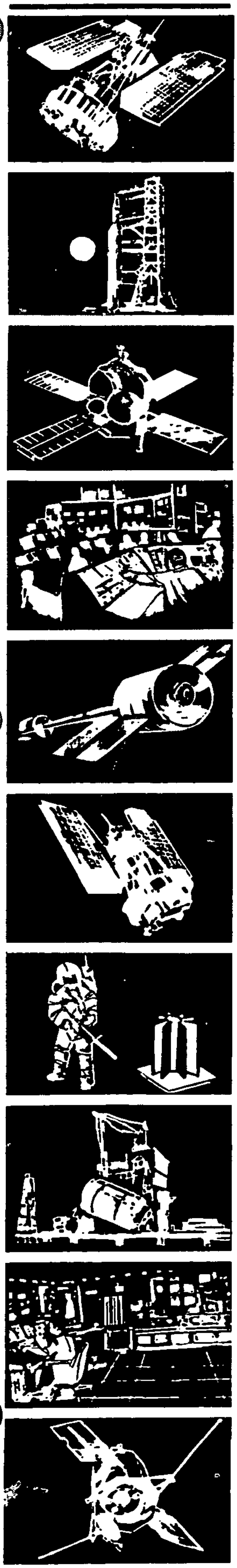
SPACE DIVISION



GE NO. 70SD5414

IMBLMS
PHASE B4

ADDITIONAL TASKS
TASK 1.0

Urine Sampling And Collection System

FINAL REPORT

(SECTION 7.0)

Contract NAS 9-10741
Phase B4

GENERAL ELECTRIC

GE No. 70SD5414
November 1971

FINAL REPORT

ON

TASK 1

URINE SAMPLING AND COLLECTION SYSTEM

(SECTION 7.0)

CONTRACT NAS9-10741

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7.0 APPENDIX

7.1 Engineering Model Requirements Specification

URINE SAMPLING & COLLECTION SYSTEM
ENGINEERING MODEL

REQUIREMENTS SPECIFICATION

1.0 SCOPE

This specification defines the performance and design requirements for the Urine Sampling and Collection System Engineering Model and establishes requirements for its design, development and test. All contract end items of the subsystem shall conform to the requirements stated herein.

1.1 Purpose

The purpose of the Urine Sampling and Collection System Engineering Model shall be to provide conceptual verification of a system applicable to manned space flight which will automatically provide for collection, volume sensing and sampling of urine.

1.2 Definitions

For the purposes of this document, the following definitions and abbreviations shall apply:

N/A

2.0 APPLICABLE DOCUMENTS

Supplemental Phase B-4 Additional Tasks, Statement of Work, Exhibit B, Contract NAS 9-10741 dated 30 April 1971, Task 1.0, Urine Sampling and Collection.

3.0 REQUIREMENTS

3.1 Performance

3.1.1 Functional Requirements

3.1.1.1 Primary Performance Requirements

3.1.1.1.1 Measurement Requirements

The Urine Sampling and Collection System shall measure the quantity of urine voided by a human subject and acquire a proportional and representative sample of the voided urine. Specifically, the model shall:

(a) Measure the volume of each urination within an accuracy of $\pm 2\%$.

(b) Provide for obtaining a gas free sample of each urination which is representative of the total urination. The volume of the sample shall be a nominal 20% of the total urination.

(c) Provide a sample container of sufficient size to collect a total sample representative of a 24-hour period (assume five urinations per man-day; four 350 ml urinations every four hours and one urination of 600 ml after eight hours sleep).

(d) Provide for sampling urinations from 50 ml minimum to 800 ml maximum. Urinations below 50 ml shall not be sampled.

3.1.1.1.2 Collection Requirements

The Urine Sampling and Collection System Engineering Model shall collect and retain all urine and associated odors. Specifically, the model shall:

(a) Provide for collection of urination volumes up to 800 ml maximum.

(b) Provide for collection of urinations at urination rates up to 45 ml/second maximum

(c) Provide for removal of the urine remaining after sampling.

3.1.1.1.3 Equipment Requirements

The Urine Sampling and Collection System Engineering Model shall conform to the functional block diagram of Figure 3.1.1.1-1.

3.1.1.1.3.1 Displays

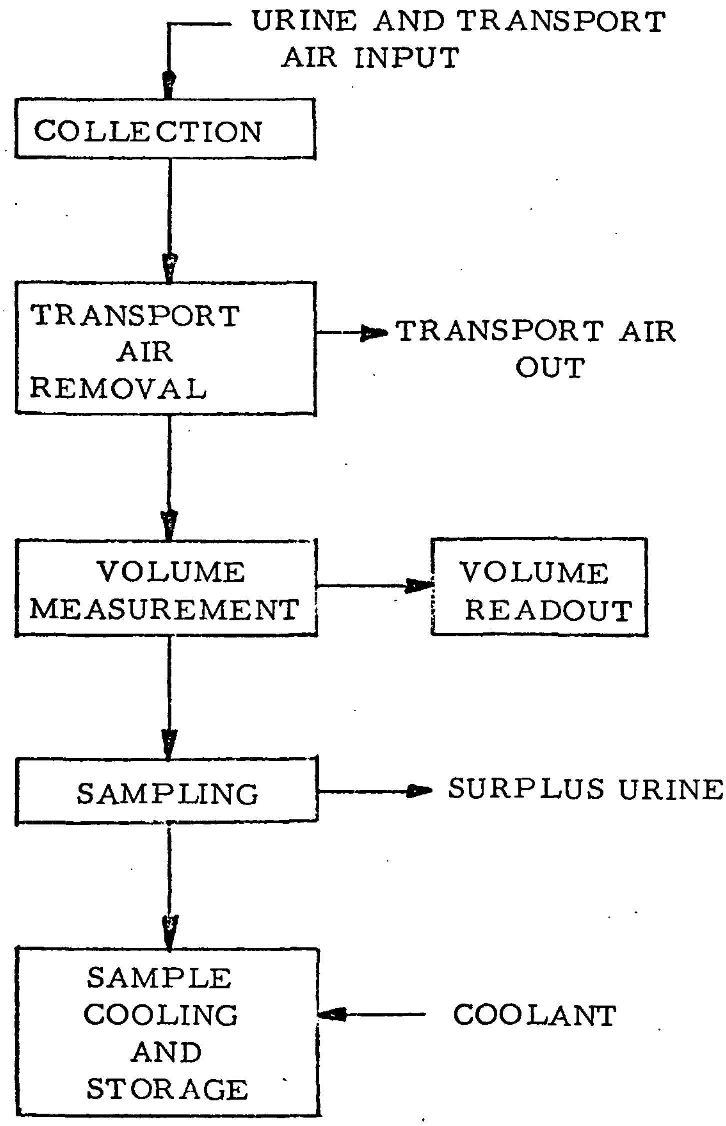


FIGURE 3.1.1.1-1. URINE SAMPLING AND COLLECTION SYSTEM ENGINEERING MODEL FUNCTIONAL BLOCK DIAGRAM

3.1.1.1.3.1.1 Urine Volume

The Model shall provide a visual readout of total urine volume per urination.

3.1.1.1.3.1.2 Operational Status

The Model shall provide a visual indication of key operational conditions.

3.1.1.1.3.2 Power Conditioning

The Model shall be designed to operate on 28 VDC unregulated power (assume input voltage range of 24 to 28 VDC).

3.1.1.1.3.3 Gravity Field Operation

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

3.1.1.1.3.4 Configuration

The Model shall be configured to provide both a functional and attractive appearance representative of a possible flight configuration. The Model shall not be optimized for minimum size, weight and power input.

3.1.1.1.3.5 Operation

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

(b) Micturition preparation time shall not exceed 30 seconds.

(c) Availability of total urine volume data (after micturition) shall not exceed 60 seconds per 100 ml of urine voided.

(d) Control elements shall be easily accessible and be positive acting.

3.1.1.1.3.6 Maintenance

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

3.1.1.1.3.7 Contamination

The Model shall be designed to minimize degradation of urine constituents due to contamination from previous urinations.

3.1.1.1.3.8 Future Growth

The Model shall consider and be designed to be compatible, in subsequent program phases, with the addition of other system features such as multiple man use, sample return, system flush, data print-out, telemetry interface, 24-hour timer, and separate container for collection of below minimum size urinations.

3.1.1.2 Secondary Performance Requirements

The Urine Sampling and Collection System Engineering Model shall conform to the block diagram of Figure 3.1.12-1, and operating phases of Figure 3.1.1.2-2.

3.1.1.2.1 Size

The Engineering Model shall be configured to fit within an envelope of 20 inches high, 8 inches wide and 14 inches deep.

3.1.1.2.2 Weight

The Engineering Model shall not be weight constrained.

3.1.1.2.3 Component Description

3.1.1.2.3.1 Urinal Assembly

The urinal assembly serve as the urine collection agency for the overall system. Specific design requirements are as follows:

(a) The urinal shall be an open funnel type design with an entrance opening approximately 2.0 inches in diameter (or a 2.0 inch square).

(b) The urinal shall not use a honeycomb (or equal) insert.

(c) The urinal shall be easily held by one hand

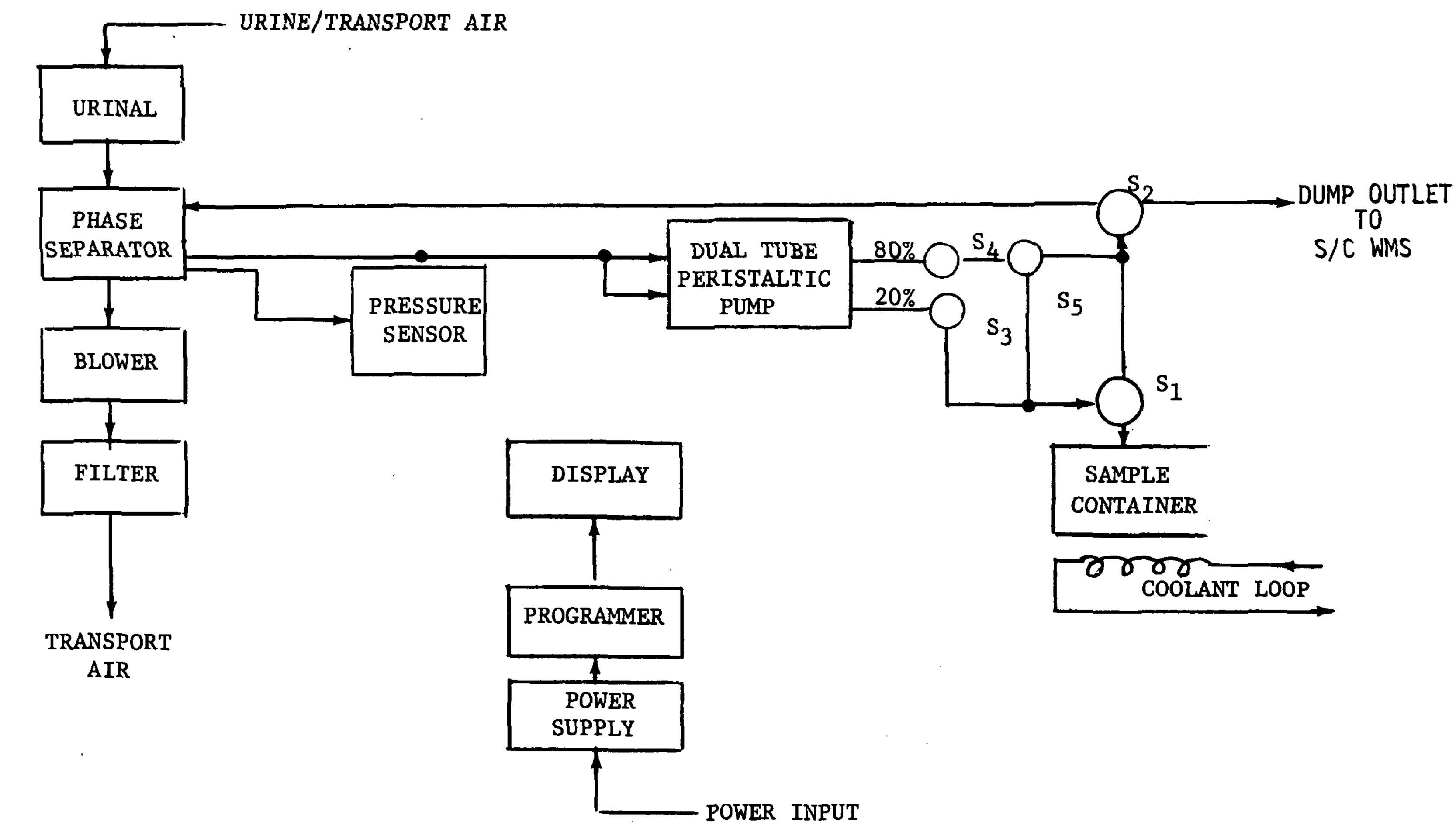
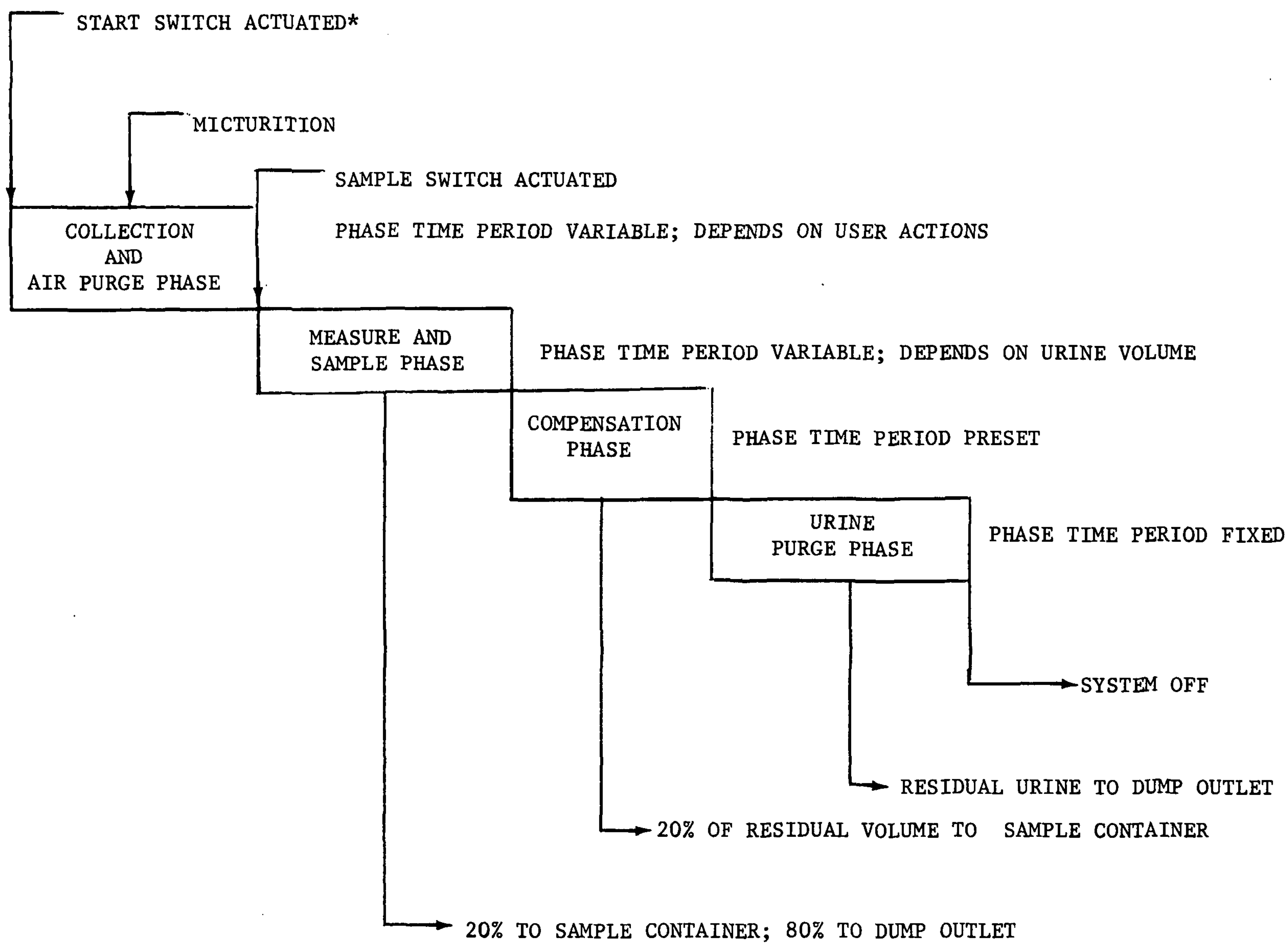


