.

3.2.1.1.7 Controls and Displays

All controls and displays required for FVMS operation shall be integral with the FVMS hardware assembly.

3.2.1.1.8 Lighting

The FVMS shall be designed to be compatable with planned ASTP illumination levels.

3.2.1.1.9 Other

3.2.1.1.9.1 Power Cable

During FVMS flight operation, the FVMS shall be compatable with interconnection of the FVMS and CM power outlets via an existing CM/DM power cable (Part No. TBD; Stowage List Item No. TBD).

3.2.1.1.9.2 Vacuum Line

During FVMS flight operation, the FVMS shall be compatable with interconnection of the FVMS and CM vent outlet via existing flexible vacuum line (Part No: TBD; stowage list item No. TBD).

3.2.1.2 Interfaces With Other Systems

No requirement.

3.2.1.3 Ground Communication Interfaces

No requirement.

3.2.1.4 Flight Crew Interfaces

The FVMS shall accomodate the following crew interfacing:

a. Mounting in operational location:

Removal of FVMS from DM stwage locker and transport and mounting in CM.

b. Preparation for operation:

Connection of power cable and vacuum line between FVMS and CM power panel and overboard vent.

c. Operation:

(1) Initiation of FVMS operation.

(2) Crew member micturition.

(3) Volume/mass recording.

(4) Termination of FVMS operation.

d. Maintenance

No requirement.

3.2.1.5 Mission Interfaces

The FVMS shall accommodate the following mission interfaces:

a. Launch Trajectory

Not applicable.

b. Orbital Characteristics

Not applicable.

c. Times of Operation

The FVMS shall be designed to permit discontinuous operation, i.e., periodic operation throughout the duration of the orbital flight period.

d. Flight Maneuvering

The FVMS shall be designed to be compatable with CM flight maneuvering resulting in less than 10^{-2} g level during FVMS operation.

e. Flight Attitude

No requirement.

f. Thruster Operation

The FVMS shall be designed to be compatable with CM thruster operation resulting in less than 10^{-2} g level during FVMS operation.

g. Waste Disposal

No requirement.

h. Outgassing of Materials

The FVMS hardware shall not discharge toxic gases or vapors to the ambient CM environment.

i. Thermal

The FVMS shall be designed to reject generated thermal energy to the ambient CM atmosphere.

j. Lighting

The FVMS shall be compatable with operation at planned CM illumination levels.

k. Gas or Liquid Venting

The FVMS shall be compatable with venting of gas and liquid (water and urine) to the spare environment via the CM overboard dump vent.

l. Acoustic Noise

The FVMS shall not generate sound pressure levels in excess of 72.5 db (reference 0.0002 dynes/cm^2) as measured in a free surround at a distance of six feet from the FVMS.

3.2.1.6 Ground Support Equipment (GSE) Interfaces

Not applicable.

3.2.1.7 Facilities Interfaces

Not applicable.

3.2.2 ZERO GRAVITY TYPE TRAINING HARDWARE

No requirements.

3.2.3 NEUTRAL BUOYANCY TYPE TRAINING HARDWARE

No requirements.

3.2.4 SIMULATOR TYPE TRAINING HARDWARE

No requirements.

3.2.5 INTERFACE CONTROL DOCUMENT LIST

The following is a list of approved ICD's:

NUMBER	TITLE
TBD	Mechanical Interface (with DM)
TBD	Mechanical Interface (with CM)
TBD	Electrical Interface (with CM)

3.3 DESIGN AND CONSTRUCTION

The FVMS shall conform to the system block diagram of FIGURE 3.3-1. All FVMS hardware elements shall be integrated itno one coherent assembly.

3.3.1 MECHANICAL

3.3.1.1 Rigging Devices

Not applicable.

3.3.1.2 Shatterable Material

Shatterable material shall not be used in FVMS flight hardware unless positive protection is provided to the astronauts.

3.3.1.3 Restriction on Coatings

Surfaces of FVMS flight hardware that are expected to be exposed to extensive or

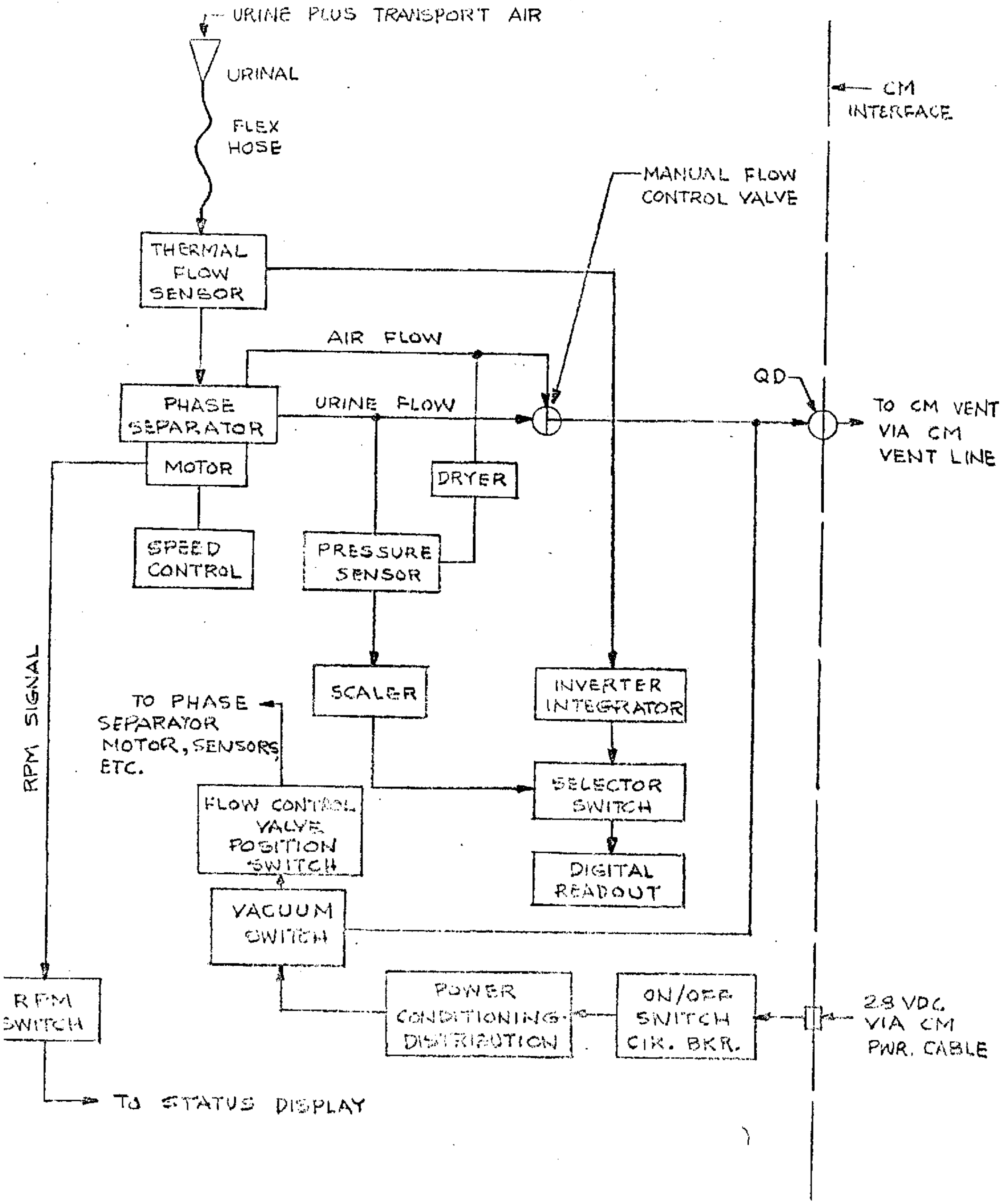


Figure 3.3-1. System Block Diagram

continuous abrasion and rubbing contact by the spacecraft crew shall not be painted, coated, or finished with materials that are subject to flaking.

3.3.1.4 Decompression

FVMS flight hardware containers or enclosures that will be within pressurized compartments of manned spacecraft shall be designed to withstand rapid decompression of the spacecraft without damage. Rapid decompression is defined as that decompression rate associated with the sudden opening of the largest inlet or outlet that vents to the space environment. The FVMS hardware shall be capable of sustaining a decompression rate of TBD psia/minute.

3.3.1.5 Mechanical Locks

All handling devices shall have positive mechanical locking provisions to prevent accidental release of the flight hardware.

