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URINE MONITORING SYSTEM
FAILURE ANALYSIS
AND
OPERATIONAL VERIFICATION
TEST REPORT

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URINE MONITORING SYSTEM
FAILURE ANALYSIS
AND
OPERATIONAL VERIFICATION
TEST (OVT) REPORT

1.0 INTRODUCTION

In flight urine volume measurement and sampling data requirements have been identified for the Shuttle Orbiter Flight Tests (OFT). These data are required to support biomedical experiments and operational requirements.

Under contracts NAS9-13748 and NAS9-15230 a prototype urine monitoring system was tested in Spacelab Mission Simulation (SMS) II and Spacelab Mission Development Tests (SMD) III. The UMS tests indicated the need for several revisions and modifications to the UMS prototype prior to final verification testing of the design and subsequent flight hardware fabrication. Consequently, the unit was returned to General Electric where the failure analysis and testing reported herein were conducted.

2.0 SUMMARY

The UMS provides for the convenient, accurate, and real time urine mass measurement and sampling of urine voids with minimal crew involvement.

System performance is characterized by a regression formula developed from volume measurement test data. When the volume measurement data was inputted to the formula, the standard error of the estimate calculated using the regression formula was found to be within 1.524% of the mean of the mass of the input.

System repeatability was found to be somewhat dependent upon the residual volume of the system and the evaporation of fluid from the separator. Evaporation, is a function of the temperature, humidity and flow rate of the air through the system. With the arbitrary 2.5 CFM used in the OVT (250% of that required by a male and 31% of that required by a female user of the Shuttle Waste Collection System (WCS) urinal) the evaporation rate was determined to be approximately 1CC/minute. For a 200 gram UMS input and a "COLLECT" Mode duration of 4 minutes this could result in a 0.5% error with the UMS reading.

Results of the residual volume test indicates that the residual fluid level is critical to the system accuracy.

The test protocol for the Operational Verification Test residual volume determination called for the residual volume in the UMS to be determined by measuring the concentration of LiCl in the flush water following the pumpout of a solution having a known concentration of LiCl. The flush water tank was disconnected during the test. Observed results indicated residual levels in the range of 9-10 ml. Results obtained during the Flushing Efficiency Test provided the first indication that the 9-10 ml residual was questionable. These tests, which employed a normal UMS cycle including the flush indicated a residual level of approximately 20 ml. Subsequent tests with LiCl solution using the normal flush cycle or with a pump out time reduced to the normal period also indicated residuals in the 20 ml range. Obviously the extended pumpout time resulting from the flush water tank being disconnected resulted in a marked reduction in the residual volume in the separator. Consequently it is recommended that the phase separator pumpout time be extended or the design modified to minimize the residual level.

The constituent fidelity evaluation of the UMS indicated the difference between the data recorded in the test were not statistically significant.

Flushing efficiency was observed to be consistently good, reducing the effects of residuals to less than 1.0 ppm in three flushes. Very little change in flushing efficiency was observed by increasing the flush volume from 50 ml to 100 ml.

3.0 SCOPE

The work performed under this portion of contract NAS 9-15230 consisted of:

1. Conducting a failure analysis to determine the cause of the SMD III failure.
2. Revisions to the hardware to prevent a recurrence of the failure.
3. Performance of an Operational Verification Test to evaluate system performance.

4.0 SUMMARY

4.1 UMS Failure Analysis

Malfunction symptoms reported during the SMD-III test program at NASA-JSC were duplicated by dumping water on the UMS control panel. The probable cause of failure was water entering the back side of the electrical connector at the pressure switch assembly/electronic box interface.

4.2 Operational Verification Test

Tests were conducted to provide information on the overall performance of the UMS including:

1. Volume measurement accuracy
2. Effects of specific gravity and residual volume on system accuracy
3. Cross contamination and flushing efficiency.
4. Constituent fidelity including a user test.
5. Long term performance stability.

5.0 FAILURE ANALYSIS

5.1 Failure Description

During the SMD-III test, the UMS malfunctioned. Essentially the UMS would not complete the DUMP cycle, i.e., the system never started the flush sequence or the water flush sequence. This failure mode can be caused by:

1. Failure of the urine pump to completely pump out the phase separator.
2. Blockage of the fluid lines downstream of the phase separator.
3. A failure of the pressure sensor which detects the residual volume in the phase separator.
4. A failure of the pressure sensor signal conditioning electronics.
5. A failure of the power to the pressure sensor assembly.
6. A failure of the system control electronics.

5.2 Failure Investigation

On receipt of the UMS at G.E., the system was directly set-up for test (without any disassembly) in an effort to duplicate the failure mode experienced during the SMD-III tests.

The first tests were conducted on 6/23/77 using 200 ml inputs of both ambient temperature (about 72°F) and 100°F water. The UMS performed as designed with no evidence of a malfunction. Between 6/23 and 7/6/77, some 250 test runs were performed under a variety of operating conditions without any evidence of a malfunction of any type. These tests included variations as noted in Table 1.

On 7/6/77 (PM), about 10 ml of tap water was dumped on the control panel in an effort to duplicate the reported wet conditions during the SMD-III tests. No immediate effect was observed. No testing was performed on 7/7/77. On 7/8/77 (AM), the UMS exhibited the failure mode reported during the SMD-III test.

On 7/11/77 (AM), 12 test runs were completed with no sign of malfunction. After the test, atout 10 ml of tap water was again dumped on the control panel. On 7/11/77 (PM), the UMS again exhibited the failure mode. At this point, the outer shell was removed to permit access to the internal components. A check of the pressure sensor output indicated (erroneously) a high (large volume) in the phase seperator. This would cause the failure mode observed.

Table 5.2-1 - TEST VARIABLE DURING POST SMD-III TESTS OF THE UMS

- INPUT VOLUME (WATER)

  0, 100, 200, 300, 900 ML

- INPUT VOLTAGE (DC)

  22 to 31 VOLTS DC

  420 HZ AC

- TEMPERATURE (WATER)

  AMBIENT (70-75°F) and 100°F

- SAMPLING

  WITH/WITHOUT

- GROUND WIRE

  WITH/WITHOUT

- TIME

  DAILY/AM AND PM

On 7/12/77 (AM), the UMS again performed satisfactorily. After 4 test runs, about 0.2 ml of tap water was placed directly on the pressure sensor electrical connector (Ref. Figure 5.2-1). It should be noted that this connector is located directly below a possible leakage spot for water trapped in the control panel recess. In a check about one hour later, the UMS again exhibited the same failure mode. By 7/13/77 (AM), the UMS had recovered and performed satisfactorily.

Over the next several days, several attempts were made without success to further duplicate the malfunction condition. In addition to strategically placing a few drops of tap water on the connector, the connector was entirely submerged in tap water. Tests made between 1 and 24 hours later showed normal operation of the UMS. This lack of further failure may be a result of leaching out (or relocating) any salt residue internal to the connector.

5.3 Conclusions

The probable cause of UMS Failure as reported during the SMD-III tests was water entering the back side of the electrical connector at the pressure sensor/electronic box interface. Potting of this connector probably would have alleviated the failure. The source of the water on the control panel is unknown and indicates that a recessed control panel, at least for one "G" operations, should not be used.

5.4 System Modifications

As a result of the finding of the failure analysis several modifications were made to the UMS to avoid future problems resulting from liquid spillage.

1. The wiring in the electrical connectors was potted or conformal coated.
2. The light detectors used to indicate slinger motor speed and the number on the sample syringe were changed from a standard sensor to a waterproof version of the standard sensor.

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Figure 5.2-1 UMS WITH OUTER SHELL REMOVED

3. Recesses were cut in the bezel around the control panel to prevent a build-up of liquid in the control panel recess.
4. Gaskets, seals and elastomeric sealants were applied to all obvious leak paths between the outside and inside of the UMS.

Table 7.1-4 (Con't)

6.0 OPERATIONAL VERIFICATION TEST

6.1 Purpose

The Urine Monitoring System was developed to provide the capability for accurately measuring urine voids and obtaining representative sample of each void in either a one "G" or a zero "G" environment. The development effort and a report on initial operational testing is included in GE Report No 76SDS4200 dated December, 1975.

The series of tests reported herein was conducted in accordance with the Operational Verification Test Plan (Appendix A) to determine:

1. The accuracy of the volume measurement and the effects of specific gravity on the measurement accuracy.
2. The residual volume* of the system and its dilution effect on the samples.
3. The efficiency of the system flush cycle and the degree to which it eliminates cross-contamination between samples.
4. The potential for urine constituent alteration within the system.
5. The performance of the system over an extended period of time and through numerous uses.

* Residual volume refers to that quantity of fluid - remaining in the UMS following completion of the pump out of the system.

6.2 Test Procedure

6.2.1 Volume Measurement

Volume measurement test consisted of the introduction of measured quantities of liquid having measured specific gravity into the UMS, cycling the system and comparing the UMS data output with the measured input. During the volume measurement data collection, the flush tank was not connected and collection of the liquid discharged from the UMS was extended through the end of the flush cycle period.