FIGURE 3.1.1.2-1 URINE SAMPLING AND COLLECTION SYSTEM - BLOCK DIAGRAM



*POWER SWITCH IN "ON" POSITION

FIGURE 3.1.1.2-2 URINE SAMPLING AND COLLECTION SYSTEM OPERATING PHASES

(d) The urinal shall be configured to minimize contamination.

(e) The urinal shall be connected to the phase separator by a non-metallic flexible line (0.375 ID).

3.1.1.2.3.2 Phase Separator Assembly

The function of the phase separator is to separate the urine from the transport air flow, mix the urine to ensure a homogenous sample and to temporarily store the urine prior to sampling. Specific design requirements are as follows:

(a) Positive dynamic phase separation shall be used with general features as shown on GE Drawings 201R812 and SK56197-544.

(b) The selected motor shall be capable of driving the impellor at a constant 400 rpm ($\pm$ 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 800 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 2 CFM transport air flow, an entering urine flow of 45 ml/second maximum and an exit urine flow of 1.25 ml/second.

(f) The impellor shall have eight vanes.

(g) Voltage input to the motor (and associated rpm controller) shall be 28 volts dc.

(h) All metallic materials in direct contact with urine shall be stainless steel, preferably type 316, coated with a baked-on layer of Teflon.

3.1.1.2.3.3 Blower Assembly

The blower assembly shall provide the transport air flow into the urinal, thru the phase separator and out thru the filter assembly. Specific design requirements are as follows:

(a) The assembly shall be capable of providing a 2 CFM transport air flow at 9 inches of water pressure head.

3.1.1.2.3.4 Filter Assembly

The function of the filter assembly is to trap airborne aerosol, bacteria and odor prior to the return of the transport air to ambient. Specific design requirements are as follows:

(a) The bacteria medium shall mechanically remove all particles 0.08 microns in size and larger.

(b) The bacteria filter medium shall be Petrosorb Ultipor .9.

(c) Activated charcoal pellets shall be located on the downstream side of the bacteria filter medium.

(d) The assembly shall be configured for replacement of the filter medium and activated charcoal pellets.

(e) Pressure drop thru the filter assembly at 2 CFM shall be less than 5 inches of water.

(f) The bacteria filter medium and charcoal pellets shall be combined into one assembly.

3.1.1.2.3.5 Peristalic Pump/Accumulator Assembly

The peristalic pump/accumulator assembly is used as the urine volume measuring device. The assembly is also used to automatically split the measured volume into two parts, a retained sample which is collected in the sample container and the remainder which is directed to a downstream waste management or water recovery system (not part of the Urine Sampling and Collection System). The assembly consists of three elements, i.e. a dual chamber accumulator, and a dual tube peristalic pump and control valves. Specific requirements are as follows:

(a) The accumulator shall be sized for a total of 25 ml per stroke (20 ml for the larger chamber and 5 ml for the small chamber).

(b) The accumulator shall incorporate a spring return capability with a nominal force equivalent to 2 psi pressure at the exit ports at the end of the discharge cycle.

(c) The accumulator shall provide integral limit switches (for operating control valves and pump motor) to control accumulator fill and discharge cycles.

(d) The accumulator shall incorporate a displacement transducer. A voltage pulse shall be generated for at least each 0.5 ml of accumulator volume for a minimum total of 50 pulses per accumulator stroke.

(e) The peristalic pump shall incorporate two tubes driven by a single 28 VDC motor.

(f) Peristalic pump operating speed shall be a nominal 150 rpm.

(g) The pump tubes shall be sized for a nominal flow ratio of 77/23, the large and small tubes connected to the corresponding accumulator chambers.

(h) The pump tubes shall be replaceable without disassembly of other major system components.

(i) The pump shall provide a nominal flow of 1.2 ml per pump revolution.

(j) Control valves shall be NC solenoid types operable on 28 VDC.

3.1.1.2.3.6 Sample Container Assembly

The sample container assembly consists of a replaceable container and a cold plate arrangement for cooling the collected urine. Specific requirements are as follows:

(a) The replaceable sample container shall be sized to accept a 400 ml urine sample (maximum for a 24-hour operating period per man).

(b) The sample container shall be designed for evacuation of residual air prior to use.

(c) The filled sample container shall be capable of normal handling without leakage.

(d) The sample container shall be configured to be compatible with a cold plate for cooling the collected urine.

(e) A rubber septum/needle arrangement shall be used for connecting the sample container void volume into the system.

(f) Cold plate heat removal shall be accomplished using coolant from an external source.

(g) Collected urine shall be cooled to and held at $5 \pm 4^{\circ}C$.

(h) Coolant shall be supplied continuously (from an external source); an active temperature control shall not be used.

(i) Cold plate pressure applied to the sample container shall not exceed 1 psi equivalent back-pressure.

3.1.1.2.3.7 Pressure Sensor

The output of the pressure sensor is used to enable start and termination of the system Measure and Sample phase. Specific design requirement are as follows:

(a) Pressure sensing range shall be 0 to 2.77 inches of water (0.1 psi).

(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) Excitation voltage shall be 6 volts; power input less than 1 watt.

(e) Performance shall not be degraded by long-term exposure to urine and sustained pressure excursions to 20 inches of water.

(f) Temperature compensation shall be provided if required.

(g) Output voltage shall be approximately 0.5 volts at 1.0 psi.

3.1.1.2.3.8 Programmer Assembly

The programmer assembly shall provide the necessary functions for automatic operation as well as the counting and scaling circuitry necessary for proper presentation to the volume display assembly.

Upon activation of the SAMPLE switch, the programmer shall count each pulse obtained from the displacement transducer of the Peristalic Pump/Accumulator Assembly. The counts thus obtained shall be weighted using a multiplying 12 bit D/A converter for the volume obtained from each pulse of the displacement transducer. The output of the D/A converter (each weighted count) shall be displayed on the volume display assembly. Specific design requirements shall be as follows:

(a) The programmer assembly shall provide completely automatic operation after the SAMPLE switch is activated. After the urine purge phase, the programmer will allow the system to be reset for the next sample . Prior to the completion of the urine purge phase, it will not be possible to reset the programmer.

(b) All switch closure inputs to the programmer assembly shall be buffered by digital switching to eliminate contact bounce.

(c) The input counter shall be capable of accepting at least 3,000 counts. Its output shall be 12 binary lines for driving the D/A converter.

(d) The D/A converter shall be 12 bit and designed for a programmed reference voltage. Its output shall be compatible with the volume display assembly.

(e) A reference supply shall be provided with the capability of supplying 0.1% regulated reference voltages at 20 ma. It shall be adjustable from 1.5 to 2.0 volts.

(f) A pressure comparator circuit shall be provided which accepts the input from the pressure transducer and provides a 5 volt output whenever a minimum adjustable pressure level is exceeded.

(g) The programmer assembly shall derive its input power from the power supply assembly.

3.1.1.2.3.9 Volume Display Assembly

The function of the volume display assembly is to visually display urine volume on an accumulating basis and retain the final value until reset. This shall be accomplished by at least a 3 digit panel meter capable of displaying at least 999 ml and associated circuitry. Specific requirements are as follows:

(a) The Input Range shall be at least 999 MV full scale.

(b) The accuracy of the reading shall be better than 0.05% of the actual reading $\pm$ one weighted count at a $25^{\circ}C$ operating temperature.

(c) The conversion time for a complete conversion shall be typically 8 MS.

(d) The volume display assembly shall operate from 115V A.C. at 400 Hz and shall consume less than 6 watts.

(e) The volume display assembly shall not be damaged by $\pm$ 10V applied to its inputs.

(f) The volume display assembly shall be capable of operating from $0^{\circ}C$ to $60^{\circ}C$.

(g) The volume display assembly shall be reset by actuation of the START switch.

3.1.1.2.3.10 Power Supply Assembly

The power supply assembly shall provide the following AC and DC voltages from a nominal 28 VDC input:

Voltage	Frequency	Power
115 volts	400 Hz	5 watts
26 volts	400 Hz	10 watts
± 5 volts	DC	5 watts
± 15 volts	DC	5 watts

Specific design requirements are listed in the following sections:

3.1.1.2.3.10.1 ±5 VDC Power Supply

(a) The input to the +5 VDC power supply shall be 26 ±2 VDC.

(b) The output of the +5 VDC power supply shall be +5 VDC ± 1% at 1 amp.

(c) The regulation of the +5 VDC power supply shall be .1% line or load.

(d) The ripple contained in the +5 VDC power supply shall be less than 1 mv.

(e) The output of the +5 VDC power supply shall be capable of withstanding a short circuit to ground indefinitely at 25°C.

(f) The +5 VDC power supply shall be capable of operating from 0 to 60°C with no more than a ± 3% change in output voltage.

3.1.1.2.3.10.2 ± 15 VDC Power Supply

(a) The input to the ± 15 VDC power supply shall be 26 ± 2 VDC.

(b) The output of the ± 15 VDC power supply shall be ± 15 VDC ± 1% at 150 ma.

(c) The regulation of the ± 15 VDC power supply shall be .01% line or load.

(d) The ripple contained in the ± 15 VDC power supply output shall be less than 1 mv.

(e) The output of the ± 15 VDC power supply shall be capable of withstanding a short circuit to ground indefinitely at 25°C.

(f) The ± 15 VDC power supply shall be capable of operating from 0 to 60°C with no more than a ± 3% change in output.

3.1.1.2.3.10.3 DC to AC Inverter

(a) The input to the DC-AC Inverter shall be 24-28 VDC.

(b) The output of the DC-AC Inverter shall be 120 VAC at 400 Hz, and 26 volts VAC at 400 Hz.

(c) The output voltage line and load regulation shall be better than $\pm$ 1%. The frequency regulation shall be better than $\pm$ 0.15% for line and load. The frequency temperature coefficient shall be 0.01%/^{o}C typically.

(d) The efficiency of the DC-AC Inverter shall not be less than 75%.

(e) The operating temperature of the DC-AC Inverter shall be 0 to 60^{o}C.

3.1.1.2.3.11 Structure Assembly

A structure assembly shall be provided for mounting and supporting the Engineering Model equipments. Specific design requirements shall be as follows:

(a) The structure assembly with other system equipments installed, shall conform to the overall envelope dimensions of 3.1.1.2.1.

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

(c) The urinal, volume display, control switches and status indicators shall be generally top mounted (8 x 14 inch envelope surface); urine sample container access for replacement thru a front panel (8 x 20 inch envelope surface) or open side (14 x 20 inch envelope surface); either or both sides may be substantially open to facilitate normal maintenance.

(d) The structure shall accommodate positioning of the urinal (and its connecting hose) up to 20 inches from the upper surface of the structure.

(e) The structure assembly shall be designed to withstand normal laboratory use.

3.1.1.2.3.12 Test Points

The Engineering Model shall include a test panel (or equal) for acquisition of data during checkout after final assembly. Provision for collecting the following data during system operation are specifically required as follows:

(a) Pressure sensor output.

(b) Phase separator motor power input

(c) Peristalic pump head switch closures

(d) Start/stop signals at each system operating phase.

3.1.1.2.4 System Operation

The Engineering Model equipment operating sequence shall be as follows (reference Figures 3.1.1.2-1 and 2):

3.1.1.2.4.1 Power ON

(a) Power ON switch actuated by user.

(b) 28 VDC externally supplied power applied to electronics

(c) Warm-up time delay completed, if required by electronics

(d) Power applied indicator light actuated (after warm-up delay).

3.1.1.2.4.2 Collection and Air Purge Phase

(e) START switch actuated by user.

(f) Power applied to blower, phase separator and pump by programmer.

(g) Valves S_1, S_2 and S_5 set in recirculate position (desirably this should be the power-off position of the valves); valves S_3 and S_4 open (accumulator does not fill during this phase).

(h) Urinal removed by user.

(i) Micturition by user.

(j) Phase separation, i.e. removal of transport air, occurs concurrently with micturition.

(k) At completion of micturition, user replaces urinal.

3.1.1.2.4.3 Measure and Sample Phase

(l) SAMPLE switch actuated by user.

(m) Blower deactivated.

(n) If micturition volume less than 50 ml as determined by the pressure sensor output, proceed directly to Urine Purge Phase. If greater than 50 ml, proceed with measure and sample and compensation phases.

(o) Valve S_2 repositioned to direct flow from 80% accumulator chamber to outlet dump.

(p) Valve S_1 repositioned to direct flow from 20% accumulator chamber to sample container.

(q) Valves S_3 and S_4 closed, permitting accumulator to fill.

(r) When the accumulator is completely filled, the pump is automatically stopped and valves S_3 and S_4 opened permitting the accumulator to discharge.