3.3.1.6 Weight and Size

The FVMS flight hardware shall be designed in units each of which will be small and light enough for one man to handle and carry. Where this requirement cannot be met, special handles or mechanical or power lift devices shall be provided as necessary and appropriate for use during pre-mission, mission, or post-mission activities.

3.3.1.7 Factors of Safety

3.3.1.7.1 Structural

The structural factors of safety shall comply with JSC TBD.

3.3.1.7.2 Fluid Systems (Gas and Liquid)

a. Low Pressure Systems. Components of low pressure systems (5 psi or less) of flight hardware shall be designed to withstand a proof pressure equal to 1.67 times the maximum operating pressure and a burst pressure equal to two times the maximum operating pressure.

b. High Pressure Systems. Components of high pressure systems (over 5 psi) of flight hardware shall be designed to withstand a proof pressure equal to two times the maximum operating pressure and a burst pressure equal to four times the maximum operating pressure.

c. Propellant Tanks and High Pressure Vessels. The selection of material, design allowable, and design parameters for propellant tanks and high pressure vessels shall be made considering the fracture toughness of the material in the fabricated condition. In addition, the critical flow depths at operating pressure shall be larger than the vessel wall thickness. The minimum design burst pressure shall be at least two times the maximum operating pressure.

3.3.1.8 Lubrication

Flight hardware shall be designed so that no lubrication is required during or after acceptance tests. Lubricants shall be limited to dry film or GOX and vacuum compatable types.

3.3.2 ELECTRICAL AND ELECTRONIC

Electrical and electronic equipment shall be designed to meet the requirements of MIL-E-5400K except as specified in the following paragraphs.

3.3.2.1 Flammability of Wiring Insulation, Materials and Accessories

Insulation used in wiring anywhere within pressurized compartments of manned spacecraft shall not be capable of sustaining combustion during operations (a) after removal of the source of ignition or (b) following melting of the electrical conductor by high currents such as those resulting from short circuits or equipment malfunction. Insulation on conductors subjected to these high currents shall not be capable of igniting the insulation, wiring accessories or other materials on other conductors that may be in contact with it. This requirement does not apply to wiring that is completely isolated from the compartment atmosphere by potting or hermetic sealing. Materials and accessories associated with wiring, such as potting, bundle ties, bundle chafe guards, heat shrinkable tubing, protective covering, solder sleeves, cable clamps, and bundle identification tags that are in contact with electrical wire bundles, shall meet these flammability requirements. See MSC-PA-D-13.

3.3.2.2 Toxicity of Wiring Insulation, Materials and Accessories

Wiring insulation used in the flight hardware shall be a material which, when operating at its maximum temperature during a nominal mission or when exposed to temperatures up to the melting point of a single wire shall not generate toxic fumes in such concentration as to impair spacecraft crew functioning or safety. Materials and accessories associated with wiring, such as potting, bundle ties, bundle chafe guards, heat shrinkable tubing, protective covering, cable clamps, bundle identification tags and identification marks shall meet this requirement.

3.3.2.3 Electrical Connectors-Keying

All electrical connectors, plugs and receptacles used in FVMS hardware shall be positively keyed and clocked and provided alignment marks to prevent incorrect connection with other accessible connectors, plugs or receptacles.

3.3.2.4 Electrical Connectors-Pin Assignment and Pin or Socket Selection

a. Electrical circuits for FVMS hardware shall not be routed through adjacent pins of an electrical connector if a short circuit between them would constitude a single failure point as defined in paragraph 3.3.7.

b. Cable connections of FVMS hardware shall be designed so that pin and socket connectors are properly used to prevent power from shorting to ground. They also shall be designed to protect personnel both when connected and disconnected and, through the use of dead facing, explosion-proof connectors (to prevent electrical arcs) or similar means, during the operations of connection and disconnection.

c. Shorting springs or clips shall not be used.

3.3.2.5 Electrical Connectors-Protective Covers or Caps

Protective covers or caps shall be placed over electrical plugs and receptacles of FVMS hardware whenever they are not connected. The protective covers or caps shall:

a. Be moisture proof.

b. Protect sealing surfaces, threads, and pins against damage.

c. Be resistant to abrasion, chipping, or flaking.

d. Be provided during stowage & secured at use location with lanyard (teflon coated braided wire), not beaded chain.

e. Comply with cleanliness requirements for plugs and receptacles on which they are used.

f. Be made of material that is compatible with the connector materials.

g. Be brightly colored so as to be easily discernible and command attention.

3.3.2.6 Materials Detrimental to Electrical Connectors

Materials containing or coated with substances that are detrimantal to metals used in electrical connectors shall not be used in FVMS hardware adjacent to exposed electrical contact surfaces. Specifically included in this category are materials containing or coated with sulfides or free sulfur.

3.3.2.7 Electrical and Electronic Piece Parts-Closure

Electrical and electronic piece parts with all-welded closure construction shall be used in flight hardware in preference to piece parts with other types of closure construction.

3.3.2.8 Protection of Exposed Electrical Circuits

Electrical circuits of flight hardware that are to be disconnected in the normal course of mission events shall be protected against short circuiting or compromising of other circuits during the remaining phases of the mission.

3.3.2.9 Protection of Electrical and Electronic Devices

Electrical and electronic devices used in FVMS hardware shall incorporate protection against reverse polarity or other improper electrical inputs during qualification, acceptance, and other tests, if such inputs could damage the devices in a way that would not be immediately and unmistakably apparent. If it is impractical to incorporate adequate protection as a part of the device, protection shall be provided externally by ground-based equipment at the interface between the device and the ground test equipment.

3.3.2.10 Corona Suppression

Electrical and electronic systems and components of FVMS hardware shall be designed so that proper functioning will not be impaired by corona discharge under any of the required operating conditions.

3.3.2.11 Moisture Protection of Electrical and Electronic Devices

Electrical connectors, wiring junctions and all electrical and electronic devices used in flight hardware shall be hermetically sealed or otherwise positively protected against moisture.

3.3.2.12 Redundant Electrical Circuits

Redundant electrical circuits in flight hardware shall not be routed through the same connector or wiring bundle as applicable.

3.3.2.13 Electrical Operating Requirements

a. FVMS flight hardware shall give specified performance when operating on direct current, unregualted, ranging normally from 23 to 30 volts. It shall withstand one second duration operating on under-voltage ranging from 20 to 23 volts on over-voltage rainging from 30 to 32 volts without damage. Flight hardware shall withstand ± 50 volt pulses for 10 microseconds duration at a repetition rate of 10 pulses per second, plus a 1 volt peak to peak (max.) ripple voltage. Specified performance shall be obtained upon return to the normal operating voltage.

b. The FVMS flight hardware shall be capable of recovery without damage after interruption of all power.

c. Electrical and electronic piece parts shall be derated in accordance with the guidance contained in RADC Reliability Notebook. Volume 2, RADC-TR-67-108 and MIL-HDBK-217.

3.3.2.14 Temperature Control

If electrical temperature control of flight hardware is required, power requirements shall be minimized.

3.3.2.15 Wire Splicing

Splicing of wires for flight hardware shall not be permitted.

3.3.2.16 Wire Bundle and Harness Protection

All wire bundles and harnesses of FVMS hardware shall be designed to withstand anticipated handling, including disconnection and reconnection, and operating deformations without damage to the wires, insulation, or electrical connections. Wire smaller than 22 gauge shall not be used. Routing and installation of all wire bundles and harnesses shall be specified on the drawings. Special precautions shall be taken to prevent damage as a result of extreme temperature conditions, chafing or any other conditions that may result in damage.

3.3.3 FLUID (GAS AND LIQUID)

3.3.3.1 Flow Restriction Requirements

Not Applicable.

3.3.3.2 Fluid Line Installation

Routing and installation of all fluid lines for flight hardware, including pressure-sensor lines, shall be specifed on the drawings. Special precautions shall be taken to prevent the installation of such lines where they would be exposed to extreme temperature conditions. A design analysis shall be made for each such line installation to show that the temperature extremes to which the line will be subjected are within limits acceptable for the fluid involved.

3.3.3.3 Service Points

a. Service points for fluid systems of FVMS hardware shall be designed with positive protection by location, connector size or type, etc., to prevent connection to incorrect fluid service lines.

b. Fluid systems of flight hardware shall be designed so that service points, including those for filling, draining, purging, or bleeding, can be located external to pressurized spacecraft compartments. Gas purge or bleed fittings shall exhaust external to the pressurized crew compartment. Fluid systems that are portable and do not require servicing after being installed in a spacecraft compartment are excluded from these requirements.

c. Service and test points for fluid systems of flight hardware not required to function in flight shall be designed to prevent leakage in flight and shall be capped immediately after servicing or test. The method and material used for capping shall be compatible with the applicable system and the expected environment.