Prior to each change in the specific gravity of the fluid being used, two aliquots of 200 grams of water were introduced into the system to minimize random cross contamination effects on the test. Specific gravity of the fluids used in the test was determined at the start of each run using a urinometer. Table 6.2-1 illustrates the order in which the test proceeded. Initially five aliquots each of 50, 100, 200, 400 and 1000 grams of water (Spec grav. 1.000 ± .004) were introduced into the UMS and measurements of separator speed and mass as indicated on the UMS printer were recorded. During this test the system blower was "on" continuously and the flush tank was disconnected.

Following the measurement accuracy test with water, tests 2 and 3 were conducted. In these tests, four aliquots each of 50, 100, 200, 400 and 1000 grams having a specific gravity of 1.015 and 1.035 respectively were introduced into the system and data recorded as in the test with water.

Table 6.2-1 VOLUME MEASUREMENT TEST

SPGR / INPUT	#1 1.0±.1	#2 1.015+.01	#3 1.035	#4 END
FLUSH *	X		X	X
FLUSH *	X		X	X
50	X	X	X	
50	X	X	X	
50	X	X	X	
50	X	X	X	
50	X			
100	X	X	X	
100	X	X	X	
100	X	X	X	
100	X	X	X	
100	X			
200	X	X	X	
200	X	X	X	
200	X	X	X	
200	X	X	X	
200	X			
400	X	X	X	
400	X	X	X	
400	X	X	X	
400	X	X	X	
400	X			
1000	X	X	X	
1000	X	X	X	
1000	X	X	X	
1000	X	X	X	
1000	X			

6.2.2 Residual Volume (Reference Table 6.2-2)

In this test three aliquots each of 50, 100, and 400 grams of a 100 mg/l solution of lithium chloride were introduced into the system alternately with three 50-gram aliquots of water. Each volume level series was repeated three times before aliquots of a higher volume were introduced. During residual volume data collection the flush system was disconnected and the blower was allowed to remain "ON" for 4 minutes, regardless of the length of the cycle, in order to standardize that condition. Water was introduced in 200-ml quantities prior to each run to flush the system. Aliquots of 100 grams of lithium chloride solution were also introduced with and without the blower "ON" and "OFF" during the cycle for comparison.

Aliquots of the outputs from these runs were transferred to 50-ml Falcon tubes, diluted 1/10 when necessary and analyzed along with an aliquot of the input solution diluted 1/10, for lithium (expressed as lithium chloride) on a Perkin-Elmer Model 290B Atomic Absorption Spectrophotometer.

6.2.3 <u>Flushing Efficiency (Ref. Table 6.2-3)</u>

Runs in Section 6.2.2 were repeated with the flush tank connected. Aliquots of the dump outputs, along with an occasional system flush output, were transferred to 50-ml Falcon tubes, diluted 1/10 when necessary, and analyzed along with an aliquot of the input solution, diluted 1/10, for lithium (expressed as lithium chloride) on a Perkin-Elmer Model 290B Atomic Absorption Spectrophotometer.

6.2.4 <u>Constituent Fidelity (Ref Table 6.2-4)</u>

The system was flushed two times with 200 ml of water. Aliquots of urine (4 1/2 hours old) in the range of 50, 100, 200, and 400 grams were introduced as available into the system with the blower "on" for 4 minutes and the flush tank connected. Prior to weighing the input, an aliquot was transferred to a 50-ml Falcon tube

Table 6.2-2 RESIDUAL VOLUME, CROSS CONTAMINATION

FLUSHING EFFICIENCY TEST

	FLUSH	50ML LICL	50ML H_2O	100ML LICL	400ML LICL	DUMP
# 1	X					
2	X					
3		X(3				
4			X(3			
5		X(3				
6			X(3			
7		X(3				
8			X(3			
9				X(3		
10			X(3			
11				X(3		
12			X(3			
13				X(3		
14			X(3			
15					X(3	
16			X(3			
17					X(3	
18			X(3			
19					X(3	
20			X(3			

Table 6.2-3 - FLUSHING EFFICIENCY TEST

	FLUSH	5.0ML LICL	FLUSH	100ML LICL
1.	X			
2.	X			
3.		X(3)		
4.			X(3)	
5.				X(3)
6.			X(3)	

Table 6.2-4

CONSTITUENT FIDELITY
TEST

	FLUSH	50ML URINE	100ML URINE	200ML URINE	400ML URINE	H_2O FLUSH
# 1	X					
2	X					
3		X				
4		X				
5		X				
6			X			
7			X			
8			X			
9				X		
10				X		
11				X		
12					X	
13					X	
14					X	

for analysis. For each input the system was purged and a sample was taken before the dump was activated. The samples and aliquots of dump outputs were transferred to 50-ml Falcon tubes.

Original urine, sample, and dump output were assayed for phosphorus and urobilinogen according to procedures outlined in Appendix B. Specific gravity data was not generally collected due to the small size of some of the samples and precipitation of solids by the time assays were completed. It was considered important to run the assays as soon as possible after collection.

6.2.5 Performance.

Unmeasured quantities of urine and water were introduced into the system with the blower "on" continuously and the flush tank connected. The system was purged and a sample withdrawn prior to the activation of the dump cycle. A large number of different sample syringes were utilized. Following each series of 40 unmeasured urine runs, series of three aliquots each of 100, 200, 400 and 800 grams of water were introduced to check performance of the UMS. Conditions and inputs were varied during the performance checks.

7.0 RESULTS AND DISCUSSION

7.1 Volume Measurement Test

Data recorded during the Volume Measurement Test is shown in Table 7.1-1. To analyze the UMS performance the data was entered into a program for use in the General Electric Mark III computer. A multiple regression routine "CURV" (Ref. Table 7.1-2) was employed in the analysis, the results of which are shown in Tables 7.1-2 and 7.1-3. Table 7.1-2 shows a portion of the "CURV" routine results. To obtain a "best" fit a transform was employed in the form of a constant (350) which was added to the UMS printer reading for mass.

Table 7.1-1. Volume Measurement Test Data

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CASE NO.	[WT]	[DATA]	[SPEED]	[SG]
1	50	341	3105	1.0000000E+00
2	50	318	3106	1.0000000E+00
3	50	363	3107	1.0000000E+00
4	50	331	3103	1.0000000E+00
5	100	675	3112	1.0000000E+00
6	100	676	3110	1.0000000E+00
7	100	668	3111	1.0000000E+00
8	100	683	3111	1.0000000E+00
9	200	1159	3115	1.0000000E+00
10	200	1149	3114	1.0000000E+00
11	200	1148	3114	1.0000000E+00
12	200	1150	3115	1.0000000E+00
13	400	1979	3117	1.0000000E+00
14	400	1971	3117	1.0000000E+00
15	400	1979	3117	1.0000000E+00
16	400	1968	3118	1.0000000E+00
17	1000	3718	3122	1.0000000E+00
18	1000	3725	3121	1.0000000E+00
19	1000	3729	3120	1.0000000E+00
20	1000	3726	3122	1.0000000E+00
21	50	315	3103	1.0150000E+00
22	50	287	3105	1.0150000E+00
23	50	280	3105	1.0150000E+00
24	50	283	3095	1.0150000E+00
25	100	665	3110	1.0150000E+00
26	100	657	3110	1.0150000E+00
27	100	663	3109	1.0150000E+00
28	100	629	3109	1.0150000E+00
29	200	1163	3113	1.0150000E+00
30	200	1161	3113	1.0150000E+00
31	200	1156	3114	1.0150000E+00
32	200	1157	3114	1.0150000E+00
33	400	1985	3118	1.0150000E+00
34	400	1988	3119	1.0150000E+00
35	400	1986	3118	1.0150000E+00
36	400	1990	3119	1.0150000E+00
37	1000	3753	3121	1.0150000E+00
38	1000	3755	3122	1.0150000E+00
39	1000	3743	3120	1.0150000E+00
40	1000	3750	3120	1.0150000E+00
41	50	274	3103	1.0350000E+00
42	50	292	3102	1.0350000E+00
43	50	287	3103	1.0350000E+00
44	50	279	3103	1.0350000E+00
45	100	654	3109	1.0350000E+00
46	100	654	3109	1.0350000E+00
47	100	657	3108	1.0350000E+00
48	100	669	3107	1.0350000E+00
49	200	1142	3112	1.0350000E+00
50	200	1154	3113	1.0350000E+00
51	200	1162	3111	1.0350000E+00
52	200	1151	3113	1.0350000E+00
53	400	1973	3117	1.0350000E+00
54	400	1992	3117	1.0350000E+00
55	400	1984	3117	1.0350000E+00
56	400	1993	3116	1.0350000E+00
57	1000	3767	3121	1.0350000E+00
58	1000	3781	3120	1.0350000E+00
59	1000	3773	3120	1.0350000E+00
60	1000	3764	3121	1.0350000E+00

Using the transformed data the "CURV" routine (ref Table 7.1-2) indicates the best fit is provided by an exponential curve (formula number 3 modified for the transform) of the form:

$$Y = A\ X\ (C+X)^{B}$$

where: Y = mass of fluid input

A = 0.0012474

B = 1.6348

C = 350 (transform)

X = UMS output for mass

Note that the formula does not include an output for speed. This is reasonable for the UMS since the speed while varying from one input level to the next is quite consistent from test to test ranging generally from 3102 to 3122 counts for a mass change of from 50 to 1000 grams. As a result the effects of the speed change are reflected in the UMS data and in this way enters the regression formula.