(s) As accumulator discharges, pulses from displacement transducer are accumulated, scaled and displaced on the volume meter.

(t) At the conclusion of discharge, the valves S_3 and S_4 are closed and the pump started to refill the accumulator.

(u) Alternate filling and discharge of the accumulator continues until the urine volume in the phase separator is reduced to the nominal 50 ml cut-off value as determined by the pressure sensor. At the 50 ml cut-off point, the pump is stopped and valves S_3 and S_4 opened to discharge the partially filled accumulator.

3.1.1.2.4.4 <u>Compensation Phase</u>

(v) After the Measure and Sample Phase is terminated at to 50 ml cut-off volume, valve S_5 is repositioned to direct flow from the 80% accumulator chamber into the sample container via valve S_1.

(w) Valves S_3 and S_4 closed and pump started.

(x) When the accumulator is filled, the pump is stopped and valves S_3 and S_4 opened to discharge a preset residual compensation volume of urine (about 10 ml) into the sample container. The volume as measured by the displacement transducer is added so that the volume meter reads the total of the measure and sample and compensation phases.

3.1.1.2.4.5 <u>Urine Purge Phase</u>

(y) At completion of the compensation phase, valves S_1 and S_5 positioned to direct the remaining accumulator flow to dump outlet via valve S_2.

(z) Valves S_3 and S_4 closed, pump started, etc. to continue accumulator operation.

(aa) After delay period (adjustable) completed, system shut-off and ready for next user.

3.1.2 Operability

3.1.2.1 Reliability

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

3.1.2.2 Maintainability

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

3.1.2.3 Useful Life

The Engineering Model shall be designed for a minimum useful laboratory life, with maintenance, of 12 months.

3.1.2.4 Operating Environment

The Engineering 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 Engineering Model.

3.1.2.6 Safety

3.1.2.6.1 User Safety

The Engineering 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 gounded to the structure with provisions on the structure for connecting to an external ground provided.

3.1.2.6.2 Equipment Safety

The Engineering 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 Hydro John

The Engineering Model shall be capable of interfacing with the General Electric Hydro John engineering prototype.

3.2.2 Electrical

The Engineering Model shall operate on nominal 28 VDC power from an external source. Connection to the model shall be via Bendix pygmy type connector.

3.2.3 Mechanical

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

3.2.4 Thermal

Coolant for control urine sample container temperature shall be supplied from an external source. Specifically, Coolanol-15 at 130 lbs/hour; $36 \pm 3^{\circ}F$ input temperature, an allowable pressure drop of 0.1 psi; and a maximum heat transfer rate of 100 BTU/hour.

3.2.5 User

The Engineering Model shall be designed for use by male subjects in a standing position only.

7.2 PERISTALTIC PUMP TEST PROGRAM

As one of two specific test efforts, the contract work statement required peristaltic pump tests as follows:

> "Perform tests of 6 to 8 weeks duration to determine the pumping volume predictability of the following pump configurations:
>
> (1) Standard configuration, i.e., tubes "loaded" at all times;
>
> (2) Modified configuration, i.e., tubes "unloaded" between each pumping cycle. The configuration exhibiting the best predictability shall be used in the engineering model."

Results of the test program had the following implications on the overall system design:

1. Long term drop in pumping capacity of the peristaltic pump can require in-flight recalibration at an estimated 4-5 day interval (for system use by 3 man crew). Note that some in-flight calibration checks should be planned. However, elimination of known excessive "drift" in a measuring device is considered desirable.

2. Variations in operating inlet and exit pressures and peristaltic pump speed also will cause short term changes (up or down) in pumping capacity. Pump exit pressure and speed can be easily held at relatively constant values. Inlet pressure, however, depends on the size of the individual micturitions (50 to 800 ml) and thus the inlet pressure can vary from a few inches of water to about 0.4 psig. Pumping capacity increase (based on the test program results) will be about $\pm$ 2 percent at maximum loading of the phase separator, decreasing linearily as the fluid volume in the phase separator is reduced. Thus if the system is calibrated for a 400 ml volume, the error introduced by variations in inlet pressure can be reduced to an estimated maximum of about $\pm$ 1 percent. (This assumes that incremental stretching of the pump tubes is also linear with increasing inlet pressure). This error can be further reduced by decreasing phase separator speed (and thus inlet pressure to the peristaltic pump) as the urine volume increases. Note that the GE USVMS

breadboard nominally provided this feature by not controlling phase separator speed. For the Engineering Model design, deactivation of the phase separator speed control circuits when the urine volume exceeds some preset value (100 ml for example) would provide the equivalent. Note that reducing phase separator speed will result in lower peak power as compared to a constant speed phase separator.

Test program details and results analyses are included in GE PIR's 1R62-71-123, 1R62-71-124 and 1R62-71-144 (Attached).

In summary, the dual tube peristaltic pump can satisfy the system requirements, albeit perhaps marginally, if periodic in-flight recalibration is acceptable. However, because of the potential problems and thus technical risk associated with the dual tube peristaltic pump, a precision accumulator was added. Tests on the pump/accumulator combination are documented in Appendix 7.3.

GENERAL ELECTRIC
SPACE DIVISION
PHILADELPHIA

PROGRAM INFORMATION REQUEST / RELEASE

PIR NO.	*CLASS. LTR.	OPERATION	PROGRAM	SEQUENCE NO.	REV. LTR.
	U	1R62	71	123	

*USE "C" FOR CLASSIFIED AND "U" FOR UNCLASSIFIED

FROM	TO
G. L. Fogal Room M4214 VF	File

DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
7/16/71		Urine Sampling and Collection System	

SUBJECT

PERISTALTIC PUMP TEST RESULTS - INTERIM REPORT

INFORMATION REQUESTED/RELEASED

This interim report summarizes the results of tests on a Holter peristaltic pump as outlined in Section 4.1, Peristaltic Pump Test Plan, PIR U-1R62-71-109.

1.0 SUMMARY

Analysis of the test data shows a definite change in pumping capacity before and after a 71 hour (over 426,000 pump revolutions) endurance run. A drop in output of about 5% occurred for the large tubes and correspondingly about 14% for the small tubes. This change in performance was unexpected based on Holter experience and GE experience with this type pump on the Biosatellite program.

2.0 DISCUSSION

2.1 Background

The commercial Holter pump used for this series of tests is a reasonable but not exact representation of the peristaltic pump planned for the Urine Sampling and Collection system engineering model. The differences are as follows:

a. Six pumping tubes are used, 3 large and 3 small, in place of one each, in order to accumulate more data.

b. The pumping tubes output ratio (large to small) is approximately 8 to 1 instead of 4 to 1 (the small tube diameter will be increased for the engineering model).

c. Pump speed is limited to 100 rpm as compared to the desired 150 rpm.

d. The individual pump tubes are not as rigidly secured to the pump housing as planned for the engineering model.

Because of these differences, the intent of this series of tests was largely exploratory, i.e. to check out the general test procedure and to provide quick look results as to whether or not a pump problem may exist.

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C. Reinhardt

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✓ RETENTION REQUIREMENTS

COPIES FOR	MASTERS FOR
☐ 1 MO.	☐ 3 MOS.
☐ 3 MOS.	☐ 6 MOS.
☐ 6 MOS.	☐ 12 MOS.
☐ MOS.	☐ MOS.
☐	☐ DO NOT DESTROY

2.2 Pump Description

A Holter Company model MC721 peristaltic pump, purchased in December, 1970 using GE funds, was used for this series of tests. This pump is described by Holter data sheets, see Appendix A. Three large silastic pump tubes and three small silastic pump tubes were tested simultaneously. Tube dimensions are shown in Figure 1 and provide a pumping ratio of about 8 to 1. A minor modification to the Holter pump rollers was required, as shown in Figure 2, to accommodate the larger tubes.

2.3 Test Set-up

Figures 3, 4 and 5 show the test set-up. The predetermining counter was added during the test series. By automatically stopping the pump after exactly 100 pump revolutions, the counter reduces data reduction requirements and minimizes error. Pump revolution count was also changed from one count per revolution to 3 per pump revolution. This improves data accuracy since the pump puts out 3 volume increments per pump revolution.

2.4 Test Results

2.4.1 Originally Installed Tubes

As previously noted, the Holter pump was purchased in December, 1970. The pump was not operated since late December 1970. Test runs 1 thru 50 used the Holter pump with these originally installed silastic tubes. Thus, the tubes were in an installed (stretched) condition for about 6.5 months before start of the test runs.

Figures 6, 7 and 8 and Tables 1 and 2 summarize the test results. Corresponding calculated data are shown in Appendix B.

Note that in Table 1, a large decrease in flow rate occurred for test runs 6 thru 11 as compared to test runs 2, 4 and 5. As shown on the data sheets of Appendix B, a 2 day no-activity interval occurred between the two series of test runs. Test runs 24 thru 33 of Table 2 were performed the same day as test runs 6 thru 11 (but after an intervening 4106 pump revolutions). One day later, for test runs 43 and 44, flow rate increased (and for tube number 1, back to the value for test runs 2, 4 and 5).

Figure 6 shows the effect of exit pressure on flow. Based on these results, exit pressure should be controlled at some value less than about 4.0 psig. Note that drop in tube number 1 flow may have been due to start of tube/line connection leakage which became excessive at 7.0 psig exit pressure. Note also (from Appendix B) that the small tubes were unable to pump against a 7.0 psig exit pressure.