3.3.3.4 Protection for Fluid System Tubing, Fittings, and Components

a. All ends of tubing, fittings, and components used in fluid systems of FVMS hardware shall be protected against damage and entry of contaminants in each step of the manufacturing process and assembly. Design drawings and process specifications shall designate the method of complying with this requirement. Equivalent protection shall be provided for tubing, fittings, and components when the fluid system is open to effect repair or replacement. All protective devices shall be designed so that it is impossible to complete hardware assembly or installation with the protective devices in place.

b. Tubing assemblies, fittings, or components of FVMS hardware shall be protected during storage and shipment as specified in paragraph 3.3.3.4a and shall be sealed in clean, transparent, moisture-proof bags with sufficient protective strength. All assemblies shall be cleaned and dried before packaging and sealing shall be done in an air-conditioned environment with 50 percent, or lower, relative humidity and 75°F, or lower, temperature.

3.3.3.5 Joining of Stainless Steel Tubing and Fittings

Stainless steel tubing and fittings for FVMS flight hardware shall be joined by brazing or welding, except where mechanical disconnects are required for replacement or servicing, or where components would be adversely affected by brazing or welding.

3.3.3.6 Flushing of Fluid System

Fluid systems of FVMS hardware shall be designed to be cleaned by flushing to remove all contaminantz which could be detrimental to the system. The systems shall be free from dead-ended piping or passages through which flushing fluid cannot be made to flow. Drain ports shall be located at the low points in the system. The flushing fluid used shall exhibit the same level of cleanliness as the planned working fluid.

3.3.3.7 Stress Corrosion

Fluid system components of FVMS hardware shall be designed so that no failures will occur due to stress corrosion resulting from exposure to specified natural and induced environments or from the fluids used in or on the system or components of the system during fabrication, cleaning, flushing, inspecting, testing, or operating.

3.3.3.8 Metals and Metal Alloys

3.3.3.8.1 Use of Titanium or Titanium Alloys

Titanium or titanium alloys shall not be used.

3.3.3.9 Moisture Separation in Zero-G Environment

The design of water separators for use in gas streams in flight hardware shall consider the fact that free moisture under zero gravity conditions may be attracted to and adhere to the surface of the tube or duct rather than to float freely throughout the stream.

3.3.3.10 System Venting

Each pressure system of FVMS hardware shall have relief capability (or equal) to assure that the pressure in the system remains below the yield point of the weakest component in the system. When practical, the relieved fluid or gas shall be ducted into the low pressure (sump) side of the system.

3.3.4 DEBRIS PROTECTION

FVMS flight hardware shall be designed so that malfunctions or inadvertent operation cannot be caused by exposure to conducting or nonconducting debris or foreign material floating in a gravity-free state.

a. Electrical circuitry shall be designed and fabricated to prevent unwanted current paths being produced by such debris.

b. Critical mechanical items shall be provided with debris-proof covers or containers, while critical electrical items shall be provided with suitable containers, potting, or epoxy coating.

c. Filters, strainers or traps shall be provided in all moving-fluid systems to trap residual debris in a manner that will eliminate it as a threat to critical mechanical or electrical components. In installations wherein flow reversal may occur, filters or strainers shall be installed on both sides of critical components.

3.3.5 CLEANLINESS

a. FVMS hardware shall be designed, manufactured, assembled, and handled in a manner to ensure the highest practical level of cleanliness. The greatest practicable precautions shall be taken to assure freedom from debris within the hardware and inaccessible areas where debris and foreign material can become lodged, trapped, or hidden shall be avoided. Protective covers shall be provided to prevent entrance of debris into inaccessible areas, or access panels shall be provided for removal of debris from these areas. Where appropriate, these protective covers may be designed for ground operations only and may be removed prior to flight.

b. FVMS hardware shall be manufactured, assembled and inspected in accordance with GE-STD-S33802, GE-SPEC-171A8347 and GE-SPEC-171A4417 as applicable. The following levels of controlled cleanliness apply:

System Assembly Area - Class 100,000
Components Assembly Area - Class 100

3.3.6 TEST PROVISIONS

3.3.6.1 Test Points

FVMS flight hardware containing electrical and fluid systems shall include checkout test points that will permit normal planned tests to be made without disconnecting tubing or electrical connectors which are normally connected in flight.

3.3.6.2 Test Equipment

Test equipment shall be designed so that failure within the equipment or interruption of power will not cause failure or damage to flight hardware being tested, and failure of the hardware being tested will not cause failure or damage to the test equipment. Electrical test equipment used with FVMS hardware shall be equipped with electrical connectors that mate with the appropriate connectors of the FVMS hardware to be tested.

3.3.7 SINGLE FAILURE POINTS

FVMS hardware shall be designed so that single failure points will not affect spacecraft crew or ground personnel safety, cause loss of a flight vehicle/module, prevent or compromise accomplishment of a primary mission objective, or cause a launch to be rescheduled.

3,3.8 REDUNDANCY

3.3.8.1 Separation of Redundant Paths

Redundant paths in FVMS hardware, such as fluid lines, electrical wiring, connectors, etc., shall be located to ensure that an event that damages one will not damage the other.

3.3.8.2 Redundant Paths-Verification of Operation

The FVMS design shall include a means of verifying satisfactory operation of each redundant path at any time the system requires testing.

3.3.9 SELECTION OF SPECIFICATIONS AND STANDARDS

Specifications and standards necessary for the design and development of FVMS hardware, in addition to those specified in this document shall be selected in the following order of preference except as otherwise specified in this document:

a. Contract

b. NASA specifications, procedures and drawings

c. NASA standards.

d. Federal specifications

e. Federal standards.

f. Military specifications.

g. Military standards.

h. Other Governmental specifications and standards.

i. Specifications and standards released by nationally recognized associations, committees, and technical societies.

j. Contractor specifications and standards.

k. Manufacturers' specifications.

3.3.10 MATERIALS, PARTS AND PROCESSES

Materials, parts, and processes used in FVMS hardware shall be of the highest quality-compatible with technical requirements specified herein.

3.3.10.1 Toxicity of Materials

a. Materials shall not be used in habitable areas of manned spacecraft which, when operating at temperatures up to the maximum anticipated in a mission, will generate toxic or noxious fumes, or dust, in such concentration as to impair crew performance or safety. Reference MSC-PA-D-67-13.

b. Fluids that can produce toxic fumes shall not be used in systems within the crew compartment if a substitute with equivalent performance exists. Where no satisfactory substitute for the fluid exists, tests shall be performed to assure that the total leakage is less than the concentration that would result in a level of toxicity that would impair crew performance or safety.

3.3.10.2 Restriction on Use of Transistors and Capacitors

Point contact, grown junction, or alloy junction transistors and tantalum slug capacitors shall not be used in FVMS hardware.

3.3.10.3 Soldering

NHB 5300.4(3A) shall apply for all soldered electrical connections in FVMS hardware. Solder connections shall be designed to meet the quality assurance requirements of paragraph 4.3.3.4 of NHB 5300.4(3A).

3.3.10.4 Welding

3.3.10.4.1 Resistance Welding

Resistance welding (spot and seam) in FVMS hardware which shall conform to MIL-W-6858C, paragraph 1.2.3, Class B.

3.3.10.4.2 Fusion Welding

Fusion welding shall conform to GE-SPEC-146A9614.

3.3.10.5 Ultrasonic Processes

3.3.10.5.1 Cleaning

Ultrasonic vibration shall not be used as a method for cleaning electronic assemblies and/or piece parts of FVMS hardware.

3.3.10.6 Etching of Wire Insulation for Potting

When etching of wire insulation is required in FVMS hardware to provide satisfactory bonding to potting materials, the open end of the wire shall not be exposed to the etchant. The preferred process is to form the wire into a "U" shape, immersing only the bent portion in the etchant. The unetched end of the wire shall not be cut off prior to neutralization of the etchant. Electrical wire or cable insulated or coated with polytetrafluorethylene or fluorinated ethylene propylene shall be etched prior to potting to assure mechanical bond strength and environmental seal. Potting shall be accomplished within three weeks after etching.

3.3.10.7 Adhesive Bonding

Adhesive bonding in FVMS hardware shall be in accordance with MIL-A-9067 and GE-SPEC-

146A9026.

3.3.10.8 Restriction on Use of Mercury

Mercury in liquid or vapor form shall not be used in FVMS hardware or in equipment used in conjunction with FVMS hardware (e.g., manometers, lights, thermometers, etc.) if a substitute of equivalent performance exists or an alternate design or method can be used. Where no satisfactory substitute exists, or an alternate design or method cannot be used, the justification for the use of mercury, the protection provided to prevent its release and a plan for decontamination in the event of its release shall be submitted with the Materials List.