Descriptive statistics for the calculated weight estimated for each level of input to the UMS are shown in Table 7.1-4

7.2 Residual Volume

Average residual volumes obtained with different volume inputs during lithium chloride runs without flush water are listed in Table 7.2-1. The method for, calculation of these residuals was as follows:

$$Vres = \frac{F}{S} \times Vsol$$

where:

F = concentration of LiCl in first water flush OUTPUT

S=concentration of LiCl input to UMS

Vsol = volume of LiCl solution input to UMS

Vres = volume of LiCl solution (Vsol) remaining in UMS after pump out

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Table 7.1-2 Computer Printout from "Curv" Multiple

Regression of UMS Volume Measurement Data

```
SET DATAM = DATA ;_+350

READY
?RUN CURV (WT,DATAM)


                                    MEAN        VARIANCE          STD DEV
DEP VARIABLE: WT                   350.00     0.12203E+06          349.33
IND VARIABLE: DATAM                1920.4     0.15288E+07          1236.5

NUMBER      CURVE               INDEX              A                B

   1     Y=A+B*X              0.98316          -187.98          0.28014
   2     Y=A*EXP(B*X)         0.92886           43.167      0.82164E-03
   3     Y=A*(X^B)            0.99884      0.12474E-02           1.6348
   4     Y=A+(B/X)            0.63089           816.39     -0.60465E+06
   5     Y=1/(A+B*X)          0.62472      0.16201E-01     -0.44269E-05
   6     Y=X/(A*X+B)          0.97748     -0.38085E-02           14.920
FOR WHICH CURVE ARE DETAILS DESIRED (NUMBER OR DONE) --?3


                        EXPECTED        INTERVAL          NON-SIMULTANEOUS
COEFFICIENTS:            VALUE           WIDTH        95.00% CONFIDENCE LIMITS

CURVE 3       A:     0.12474E-02     0.26989E-03     0.11198E-02     0.13897E-02
A*(X^B)       B:          1.6348     0.29235E-01          1.6202          1.6494

 50117.61 = F-STATISTIC FOR FIT OF TRANSFORMED DATA BY A
             "LINEAR EQUIVALENT" FORMULA, A 100.00% VALUE


TYPE 1 FOR CONFIDENCE LIMITS ON ESTIMATED WT
OR   2 FOR PREDICTION LIMITS ON OBSERVATIONS OF WT
OR   3 FOR RESIDUALS AND PERCENT DIFFERENCE
OR   0 FOR NO TABULATION.    WHICH --?3
```

Table 7.1-3 "Curv" Routine Results

DATAM	WT OBSERVED	WT ESTIMATED	RESIDUAL	% DIFF
691.00	50.000	54.711	-4.7108	-8.61
668.00	50.000	51.765	-1.7653	-3.41
713.00	50.000	57.587	-7.5872	-13.18
681.00	50.000	53.422	-3.4224	-6.41
1025.0	100.00	104.24	-4.2391	-4.07
1026.0	100.00	104.41	-4.4054	-4.22
1018.0	100.00	103.08	-3.0778	-2.99
1033.0	100.00	105.57	-5.5724	-5.28
1509.0	200.00	196.17	3.8335	1.95
1499.0	200.00	194.05	5.9543	3.07
1498.0	200.00	193.83	6.1659	3.18
1500.0	200.00	194.26	5.7426	2.96
2329.0	400.00	398.80	1.1979	0.30
2321.0	400.00	396.57	3.4350	0.87
2329.0	400.00	398.80	1.1979	0.30
2318.0	400.00	395.73	4.2726	1.08
4068.0	1000.0	992.50	7.4985	0.76
4075.0	1000.0	995.30	4.7050	0.47
4079.0	1000.0	996.89	3.1071	0.31
4076.0	1000.0	995.69	4.3055	0.43
665.00	50.000	51.386	-1.3858	-2.70
637.00	50.000	47.896	2.1038	4.39
630.00	50.000	47.039	2.9613	6.30
633.00	50.000	47.405	2.5945	5.47
1015.0	100.00	102.58	-2.5816	-2.52
1007.0	100.00	101.26	-1.2632	-1.25
1013.0	100.00	102.25	-2.2514	-2.20
979.00	100.00	96.701	3.2992	3.41
1513.0	200.00	197.02	2.9827	1.51
1511.0	200.00	196.59	3.4083	1.73
1506.0	200.00	195.53	4.4707	2.29
1507.0	200.00	195.74	4.2584	2.18
2335.0	400.00	400.48	-0.48304	-0.12
2338.0	400.00	401.32	-1.3246	-0.33
2336.0	400.00	400.76	-0.76348	-0.19
2340.0	400.00	401.89	-1.8860	-0.47
4103.0	1000.0	1006.5	-6.4999	-0.65
4105.0	1000.0	1007.3	-7.3021	-0.72
4093.0	1000.0	1002.5	-2.4926	-0.25
4100.0	1000.0	1005.3	-5.2970	-0.53
624.00	50.000	46.309	3.6915	7.97
642.00	50.000	48.512	1.4877	3.07
637.00	50.000	47.896	2.1038	4.39
629.00	50.000	46.917	3.0833	6.57
1004.0	100.00	100.77	-0.77044	-0.76
1004.0	100.00	100.77	-0.77044	-0.76
1007.0	100.00	101.26	-1.2632	-1.25
1019.0	100.00	103.24	-3.2434	-3.14
1492.0	200.00	192.57	7.4335	3.86
1504.0	200.00	195.10	4.8950	2.51
1512.0	200.00	196.80	3.1955	1.62
1501.0	200.00	194.47	5.5308	2.84
2323.0	400.00	397.12	2.8762	0.72
2342.0	400.00	402.45	-2.4477	-0.61
2334.0	400.00	400.20	-0.20271	-0.05
2343.0	400.00	402.73	-2.7286	-0.68
4117.0	1000.0	1012.1	-12.120	-1.20
4131.0	1000.0	1017.8	-17.753	-1.74
4123.0	1000.0	1014.5	-14.533	-1.43
4114.0	1000.0	1010.9	-10.915	-1.08

5.3354 = STANDARD ERROR OF ESTIMATE
1.524% OF MEAN OF WT

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Table 7.1-4 Descriptive Statistics of UMS Output for Various Input Volumes

NAME OF VARIABLE: W1 (50 Gram Input)

NO. OBSERVATIONS	12		
AVERAGE	50.070		
VARIANCE	13.286		
STD DEV	3.6450		
SE MEAN	1.0522		
COEF VAR	7.28%		
RANGE	11.279	"SECOND" RANGE	7.7941
MAXIMUM	57.587	NEXT LARGEST	54.711
MINIMUM	46.309	NEXT SMALLEST	46.917

	SIGMA LIMITS		NUMBER OF OBSERVATIONS OUTSIDE THE LIMITS		
	LOWER	UPPER	BELOW	ABOVE	TOTAL
2.00*SIGMA	42.780	57.360	0	1	1
1.50*SIGMA	44.603	55.538	0	1	1
1.00*SIGMA	46.425	53.715	1	2	3

NAME OF VARIABLE: W2 (100 Gram Input)

NO. OBSERVATIONS	12		
AVERAGE	102.18		
VARIANCE	5.3164		
STD DEV	2.3057		
SE MEAN	0.66561		
COEF VAR	2.26%		
RANGE	8.8716	"SECOND" RANGE	3.6343
MAXIMUM	105.57	NEXT LARGEST	104.41
MINIMUM	96.701	NEXT SMALLEST	100.77

	SIGMA LIMITS		NUMBER OF OBSERVATIONS OUTSIDE THE LIMITS		
	LOWER	UPPER	BELOW	ABOVE	TOTAL
2.00*SIGMA	97.567	106.79	1	0	1
1.50*SIGMA	98.720	105.64	1	0	1
1.00*SIGMA	99.873	104.48	1	1	2

NAME OF VARIABLE: W3 (200 Gram Input)

NO. OBSERVATIONS	12		
AVERAGE	195.18		
VARIANCE	1.8826		
STD DEV	1.3721		
SE MEAN	0.39608		
COEF VAR	0.70%		
RANGE	4.4508	"SECOND" RANGE	2.9703
MAXIMUM	197.02	NEXT LARGEST	196.80
MINIMUM	192.57	NEXT SMALLEST	193.83