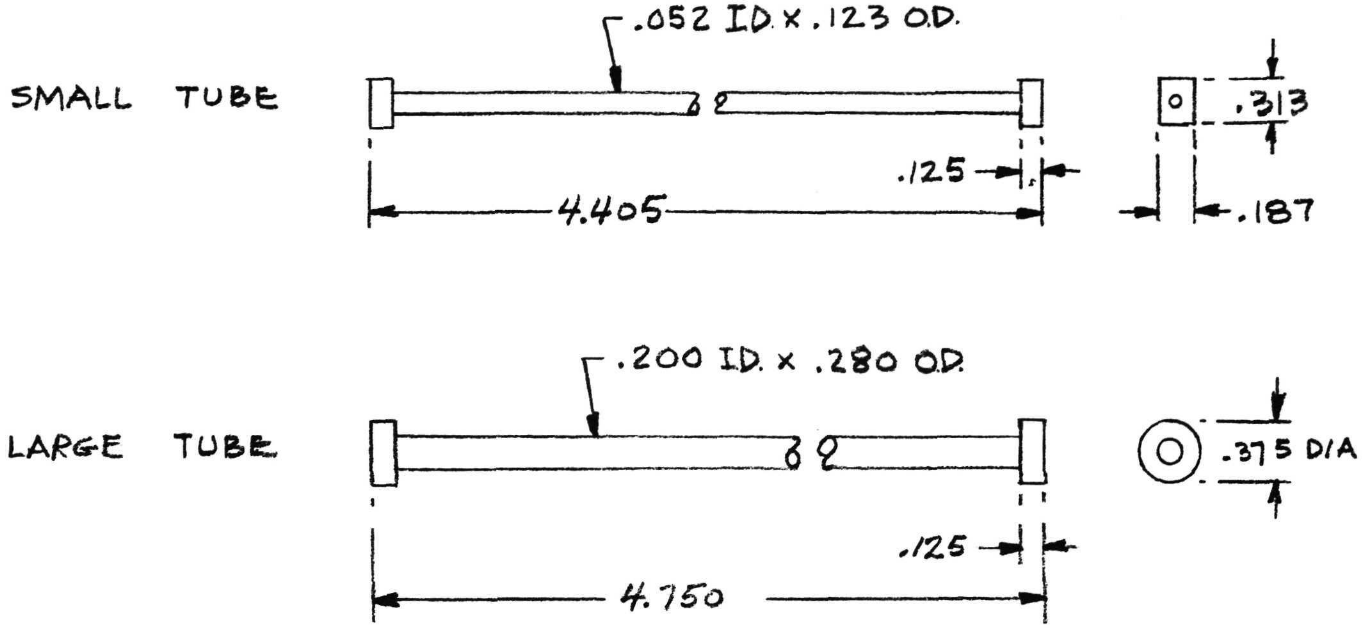


Figure 1. Pump Tube Dimensions

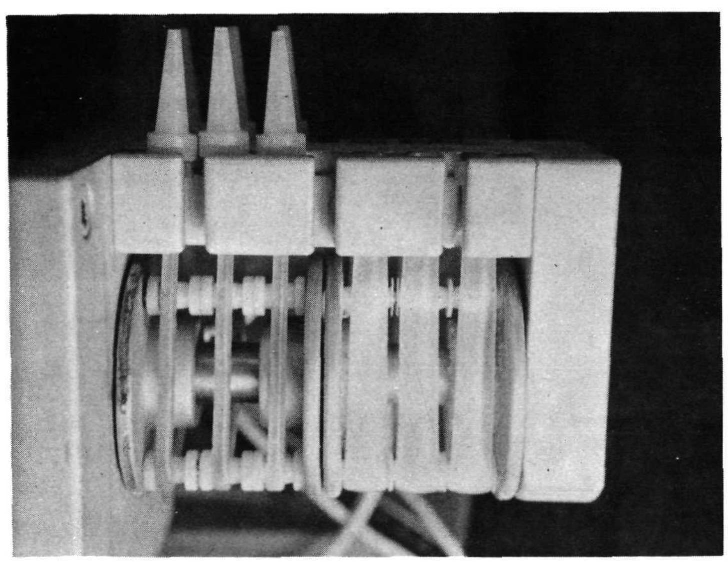


Figure 2. Holter Pump Head Modified for Large Pump Tubes

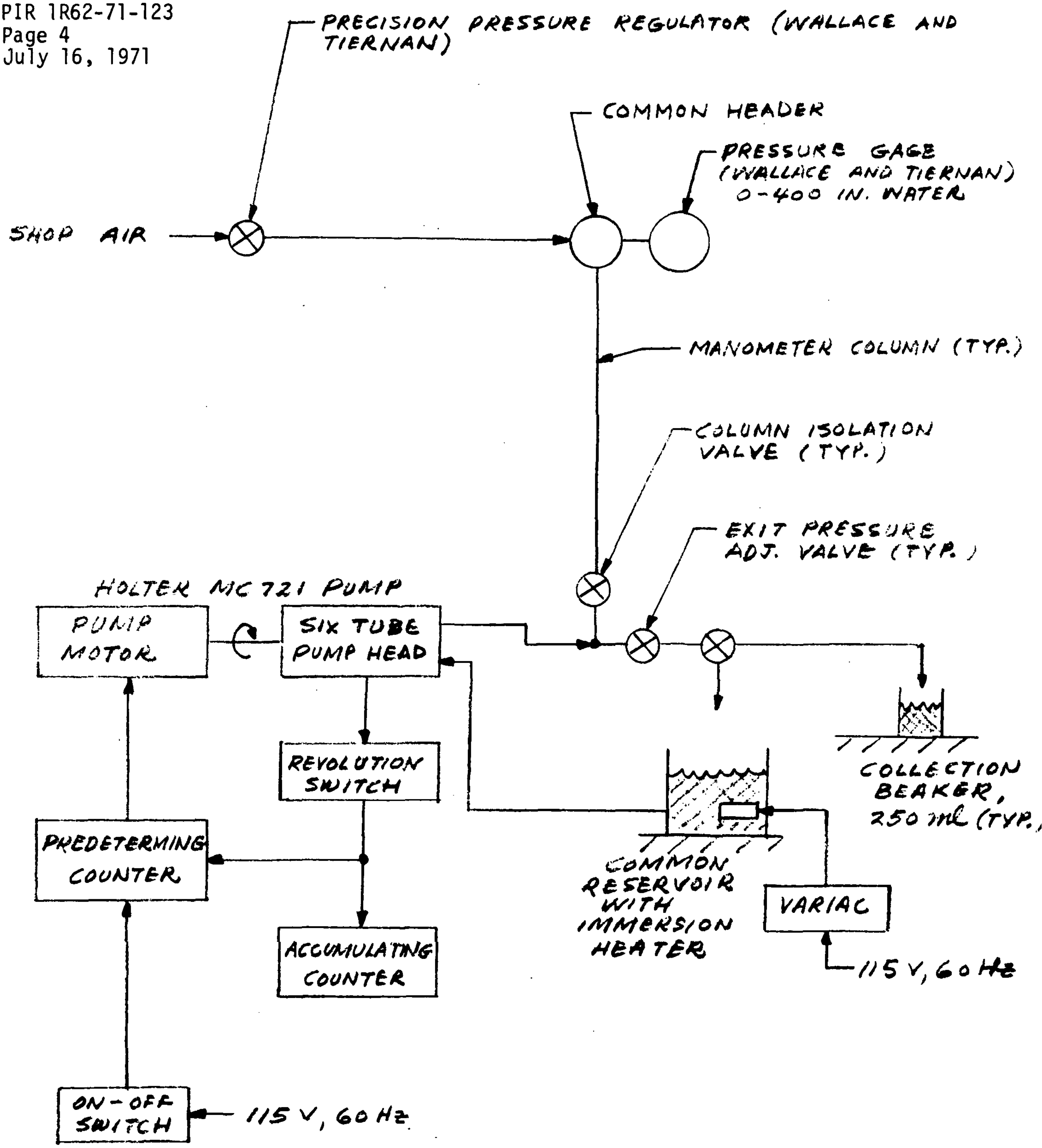


Figure 3. Test Set-up Block Diagram
(Manual Control Mode)

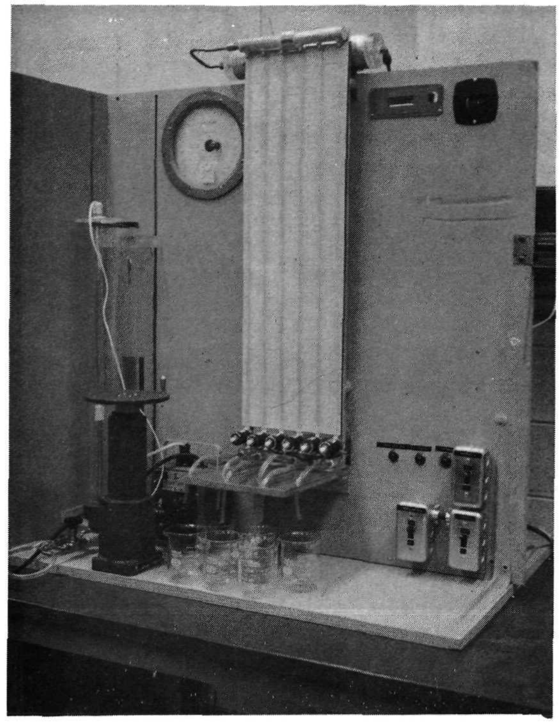


Figure 4. Test Set-up (Front View)

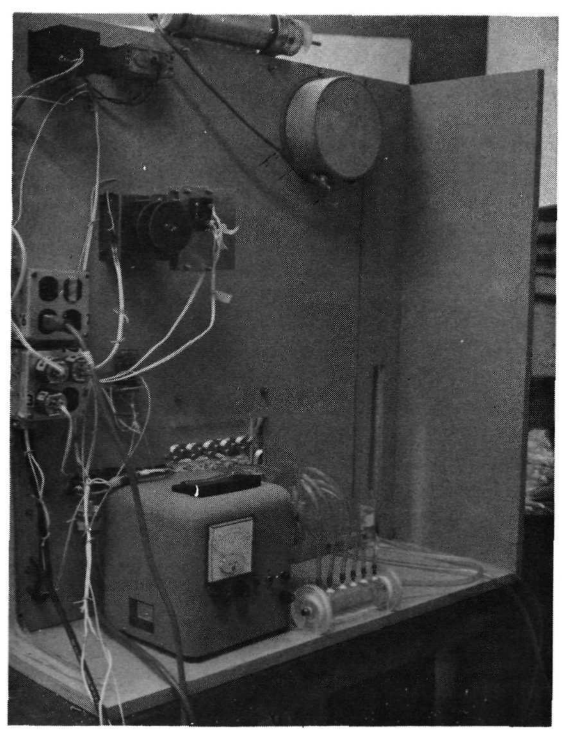


Figure 5. Test Set-up (Back View)

Table 1 Flow Comparison at 0 psig Inlet and Exit Pressure Conditions

Pump Tube Number	Flow-grams per 100 pump revolutions		
	Mean Values from Test Run		Difference
	2, 4, 5	6 thru 11	
1	109.6	103.7	5.9
2	116.1	111.2	5.9
3	106.8	101.4	5.4
4	*	*	-
5	*	15.0	-
6	*	15.3	-

* Air Purge Incomplete.

Table 2 Flow Comparison at 4.0 psig Exit and
0 psig Inlet Pressure Conditions

Pump Tube Number	Flow-grams per 100 pump revolutions		
	Mean Values from Test Runs		Difference
	24 thru 33	43, 44	
1	103.9	109.6	5.7
2	113.0	113.0	0.0
3	101.9	103.7	1.8
4	14.3	14.4	0.1
5	13.1	13.1	0.0
6	13.1	13.2	0.1

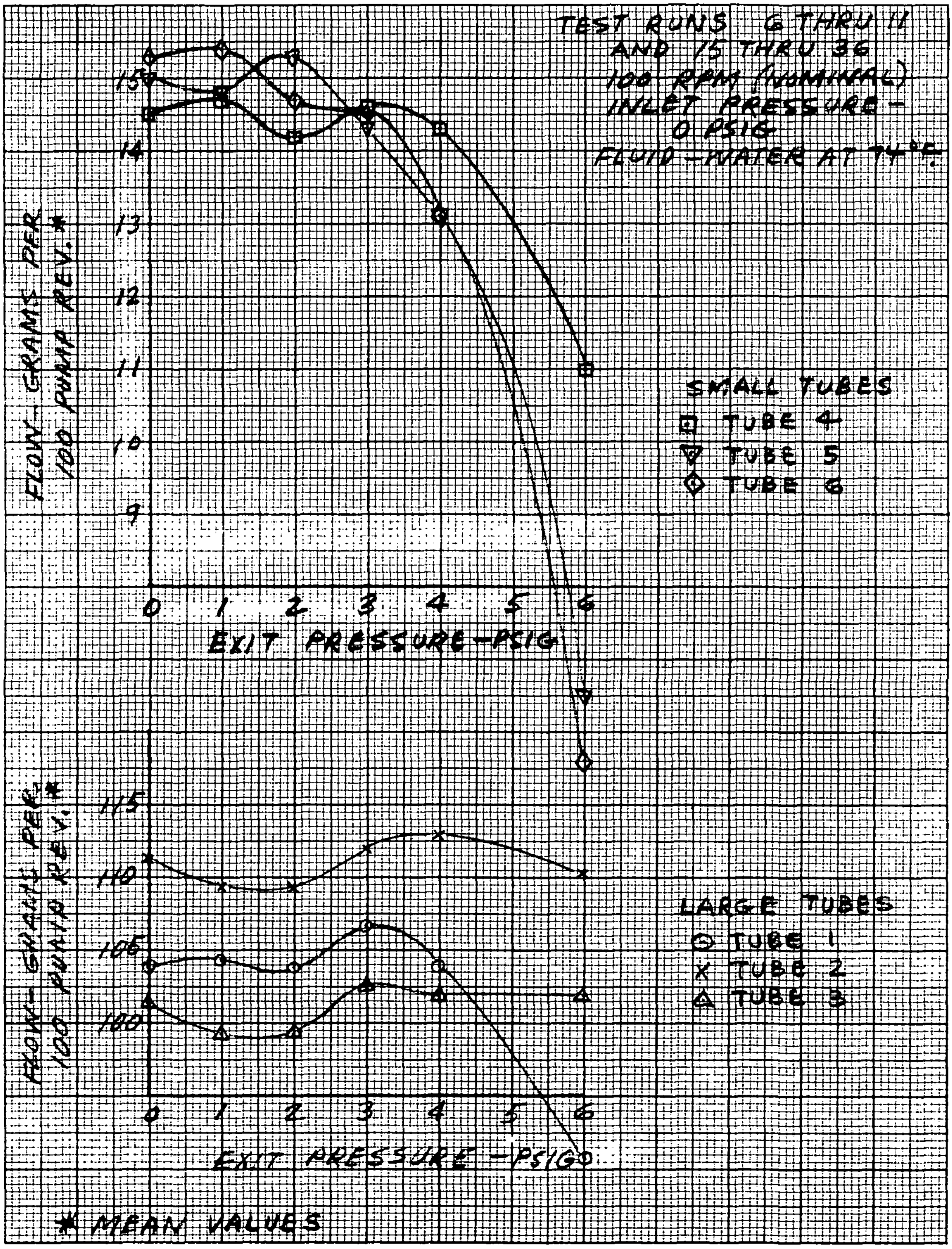


Figure 6. Flow as a Function of Exit Pressure (Zero PSIG Inlet Pressure).

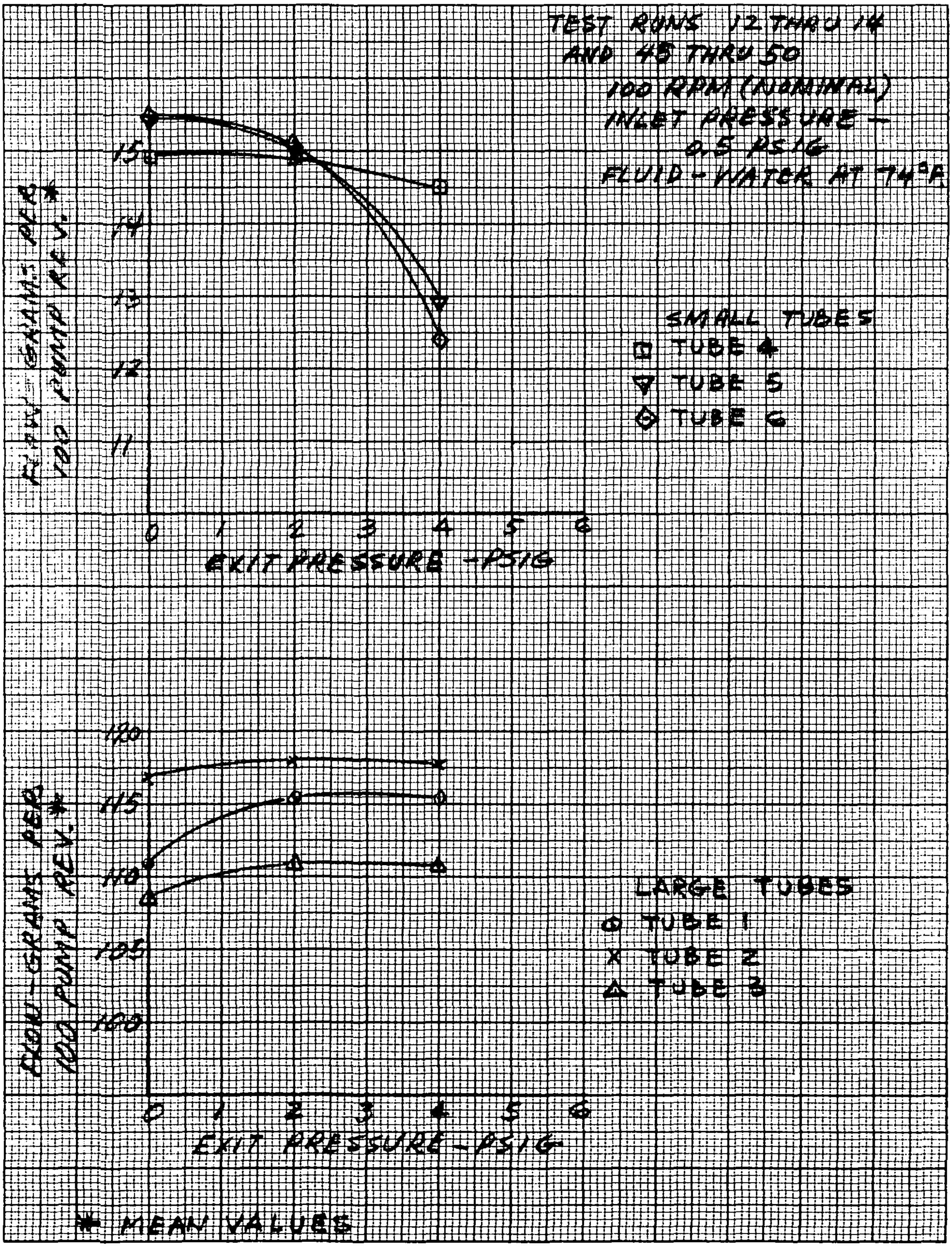


Figure 7. Flow as a Function of Exit Pressure (0.5 PSIG Inlet Pressure).