3.3.10.9 Brazing

Brazing processes shall comply with MIL-B-7883B & GE-SPEC-147A1845. Superalloy and refractory alloy brazing shall be accomplished in accordance with recommendations of face and cone provided by brazing alloy suppliers or producers.

3.3.10.10 Engraving

Engraving shall be in accordance with GE-SPEC-118A1526.

3.3.10.11 Riveting

Riveting shall be accomplished in accordance with GE-SPEC-171A4287.

3.3.10.12 Non Destructive Testing

Non-destructive testing shall be performed in accordance with GE-STD-S33125.

3.3.11 STANDARD PARTS

NASA, Air Force-Navy (AN), Military Standards (MS) or Joint Army-Navy (JAN) standard parts shall be used in FVMS hardware where applicable. Maximum economic standardization of parts and components shall be provided. Where identical or similar functions are performed in more than one application within the system, effort shall be made to use only one item design for all system applications.

3.3.12 FUNGUS RESISTANCE

Materials shall be selected for fungus resistance, unless in hermetically sealed components, in accordance with MIL-STD-810B, Method 508.

3.3.13 CORROSION PREVENTION

Metals used shall be corrosion-resistant type or suitably treated to resist corrosive conditions likely to be met in manufacture, assembly, testing, servicing, storage, or normal service use. Protective coatings shall not crack, ship, peel, or scale with age when subjected to the environmental extremes specified. Corrosion prevention shall be in accordance with MIL-STD-171. Unless suitably protected against electrolyti corrosion, dissimilar metal contact shall be in accordance with MIL-STD-889. Any protection used shall offer a low impedance path to radio frequency currents.

3.3.14 INTERCHANGEABILITY AND REPLACEABILITY

Items of FVMS hardware with the same part numbers shall be physically and functionally interchangeable.

3.3.15 WORKMANSHIP

Workmanship on FVMS hardware shall be in accordance with the best practice for high quality equipment within the state-of-the-art.

3.3.16 ELECTROMAGNETIC INTERFERENCE

a. Electrical and electronic FVMS hardware shall perform as specified when operating either independently or in conjunction with other equipment with which there are electrical connections, or which may be installed nearby, and shall not, in itself, be a source of interference that might adversely affect the operation of other equipments. FVMS hardware shall be designed to meet the requirements and limits of MIL-STD-461.

b. Interference control shall be considered in the basic design of all electronic and electrical FVMS hardware. The design shall be such that before interference control components are applied, the amount of interference internally generated and propagated shall be the minimum achievable. The application of interference control components (e.g., filtering, shielding, bonding) shall conform to good engineering practice and, wherever practical, shall be an integral part of the system.

c. FVMS flight hardware shall provide for electrically bonding to the spacecraft structure. The negative return shall be isolated from the chassis ground, and shall be brought out through an individual connector pin or terminal so that it can be connected to the spacecraft negative bus that, in turn, is connected to the spacecraft structure at one point only. The chassis ground shall be brought out through an individual connector pin or terminal. The signal returns shall be brought out through individual connector pins or terminals except that signals returns that are unsusceptible to EMI may share a common return. All power converters shall present a balanced load to the power line and the primary shall be shielded electrostatically, if required from the secondary. DC isolation between chassis ground, negative return and signal returns shall be not less than one megohm. RF decoupling shall be provided on the power input lines. If the electromagnetic interface (EMI) requirements of the flight hardware cannot be met under these requirements, bonding and bonding straps will be as specified in tha applicable Interface Control Document.

d. The shields of all radio frequency signal wires (signals above 100 kc or with a rise time less than 10 microseconds and occurring more than one time in 30 minutes) in flight hardware, where the outer shield is used for radio frequency return, shall be grounded at both ends and at any other convenient point between the two ends. When bonding straps are used to meet the EMI requirements, wire shields shall be carried through the connector of the using equipment and grounded to the inside of the case as close to the connector as possible. The length from connector to ground shall not be greater than two inches internally. All other shielded wires shall have their shields grounded at one end only. If the shield is designed to retain a signal, it shall be grounded at the source end. If the shield is designed to exclude signals, it shall be grounded at the receiving end.

e. FVMS hardware shall be designed to avoid permanent and residual magnetic fields wherever possible.

3.3.17 IDENTIFICATION AND MARKING

a. FVMS hardware shall be marked for identification in accordance with GE-SPEC-118A1526. Conspicuous markings or labels shall be affixed to FVMS hardware to warn ground support personnel and astronauts of the presence of hazardous conditions. All loose FVMS items shall be identified as to FVMS usage.

b. FVMS hardware or equipment that is not suitable for use in flight, and that could be accidentally substituted for flight hardware or backup hardware shall be red striped with material compatible red paint to prevent such substitution. In the event the hardware is too small to be easily striped, or if test results would be affected by striping, a conspicuous red tag marked NOT FOR FLIGHT USE shall be firmly attached.

c. Wires and Cables. Wires and cables for FVMS hardware shall not be identified by hot stamping directly onto primary or secondary (shield) insulation.

3.3.18 STORAGE

FVMS hardware shall have a storage life of TBD years. Control shall be maintained on all parts and materials that are sensitive to age or the storage environments specified in paragraphs 3.1.2.4 and 3.1.2.5. These parts and materials shall be identified, and if deterioration is a factor during storage or after installation for use, the maintenance procedures shall indicate a replacement cycle and/or the necessary resting.

3.3.19 PYROTECHNIC DEVICES

Not Applicable.

3.3.20 HYDROGEN EMBRITTLEMENT

Preference shall be given to metals which are not susceptible to delayed fracture due to hydrogen pickup from acid cleaning or plating. Where it is necessary to use metals which are susceptible to hydrogen pickup, coating methods for high strength steels shall be selected in accordance with restrictions in MIL-S-5002. In addition, the following methods shall be employed to minimize damage:

(1) Organic coating, vacuum deposition, mechanical plating, metal spraying and other non-hydrogen-producing processes shall be used in preference to electroplating or chemical plating.

(2) If plating is necessary, low-hydrogen-embrittlement baths shall be used.

(3) Parts shall be embrittlement relieved immediately after plating according to the applicable plating specification.

(4) Where practicable, parts shall be mechanically stressed relieved prior to plating by shot peening in accordance with MIL-S-13165B.

(5) Neither acid nor alkaline cathodic cleaning shall be used on metals susceptible to hydrogen embrittlement; anodically cleaning is acceptable.

4.0 TEST/PRODUCT ASSURANCE REQUIREMENTS

4.1 Verification Matrix

The FVMS hardware performance requirements shall be verified as shown in Figure 4.1-1. Verification methods shall be as defined in the following section.

4.1.1 Similarity

Verification by similarity shall be used if it can be shown that the article is substantially similar or identical in design, manufacturing processes and quality control to another article that has been previously qualified to equivalent or more stringent criteria. Verification by similarity may pertain to characteristics such as material, configuration, functional element or assembly, and can be applied selectively for applicable environments. Previous qualification tests conducted on articles for other programs will be applicable provided:

a. There are no changes in:

   (1) Design and specifications including operating limits, weight, dimensions, materials, performance and tolerance, reliability and quality.

   (2) Fabrication methods.

   (3) Inspection techniques.

   (4) Manufacturing environment and tests up to the point where qualification tests would normally be initiated.

b. Present articles are from the same manufacturing continuous-built lot as the qualified article.

c. Present articles are interchangeable with previously qualified articles.

4.1.2 Analysis

Verification by analysis shall be used in lieu of testing whenever it can be shown by generally accepted analytical technical requirements.

4.1.3 Inspection

Verification by inspection shall be used whenever it can be shown that inspection

FIGURE 4.1-1. VERIFICATION MATRIX

Nomenclature Criticality Category 4 End Item No.