	SIGMA LIMITS		NUMBER OF OBSERVATIONS OUTSIDE THE LIMITS		
	LOWER	UPPER	BELOW	ABOVE	TOTAL
1.50*SIGMA	193.12	197.24	1	0	1
1.00*SIGMA	193.81	196.55	1	3	4

Table 7.1-4 (Con't)

NAME OF VARIABLE: W4 (400 GRAM INPUT)

NO. OBSERVATIONS	12		
AVERAGE	399.74		
VARIANCE	5.4526		
STD DEV	2.3351		
SE MEAN	0.67408		
COEF VAR	0.58%		
RANGE	7.0013	"SECOND" RANGE	5.8827
MAXIMUM	402.73	NEXT LARGEST	402.45
MINIMUM	395.73	NEXT SMALLEST	396.57

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	SIGMA LIMITS LOWER	UPPER	NUMBER OF OBSERVATIONS OUTSIDE THE LIMITS BELOW	ABOVE	TOTAL
1.50*SIGMA	396.24	403.24	1	0	1
1.00*SIGMA	397.40	402.07	3	2	5

NAME OF VARIABLE: W5 (1000 GRAM INPUT)

NO. OBSERVATIONS	12		
AVERAGE	1004.8		
VARIANCE	68.658		
STD DEV	8.2860		
SE MEAN	2.3920		
COEF VAR	0.82%		
RANGE	25.252	"SECOND" RANGE	19.238
MAXIMUM	1017.8	NEXT LARGEST	1014.5
MINIMUM	992.50	NEXT SMALLEST	995.30

	SIGMA LIMITS LOWER	UPPER	NUMBER OF OBSERVATIONS OUTSIDE THE LIMITS BELOW	ABOVE	TOTAL
1.50*SIGMA	992.35	1017.2	0	1	1
1.00*SIGMA	996.49	1013.1	3	2	5

Table 7.2-1 Residual Volumes
Obtained during Lithuim Chloride
Runs without Flush Connected

VOL. LiCl INPUTS (ml)	VOL. H_2O INPUTS (ml)	RESIDUAL VOL. (ml) $\pm\sigma$
50	50	9.0±0.3
100	50	9.8±0.2
100	100	10.4±0.4
400	50	9.5±0.3

- NO FLUSH HOOK-UP
- BLOWER ON 4 MIN.
- COLLECTED DURING "FLUSH" PERIOD

100	50	10.3±0.0

- NO FLUSH HOOK-UP
- NO BLOWER
- COLLECTED DURING "FLUSH"PERIOD

Dilution volume may differ slightly from these values because of evaporation within the unit after the input is dumped. In actual use, the residual volume could be significantly higher than 10 ml, since the flush tank would be connected and evaporated liquid would be replaced by the flush water. Estimation of residual volume from the data obtained with the flush during the flushing efficiency runs indicated an increase of approximately 12 ml. Approximately 13 ml of liquid was collected on runs similar to the residual volume runs by extending the collection period through the flush cycle period. These results altered the initial concept that output during this time was negligible and probably accounts for the apparent difference in volumes left in the unit under these two conditions. Residual volume consistency was affected by the condition of the blower during a run, since a significant amount of evaporation took place over a period of time with the blower "on." It can be seen from Table 7.2-2 that evaporation loss was at the lowest level and was most consistent with no blower. The calculated residual volume value was exactly the same each time the system was operated without the blower. The least amount of variation was observed when the blower was "on" only during the cycle and the cycle was limited to the time required for input, output and flush.

An estimate of the evaporation rate was made as follows:

Air Flow Rate	- 2.5 CFM
Time	- 4 min.
Relative Humidity Inlet	- 20% (Estimated)
Relative Humididty Outlet	- 85% (Estimated)
Absolute Humidity Inlet	(70°F-20%RH)=.005 #H_2O/#Dry Air
Absolute Humidity Outlet	(72°F 85%RH)=.014 #H_2O/#Dry Air
Water Lost Thru Evaporation	=.009 #H_2O/#Dry Air
Approximate Evaporation Rate In UMS with Blower On	= 1cc/MIN

Table 7.2-2 Mean Volume Loss (Input - Output) with

Inputs of Specific Gravity 1.00

VOL (ml)	COND. #1 • BLOWER ON CONTINUOUSLY • NO FLUSH, COLLECTED DURING FLUSH	COND. #2 • NO BLOWER • NO FLUSH	COND. #3 • BLOWER ONLY DURING CYCLE • NO FLUSH, COLLECTED DURING FLUSH	COND. #4 • BLOWER ON 4 MIN. • NO FLUSH, COLLECTED DURING FLUSH	COND. #5 • BLOWER ON 4 MIN. • FLUSH	COND. #6 • BLOWER ONLY DURING CYCLE • FLUSH	COND. #7 • BLOWER ON CONTINUOUSL • FLUSH
50	2.7±0.4	0.4±0.1	1.8±0.2	2.5±0.4	6.6±0.5	6.4±0.4	--
100	3.2±0.5	0.4±0.1	2.2±0.3	2.6±0.3	7.0±0.5	6.1±0.3	6.1±0.5
200	3.6±0.1	--	2.1±0.1	--	7.1±0.3	6.3±0.4	6.2±0.2
400	3.4±0.3	--	--	3.1±0.4	7.2±0.5	6.5±0.7	6.7±0.3
800	--	--	--	--	7.8±0.4	7.0±0.4	7.3±0.4
1000	4.1±0.4	--	--	--	--	6.6±0.5	--

This value while an estimate, indicates the impact of evaporation on the accuracy of UMS data.

Table 7.2-3 presents the results of a test similar to those reported in Table 7.2-2 except that fluid having a specific gravity of 1.035 instead of 1.000 was used. Test results presented in table 7.2-3 are indistinguishable from those in table 7.2-2.

7.3 Flushing Efficiency

Table 7.3-1 shows the mean concentration of lithium chloride in simulated flush outputs taken from residual volume runs. A slight increase in amount of lithium chloride removed by the first water input was observed when the volume of water was increased from 50 to 100 ml.

The mean concentrations of lithium chloride in water outputs from runs in which the flush tank was connected are listed in Table 7.3-2. The lower residual LiCl concentration observed during these runs is apparently the result of the increase in residual volume of liquid in the separator due to the use of the flush cycle and the resulting reduction in system pump out time. Spot checks of the second output of the system flush (approximately 52 ml) indicated that the concentration of lithium chloride was 7 mg/l. during the flushing efficiency runs. In addition to the effect of differences in conditions, the greater flushing efficiency of the fine spray of the system flush may have contributed to the higher concentrations of lithium chloride in these flushes.

7.4 Urine Constituent Fidelity

Reductions in concentration of urine constituents tested during processing by the UMS appear to be primarily the result of dilution. Table 7.4-1 lists the mean levels

Table 7.2-3 Mean Wt/Volume Loss

(Input - Output) with

Inputs of Specific Gravity 1.035

		COND.#1 • BLOWER ON CONTINUOUSLY • NO FLUSH, COLLECTED DURING FLUSH CYCLE		COND.#6 • BLOWER ONLY DURING CYCLE • FLUSH	
VOL. (ml)	WT. (g)	VOL LOSS (ml)	WT LOSS±σ (g)	VOL LOSS (ml)	WT LOSS±σ (g)
48.3	50	2.1	2.2±0.1	7.1	7.4±0.1
96.6	100	2.6	2.7±0.8	7.3	7.6±0.4
193.2	200	2.6	2.7±0.5	7.3	7.6±0.3
386.5	400	3.4	3.5±1.1	7.8	8.1±0.6
772.9	800	--	--	7.3	7.6±0.2
966.2	1000	4.0	4.1±0.3	--	--

Table 7.3-1 Mean Concentration of LiCl In Simulated Flush Outputs (Residual Volume Runs)

VOL LiCl INPUTS (ml)	VOL H_2O INPUTS	CONC LiCl IN UNIT (ppm)	CONC. LiCl (mg/l) IN WATER OUTPUT #1	#2	#3
50	50	107	19	2	1
100	50	104	20	3	1
100	100	103	11	2	1
400	50	97	18	3	<1

- BLOWER ON 4 MIN.
- NO FLUSH
- COLLECTED DURING FLUSH PERIOD

100	50	102	21	4	2

- NO BLOWER
- NO FLUSH

Table 7.3-2 Mean Concentration of LiCl In Water Outputs Following System Flush of LiCl Inputs (100 mg/l)

VOL LiCl INPUTS (ml)	VOL H_2O INPUTS	CONC LiCl IN UNIT (ppm)	CONC. LiCl (mg/l) IN 50-ml WATER OUTPUT #1	#2	#3
50	50	70	2	<1(0.3)	<1(0.1)
100*	50	86	2	<1(0.2)	<1(0.1)
400	50	94	2	<1(0.4)	<1(0.03)

- BLOWER ON 4 MIN.
- FLUSH ATTACHED (APPROX 52 ml X 2)
- COLLECTED ONLY DURING DUMP.