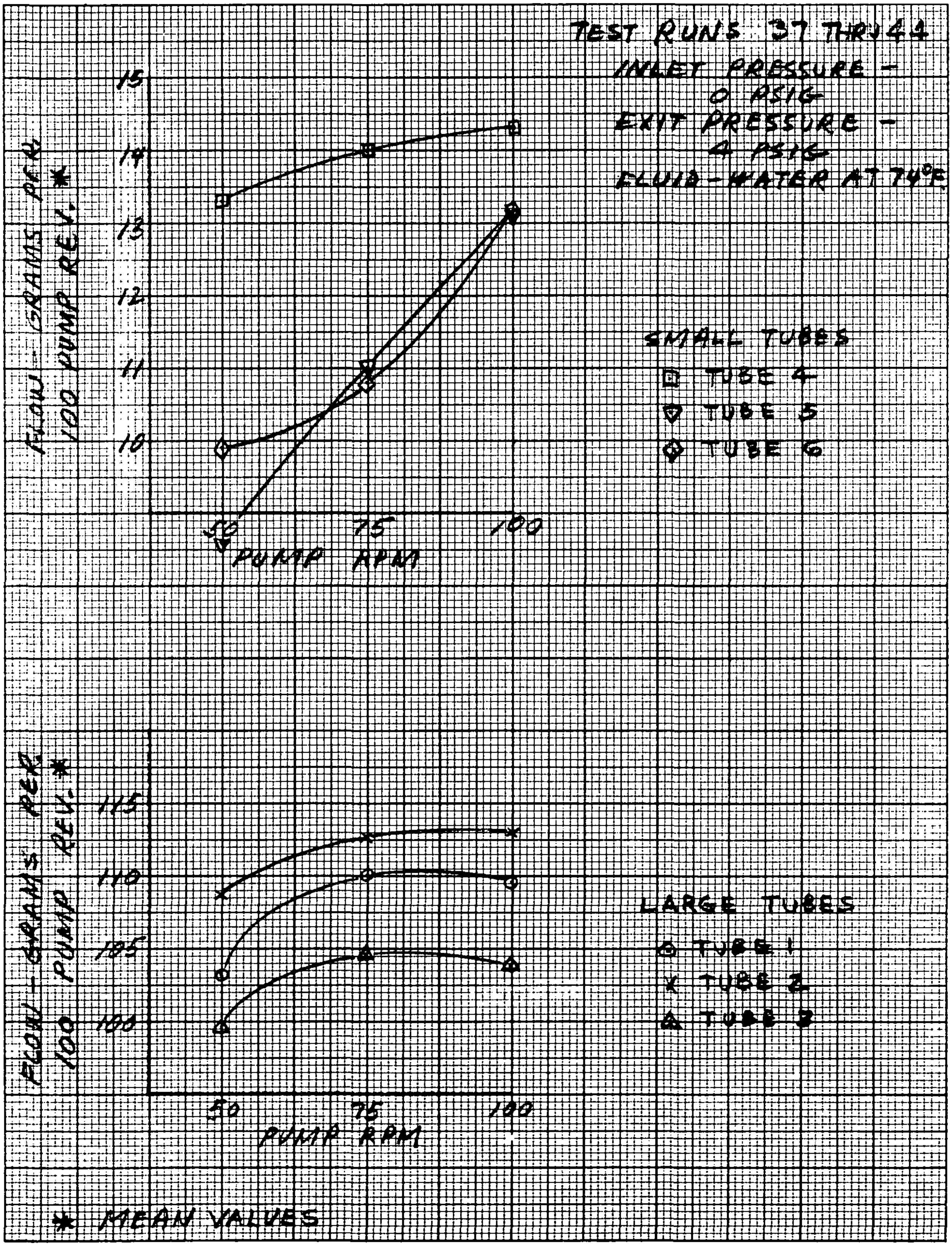


Figure 8. Flow as a Function of Pump Speed.

As shown in Figure 7, an increase in inlet pressure increases the flow rate for the larger tubes. At the 0.5 psig inlet condition shown, the flow rate for tube number 2 (at 4.0 psig exit pressure) is about 4.5% higher as compared to a zero psig inlet condition. For an 800 ml micturition and assuming phase separator performance similar to that for the GE USVMS breadboard, maximum inlet pressure will be about 0.4 psig. Assuming a linear effect, a 3.6% increase over zero inlet conditions can be expected. For the small tubes, little to no increase in flow occurred at the 0.5 psig inlet pressure. This may be due to the greater "stiffness" of the small tubes (i.e. wall thickness/diameter ratio) as compared to the large tubes.

Figure 8 shows the effect of pump speed on flow, higher speed producing higher flow particularily for the smaller tubes. Again, tube "stiffness" may account for the difference between the large and small tubes.

2.4.2 Spare Tubes Installed

Along with the Holter pump purchased in December 1970, spare silastic tubes were also obtained. After completion of test runs 1 thru 50, the originally installed pump tubes were replaced by the unstretched (spare) tubes and the testing resumed. Actually, because of a defect in one of the spare small tubes, only 2 of the 3 small tubes were replaced. Thus, tube number 4 is one of the originally installed small tubes.

Tests using the unstretched spare tubes consisted of an initial series of test runs (to compare with the test runs 1 thru 50), an endurance test of 71 hours, and a post endurance series of tests for comparison with the pre endurance tests. With the exception of the endurance test, all test runs (including test runs 1 thru 50) were made using water at ambient temperature as the fluid. The endurance test utilized raw urine (i.e. no disinfectant added) at a nominal 100^{o}F. Planned use of a germicide proved impractical in that a precipitate formed in the resulting mixture. Vancide BN and Mikro-Quat both gave similar results.

Figure 9 and Tables 3 thru 6 summarize the test results. Corresponding calculated data are included in Appendix B.

Referring to Figure 9, flow values appear to be significantly more consistant than the corresponding values for the originally installed tubes, see Figure 6. Average output for the small tubes was about the same in either case; output increased about 4.5% for the large tubes. This increase may be attributed to possible creep of the originally installed tubes, creep causing the tubes to elongate slightly causing reduced tube tension and less effective sealing (valve) action as the pump rotates and thus a lower flow. This should be particularly apparent at higher exit pressures (as evident in Figure 6 and the lack of in Figure 9). Note that the small relatively "stiff" tubes (and therefore higher stressed), exhibit a more pronounced effect than the large tubes (see Figure 6).

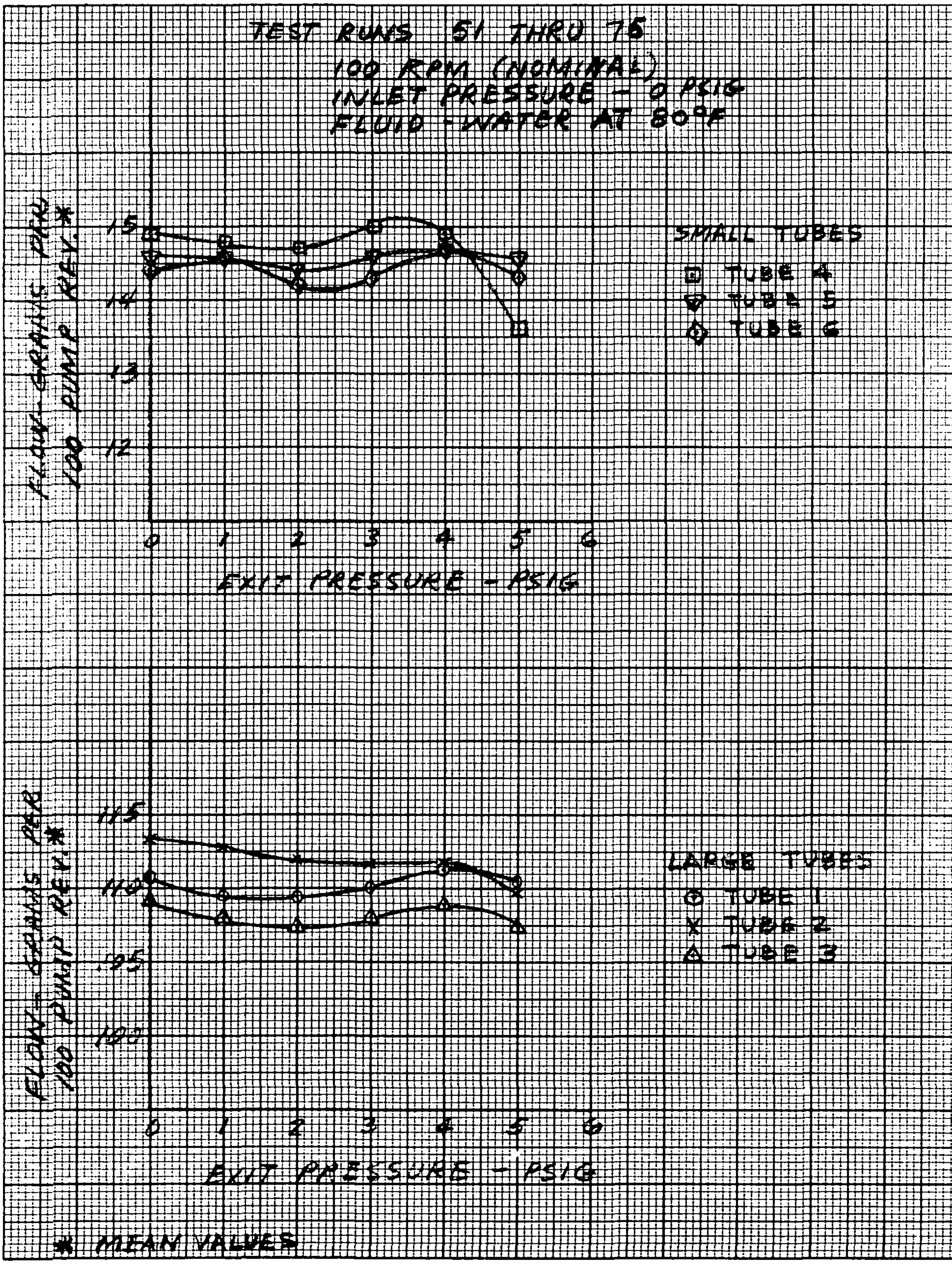


Figure 9. Flow as a Function of Exit Pressure (Zero PSIG Inlet Pressure).

Table 3 Pre Endurance Test Flow Comparison at Zero Psig Inlet and Exit Pressure Conditions

Pump Tube Number	FLow-grams per 100 Pump Revolutions Mean Value from Test Runs 73-75	 77-80	 Difference
1	110.6	106.5	4.1
2	113.3	111.2	2.1
3	108.8	109.6	0.2
4	14.9	14.5	0.4
5	14.6	14.2	0.4
6	14.4	14.0	0.4

Table 4 Post Endurance Test Flow Comparison at Zero Psig Inlet and Exit Pressure Conditions

Pump Tube Number	Flow-grams per 100 Pump Revolutions Mean Value from Test Runs 87-96	 116-125	 126-135	 Maximum Difference
1	105.5	104.5	104.7	1.0
2	106.1	104.0	104.5	2.1
3	106.2	104.1	103.9	2.3
4	12.9	12.8	12.7	0.2
5	12.2	12.1	12.1	0.1
6	12.6	12.5	12.5	0.1

Table 5 Flow Comparison at 4.0 Psig Exit Pressure; 0 Psig Inlet Pressure Conditions, Pre and Post Endurance Test

Pump Tube Number	Flow-grams per 100 Pump Revolutions Mean Value from Test Runs 51 thru 60 PRE ENDURANCE	 81 thru 85	 106-115 POST ENDURANCE
1	111.2	105.7	104.2
2	111.7	109.9	104.7
3	108.9	108.7	105.1
4	14.9	14.5	12.6
5	14.7	13.8	12.0
6	14.7	13.7	12.5

Table 6 Post Endurance Test Flow Comparison at Zero Psig Inlet and Exit Pressure Conditions

Pump Tube Number	Flow-grams per 100 Pump Revolutions				
	Mean Value from Test Runs				Maximum Difference
	139-145	147-152	154-158	160-166	
1	*	*	*	*	-
2	106.4	104.1	103.3	106.0	3.1
3	104.7	101.8	102.1	104.2	2.9
4	12.9	12.9	12.9	13.0	0.1
5	12.3	12.4	12.4	12.1	0.3
6	12.4	12.2	12.2	12.2	0.2

* Tube connection leak

Tables 3 and 4 present pre and post endurance test flow data for zero psig inlet and exit pressure conditions. Duration of the endurance test was 71 hours (approximately 426,000 pump revolutions). A comparison of Tables 3 and 4 indicates a definite reduction in flow capacity of about 5% for the large pump tubes and about 14% for the small tubes. As noted above, tube creep, which would be more severe in the small tubes because of the higher stress levels, may be the cause of this flow reduction.

Referring to Table 3, an intervening 11,400 pump revolutions occurred between the two series of test runs (see test run 76) with a significant flow reduction occurring for some tubes. Table 5 shows the same effect for 4.0 psig exit pressure conditions, particularily when compared with post endurance test results. These results might suggest that the effect of possible tube creep is very high during the first few hours of operation. Table 6 shows results of additional tests which also tend to confirm the above. Short duration endurance runs where made between each series of test runs listed. Thus test run 146 lasted 2 hours (12,000 pump revolutions; test run 153 for 10 minutes (1000 pump revolutions) and with an exit pressure of 4.0 psig; test run 159 for 5 hours (30,000 pump revolutions).

3.0 CONCLUSIONS AND RECOMMENDATIONS

Although the data are sometimes inconsistant, trends are evident and lead to the following:

a. A decrease in pump flow rate will occur as the number of pump revolutions increases. There is some evidence that the rate of change becomes progressively less as the number of pump revolutions increases. This suggests a run-in period may be beneficial.

b. Probable cause for the decrease in pump flow rate may be "creep" of the stressed tubes. The greater reduction in flow for the small tubes, which operate at higher stress levels, tends to confirm the creep hypothesis. Tests using the loaded/unloaded tube pump (see Section 4.2 of the test plan) will further explore this hypothesis.

c. Both inlet and exit pressure conditions should be maintained at constant values for consistent flow rates. Thus, the addition of a check value downstream of the peristaltic pump is recommended. (Note that the exit pressure for the small tube is already controlled by the sample container "foam restraint".

   Inlet pressure is more difficult to control since the pressure will be a function of the total urine volume and phase separator impellor RPM. Two possible solutions are

   (1) Deactivate the phase separator motor speed control for exit pressures exceeding the pressure corresponding to the 50 ml cut-off value. The motor torque-speed characteristic will automatically result in lower impellor RPM as the total urine volume increases.

(2) Provide active control of impellor RPM to maintain some reset exit pressure (slightly higher then the 50 ml cut-off value).

Both of these possible solutions (and others) are recommended for consideration.

d. If possible, decrease the wall thickness of the pump tubes, particularly the small diameter tubes, to reduce stiffness (and thus stress levels). This change should result in less creep and better sealing action at higher exit pressure conditions.

e. Consider an increase in pump "roller" diameter to increase seal area.

f. Pump motor speed control is also required (control of motor input voltage may be a satisfactory indirect means).

g. Minimize line length/volume, especially that associated with the small pump tube, to facilitate purging of air from lines.