Requirements For Verification

TEST TYPES:

A. Development
B. Qualification
C. Reliability
D. Integrated Systems
E. Flight Verification
F. Post Flight
N/A Not Applicable

VERIFICATION METHODS:

1. Test
   a. Functional
   b. Mechanical
   c. Electrical/Magnetic
   d. Environmental
   e. Materials Compatibility
   f. Life
   g. Off Limits
   h. Combined Tests
   i. Other Tests (Specify)
2. Assessment
   a. Similarity
   b. Analysis
   c. Inspection
   d. Demonstration

Section 3.0 Performance/Design Requirement Reference	Test Types/ Verification Methods A	B	C	D	E	F	N/A	Section 4.0 Test/Assessment Requirement
3.1.1							X	
3.1.1.1.1(a)	1a	1a						4.2.1.2.1/4.2.2.2.1
3.1.1.1.1(b)	1a	1a						4.2.1.2.1/4.2.2.2.1
3.1.1.1.1(c)	2c	2c						4.2.1.1.2/4.2.2.1.3
3.1.1.1.1(d)	2b	2b						4.2.1.1.1/4.2.2.1.2
3.1.1.1.1(e)	2c	2c						4.2.1.1.2/4.2.2.1.3
3.1.1.1.2(a)	2c	2c						4.2.1.1.2/4.2.2.1.3
3.1.1.1.2(b)	2c	2c						4.2.1.1.2/4.2.2.1.3
3.1.1.1.2(c)	1a	1a						4.2.1.2.1/4.2.2.2.1
3.1.1.1.2(d)	1a	1a						4.2.1.2.1/4.2.2.2.1
3.1.1.1.3	2b	2b						4.2.1.1.1/4.2.2.1.2
3.1.1.1.4	2b	2b						4.2.1.1.1/4.2.2.1.2
3.1.1.1.5.1.1	2c	2c						4.2.1.1.2/4.2.2.1.3
3.1.1.1.5.1.2	1a	1a						4.2.1.2.1/4.2.2.2.1
3.1.1.1.5.2	2c	2c						4.2.1.1.2/4.2.2.1.3
3.1.1.1.5.3	2c	2c						4.2.1.1.2/4.2.2.1.3
3.1.1.1.5.4	2c	2c						4.2.1.1.2/4.2.2.1.3
3.1.1.1.5.5	1a	1a						4.2.1.2.1/4.2.2.2.1
3.1.1.1.5.6	2c	2c						4.2.1.1.2/4.2.2.1.3
3.1.1.1.5.7	2d	2d						4.2.1.1.3/4.2.2.1.4
3.1.1.1.5.8	1c	1c						4.2.1.2.3/4.2.2.2.3
3.1.1.1.5.9	2c	2c						4.2.1.1.2/4.2.2.1.3
3.1.1.1.5.10	2b	2b						4.2.1.1.1/4.2.2.1.2
3.1.1.1.5.11	2b	2b						4.2.1.1.1/4.2.2.1.2
3.1.1.1.5.12	2c	2c						4.2.1.1.2/4.2.2.1.3
3.1.2							X	
3.1.2.1	2b	2b						4.2.1.1.1/4.2.2.1.2
3.1.2.2.1		2b						4.2.2.1.2
3.1.2.3		1f						4.2.2.2.6
3.1.2.4	1d	1d						4.2.1.2.4/4.2.2.2.4

FIGURE 4.1.-1. VERIFICATION MATRIX (Continued)

Section 3.0 Performance/Design Requirement Reference	Test Types/ Verification Methods							Section 4.0 Test/Assessment Requirement
	A	B	C	D	E	F	N/A	
3.1.2.5	1d	1d						4.2.1.2.4/4.2.2.2.4
3.1.2.6		2b						4.2.2.1.2
3.1.2.7		2c						4.2.2.1.3
3.1.2.8		2c						4.2.2.1.3
3.2.1							X	
3.2.1.1.1		2c						4.2.2.1.3
3.2.1.1.2		2c						4.2.2.1.3
3.2.1.1.4	1c	1c						4.2.1.2.3/4.2.2.2.3
3.2.1.1.6		1i						4.2.2.2.9
3.2.1.1.7		2c						4.2.2.1.3
3.2.1.1.8		2b						4.2.2.1.2
3.2.1.1.9		2d						4.2.2.1.4
3.2.1.4		2d						4.2.2.1.4
3.2.1.5		2b						4.2.2.1.2
3.3	2c	2c						4.2.1.1.2/4.2.2.1.3
3.3.1.2		2c						4.2.2.1.3
3.3.1.3		2c						4.2.2.1.3
3.3.1.4		1d						4.2.2.2.4
3.3.1.5		2d						4.2.2.1.4
3.3.1.6		2d						4.2.2.1.4
3.3.1.7		2b						4.2.2.1.2
3.3.1.8		2c						4.2.2.1.3
3.3.2		2c						4.2.2.1.3
3.3.2.1	2b	2b						4.2.1.1.1/4.2.2.1.2
3.3.2.2		2b						4.2.2.1.2
3/3/2/3		2d						4.2.2.1.4
3.3.2.4		2c						4.2.2.1.3
3.3.2.5		2c						4.2.2.1.3
3.3.2.6		2b						4.2.2.1.2
3.3.2.7		2c						4.2.2.1.3
3.3.2.8		2c						4.2.2.1.3
3.3.2.9		2d						4.2.2.1.4
3.3.2.10		1c						4.2.2.2.3
3.3.2.11		2c						4.2.2.1.3
3.3.2.12		2c						4.2.2.1.3
3.3.2.13a	1g	1g						4.2.1.2.7/4.2.2.2.7
3.3.2.13b	1c	1c						4.2.1.2.3/4.2.2.2.3
3.3.2.13c	2c	2c						4.2.1.1.2/4.2.2.1.3
3.3.2.14		2b						4.2.2.1.2
3.3.2.15		2c						4.2.2.1.3
3.3.2.16		2c						4.2.2.1.3
3.3.2.17		2c						4.2.2.1.3
3.3.3.2		2b						4.2.2.1.2
3.3.3.3a		2d						4.2.2.1.4
3.3.3.3.b/c		2c						4.2.2.1.3
3.3.3.4		2c						4.2.2.1.3
3.3.3.5		2c						4.2.2.1.3

FIGURE 4.1-1. VERIFICATION MATRIX (Continued)

Section 3.0 Performance/Design Requirement Reference	Test Types/ Verification Methods							Section 4.0 Test/Assessment Requirement
	A	B	C	D	E	F	N/A	
3.3.3.6		2c						4.2.2.1.3
3.3.3.7		2b						4.2.2.1.2
3.3.3.8		2c						4.2.2.1.3
3.3.3.9	2b	2b						4.2.1.1.1/4.2.2.1.2
3.3.3.10	2b	2b						4.2.1.1.1/4.2.2.1.2
3.3.4		2c						4.2.2.1.3
3.3.5		2c						4.2.2.1.3
3.3.6.1	1a	1a						4.2.1.2.1/4.2.2.2.1
3.3.6.2	2b	2b						4.2.1.1.1/4.2.2.1.2
3.3.7	2b	2b						4.2.1.1.1/4.2.2.1.2
3.3.8.1	2b	2b						4.2.1.1.1/4.2.2.1.2
3.3.8.2	2c	2c						4.2.1.1.2/4.2.2.1.3
3.3.10.1		2b						4.2.2.1.2
3.3.10.2		2c						4.2.2.1.3
3.3.10.3		2c						4.2.2.1.3
3.3.10.4		2c						4.2.2.1.3
3.3.10.5.1		2c						4.2.2.1.3
3.3.10.6		2c						4.2.2.1.3
3.3.10.7		2c						4.2.2.1.3
3.3.10.8		2c						4.2.2.1.3
3.3.10.9		2c						4.2.2.1.3
3.3.10.10		2c						4.2.2.1.3
3.3.10.11		2c						4.2.2.1.3
3.3.10.12		2c						4.2.2.1.3
3.3.11		2b						4.2.2.1.2
3.3.12		2b						4.2.2.1.2
3.3.13		2b						4.2.2.1.2
3.3.14		2b						4.2.2.1.2
3.3.15		2c						4.2.2.1.3
3.3.16a	1c	1c						4.2.1.2.3/4.2.2.2.3
3.3.16b	2b	2b						4.2.1.1.1/4.2.2.1.2
3.3.16c/d		2c						4.2.2.1.3
3.3.16e	2b	2b						4.2.1.1.1/4.2.2.1.2
3.3.17		2c						4.2.2.1.3
3.3.18		2c						4.2.2.1.3
3.3.20		2c						4.2.2.1.3

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techniques are adequate to assure that the article will meet the applicable technical requirements. Inspection shall be used to verify the construction features, compliance with drawings, workmanship and physical condition of the article and validation of documentation.

4.1.4 Demonstration

Verification by demonstration shall be used whenever it can be shown that demonstration is adequate to assure that the article will meet the applicable technical requirements. Demonstration will be used to verify such requirements as service and access, handling, convenience and ease of operation. Demonstration may be used to verify "zero g" performance during orbital flight.

4.1.5 Test

Verification by test shall be used whenever the verification methods of paragraph 4.1.1 through 4.1.4 cannot be applied.