* 2nd FLUSH HAD CONC. OF 7ppm		28			

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Table 7.4-1 Mean Levels of Urobilinogen and Phosphorus in Sample and Dump Outputs of Individual Urines Expressed as Percent of Input Level

(BLOWER ON 4 MIN. - FLUSH ATTACHED)

MEAN VOL OF INPUT	MEAN % OF INPUT UROBILINOGEN		MEAN % OF INPUT PHOSPHORUS	
	SAMPLE	DUMP	SAMPLE	DUMP
49.9	73.6	66.5	75.7	69.6
99.2	79.6	84.3	90.3	90.9
197.3	90.2	89.5	92.0	91.4
401.3	89.9	92.9	91.8	94.4

of phosphorus and urobilinogen in sample and dump outputs of individual urine expressed as percent of input level. Most of the output levels observed with these constituents and with lithium chloride, as shown in Table 7.4-2, are in the range expected with an estimated 22-ml residual volume. Urobilinogen was chose as one constituent to be monitored because of its sensitivity to oxidation. Mean levels of urobilinogen were only slightly lower than those of phosphorus in the outputs monitored indicating the possibility of a slight change in the urine input due to the UMS.

7.5 Performance

The UMS continued to operate well throughout the use test. A total of approximately 600 urine and water samples were introduced into the system. In addition, data runs consisting of a total of approximately 180 inputs were performed during the period of the use test. Inputs of the volume measurement, residual volume, flushing efficiency and constituent fidelity runs totaled approximately 300, bringing the number of "uses" during the Operation Verification Test to 1080.

The septum was changed at the start of the use test. Initial penetration of the septum was sometimes difficult and teflon spray applied to the "needle" did not seem to reduce the friction noticably. Leakage began after about 190 uses and was extensive enough after 212 uses to require that the sample port be plugged.

Near the conclusion of the test it was observed that after extended use the collect light on the UMS panel began to flash on and off. This anomoly was found to be due to a faulty sensor used to monitor the speed of the separator.
The component was replaced and no further problems were experienced.

Table 7.4-2 Levels of LiCl in Dump

Output of LiCl Inputs Expressed as

Percentage of Input Level

WT OF INPUT	MEAN % OF INPUT LiCl CONCENTRATION IN DUMP
50	70.3
100	86.3
400	93.7

8.0 RECOMMENDATIONS

The following conclusions and recommendations were drawn from the Operation Verification Test:

1. The system performs very well over an extended period. It is recommended, however, that the septum be redesigned to extend its life.
2. The problem with the optical device used to indicate motor speed is an annoyance and in no way affected the performance of the unit. It has been learned however that devices of the type used on the UMS are subject to inherent failure similar to that observed during the test. Although the speed of the motor is quite repeatable between tests, therefore minimizing the importance of the sensor, it is felt that on future systems a different type sensor be employed.
3. Testing performed on the UMS prior to the Operational Verification Test indicated that the pressure transducer used to measure fluid level is somewhat temperature sensitive. Although the transducer imcorporates a temperature compensation network to minimize this problem the response of the compensation network does not match the response of the sensor on the basis of time. A brief test was performed to determine the time for stability of the snesor. Time observed to achieve stability was in excess of a time considered reasonable for UMS purposes. It is recommended that careful attention be given to transducer temperature compensation and response to temperature changes on future UMS type programs.
4. The urine constituents tested do not appear to be altered significantly during processing by the system.
5. The system performs very well over an extended period. It is recommended, however, that the septum be redesigned to extend its life.

APPENDIX A

OPERATIONAL VERIFICATION

TEST PLAN

URINE MONITORING SYSTEM (UMS)

OPERATIONAL VERIFICATION TEST PLAN

Prepared By: E. J. Glanfield, Engineer
Environmental Engineering

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1.0 INTRODUCTION

The Urine Monitoring System (UMS) was developed under contract NAS 9-15230 to provide accurate volume measurement of urine voids and to provide representative samples of each void. Following operation in the recent SMS III tests performed at NASA, JSC the UMS was returned to General Electric for refurbishment and operational testing. This plan describes the testing to be performed.

2.0 PURPOSE

The purpose of the testing described herein is to verify the operating capabilities of the system particularly:

1. Determination of the volume measurement of the system.

2. Determination of the effect of varying fluid specific gravities on the volume measurement accuracy.

3. Quantification of the residual volume and its dilution effect on the samples.

4. Determination of the efficiency of the system's flushing procedure and the degree of elimination of cross-contamination.

5. Determination of the degree of urine constituent alteration as a result of the systems operations.

In addition, a user test shall be performed to demonstrate the ability of the system to operate in a consistent manner for extended periods of time and for numerous uses.

3.0 MEASUREMENT ACCURACY/INFLUENCE OF SPECIFIC GRAVITY & RESIDUAL VOLUME

3.1 Purpose

The purpose of this portion of the test is:

1. To determine the volume measurement accuracy of the UMS and to determine the influence of variable fluid specific gravities on the measurement accuracy.

2. To quantify the repeatability of the amount of residual fluid retained in the UMS between runs.

3.2 Method

3.2.1 Measurement Accuracy/Influence of Specific Gravity

Determination of the volume measurement accuracy of the UMS will be accomplished by comparing the known volume of selected aliquots of fluid introduced into the system to the volume of the aliquots as measured by the UMS. To support the precision required, the aliquots to be introduced into the UMS will be determined gravimetrically.

The influence of fluids with varying specific gravities on the volume measurement accuracy will be determined in a similar manner except that the volumes will be adjusted mathematically with the measured fluid specific gravity.

3.2.2 Residual Volume

Determination of the repeatability of residual volume will be accomplished concurrently with paragraph 3.2.1. This will be determined by volumetrically comparing the input and output of the UMS and recording the difference. This determination will be made only during the series in paragraph 3.4.3.1.

3.3 Hardware Required

1. Gravimetric balance (Accuracy: $\pm$ 0.05%) (Range: 50 to 1500 grams)
2. Ten liters of distilled water in single container
3. Six liters of water containing Na Cl with specific gravity of 1.015 $\pm$ .01
4. Six liters of water containing Na Cl with specific gravity of 1.035 $\pm$ .01
5. Three Falcon tubes
6. Two - 1 liter flask
7. Two - 250 ml flasks
8. UMS system with data printout

3.4 Procedure

3.4.1 System Preparation

Disconnect flush tank from UMS.

3.4.2 Flush

Establish that UMS is connected in normal configuration. Turn UMS on. Introduce 200 cc's of "Super-Q" water into urinal. Initiate purge cycle. Initiate dump cycle. Repeat above twice.

3.4.3 Data Runs

3.4.3.1 Distilled Water Series (Sp. Gr. = 1.0)

1. Secure container of water with specific gravity of 1.0 $\pm$ 0.1
2. Agitate container to insure homogenity
3. Obtain sample for specific-gravity determination (use Falcon tube)
4. Decant approximately 50 ml into 250 mltared container
5. Weigh container to determine net fluid weight (record)
6. Activate collect switch
7. Introduce volume into UMS
8. Activate dump switch (record data output) (see paragraph 3.4.3.4)
9. Allow system to empty and shut itself off
10. Repeat steps 2 through 9 four times
11. Repeat the above steps for each of the following volumes: 100 cc, 200 cc, and 1,000 cc

3.4.3.2 Water Series (Sp. Gr. = 1.015 + 0.01)

1. Repeat steps 1 through 9 in paragraph 3.4.3.1 using water with specific gravity of 1.015
2. Repeat step 10 but do only three times
3. Repeat step 11

3.4.3.3 Water Series (Sp. Gr. = 1.035

1. Repeat flush in paragraph 3.4.1
2. Repeat paragraph 3.4.3.2 except use water with specific gravity of 1.035

3. Repeat flush in paragraph 3.4.1

3.4.3.4 Residual Volume

1. Collect output volume from step 8 in paragraph 3.4.3.1
2. Weigh output to determine net weight of fluid (record data)
3. Repeat for all tests in paragraph 3.4.3.1

4.0 RESIDUAL VOLUME & FLUSHING EFFICIENCY

4.1 Purpose

The purpose of this phase is:

1. To quantify the amount of residual fluid retained in the UMS between runs and the dilution effect of this volume on the fluid analyses

2. To determine effectiveness of the UMS flushing technique

4.2 Method

Water containing a known concentration of lithium chloride (LiCl) will be introduced into the UMS so that the residual volume concentration of LiCl will be known. Known volumes of water, not containing LiCl, will then be introduced. The system and system outflow will then be sampled to determine the LiCl content. From this data the residual volume will be determined. Also a comparison of the sample and output concentration of LiCl can be made.

A similar method will be used to determine the effectiveness of the flushing technique integral with the UMS.