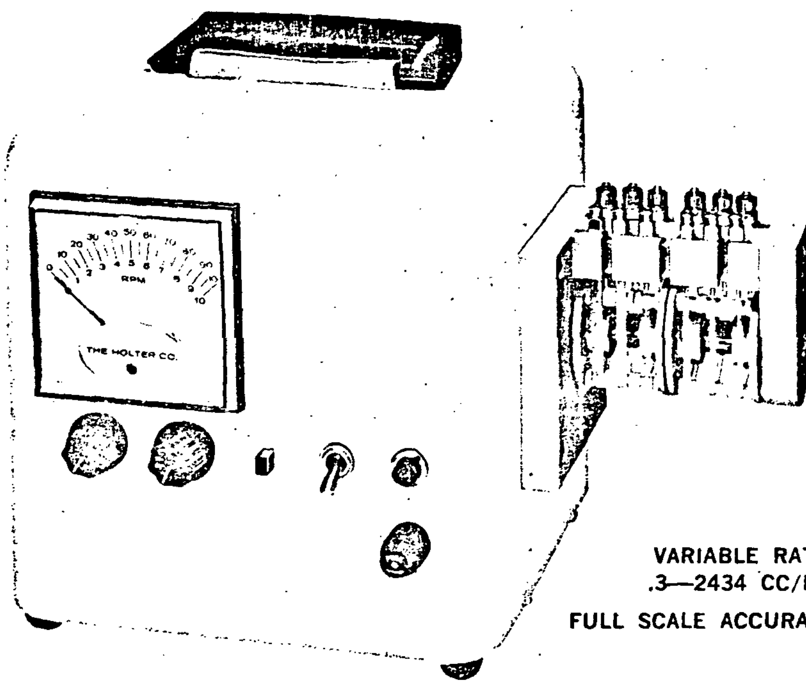
APPENDIX H

SOME OF THE MANY USES:

- Chromatography—Titration—Dilution Studies.
- Multiple Column Chromatography.
- Continuous Fermentation Studies.
- Continuous Feeding of Multiple Biological Systems.
- Six (or twelve) Channel Simultaneous Drug Administration.
- Continuous Toxicology Threshold Studies.
- Multiple Research Test Control Studies.
- Reagent Proportioning and Mixing for Automated Chemical Analysis.

MULTI-CHANNEL ROLLER PUMP

MODEL MC-721



VARIABLE RATE
.3—2434 CC/HR
FULL SCALE ACCURACY ±1%

- The MC-721 is a virtually non-pulsatile, multiple channel roller pump capable of infusing or withdrawing six fluids* simultaneously in linear related proportions.
- Four sizes of precision molded silicone rubber pumping chambers provide flows in 2:1, 4:1 and 10:1 ratios. Silicone rubber possesses almost infinite flex life and near ideal memory unlike generally used plastics (PVC or polyethylene). Useful life 2000 hours or more per chamber.
- Fully transistorized, solid state electronic current feedback power supply and total occlusion of pumping chambers of the MC-721 contribute to full scale reproducibility of ±1%.

*Also available with twelve channel output—Model MC-723.

EXTRACORPOREAL MEDICAL SPECIALTIES, INC.
Church Road • Mt. Laurel Township, N.J., U.S.A. 08057 • (609) 235-7530

HOLTER
MULTI-CHANNEL ROLLER PUMP

MODEL MC-721

PHYSICAL AND ELECTRICAL DETAILS

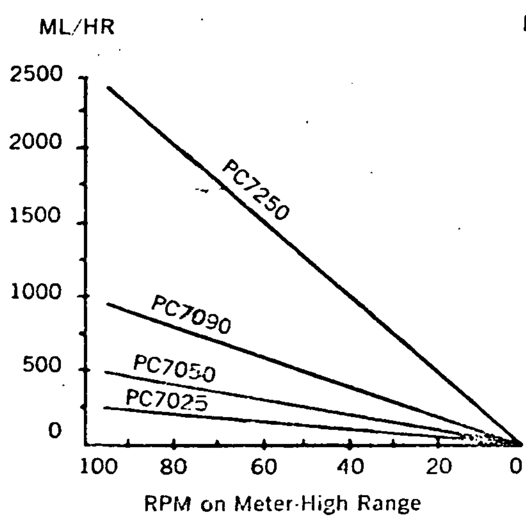
- Fold over carrying handle.
- Corrosive and chip resistant case.
- 110V-50 or 60 cycles—220V available on request.
- 7 foot-3 wire grounded type supply cord.
- Off-on switch with indicator light.
- Scale switch-dual range.
- Coarse and fine speed adjustments.
- Overload safety fuse.
- Weight 16 lbs.
- Size 9¾ x 9¾ x 13".

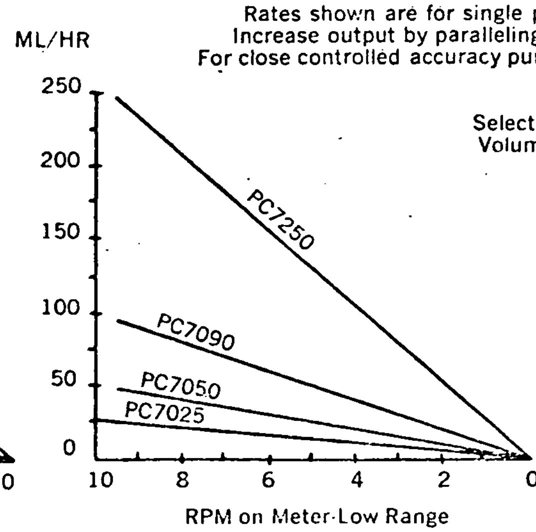
ACCESSORIES (Included with each unit)

- Pumping chambers (2) PC7025, (1) PC7050, (1) PC7090, (2) PC7250 (See graph for individual pumping ranges).
- Six pair of Luer or tapered plastic laboratory type fittings. (Specify).
- Six autoclavable, nylon 4-way stopcocks for use in calibrating rates, paralleling inlet and outlet flows to double output rates, and limited metering regulations of each pumping channel.

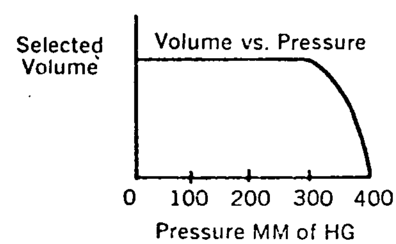
FEATURES

- Infinitely variable dual range (0-10 RPM) (0-100 RPM).
- Insensitive to pressure changes up to 350 MM HG.
- Virtually non-pulsatile.
- Easily and quickly purged of air.
- Guaranteed 6 months against manufacturing defects.
- Meter equipped with zero adjustments.
- Autoclavable silicone rubber pumping chambers (reusable).
- Pumping chambers color coded for positive identification.
- Easy snap-in, snap-out pump chamber mounts.
- Self priming.
- Occlusion of pumping chambers at roller eliminates flow with pump off.
- Adaptable to both hot and cold environmental conditions.





Rates shown are for single pumping chamber.
Increase output by paralleling inlets and outlets.
For close controlled accuracy pump must be calibrated.



PUMPING OUTPUTS PER SIZE CHAMBER

PC7025—.3—236 CC/HR.
PC7050—.6—484 CC. HR.
PC7090—1.0—970 CC HR.
PC7250—3.0—2434 CC. HR.

See instruction sheet prior to use.

EXTRACORPOREAL MEDICAL SPECIALTIES, INC.

Church Road • Mt. Laurel Township, N.J., U.S.A. 08057 • (609) 235-7530

HP12/168

APPENDIX D

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PERISTALTIC PUMP PERFORMANCE EVALUATION

REDUCED DATA

EQUIPMENT: HOLTER MODEL MC721 PUMP - ORIGINALLY INSTALLED PUMP TUBES. FLUID-WATER AT AMBIENT TEMPERATURE (75 ± 3 °F). PUMP SPEED - 100 RPM.

Run No.	Date	E/I	Number pump rev.	Tube 1		Tube 2		Tube 3		Tube 4		Tube 5		Tube 6	
				a	b	a	b	a	b	a	b	a	b	a	b
1	6/18	0/0	217	PURGE LARGE TUBE LINES OF AIR											
2	6/18	0/0	300	327.6	1.092	354.3	1.181	323.4	1.078	—	—	—	—	—	—
3	6/18	0/0	1515	WARM-UP AND SMALL TUBE LINE PURGE											
4	6/18	0/0	261	287.1	1.100	301.9	1.156	278.1	1.065	—	—	—	—	—	—
5	6/18	0/0	103	113.0	1.097	118.3	1.148	109.3	1.061	—	—	15.3	.148	16.0	.155
	MEAN VALUES				1.096		1.161		1.068						
6	6/21	0/0	98	101.3	1.033	108.7	1.109	99.5	1.015	—	—	14.7	.150	15.0	.153
7			119	123.5	1.037	132.8	1.115	121.4	1.020	—	—	18.0	.151	18.1	.152
8			107	111.8	1.044	119.8	1.119	109.6	1.024	—	—	16.1	.150	16.5	.154
9			122	126.3	1.035	135.4	1.109	123.4	1.011	—	—	18.4	.150	18.6	.152
10			105	108.9	1.037	116.4	1.108	106.1	1.010	—	—	15.8	.150	16.1	.153
11			110	114.3	1.039	122.7	1.115	111.0	1.009	16.0	.145	16.5	.150	16.8	.152
	MEAN VALUES				1.037		1.112		1.014		—		.150		.153
12	6/21	0/5	112	123.6	1.103	130.9	1.168	121.4	1.083	16.6	.148	17.1	.152	17.5	.156
13			107	118.5	1.107	125.0	1.168	116.0	1.084	16.1	.150	16.4	.153	16.7	.156
14			114	127.5	1.118	133.6	1.171	124.0	1.087	17.0	.149	17.8	.156	17.4	.152
	MEAN VALUES				1.109		1.169		1.085		.149		.154		.155
15	6/21	1/0	104	107.7	1.035	115.1	1.106	103.4	.994	16.5	.158	15.4	.148	17.7	.170
16			112	118.1	1.054	121.7	1.086	113.1	1.009	15.4	.137	16.6	.148	15.8	.141
17			168	174.5	1.038	182.6	1.086	163.7	.974	24.5	.145	25.1	.149	25.2	.150
	MEAN VALUES				1.042		1.093		.992		.147		.148		.154
			6132	ACCUMULATED REV. (INCLUDING MISC.)											

E/I=exit/inlet pressure in psig; a=total fluid pumped,grams; b=fluid pumped/rev.,grams

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PERISTALTIC PUMP PERFORMANCE EVALUATION

REDUCED DATA

EQUIPMENT: HOLTER MODEL MC721 PUMP - ORIGINALLY INSTALLED PUMP TUBES. FLUID - WATER AT AMBIENT TEMPERATURE (75 ± 3°F). PUMP SPEED-100RPM

Run No.	Date	E/I	Number pump rev.	Tube 1		Tube 2		Tube 3		Tube 4		Tube 5		Tube 6	
				a	b	a	b	a	b	a	b	a	b	a	b
18	6/21	2/0	105	109.1	1.039	115.0	1.095	104.2	.992	14.7	.140	16.0	.152	15.2	.144
19			141	145.9	1.034	154.7	1.097	138.4	.981	20.0	.141	20.8	.147	21.7	.153
20			109	113.5	1.041	118.2	1.084	109.3	1.002	16.0	.146	17.4	.159	15.7	.144
	MEAN		VALUES		1.038		1.092		.992		.142		.153		.147
21	6/21	3/0	105	110.9	1.056	118.1	1.124	107.4	1.022	15.5	.147	14.9	.141	15.5	.147
22			93	99.3	1.067	103.5	1.112	96.0	1.032	13.9	.149	13.7	.147	13.5	.145
23			117	125.8	1.075	131.4	1.123	119.8	1.023	16.6	.141	16.4	.140	16.9	.144
	MEAN		VALUES		1.066		1.120		1.026		.146		.143		.145
24	6/21	4/0	113	117.7	1.041	125.1	1.107	112.3	.993	15.3	.135	15.1	.133	14.0	.123
25			116	121.4	1.046	128.8	1.110	118.6	1.022	17.3	.149	15.8	.136	15.5	.133
26			101	105.6	1.045	115.4	1.142	104.0	1.029	14.7	.145	12.6	.124	13.2	.130
27			119	122.9	1.032	133.0	1.117	121.3	1.019	17.0	.142	16.2	.136	16.4	.137
28			105	108.3	1.031	117.3	1.117	106.4	1.013	14.6	.139	13.4	.127	13.8	.131
29			112	116.3	1.038	125.0	1.116	114.3	1.020	16.2	.144	14.8	.132	14.5	.129
30			101	104.3	1.033	113.6	1.125	103.2	1.022	14.1	.140	13.0	.129	12.4	.123
31			101	104.6	1.035	123.3	1.220	102.7	1.016	14.6	.144	12.9	.127	13.8	.136
32			106	110.4	1.041	119.0	1.122	109.4	1.032	15.3	.144	13.8	.130	13.3	.125
33			95	99.6	1.048	106.8	1.124	97.7	1.028	14.5	.152	13.3	.140	13.3	.140
	MEAN		VALUES		1.039		1.130		1.019		.143		.131		.131
34	6/2	6/0	101	92.3	.913	113.1	1.119	103.3	1.022	11.1	.109	7.1	.070	5.2	.051
35			121	109.2	.902	132.7	1.095	123.2	1.018	13.1	.108	6.7	.055	6.8	.056
36			101	91.4	.904	111.0	1.099	102.7	1.016	11.5	.113	7.1	.070	6.1	.060
	MEAN		VALUES		.906		1.104		1.019		.110		.065		.056
			9291	ACCUMULATED REV. (INCLUDING MISC.)											