4.2 Test Types

4.2.1 Development

Laboratory development tests shall be performed to acquire data to support the design and development process, to verify feasibility of the design approach by evaluating hardware performance under simulated or actual environmental conditions, and to verify selected performance/design requirements. These tests shall be performed on hardware that is representative of, but not necessarily identical to, the flight hardware. Specific tests shall be performed as stated below.

4.2.1.1 Assessment

4.2.1.1.1 Analysis

a. The usage requirements of 3.1.1.1.1 (d) shall be verified by analysis.

b. The future sampling requirement of 3.1.1.1.3 shall be verified by analysis.

c. The disposal requirement of 3.1.1.1.4 shall be verified by analysis.

d. The safety requirements of 3.1.1.1.5.10.1 and 3.1.1.1.5.10.2 shall be verified by analysis.

e. Operation in a nominal gravity environment as required by 3.1.1.1.5.11 shall be verified by analysis.

f. The reliability and useful life requirements of 3.1.2.1 shall be verified by a reliability analysis.

g. The flammability requirements of 3.3.2.1 shall be verified by analysis.

h. The moisture separation requirement of 3.3.3.9 shall be verified by analysis.

i. The venting requirement of 33.3.10 shall be verified by analysis.

j. The test equipment requirement of 3.3.6.2 shall be verified by analysis.

k. The single point failure requirement of 3.3.7 shall be verified by analysis.

l. The redundancy requirement of 3.3.8.1 shall be verified by analysis.

m. The electrical interferance requirements of 3.3.16 (b) and (e) shall be verified by analysis.

4.2.1.1.2 Inspection

The following requirements shall be verified by inspecting either documentation (validation of records) and/or engineering prototype hardware as indicated below for the referenced paragraphs (in parenthesis).

a. (3.1.1.1.1(c) Air transport - Validate drawings and inspect hardware.

b. (3.1.1.1.1(e) Urinal contact - Validate drawings and inspect hardware.

c. (3.1.1.1.2(a) Thermal flow meter - Validate drawings and inspect hardware.

d. (3.1.1.1.2(b) Secondary sensor - Validate drawings and inspect hardware.

e. (3.1.1.1.5.1.1) Urinal assembly - Validate drawings and inspect hardware.

f. (3.1.1.1.5.2) Volume measurement - Validate drawings and inspect hardware.

g. (3.1.1.1.5.3) Phase separator - Validate drawings and inspect hardware.

h. (3.1.1.1.5.4) Mass measurement - Validate drawings and inspect hardware.

i. (3.1.1.1.5.6) Display - Validate drawings and inspect hardware.

j. (3.1.1.5.9) Data acquisition - Validate drawings and inspect hardware.

k. (3.1.1.1.5.12) Standardization - Validate drawings.

l. (3.3.) Design - Validate drawings and inspect hardware.

m. (3.3.2.13c) Derating - Validate drawings.

n. (3.3.8.2) Redundancy - Validate drawings.

4.2.1.1.3 Demonstration

a. The operation requirement of 3.1.1.1.5.7 shall be verified by demonstration of engineering phototype hardware.

4.2.1.2 Test

4.2.1.2.1 Functional

a. The collection range requirement of 3.1.1.1.1 (a) shall be verified by development testing of engineering prototype hardware.

b. The flow rate range requirement of 3.1.1.1.1 (b) shall be verified by development testing of engineering prototype hardware.

c. The inflight calibration check requirement of 3.1.1.1.2 (d) and 3.1.1.5.5 shall be verified by development test of engineering prototype hardware.

d. The air transport flow requirement of 3.1.1.1.5.1.2 shall be verified by test of engineering prototype hardware.

e. The accuracy requirement of 3.1.1.1.2 (c) shall be verified by test of engineering prototype hardware.

f. The test point requirement of 3.3.6.1 shall be verified by development testing of engineering prototype hardware.

4.2.1.2.2 Mechanical

Not Applicable.

4.2.1.2.3 Electrical/Magnetic

a. The operating voltage requirements of 3.1.1.1.5.8 and 3.2.1.1.4 shall be verified by development tests of engineering prototype hardware.

b. The recovery requirement of 3.3.2.13b shall be verified by development tests of engineering prototype hardware.

c. The EMI requirement of 3.3.16a shall be verified by development tests of engineering prototype hardware.

4.2.1.2.4 Environmental

a. Selected environmental requirements of 3.1.2.4 and 3.1.2.5 shall be verified by development test of engineering prototype hardware.

4.2.1.2.5 Materials Compatibility

Not Applicable.

4.2.1.2.6 Life

a. Not applicable.

4.2.1.2.7 Off-Limits

a. The off-limit voltage requirements of 3.3.2.13a shall be verified by development tests of eningeering prototype hardware.

4.2.1.2.8 Combined Tests

Not applicable.

4.2.1.2.9 Special Tests

Not applicable.

4.2.2 Qualification

Qualification tests shall be performed to verify the performance/design/-construction requirements of the end-item. Qualification shall be performed on end-item hardware produced using the same materials and processes, under the same conditions as those intended for flight hardware, and which is the same configuration as flight hardware. Specific tests shall be performed as stated below.

4.2.2.1 Assessment

4.2.2.1.1 Similarity

a. Not applicable.

4.2.2.1.2 Analysis

a. The usage requirement of 3.1.1.1.1(d) shall be verified by analysis.
b. The future sampling requirement of 3.1.1.1.3 shall be verified by analysis.
c. The disposal requirement of 3.1.1.1.4 shall be verified by analysis.
d. The safety requirements of 3.1.1.1.5.10 shall be verified by analysis.
e. The gravity field requirement of 3.1.1.1.5.11 shall be verified by analysis.
f. The reliability goals of 3.1.2.1 shall be assessed by analysis.
g. The maintainability requirement of 3.1.2.2.1 shall be verified by analysis.

h. The transportability requirement of 3.1.2.6 shall be verified by analysis.

i. The lighting requirement of 3.3.1.1.8 shall be verified by analysis.

j. The mission interface requirements of 3.2.1.5 shall be verified by analysis.

k. Structural and fluid system factors of safety, Section 3.3.1.7, shall be verified by analysis.

l. The flammability and toxicity requirements of 3.3.2.1 and 3.3.2.2 shall be verified by analysis.

m. The material requirement of 3.3.2.6 shall be verified by analysis.

n. The temperature control requirement of 3.3.2.14 and 3.3.3.2 shall be verified by analysis.

o. The stress corrosion requirement of 3.3.3.7 shall be verified by analysis.

p. The moisture separation requirement of 3.3.3.9 shall be verified by analysis.

q. The venting requirement of 3.3.3.10 shall be verified by analysis.

r. The test equipment requirement of 3.3.6.2 shall be verified by analysis.

s. The single point failure requirement of 3.3.7 shall be verified by analysis.

t. The redundancy requirement of 3.3.8.1 shall be verified by analysis.

u. The toxicity requirement of 3.3.10.1 shall be verified by analysis.

v. The standard parts requirement of 3.3.11 shall be verified by analysis.

w. The fungus resistance requirement of 3.3.12 shall be verified by analysis.

x. The corrosion prevention requirement of 3.3.13 shall be verified by analysis.

y. The interchangeability requirement of 3.3.14 shall be verified by analysis.

z. The electrical interference requirements of 3.3.16(b) and (e) shall be verified by analysis.