4.3 Hardware Requirements

1. 50 1 of water containing 8 mg/1 of LiCl
2. 50 1 of distilled water
3. 25 Falcon tubes
4. 20-250 ml containers
5. 6-1,000 ml containers
6. Gravimetric balance
7. UMS

4.4 Procedure

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4.4.1 System Preparation

Disconnect flush tank.

4.4.2 Flush

Same as 3.4.2.

4.4.3 Data Runs

4.4.3.1 Residual Volume/Cross-Contamination

1. Secure container of LiCl
2. Agitate container to insure homogenity
3. Obtain sample for LiCl concentration determination and specific gravity (use Falcon tube)
4. Decant approximately 50 ml into 250 ml tared container
5. Weigh container to determine net fluid weight (record)
6. Activate UMS collect switch
7. Introduce volume into UMS
8. Activate dump switch
9. Collect output and weigh to determine net fluid weight
10. Agitate output volume and collect sample for specific gravity and LiCl analyses (use Falcon tube)
11. Allow system to shut itself off
12. Repeat steps 2 through 11 two times
13. Repeat steps 2 through 12 using distilled water containing no LiCl
14. Repeat steps 2 through 12 (water with LiCl)
15. Repeat step 13 (water with no LiCl)
16. Repeat step 14
17. Repeat step 15
18. Repeat steps 2 through 12 using 100 ml aliquots (water with LiCl)
19. Repeat step 13 (50 ml aliquots without LiCl)
20. Repeat step 18
21. Repeat step 19
22. Repeat step 18

23. Repeat step 19
24. Repeat steps 2 through 12 using 400 ml aliquots (water with LiCl)
25. Repeat step 13
26. Repeat step 24
27. Repeat step 25
28. Repeat step 24
29. Repeat step 25

4.3.3.2 Flushing Efficiency

1. Install UMS flush tank filled with distilled water
2. Interconnect flush tank with UMS
3. Activate UMS and dump two times (determine volume of each dump)
4. Repeat steps 1 through 13 in paragraph 4.4.3.1
5. Repeat step 18 and 19 in paragraph 4.4.3.1

5.0 CONSTITUENT FIDELITY

5.1 Purpose

The purpose of this portion of the test is to determine the effects of the UMS on the urine constituents.

5.2 Method

Determination of the degree of urine constituent alteration will be accomplished by sampling urine prior to introduction into the system and after being processed by the system. In addition, a sample of the urine will be obtained through the normal sample collection scheme of the UMS. The analyses of these samples will be compared to determine the amount of constituent adulteration.

5.3 Hardware Requirements

1. 3 1 of urine
2. 12 UMS sample tubes
3. 13 Falcon tubes
4. 10-250 ml containers

5. 5-500 ml containers
6. 1 Gravimetric balance
7. UMS

5.4 Procedures

5.4.1 System Preparation

Fill flush tank and connect to UMS.

5.4.2 Flush

Same as paragraph 3.4.2.

5.4.3 Data Runs

1. Secure container of urine
2. Agitate to insure homogenity
3. Obtain sample for chemical analysis (use Falcon tube)
4. Decant approximately 50 ml into tared, 250 ml container
5. Weigh container to determine net fluid weight (record)
6. Activate UMS collect switch
7. Introduce volume into UMS
8. Activate purge switch
9. Install sample container
10. Fill sample container
11. Activiate dump switch and collect output (record output)
12. Agitate output and collect sample (use Falcon tube)
13. Repeat steps 2 through 12 two times
14. Repeat steps 2 through 13 using 100 ml of urine
15. Repeat steps 2 through 13 using 200 ml of urine
16. Repeat steps 2 through 13 using 400 ml of urine
17. Flush system with a minimum of 2,000 of distilled water in four or more aliquots
18. Deactivate system

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6.0 USER TEST

6.1 Purpose

The User Test is intended to provide information on the ability of the UMS to perform in a consistent maintenance free manner for extended periods and through numerous uses.

6.2 Method

This test shall consist of introducing both measured samples and unmeasured samples into the UMS. The unmeasured samples shall be provided by volunteer users and shall be in the form of fresh urine voids. Samples of each, urine input shall be collected for specific gravity determination. Measure samples shall be periodically introduced into the system to provide a check on the consistency of the system performance during the test.

6.3 Hardware required

1. Gravimetric balance (Accuracy: $\pm$ 0.05%) (Range: 50 to 1500 grams)
2. Room temperature water supply (Sp GR 1.0 +- 0.1)
3. Two - 1 liter flasks
4. UMS system with data printout
5. Source of fresh urine samples
6. Recorder (strip chart)

6.4 Procedure

6.4.1 Preparation

6.4.1.1 Fill and connect flush tank to UMS.

6.4.1.2 Assemble test system as per Figure 1.

6.4.1.3 Energize power supply #1, #2 and #3.

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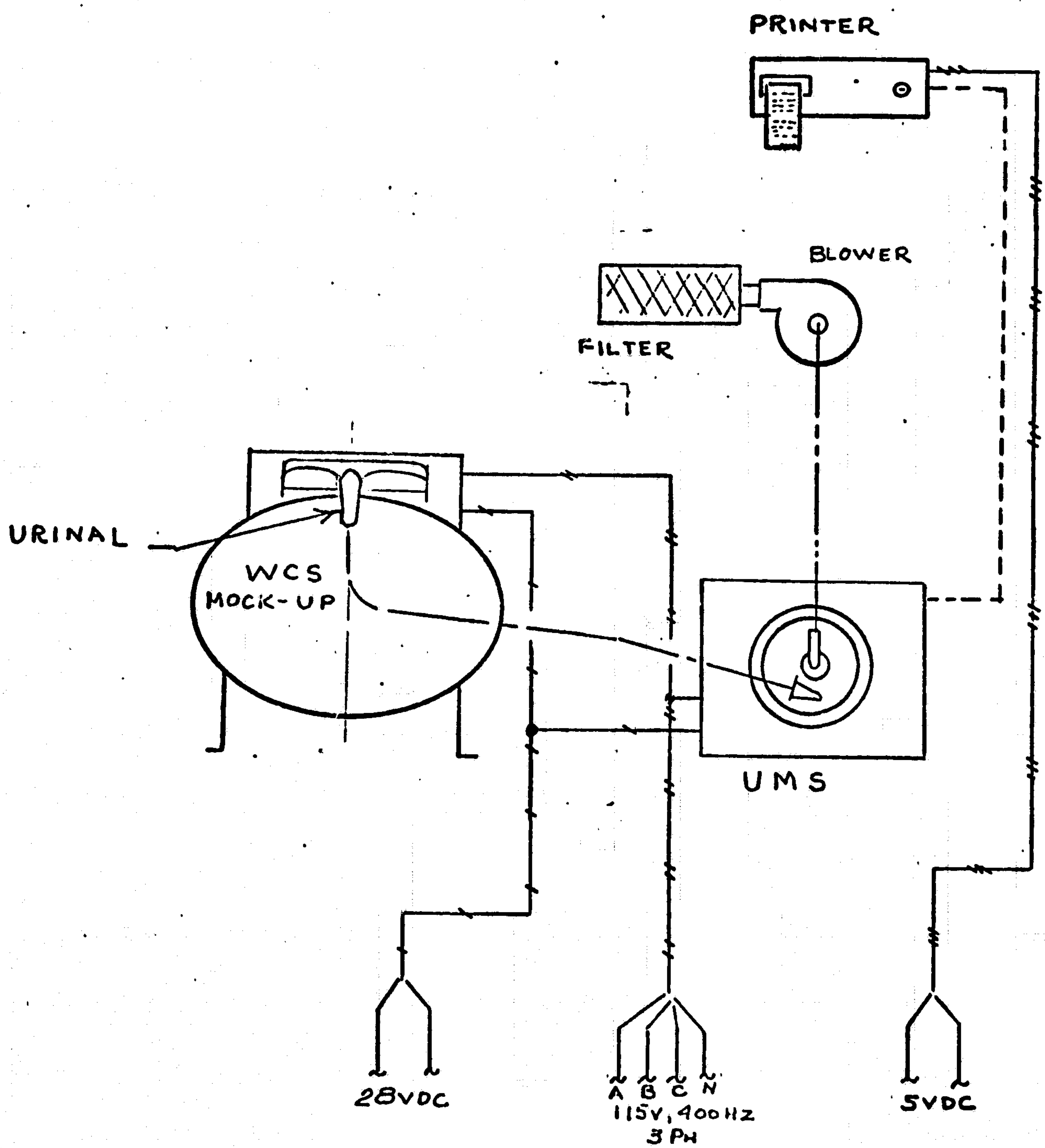

FIG. 1 UMS USER TEST
GENERAL ARRANGEMENT

6.4.2 Data Run

1. Secure container of room temperature water (Sp GR 1.0)
2. Place 100 grams of water in 400 ml beaker
3. Weigh container to determine net weight of fluid and record weight.
4. Activate collect switch on UMS.
5. Introduce water sample into UMS
6. Activate the dump switch
7. Allow the system to empty and shut itself off
8. Repeat steps 2 through 7 two times.
9. Repeat steps 2 through 8 for each of the following volumes 200 cc, 400 cc, 800 cc.
10. Compare data from test with that collected in paragraph 3.4.3.1.