E/I=exit/inlet pressure in psig; a=total fluid pumped, grams; b=fluid pumped/rev., grams

REDUCED DATA

EQUIPMENT: HOLTER MODEL MC721 PUMP – ORIGINALLY INSTALLED PUMP TUBES. FLUID – WATER AT AMBIENT TEMPERATURE (75 ± 3°F)

Run No.	Date	E/I	Number pump rev.	Tube 1 a	Tube 1 b	Tube 2 a	Tube 2 b	Tube 3 a	Tube 3 b	Tube 4 a	Tube 4 b	Tube 5 a	Tube 5 b	Tube 6 a	Tube 6 b
UNABLE TO OPERATE AT 7.0 PSIG EXIT PRESSURE DUE TO TUBE CONNECTION LEAKAGE. SMALL TUBES ALSO UNABLE TO PUMP AT THIS PRESSURE.															
PUMP SPEED REDUCED TO 75 RPM															
37	6/22	4/0	102	114.1	1.118	116.5	1.142	105.1	1.030	14.0	.137	11.7	.114	10.9	.106
38			103	112.6	1.093	115.5	1.121	109.5	1.063	14.2	.137	10.3	.100	10.9	.105
39			103	112.3	1.090	115.0	1.116	107.8	1.046	15.1	.146	12.0	.116	11.6	.112
	MEAN VALUES				1.100		1.126		1.046		.140		.110		.108
PUMP SPEED REDUCED TO 50 RPM															
40	6/22	4/0	109	113.3	1.039	115.6	1.060	109.4	1.003	14.7	.134	9.3	.085	11.0	.100
41			102	104.5	1.024	116.4	1.141	100.8	.988	12.9	.126	9.0	.088	9.8	.096
42			106	109.6	1.033	112.1	1.057	105.6	.996	14.9	.140	9.1	.085	10.8	.101
	MEAN VALUES				1.032		1.086		.996		.133		.086		.099
PUMP SPEED INCREASED TO 100 RPM															
43	6/22	4/0	110	120.5	1.095	123.9	1.126	114.3	1.039	15.9	.144	14.6	.132	13.5	.122
44			103	113.0	1.097	116.7	1.133	106.7	1.035	14.8	.143	13.4	.130	14.6	.141
	MEAN VALUES				1.096		1.130		1.037		.144		.131		.132
45	6/22	4/5	102	117.2	1.149	119.0	1.166	111.7	1.095	14.1	.138	12.5	.122	11.6	.113
46			103	118.6	1.151	121.7	1.181	114.8	1.114	15.3	.148	14.4	.139	13.3	.129
47			102	118.7	1.163	120.9	1.185	113.4	1.111	15.1	.148	12.9	.126	13.2	.129
	MEAN VALUES				1.154		1.177		1.107		.145		.129		.124

E/I=exit/inlet pressure in psig; a=total fluid pumped,grams; b=fluid pumped/rev.,grams

REDUCED DATA

EQUIPMENT: HOLTER MODEL MC 721 PUMP – ORIGINALLY INSTALLED PUMP TUBES. FLUID – WATER AT AMBIENT TEMPERATURE (75 ± 3 °F). PUMP SPEED – 100 RPM.

Run No.	Date	E/I	Number pump rev.	Tube 1 a	Tube 1 b	Tube 2 a	Tube 2 b	Tube 3 a	Tube 3 b	Tube 4 a	Tube 4 b	Tube 5 a	Tube 5 b	Tube 6 a	Tube 6 b
48	6/22	2/5	105	120.8	1.150	123.4	1.175	116.3	1.107	15.3	.145	15.6	.148	15.5	.147
49			106	123.3	1.163	125.8	1.186	118.1	1.114	15.3	.144	16.5	.155	16.3	.153
50			105	120.8	1.150	123.9	1.180	116.1	1.105	16.6	.158	15.4	.146	16.1	.153
	MEAN VALUES				1.154		1.180		1.109		.149		.150		.151
			11655 ACCUMULATED REV. (INCLUDING MISC.)												
	6/22		PUMP TUBES REMOVED; NO DAMAGE BASED ON VISUAL INSPECTION.												
	6/22		UNUSED SPARE TUBES INSTALLED EXCEPT FOR TUBE NO. 4 (TUBE NO. 4 PREVIOUSLY TUBE NO. 4, 5 OR 6).												
51	6/24	4/0	105	118.6	1.130	116.7	1.111	113.2	1.078	16.0	.152	14.9	.142	15.4	.147
52			105	117.3	1.117	118.0	1.124	115.4	1.099	15.3	.148	15.9	.151	14.8	.141
53			113	125.3	1.109	126.6	1.120	123.4	1.092	16.6	.147	16.4	.145	17.1	.151
54			106	117.3	1.107	118.7	1.120	115.3	1.088	15.6	.147	15.7	.148	14.7	.139
55			110	122.5	1.114	122.9	1.117	119.6	1.087	16.4	.149	16.5	.150	16.9	.154
56			104	115.8	1.113	116.4	1.119	113.4	1.090	15.2	.146	15.1	.145	14.6	.140
57			110	121.8	1.107	122.8	1.116	120.7	1.097	16.5	.150	15.8	.144	16.3	.148
58			109	119.9	1.100	121.8	1.117	118.1	1.083	16.6	.152	16.4	.150	15.4	.141
59			105	117.4	1.118	116.7	1.111	113.3	1.079	15.1	.144	15.4	.147	15.4	.147
60			109	120.8	1.108	121.2	1.112	119.0	1.092	16.6	.152	16.0	.147	17.1	.157
	MEAN VALUES				1.112		1.117		1.089		.149		.147		.147
			NEXT SERIES AT 5 PSIG EXIT PRESSURE; TUBE CONNECTION LEAK AT 6.0 PSIG.												

E/I=exit/inlet pressure in psig; a=total fluid pumped,grams; b=fluid pumped/rev.,grams

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PERISTALTIC PUMP PERFORMANCE EVALUATION

REDUCED DATA

EQUIPMENT: HOLTER MODEL MC721 PUMP - UNUSED SPARE TUBES INSTALLED. FLUID-WATER AT AMBIENT TEMPERATURE (75 ± 3 °F). PUMP SPEED - 100 RPM

Run No.	Date	E/I	Number pump rev.	Tube 1		Tube 2		Tube 3		Tube 4		Tube 5		Tube 6	
				a	b	a	b	a	b	a	b	a	b	a	b
61	6/24	5/0	107	119.6	1.118	115.7	1.081	113.4	1.060	14.1	.132	15.4	.144	14.8	.138
62			102	112.3	1.101	112.1	1.099	110.0	1.078	14.4	.141	15.4	.151	15.2	.149
63			103	114.0	1.107	114.5	1.112	111.3	1.081	13.8	.134	14.8	.144	14.6	.142
	MEAN		VALUES		1.105		1.097		1.073		.136		.146		.143
64	6/24	3/0	107	116.8	1.092	118.2	1.105	115.2	1.077	15.9	.149	15.7	.147	15.1	.141
65			118	130.9	1.109	132.6	1.124	126.7	1.074	17.6	.149	16.5	.140	17.5	.148
66			105	115.4	1.099	117.9	1.123	114.2	1.088	16.1	.153	15.9	.151	14.6	.139
	MEAN		VALUES		1.100		1.117		1.080		.150		.146		.143
67	6/24	2/0	128	140.3	1.096	143.4	1.120	137.4	1.073	18.6	.145	18.4	.143	18.2	.142
68			110	120.4	1.095	123.2	1.120	116.2	1.056	16.0	.145	15.1	.137	15.7	.143
69			101	110.1	1.090	113.0	1.119	110.0	1.089	15.3	.151	15.4	.152	14.2	.141
	MEAN		VALUES		1.094		1.120		1.073		.147		.144		.142
70	6/24	1/0	114	124.0	1.088	128.1	1.124	122.8	1.077	17.4	.153	15.9	.139	16.4	.144
71			108	119.1	1.103	122.0	1.130	116.7	1.081	15.6	.144	16.4	.152	15.9	.147
72			106	116.0	1.094	120.0	1.132	114.7	1.082	15.6	.147	15.6	.147	15.5	.146
	MEAN		VALUES		1.095		1.129		1.080		.148		.146		.146
73	6/24	0/0	106	117.0	1.104	120.0	1.132	115.1	1.086	15.8	.149	15.4	.145	15.3	.144
74			106	117.6	1.109	120.6	1.138	115.8	1.092	15.8	.149	15.7	.148	15.3	.144
75			106	117.0	1.104	119.8	1.130	115.1	1.086	15.8	.149	15.4	.145	15.4	.145
	MEAN		VALUES		1.106		1.133		1.088		.149		.146		.144
76	6/24	0/0	11400			RECIRCULATE FLOW									

E/I=exit/inlet pressure in psig; a=total fluid pumped,grams; b=fluid pumped/rev.,grams

REDUCED DATA

EQUIPMENT: HOLTER MODEL MC721 PUMP - UNUSED SPARE TUBES INSTALLED. FLUID - WATER AT AMBIENT TEMPERATURE (75 ± 3 °F). PUMP SPEED - 100 RPM

Run No.	Date	E/I	Number pump rev.	Tube 1 a	Tube 1 b	Tube 2 a	Tube 2 b	Tube 3 a	Tube 3 b	Tube 4 a	Tube 4 b	Tube 5 a	Tube 5 b	Tube 6 a	Tube 6 b
77	6/24	0/0	99	105.3	1.064	109.9	1.110	107.6	1.087	14.4	.145	14.2	.143	13.9	.140
78			99	105.8	1.069	110.5	1.116	108.1	1.092	14.3	.144	14.2	.143	13.8	.139
79			99	105.8	1.069	110.4	1.115	108.2	1.093	14.5	.146	14.0	.141	14.0	.141
80			101	107.0	1.059	111.7	1.106	109.8	1.087	14.6	.145	14.3	.142	14.1	.140
	MEAN VALUES				1.065		1.112		1.090		.145		.142		.140
81	6/24	4/0	100	104.1	1.041	108.8	1.088	107.2	1.072	13.8	.138	13.8	.138	13.8	.138
82			97	102.6	1.058	106.5	1.098	106.0	1.093	14.6	.151	13.4	.138	12.3	.127
83			100	106.0	1.060	110.0	1.100	108.3	1.083	14.0	.140	13.8	.138	15.0	.150
84			99	105.3	1.064	109.3	1.104	108.7	1.098	14.3	.144	13.6	.137	13.8	.139
85			102	108.3	1.062	112.7	1.105	111.3	1.091	15.6	.153	14.4	.141	13.6	.133
	MEAN VALUES				1.057		1.099		1.087		.145		.138		.137
			17850	ACCUMULATED REV. (INCLUDING MISC.)											
	ENDURANCE TEST - REPLACED WATER WITH URINE														
86	6/24	0/0	426 000		RECIRCULATE FLOW (71 HOURS CONT.)										
	REPLACED URINE WITH WATER. MODIFIED PUMP REV. COUNTER TO REGISTER 3 COUNTS PER PUMP REVOLUTION.														
87	6/29	0/0	103.7	109.3	1.054	109.8	1.059	109.8	1.059	—	—	12.8	.123	13.1	.126
88			105.0	111.0	1.057	111.4	1.061	111.2	1.059	13.6	.130	12.8	.122	13.2	.126
89			104.0	110.0	1.058	110.5	1.063	110.7	1.064	13.3	.128	12.7	.122	13.1	.126
90			105.7	111.7	1.057	112.1	1.061	112.5	1.064	13.6	.129	12.9	.122	13.4	.127
91			103.3	109.6	1.061	110.1	1.066	109.8	1.063	13.3	.129	12.6	.122	13.0	.126
92			103.0	108.6	1.054	109.5	1.063	109.0	1.058	13.3	.129	12.6	.122	13.1	.127

E/I=exit/inlet pressure in psig; a=total fluid pumped,grams; b=fluid pumped/rev.,grams

REDUCED DATA

EQUIPMENT: HOLTER MODEL MC721 PUMP - UNUSED SPARE TUBES INSTALLED. FLUID - WATER AT AMBIENT TEMPERATURE (75 ± 3°F). PUMP SPEED - 100 RPM

Run No.	Date	E/I	Number pump rev.	Tube 1		Tube 2		Tube 3		Tube 4		Tube 5		Tube 6	
				a	b	a	b	a	b	a	b	a	b	a	b
93			105.7	109.1	1.032	110.0	1.041	110.1	1.042	13.3	.126	12.6	.119	13.0	.123
94			102.7	109.7	1.068	110.4	1.075	110.6	1.077	13.4	.130	12.7	.124	13.1	.128
95			103.3	108.9	1.054	109.6	1.061	110.2	1.067	13.3	.129	12.6	.122	13.1	.127
96			103.3	108.5	1.050	109.3	1.058	110.1	1.066	13.3	.129	12.5	.121	13.1	.127
	MEAN VALUES				1.055		1.061		1.062		.129		.122		.126
97	6/29	1/0	104.0	109.0	1.048	109.3	1.051	111.1	1.068	13.6	.131	—	—	13.1	.126
98			107.3	112.7	1.050	113.3	1.056	114.5	1.067	14.0	.130	13.1	.122	13.1	.122
99			105.7	111.3	1.053	111.9	1.059	112.7	1.066	14.7	.139	13.4	.127	13.6	.129
	MEAN VALUES				1.050		1.055		1.067		.133		.124		.126
100	6/29	2/0	104.0	109.0	1.048	109.0	1.048	110.2	1.060	13.1	.126	12.4	.119	13.5	.130
101			103.0	107.4	1.043	107.7	1.046	109.1	1.059	13.3	.129	12.4	.120	12.9	.125
102			102.7	107.9	1.051	108.0	1.052	108.9	1.060	13.3	.130	12.6	.123	13.0	.127
	MEAN VALUES				1.047		1.049		1.060		.128		.121		.127
103	6/29	3/0	103.7	108.7	1.048	108.4	1.045	110.7	1.068	13.3	.128	13.0	.125	13.4	.129
104			110.7	115.6	1.044	*	*	117.2	1.059	14.2	.128	13.6	.123	13.8	.125
105			102.0	106.5	1.044	*	*	108.5	1.064	12.6	.124	—	—	12.8	.125
	MEAN VALUES				1.045		1.045		1.064		.127		.124		.126
106	6/29	4/0	104.3	108.4	1.039	*	*	109.4	1.049	13.4	.128	12.7	.122	13.4	.128
107			103.3	107.3	1.039	*	*	109.4	1.059	12.5	.121	12.3	.119	12.4	.120
108			104.3	108.3	1.038	*	*	109.7	1.052	13.6	.130	12.3	.118	13.6	.130
109			109.0	113.3	1.039	*	*	114.2	1.048	13.8	.127	12.9	.118	13.6	.125
110			103.0	107.2	1.041	*	*	107.7	1.046	13.0	.126	12.8	.124	12.8	.124
111			110.3	117.1	1.062	116.6	1.057	116.1	1.053	13.0	.118	12.7	.115	13.3	.121
112			106.7	111.3	1.043	112.1	1.051	112.5	1.054	13.6	.127	12.4	.116	13.4	.126

E/I=exit/inlet pressure in psig; a=total fluid pumped,grams; b=fluid pumped/rev.,grams

* TUBE CONNECTION LEAK

REDUCED DATA

EQUIPMENT: HOLTER MODEL MC721 PUMP - UNUSED SPARE TUBES INSTALLED. FLUID - WATER AT AMBIENT TEMPERATURE (75 ± 3°F). PUMP SPEED - 100 RPM.