4.2.2.1.3 Inspection

The following requirements shall be verified by inspecting either documentation (validation of records) and/or qualification hardware as indicated below. The reference paragraphs are indicated in parenthesis.

a. (3.1.1.1.1(c) Air Transport - Validate drawings and inspect hardware.

b. (3.1.1.1.1(e) Urinal Contact - Validate drawings and inspect hardware.

c. (3.1.1.1.2(a) Thermal Flow Meter - Validate drawings and inspect hardware.

d. (3.1.1.1.2(b) Secondary Sensor - Validate drawings and inspect hardware.

e. (3.1.1.1.5.1.1) Urinal Assembly - Validate drawings and inspect hardware.

f. (3.1.1.1.5.2) Volume Measurement - Validate drawings and inspect hardware.

g. (3.1.1.1.5.3) Phase Separator - Validate drawings and inspect hardware.

h. (3.1.1.1.5.4) Mass Measurement - Validate drawings and inspect hardware.

i. (3.1.1.1.5.6)Display - Validate drawings and inspect hardware.

j. (3.1.1.1.5.9) Data Acquisition - Validate drawings and inspect hardware.

k. (3.1.1.1.5.12) Standardization - Validate drawings and inspect hardware.

l. (3.1.2.7) Human Engineering - Inspect hardware.

m. (3.1.2.8) Safety - Inspect hardware, validate specs and operating procedures.

n. (3.2.1.1.1 and 3.2.1.1.2) Envelope, etc. - Validate drawings and operating procedures; inspect hardware.

o. (3.2.1.1.7) Controls - Validate drawings and inspect hardware.

p. (3.3) Design - Validate drawings and inspect hardware.

q. (3.3.1.2) Shatterable Material - Inspect hardware and validate parts and materials list.

r. (3.3.1.3) Restriction on Matings - Inspect hardware and validate parts and materials list.

s. (3.3.1.8) Lubrication - Validate drawings and parts and materials list.

t. (3.3.2) Electrical - Validate drawings.

u. (3.3.2.4) Electrical Connections - Pin or socket selection - Inspect hardware and drawings.

v. (3.3.2.5) Electrical Connectors - Protective or caps - Inspect hardware and drawings.

w. (3.3.2.7) Electrical and Electronic Piece Parts - Closure - Inspect hardware and drawings.

x. (3.3.2.8) Protection of Exposed Electrical Circuits - Inspect hardware and drawings.

y. (3.3.2.11) Mositure Protection of Electrical and Electronic Devices - Inspect hardware and drawings.

z. (3.3.2.12) Redundant Electrical Circuits - Inspect drawings.

aa. (3.3.2.13c) Derating - Inspect drawings.

bb. (3.3.2.15) Wire Splicing - Inspect hardware.

cc. (3.3.2.16) Wire Bundle and Harness Protection - Inspect hardware and drawings.

dd. (3.3.2.17) Radiographic Inspection - Inspect QA and Manufacturing logs.

ee. (3.3.3.3b and c) Service Points - Inspect drawings and hardware.

ff. (3.3.3.4) Fluid System Protection - Inspect drawings and hardware.

gg. (3.3.3.5) Joining of Tubing and Fittings - Inspect drawings and hardware.

hh. (3.3.3.6) Flushing of Fluid System - Inspect drawings and hardware.

ii. (3.3.3.8) Metals - Inspect drawings.

jj. (3.3.4) Debris Protection - Inspect hardware and drawings.

kk. (3.3.5) Cleanliness - Inspect QA and manufacturing logs.

ll. (3.3.10.2) Restriction on Use of Transistors and Capacitors - Validate parts and materials list.

mm. (3.3.10.3) Soldering - Inspect hardware and manufacturing logs.

nn. (3.3.10.4.1 and 3.3.10.4.2) Welding - Inspect hardware and manufacturing logs.

oo. (3.3.10.5.1) Ultrasonic Cleaning - Validate manufacturing logs and cleaning certification.

pp. (3.3.10.6) Etching of Wire Simulation for Potting - Inspect manufacturing logs.

qq. (3.3.10.7) Adhesive Bonding - Inspect manufacturing logs.

rr. (3.3.10.8) Restriction on Use of Mercury - Inspect parts and materials list.

ss. (3.3.10.9) Brazing - Validate manufacturing logs.

tt. (3.3.10.10) Engraving - Inspect hardware and manufacturing logs.

uu. (3.3.10.11) Riveting - Inspect hardware and manufacturing logs.

vv. (3.3.10.12) Testing - Inspect hardware and manufacturing logs.

ww. (3.3.15) Workmanship - Inspect hardware.

xx. (3.3.16c/d) Electromagnetic Interference - Inspect hardware, drawings and validate Electromagnetic Control (EMC) Plan.

yy. (3.3.17a, b and c) Identification and Marking - Inspect hardware.

zz. (3.3.18) Storage - Proper marking of all sensitive parts shall be verified by inspection of hardware.

aaa. (3.3.20) Hydrogen Embrittlement - Inspect drawings.

4.2.2.1.4 Demonstration

a. The semi-automatic operation requirement of 3.1.1.1.5.7 shall be demonstrated.

b. The power cable and vacuum line compatibility requirement of 3.2.1.1.9 shall be demonstrated.

c. The flight crew interface requirements of 3.2.1.4 shall be demonstrated.

d. The mechanical lock requirement of 3.3.1.5 shall be demonstrated.

e. The mobility requirement of 3.3.1.6 shall be demonstrated.

f. The keyed electrical connector requirement of 3.3.2.3 shall be demonstrated.

g. The protection requirements of 3.3.2.9 shall be demonstrated.

h. The service point connection requirement of 3.3.3.3a shall be demonstrated.

4.2.2.2 Test

4.2.2.2.1 Functional

a. The collection range requirement of 3.1.1.1.1(a) shall be verified during the qualification test cycle.

b. The flow rate range requirement of 3.1.1.1.1(b) shall be verified during the qualification test cycle.

c. The accuracy requirement of 3.1.1.1.2(c) shall be verified during the qualification test cycle.

d. The inflight calibration check requirement of 3.1.1.1.2(d) and 3.1.1.1.5.5 shall be verified during the qualification test cycle.

e. The air transport flow requirement of 3.1.1.1.5.1.2 shall be verified during the qualification test cycle.

f. The test point requirement of 3.3.6.1 shall be verified during the qualification test cycle.

4.2.2.2.2 Mechanical

Not applicable.

4.2.2.2.3 Electrical/Magnetic

a. The power conditioning requirement of 3.1.1.1.5.8 and 3.2.1.1.4 shall be verified during the qualification test cycle.

b. The corona suppression requirement of 3.3.2.10 shall be verified during the qualification test cycle.

c. The recovery equipment of 3.3.2.13b shall be verified during the qualification test cycle.

d. The EMI requirement of 3.3.16a shall be verified during the qualification test cycle.

4.2.2.2.4 Environmental

a. Selected environmental requirements of 3.1.2.4 and 3.1.2.5 shall be verified during the qualification test cycle.

b. The decompression equipment of 3.3.1.4 shall be verified during the qualification test cycle.

4.2.2.2.5 Material Compatibility

Not applicable.

4.2.2.2.6 Life

a. The useful life requirement of 3.1.2.3 shall be verified during the qualification test cycle.

4.2.2.2.7 Off Limits

a. The off limit operating requirement of 3.3.2.13a shall be verified during the qualification test cycle.

4.2.2.2.8 Combined Tests

Not applicable.

4.2.2.2.9 Special Tests

a. The environmental control requirement of 3.2.1.1.6 shall be verified during the qualification test cycle.

4.2.3 Reliability

Not applicable.

4.2.4 Other Tests

Not applicable.

4.3 Rejection

4.3.1 Qualification Failure

Any failure of a test specimen shall disqualify the entire class of hardware (all items of hardware made to the same specifications and intended for the same application as the qualification hardware). Where a failure occurs, design or procedural changes shall be introduced into test hardware and, upon Development Center approval, qualification tests shall be reinstated. However, if the cause of failure is a quality defect that can be detected by nondestructive inspection, those units of the sample that have already been tested without failure need not be retested.

4.3.2 Reliability Test Failure

Not applicable.

5.0 DATA LIST

5.1 General

Documentation shall be provided in accordance with the requirements of this section. Documentation shall be categorized into one of the following three types.

Type I Those documents that shall be submitted for approval. With the exception of Engineering Change Proposals, implementation of these documents, and any changes thereto, shall not proceed until after (1) approval or (2) 14 days after receipt of document if no notice has been received that the document is disapproved or that implementation of the document shall be delayed. Engineering Change Proposals are Type I documents, but implementation shall not proceed until approval is received. Each Type I document shall be clearly marked prior to submittal with PRELIMINARY-NASA APPROVAL PENDING or APPROVED BY NASA - REFERENCE ------ as appropriate. Approved documents shall be submitted for use within seven days after receipt of approval.

Type II Those documents that shall be submitted for review. Implementation of these documents may proceed without formal approval, but implementation shall not proceed prior to submittal of the documents. Implementation of subsequent changes to these documents shall not proceed prior to submittal of the changes. Each Type II document shall be clearly marked PRELIMINARY until ready for submittal.

Type III Those required documents that are not submitted but shall be retained and made available upon request.

Type I and Type II documents shall be submitted in accordance with Table 5-1. Documents that may require changes shall be submitted with a refastening binding so that revised or additional pages may be submitted as appropriate in lieu of complete resubmittal of the document. An instruction sheet shall accompany each submittal of revised and additional pages detailing the exact means for insertion. For Type I documents, the revised and additional pages shall be submitted within seven days after receipt of approval of the change. For Type II documents, revised and additional pages shall be submitted prior to start of implementation of the change.