6.4.3 User Test

1. Secure users to provide urine samples (ideally 40 uses per day are desired)
2. Users should introduce urine (unmeasured) directly into the UMS. If sufficient "volunteers" cannot be obtained water samples (measured) shall be used to provide the desired 40 "uses" per day.
3. Users Operating Procedure
   a. Install sample container into UMS receiver.
   b. Depress "Collect" switch
   c. Introduce urine into UMS
   d. Depress the "Purge" switch
   e. Depress and hold the "Sample" switch until the sample container piston moves to approximately the 3/4 full position at which time release the "Sample" switch.
   f. Remove the sample container.
   g. Depress the "Dump" switch and allow the UMS to complete its cycle and shutdown.
   h. Place sample container in the appropriate container.
4. Once each day a data run shall be made as per Section 6.4.2.
5. The test will be conducted for a minimum of 15 days after which the UMS shall be flushed thoroughly and inspected.

APPENDIX B

ASSAY PROCEDURES

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UROBILINOGEN ASSAY

PRINCIPLE

Urobilinogen is determined photometrically by applying Ehrlich's aldehyde reaction with *p* - dimethylaminobenzaldehyde directly to urine. Ascorbic acid is added as a reducing agent. After the formation of the urobilinogen-aldehyde, the acidity is decreased by addition of sodium acetate. This intensifies the urobilinogen-aldehyde color and inhibits color formation by substances such as indole and skatole derivatives. A blank is prepared by adding sodium acetate at the same time as the Ehrlich's reagent, preventing developing of the urobilinogen-aldehyde color. The method is not completely specific.

REAGENTS

1. Ehrlich's reagent - Dissolve 0.7 g *p* - dimethylaminobenzaldehyde in 150 ml conc. HCL, AR grade. Add 100 ml distilled water.

2. Sodium Acetate Saturated - Dissolve AR grade sodium acetate in distilled water until crystals remain (to insure saturation).

PROCEDURE

1. Test urine for bilirubin. If more than a faint trace is present, mix 2.0 ml 10 percent $BaCl_2$ with 8.0 ml urine and filter. The final result must then be multiplied by 1.25 to correct for this 4:5 dilution.

2. Reduce light in room to one 100 watt incandescent bulb.

3. Dissolve 100 mg ascorbic acid in 10 ml clear urine (centrifuge if turbid) and place 1.5 ml aliquots in each of two cuvettes, one labeled "B" for blank and the other "X" for unknown.

4. To "B" add 4.5 ml freshly prepared mixture of 1 vol. Ehrlich's reagent and 2 vol. saturated sodium acetate and mix. Measure absorbance immediately against water at 562 nm.

PROCEDURE (continued)

5. To "X" add 1.5 ml of Ehrlich's reagent, mix thoroughly, and immediately add 3.0 ml saturated sodium acetate. Measure absorbance immediately against water at 562 nm.

6. Calculate Ehrlich units/100 ml, assuming 0.346 mg urobilinogen/100 ml of final colored solution has an absorbance of 0.384.

$$\frac{A_{"X"} - A_{"B"}}{0.384} \times 0.346 \times \frac{6.0}{1.5} = \text{Ehrlich units/100 ml}$$

$$A_{"X"} - A_{"B"} \times 3.604 \doteq \text{Ehrlich units/100 ml urine}$$

REFERENCE

Henry, R. J., S. L. Jacobs and S. Beckman, Clinical Chemistry 7, 231 (1961).

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PHOSPHORUS ASSAY

PRINCIPLE

A trichloracetic acid filtrate is treated with ammonium molybdate solution (molybdic acid), which combines with phosophate to form phosphomolybdate. The molybdate thus formed is reduced with ferrous sulfate and the blue color produced is measured photometrically and is proportional to the amount of phosphorus originally present.

REAGENTS

1. Trichloracetic Acid, 12.0% (w/v) - Dissolve 120.0 g of trichloracetic acid in water and dilute to exactly 1 liter.

2. Trichloracetic acid, 34.0% (w/v) - Dissolve 340.0 g of trichloracetic acid in water and dilute to exactly 1 liter.

3. Sulfuric acid, 10 N - Add slowly to about 700 ml of distilled water 278 ml of concentrated sulfuric acid. Cool and dilute to 1 liter with distilled water.

4. Ammonium molybdate, stock solution, 10% - Add 40 g of $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$ into a liter beaker and add 400 ml of 10 N sulfuric acid with constant stirring to prevent caking. When completely dissolved, transfer the solution to a 400 ml volumetric flask and wash in quantitatively with 10 N sulfuric acid to the mark.

5. Ferrous sulfate-ammonium molybdate reagent - Prepare just prior to using. Transfer 10.0 ml of ammonium molybdate stock solution to a 100 ml volumetric flask and dilute to about 70 ml. Add 4.0 g of $FeSO_4 \cdot 7H_2O$, make up to volume with water and shake until the crystals are dissolved. Transfer to a brown glass bottle.

PROCEDURE

1. Dilute 1.0 ml of the urine specimen to 100 ml. This dilution will suffice with most urines. If, however, this dilution factor yields a final color too light or too dark, another appropriate dilution is selected.

2. Transfer 2.0 ml of diluted urine to a cuvette and add 1.0 ml of 34% trichloracetic acid. (If the urine contains proteins, a turbidity will be produced after the addition of the trichloracetic acid. In this case, proceed as follows: Pipette 4.0 ml of diluted urine from step 1 into a test tube, add 2.0 ml of 34 percent trichloroacetic acid, mix and allow the mixture to stand at room temperature for about 10 minutes. After centrifuging, pipette 3.0 ml of the supernatant fluid into a cuvette and proceed with the following.) For blank determination substitute 2 ml of distilled water for urine dilution.

PROCEDURE (continued)

3. Add 2.0 ml of the ferrous sulfate-molybdate reagent and read absorbance at 660 nm after 1 min. but within 2 hours.

   (A Hitachi Model 100 - 20 Photometer was used for all determinations.)

4. Calculate mg % P using standard curve for phosphorus established as described below.

STANDARDIZATION

1. Prepare a stock solution, 30 mg % P by dissolving 131.6 mg KH_2PO_4 in 100 ml distilled water.

2. Prepare working solutions by diluting stock 1/100 and 2/100 in 11.5% TCA.

3. Transfer 3.0 ml of each standard to a cuvette. For blank determination substitute 11.5% TCA.

4. Add 2.0 ml of ferrous sulfate-molybdate reagent and read absorbance at 660 nm after 1 min. but within 2 hours.

REFERENCE

1. Taussky, H. H., and Shorr, E., J. Biol. Chem., 202, 675-685 (1953).

APPENDIX C

TEST DATA

Urobilinogen Levels in Urine Samples Before and After Introduction into the UMS.

Run No.	Wt. of Urine (g)	Urobilinogen (Ehrlich Units/100 ml) Original	Sample	Dump
258	49.9	.70	.51	.49
266	50.3	.37	.27	.28
267	49.5	.56	.42	.30
253	99.5	1.10	.80	.91
254	100.2	.63	.50	.55
255	99.1	.36	.36	.39
251	197.5	.58	.52	.54
256	198.3	.55	.55	.54
263	193.3	.36	.35	.34
264	201.0	.81	.70	.66
260	403.0	.35	.32	.33
261	400.2	.42	.40	.39
265	400.6	.50	.41	.46

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Phosphorus Levels in Urine Samples Before and After Introduction in the UMS

Run No.	Wt. of Urine (g)	Phosphorus (mg %) Original	Sample	Dump
258	49.9	150.4	112.6	104.9
266	50.3	70.4	52.6	47.6
267	49.5	44.3	34.4	31.6
253	99.5	75.9	65.0	69.4
254	100.2	34.8	33.8	31.8
255	99.1	32.0	29.1	26.7
251	197.5	65.4	61.3	63.2
256	198.3			
263	193.3	63.0	58.9	58.3
264	201.0	48.4	43.1	41.1
260	403.0	46.4	43.7	42.1
261	400.2	59.9	52.8	55.7
265	400.6	99.8	93.5	99.6

LICL CONCENTRATIONS IN OUTPUTS AND SIMULATED FLUSHES FOLLOWING INPUT OF 100 PPM LICL UNDER VARIOUS SETS OF CONDITIONS.

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SET OF CONDITIONS #2

	Run	Wt. In.	In - Out Diff.	LiCl PPM Out	Residual Volume	Estim. Dilution
LiCl	105	100.0	0.7	93		7.5
	106	100.0	0.3	105		
	107	100.0	0.4	102		
H_2O	108	50.0	-	21	10.3	
	109	50.0	0.5	4		
	110	50.0	0.6	1		
LiCl	111	100.0	0.5	93		7.5
	112	100.0	0.3	102		
	113	100.0	0.1	102		
H_2O	114	50.0	0.5	21	10.3	
	115	50.0	0.4	4		
	116	50.0	0.6	2		
LiCl	117	100.0	0.4	94		6.4
	118	100.0	0.5	97		
	119	100.0	0.4	102		
H_2O	120	50.0	0.1	21	10.3	
	121	50.0	0.4	4		
	122	50.0	0.4	2		

• No Blower • No Flush Water (cond. 2)

(Collected during flush cycle)

SET OF CONDITIONS #4

	Run	Wt. In.	In - Out Diff.	LiCl PPM Out	Residual Volume	Estim. Dilution
LiCl (100 ppm)	123	400.0	2.9	---	9.5 ± 0.3	
	124	400.0	2.7	93		
	125	400.0	2.8	98		
H_2O	126	50.0	1.7	18	9.2	
	127	50.0	2.2	3		
	128	50.0	2.7	< 1		
LiCl	135*	400.0	3.3	91		39.6
	136	400.0	10.0**	95		
	137	400.0	4.2	93		
H_2O	138	50.0	1.9	18	9.6	
	139	50.0	2.4	3		
	140	50.0	2.1	<1		
LiCl	141	400.0	3.6	94		25.5
	142	400.0	3.2	93		
	143	400.0	2.9	96		
H_2O	144	50.0	1.9	18	9.2	
	145	50.0	2.7	3		
	146	50.0	2.6	<1		
	Flushed 2X with 300 ml H_2O					
LiCl	147	400.0	3.5	98		8.2
	148	400.0	2.9	98		
	149	400.0	2.9	100		
H_2O	150	50.0	2.3	20	10.0	
	151	50.0	2.8	3		
	152	50.0	2.8	1		

* Followed same output as 128.

** DC power supply turned off by someone.

- Blower 4 min.
- No Flush Water.

(cond. 4)

(Collected before flush cycle)

SET OF CONDITIONS #4

	Run	Wt. In.	In - Out Diff.	LiCl PPM Out	Residual Volume	Estim. Dilution
	2 H_2O Flushes					
LiCl	153	50.0	2.9	88		6.8
	154	50.0	3.1	103		
	155	50.0	2.4	105		
H_2O	156	50.0	2.9	19	9.2	
	157	50.0	3.0	2		
	158	50.0	2.5	< 1		
LiCl	159	50.0	2.9	90		5.5
	160	50.0	3.3	106		
	161	50.0	3.0	110		
H_2O	162	50.0	2.7	19	8.6	
	163	50.0	2.9	2		
	164	50.0	2.8	1		
LiCl	165	50.0	3.3	90		5.5
	166	50.0	1.8	105		
	167	50.0	2.7	105		
H_2O	168	50.0	2.8	19	9.2	
	169	50.0	2.7	3		
	170	50.0	2.9	1		
					$9.0 \pm .3$	

- Blower 4 min.
- No Flush Water (cond. 4)

(Collected during flush cycle)

SET OF CONDITIONS #4

	Run	Wt. In.	In - Out Diff.	LiCl PPM Out	Residual Volume	Estim. Dilution
Flush 2X H_2O						
LiCl	171	100.0	2.0	96		4.2
	172	100.0	2.3	101		
	173	100.0	2.4	101		
H_2O	174	50.0	2.1	20	9.9	
	175	50.0	2.2	3		
	176	50.0	2.3	1		
LiCl	177	100.0	2.5	95		5.3
	178	100.0	2.1	104		
	179	100.0	2.5	107		
H_2O	180	50.0	2.0	21	9.8	
	181	50.0	2.2	3		
	182	50.0	2.4	< 1		
LiCl	183	100.0	2.5	93		7.5
	184	100.0	2.8	101		
	185	100.0	2.2	104		
H_2O	186	50.0	2.3	20	9.6	
	187	50.0	2.0	3		
	188	50.0	2.2	1		
					9.8 ± 0.2	

- Blower 4 min.
- No Flush Water

(cond. 4)

SET OF CONDITIONS #5

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	Run	Wt. In.	In - Out Diff.	LiCl PPM Out	Residual Volume	Estim. Dilution
Flushed 2X						
LiCl	189	50.0	5.9	67		24.6
	190	50.0	-	70		
	191	50.0	6.8	72		
H_2O	192	50.0	6.7	2		
	193	50.0	6.6	0.3		
	194	50.0	6.3	0.02		
LiCl	196	50.0	6.2	72		19.4
	197	50.0	6.9	71		
	198	50.0	6.9	70		
H_2O	199	50.0	7.0	1		
	200	50.0	7.7	0.3		
	201	50.0	7.4	0.2		
LiCl	202	50.0	5.7	72		19.4
	203	50.0	7.2	69		
	204	50.0	6.6	69		
H_2O	205	50.0	6.5	2		
	206	50.0	-	0.3		
	207	50.0	6.3	0.1		

- Blower 4 min.
- Flush connected. (cond. 5)

(Collected only during dump cycle)

SET OF CONDITIONS #5

	Run	Wt. In.	In - Out Diff.	LiCl PPM Out	Residual Volume	Estim. Dilution
LiCl	208	100.0	6.3	85		17.6
	209	100.0	7.5	85		
	210	100.0	7.0	88		
#2 Flush	210a	(51.9 out)		7		
H_2O	211	50.0	6.3	2		
	212	50.0	6.9	0.2		
	213	50.0	-	0		
LiCl	214	100.0	6.7	84		19.0
	215	100.0	6.7	88		
	216	100.0	6.6	82		
#2 Flush	216a	(52.2 out)		7		
H_2O	217	50.0	6.7	2		
	218	50.0	6.7	0.2		
	219	50.0	6.9	0.2		
LiCl	220	100.0	6.7	90		11.1
	221	100.0	6.7	87		
	222	100.0	6.3	87		
#2 Flush	222a	(52.3 out)		7		
H_2O	223	50.0	6.1	2		
	224	50.0	7.2	0.3		
	225	50.0	6.8	0.3		

- Blower 4 min.
- Flush Connected (cond. 5)

(Collected only during dump cycle)

SET OF CONDITIONS #5

	Run	Wt. In.	In - Out Diff.	LiCl PPM Out	Residual Volume	Estim. Dilution
LiCl	226	400.0	7.8	93		30.1
	227	400.0	6.4	92		
	228	400.0	7.5	94		
H_2O	229	50.0	6.3	2		
	230	50.0	6.9	(0.3)		
	231	50.0	6.9	0		
LiCl	232	400.0	6.9	92		34.8
	233	400.0	6.2	93		
	234	400.0	6.8	92		
H_2O	235	50.0	6.0	2		
	236	50.0	7.5	(0.3)		
	237	50.0	7.0	(0.1)		
LiCl	238	400.0	7.8	95		21.0
	239	400.0	6.7	96		
	240	400.0	7.6	96		
H_2O	241	50.0	6.6	2		
	242	50.0	6.8	(0.7)		
	243	50.0	7.6	0		

• Blower 4 min. • Flush Connected (cond. 5)

(Collected during dump cycle)

SET OF CONDITIONS #4

	Run	Wt. In.	In - Out Diff.	LiCl PPM Out	Residual Volume	Estim. Dilution
LiCl	344	100.0	1.8	88		(13.6*)
	345	100.0	2.7	100		
	346	100.0	2.5	103		
H_2O	347	100.0	3.0	10	9.7	
	348	100.0	3.0	2		
	349	100.0	2.7	-		
LiCl	350	100.0	2.8	} 102		
	351	100.0	2.6			
	352	100.0	2.6	103		
H_2O	353	100.0	2.9	11	10.7	
	354	100.0	2.9	2		
	355	100.0	2.9	1		
LiCl	356	100.0	3.0	90		11.1
	357	100.0	—	97		
	358	100.0	3.1	- (103)		
H_2O	359	100.0	2.9	11	10.7	
	360	100.0	3.0	1		
	361	100.0	3.1	1		
			2.8 ± 0.3			

$$* \frac{(\text{conc. LiCl put in X vol. LiCl put in}) - (\text{conc. LiCl out x vol. LiCl out})}{\text{conc. LiCl out}}$$

- Blower on 4 min.
  (Collected during flush cycle)
- No flush water.

(Cond. 4)

SET OF CONDITIONS #4 MODIFIED

	Run	Wt. In.	In - Out Diff.	LiCl PPM Out	Residual Volume	Estim. Dilution
LiCl	362	100.0	15.4			
	363	100.0	15.3			
	364	100.0	-	101		
	365	100.0	14.3	103		
H_2O	366	100.0	—	11	10.7	
					10.4 ± 0.4	

- Blower on 4 min.
- No flush water

Collected only during dump, but still ran unit through flush period.