6.0 PREPARATION FOR DELIVERY

6.1 Handling and Storage

6.1.1 Handling

Articles and materials shall be protected during all phases of fabrication, processing, and storage to prevent handling damage. Special handling instructions shall be forwarded to the receiving activities. Evidence of initial and periodic proof testing of handling equipment shall be maintained.

TABLE 5-1. DOCUMENTATION REQUIREMENTS

Document	Initial Submittal	Changes	Document Type	Document Classification	Section Responsible For Preparation
End-Item Specs, Part I	Prior to PDR	As required	I	Configuration MGT	Engineering
End-Item Specs, Part II	Prior to CARR	As required by ECP/AN	I	Configuration MGT	Engineering
Engineering Change Proposals (ECP's)	As acquired	As required prior to approval of ECP	I	Configuration MGT	Engineering
Specification Alteration Notice (AN's)	As required	As required	II	Configuration MGT	Engineering
Specification Revision Charts	With first revision of each specification	With each subsequent revision of each specification	II	Configuration MGT	Product Assurance
Engineering Drawings	As completed	Alteration Notices (AN's) immediately after approval. After CDR approval of ECP's required for "Major" changes	II	Configuration MGT	Engineering
Technical Reports	To be available at Design Reviews	As required	III	Configuration MGT	Engineering
a. Study Reports					
b. Design Analysis					

TABLE 5-1. DOCUMENTATION REQUIREMENTS

Document	Initial Submittal	Changes	Document Type	Document Classification	Section Responsible For Preparation
End-Item Acceptance Data Package	To be available at applicable Acceptance Review - to be delivered with applicable hardware after acceptance.	As required as the result of action items from the Acceptance Review	II	QA	Product Assurance
Material Review Board Records	To be available at all times for inspection and review with the equipment - to be delivered with applicable hardware after acceptance.	As required	III	QA	Product Assurance
Design and Process Standards	As requested	As required	III	QA	Product Assurance
Inspection and Test Records and Data	As requested	Not applicable	III	QA	Product Assurance
Quality and Inspection System Plan	Prior to PDR	As required	I	QA	Product Assurance
ALERT Responses	As soon as possible after ALERT receipt	Not applicable	I	QA	Product Assurance
Metrology System Procedures	As requested	As required	III	QA	Product Assurance
Materials Identification Control and Verification Program Plan	Prior to PDR	As required	I	QA	Product Assurance
Failure Mode Effects and Criticality Analyses	Prel: Prior to PDR Final: Prior to CDR	As required	II	Reliability	Engineering

TABLE 5-1. DOCUMENTATION REQUIREMENTS

Document	Initial Submittal	Changes	Document Type	Document Classification	Section Responsible For Preparation
Acceptance Test Requirements	Prior to CDR	As required	I	Reliability	Product Assurance
Acceptance Test Procedures	Prior to CDR	As required	II	Reliability	Product Assurance
Reliability Program Plan	Prior to PDR	As required	I	Reliability	Product Assurance
Approved Parts and Non-metallic Materials Lists	Prior to CDR	As required	II	Reliability	Product Assurance
Safety Assessment Reports	At each major milestone, i.e. PDR, CDR, CARR	As required	II	Safety	Safety
Equipment Logs	To be available at all times for inspection and review with the equipment - to be delivered with applicable hardware	As required as the result of inspections and reviews	II	QA/Reliability	Product Assurance
Failure Reports	24 Hours after failure occurs	As required	II	QA/Reliability	Product Assurance
Failure Analysis Reports	1 month after occurence of failure	As required	II	QA/Reliability	Product Assurance
Corrective Action Reports	1 month after occurence of failure	As required	II	QA/Reliability	Product Assurance
Test Specification and Test Procedures					
a. Development					
1. To verify end-item spec. Section 3.0 requirements	Prior to start of applicable tests	As required	II	Test	Engineering

TABLE 5-1. DOCUMENTATION REQUIREMENTS

Document	Initial Submittal	Changes	Document Type	Document Classification	Section Responsible For Preparation
b. Qualification	Prior to start of applicable tests	As required	I	Test	Product Assurance
c. Acceptance	Prior to start of applicable tests	As required	I	Test	Product Assurance
Test Reports					
a. Development 1. To verify end-item spec Section 3.0 requirements	1 month after completion of tests	As required	II	Test	Engineering
b. Qualification	1 month after completion of tests	As required	II	Test	Product Assurance
c. Acceptance	Prior to CARR	As required	II	Test	Product Assurance
Operating, Maintenance and Handling Procedures					
a. Flight Hardware	Prior to CDR	As required	II	Operations	Engineering
b. Ground Support Equipment	Prior to delivery	As required	II	Operations	Engineering
Spares Requirements	Prior to CDR	As required by ECP/AN	I	Operations	Engineering

6.1.2 Storage

Articles and materials to be stored shall be protected against deterioration, damage, and substitution. Articles and materials subject to age deterioration shall include on the container an indication of the date that the critical life of the article or material was initiated and the date at which the useful life will be expended. Procedures shall be generated and utilized to ensure the safety of personnel and the maintenance, positive identification, periodic inspection and periodic test of articles.

6.2 Preservation, Marking and Labelling, Packaging and Packing

6.2.1 Preservation

Articles and materials subject to deterioration, contamination or corrosion through exposure to air, moisture, or other elements during fabrication and storage shall be cleaned and preserved by methods which ensure maximum life and utility.

6.2.2 Marking and Labelling

Appropriate marking and labelling for packaging, shipment and storage of articles and materials shall be provided in accordance with applicable specification and/or contractual requirements. Critical, sensitive, dangerous and high-value articles shall be given special attention.

6.2.3 Packaging

Articles and materials shall be packaged to prevent deterioration, corrosion, damage and contamination. Packaging procedures and instructions shall be utilized and provided for protection to articles and materials while at the contractor's plant, during transportation to destination, and upon arrival at destination. When maintenance of specific internal or external environments are necessary those shall be included in the packaging and necessary environmental requirements shall be detailed on the exterior of the package or reference environmental procedures. When existing packaging specifications are not adequate to fully protect critical, sensitive, dangerous, or high-value articles, special packaging shall be designed, documented and utilized.

6.2.4 Packaging Protection

Cushioning, blocking, bracing, or bolting, as applicable, shall be provided to prevent rupture of flexible barriers, transmission of shock and vibration. Tests shall be performed when necessary to ensure proper packing protection.

6.3 Shipping

All articles and materials shipped shall be controlled to ensure that:

a. All fabrication, assembly, inspection and testing operations authorized and required to be performed at the plant or test site have been satisfactorily completed.

b. Accompanying documents have been properly preserved and packaged in accordance with applicable contractor's stamps.

c. All articles and materials have been preserved and packaged in accordance with applicable procedures and requirements.

d. All articles and materials have been identified and marked in accordance with applicable procedures and specifications.

e. In the absence of packing and marking requirements in the contract, packing and marking of articles and materials shall comply with Interstate Commerce Commission rules and regulations.

f. Handling devices and transportation methods conform to applicable specifications and requirements.

g. The loading and transportation methods conform to applicable specifications and requirements.

In the event of any unscheduled removal of an article or material from its container, the extent of reinspection and retest shall be as authorized by the Johnson Space Center or its designated Government quality representative.

7.0 NOTES

The information contained in this section is for administrative convenience only and is not part of the end-item specification in the contractual sense.

7.1 Definitions and Acronyms

7.1.1 Definitions

TBD

7.1.2 Acronyms

CARR	Customer Acceptance Readiness Review
CCB	Configuration Control Board
CDR	Critical Design Review
CM	Command Module
DM	Docking Module
DTO	Design Test Objective
ECP	Engineering Change Proposal
EMC	Electromagnetic Control
FMEA	Failure Mode and Effects Analysis
FVMS	Fluid Volume Measurement System
GSE	Ground Support Equipment
ICD	Interface Control Document
MRB	Material Review Board
PDR	Preliminary Design Review
SCN	Specification Change Notice
TBD	To Be Determined

7.2 Post Delivery (Preliminary)

7.2.1 Post Delivery Tests

a. Receiving Inspection - This inspection shall consists of a document and hardware review to verify completeness of material and a visual inspection for shipping and handling damage.

b. Installation and Interface Verification - This test shall verify the interfaces between FVMS equipment and ASTP facilities prior to initial application of power.

c. Integrated Systems Test - This test shall be a limited functional test of FVMS equipment to verify functional, operational, physical and electromagnetic compatibility in meeting mission performance requirements.

7.2.2 Flight Crew Requirements

A separate crew systems review shall be conducted at CARR.

7.2.3 Base Support (Facility) Requirements

The following are preliminary requirements for Base Support:

TBD