Run No.	Date	E/I	Number pump rev.	Tube 1		Tube 2		Tube 3		Tube 4		Tube 5		Tube 6	
				a	b	a	b	a	b	a	b	a	b	a	b
113			107.0	110.7	1.035	111.1	1.038	111.9	1.046	13.6	.127	13.4	.125	12.9	.121
114			105.7	109.8	1.039	109.7	1.038	110.4	1.044	13.2	.125	12.4	.117	13.5	.128
115			105.7	110.3	1.044	111.0	1.050	111.8	1.058	13.3	.126	12.9	.122	13.2	.125
	MEAN VALUES				1.042		1.047		1.051		.126		.120		.125
			ADDED PREDETERMING COUNTER												
116	6/29	0/0	100		1.037		1.038		1.037		.128		.121		.126
117			100		1.040		1.040		1.041		.128		.121		.125
118			100		1.043		1.040		1.040		.128		.121		.125
119			100		1.043		1.039		1.041		.129		.121		.126
120			100		1.046		1.040		1.040		.127		.121		.125
121			100		1.047		1.040		1.042		.128		.121		.126
122			100		1.048		1.041		1.042		.129		.121		.125
123			100		1.047		1.040		1.042		.127		.121		.125
124			100		1.048		1.041		1.042		.128		.121		.125
125			100		1.047		1.040		1.041		.127		.121		.126
	MEAN VALUES				1.045		1.040		1.041		.128		.121		.125
126	6/30	0/0	100		1.048		1.052		1.042		.128		.122		.126
127			100		1.048		1.047		1.034		.127		.121		.125
128			100		1.048		1.043		1.034		.127		.121		.125
129			100		1.047		1.043		1.035		.128		.121		.125
130			100		1.045		1.042		1.037		.127		.121		.125
131			100		1.043		1.042		1.029		.136		.121		.126
132			100		1.043		1.042		1.038		.128		.121		.125
133			100		1.048		1.047		1.047		.127		.121		.125
134			100		1.049		1.047		1.047		.127		.121		.125
135			100		1.050		1.048		1.048		.128		.121		.125
	MEAN VALUES				1.047		1.045		1.039		.127		.121		.125

E/I=exit/inlet pressure in psig; a=total fluid pumped,grams; b=fluid pumped/rev.,grams

PROGRAM: [illegible] SAMPLING AND COLLECTION SYSTEM

TEST: PERISTALTIC PUMP PERFORMANCE EVALUATION

REDUCED DATA

EQUIPMENT: HOLTER MODEL MC 721 PUMP - UNUSED SPARE TUBES INSTALLED. FLUID - WATER AT AMBIENT TEMPERATURE (75 ± 3°F). PUMP SPEED - 100 RPM.

Run No.	Date	E/I	Number pump rev.	Tube 1 a	Tube 1 b	Tube 2 a	Tube 2 b	Tube 3 a	Tube 3 b	Tube 4 a	Tube 4 b	Tube 5 a	Tube 5 b	Tube 6 a	Tube 6 b
136	6/30	0/0	40500		RECIRCULATE FLOW										
137	6/30	0/0	100		*		*		1.034		.129		.124		.126
138			100		1.037		1.049		1.055		.127		.122		.125
139	7/1	0/0	100		*		1.061		1.042		.127		.122		.125
140			100		*		1.064		1.047		.129		.124		.125
141			100		*		1.065		1.047		.129		.123		.125
142			100		*		1.066		1.047		.129		.123		.124
143			100		*		1.065		1.047		.129		.123		.124
144			100		*		1.064		1.047		.129		.124		.124
145			100		*		1.064		1.048		.129		.123		.124
	MEAN VALUES						1.064		1.047		.129		.123		.124
146	7/1	0/0	12000		RECIRCULATE FLOW										
147	7/1	0/0	100		*		1.046		1.017		.128		.124		.121
148			100		*		1.040		1.019		.129		.123		.122
149			100		*		1.040		1.019		.129		.123		.122
150			100		*		1.041		1.018		.128		.123		.122
151			100		*		1.039		1.018		.129		.124		.122
152			100		*		1.037		1.019		.128		.124		.122
	MEAN VALUES						1.041		1.018		.129		.124		.122
153	7/1	0/0	1000		RECIRCULATE FLOW										
154	7/1	0/0	100		*		1.033		1.019		.129		.124		.121
155			100		*		1.031		1.019		.129		.124		.123
156			100		*		1.035		1.022		.129		.124		.121

E/I=exit/inlet pressure in psig; a=total fluid pumped,grams; b=fluid pumped/rev.,grams

* TUBE CONNECTION LEAK

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PERISTALTIC PUMP PERFORMANCE EVALUATION

REDUCED DATA

EQUIPMENT: HOLTER MODEL MC 721 PUMP - UNUSED SPARE TUBES INSTALLED. FLUID - WATER AT AMBIENT TEMPERATURE (75 ± 3°F). PUMP SPEED - 100 RPM.

Run No.	Date	E/I	Number pump rev.	Tube 1 a	Tube 1 b	Tube 2 a	Tube 2 b	Tube 3 a	Tube 3 b	Tube 4 a	Tube 4 b	Tube 5 a	Tube 5 b	Tube 6 a	Tube 6 b
157			100		*		1.033		1.023		.129		.124		.122
158			100		*		1.033		1.023		.129		.124		.122
	MEAN VALUES						1.033		1.021		.129		.124		.122
159	7/2	0/0	30000		RECIRCULATE FLOW										
160	7/2	0/0	100		*		1.052		1.035		.129		.121		.122
161			100		*		1.060		1.037		.130		.122		.123
162			100		*		1.059		1.034		.129		.121		.122
163			100		*		1.057		1.034		.130		.123		.122
164			100		*		1.054		1.033		.130		.121		.123
165			100		*		1.060		1.041		.129		.121		.122
166			100		*		1.059		1.040		.131		.121		.123
	MEAN VALUES						1.058		1.036		.130		.121		.122

E/I=exit/inlet pressure in psig; a=total fluid pumped,grams; b=fluid pumped/rev.,grams

* TUBE CONNECTION LEAK

GENERAL ELECTRIC
MISSILE AND SPACE DIVISION
PHILADELPHIA

PROGRAM INFORMATION REQUEST / RELEASE

PIR NO.	*CLASS. LTR.	OPERATION	PROGRAM	SEQUENCE NO.	REV. LTR.
	U	1128 1R62	1T7 71	01-002 124	

*USE "C" FOR CLASSIFIED AND "U" FOR UNCLASSIFIED

FROM	TO
G. L. Fogal	File

DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
7-16-71		Urine Sampling and Collection System	

SUBJECT

PERISTALTIC PUMP TEST RESULTS - SECOND INTERIM REPORT

INFORMATION REQUESTED/RELEASED

This second interim report summarizes the results of tests using the GE USVMS breadboard Peristaltic pump.

1.0 SUMMARY

Analysis of test data shows a change (reduction) in pumping capacity as a function of increase in number of pump revoltions. This change was approximately linear with number of pump revolutions and at 450,000 pump revolutions amounted to about a 7% and 4.5% reduction respectively for the large and small pump tubes.

2.0 DISCUSSION

2.1 Background

Previous tests using a Holter model MC721 commercial pump indicated a reduction in pumping capacity when comparing pre and post 71 hour endurance test data (see PIR U 1R62-71-123). Other data obtained as part of the same series of tests appeared to indicate that this reduction might occur primarily during the first few hours of operation. The GE USVMS breadboard model was selected to check this possibility.

2.2 Pump Description

The GE USVMS breadboard model peristaltic pump design is basically identical with the Biosatellite pump, see Figure 1, with an additional pump head added to accommodate a second (and larger) silastic pump tube, see Figure 2. The pump head design (configuration and dimensions) is essentially the same as for the halter model MC721 pump. Also, the large tubes are identical for both units.

It should be noted that the GE USVMS breadboard model pump had not been used for about 18 months prior to the current tests. The pump tubes were not replaced for the current tests.

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PAGE NO. 1 OF 10

✓ RETENTION REQUIREMENTS

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☐ 3 MOS.	☐ 6 MOS.
☐ 6 MOS.	☐ 12 MOS.
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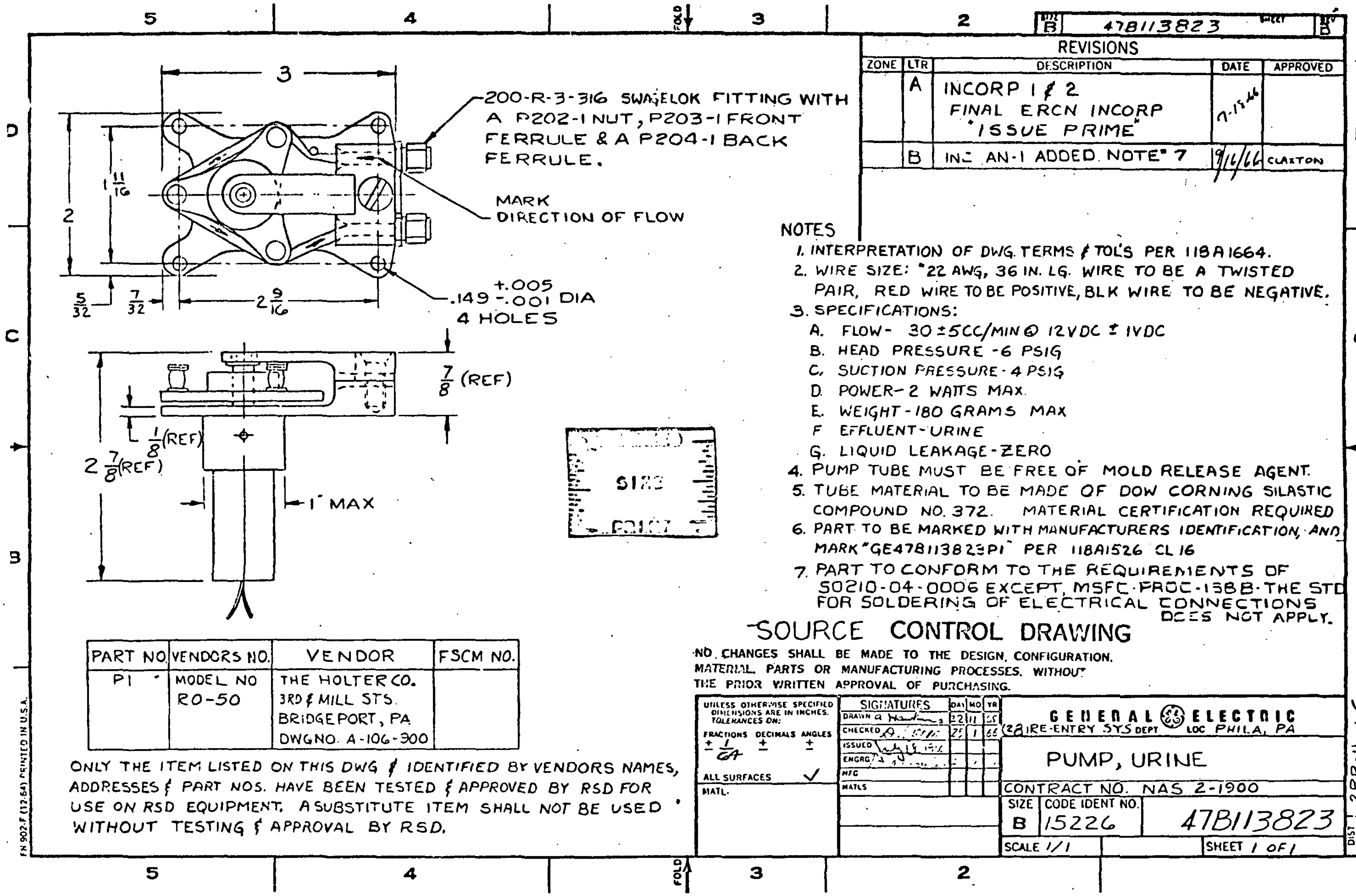

Figure 1. Urine Pump (47B113823)

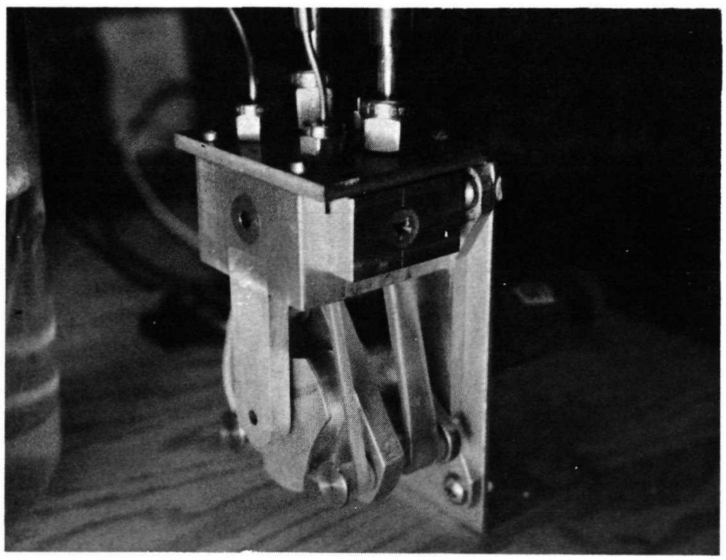

Figure 2. Pump Head Modified for Dual Tube Operation

2.3 Test Set-Up

Figures 3 and 4 illustrate the test set-up. All tests were run at zero inlet and exit pressures and only manual control was provided. The pump revolution switch provides 3 "counts" per pump revolution.

2.4 Test Results

The test consisted of continuous operation of the pump under zero inlet and exit pressure conditions. Periodically, operation was interrupted to check pumping capacity. Pump speed was set at a nominal 150 RPM (as planned) for the Urine Sampling and Collection System Engineering Model).

Figure 5 summarizes the test results. Corresponding reduced data are included as Appendix A. Note that the reduction in pumping capacity appears to be linear with an increase in number of pump revolutions. At 450,000 pumps revolutions (320,000 required for a 28 day SKYLAB mission), the pumping capacity reduction amounts to about 7% and 4.5% respectively in the large and small pump tube. Note also that the reduction for the small tube is considerably less (4.5% as compared to 14%) than that obtained using the halter model MC721 pump.

Table 1 shows that pumping predictability (for the short term) is within the limits required for the Urine Sampling and Collection System Application, less than ±1.5%. Thus, repeated calibrations of the system could be used to alleviate the long term changes noted above. Assuming a 1% change (in pumping capacity) between calibrations can be tolerated, on the order of six in-flight calibrations would be required for a 28 day SKYLAB mission.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The continuous change in pumping capacity would require in-flight recalibration approximately every 4 to 5 days. Although undesirable, this number does not appear to be excessive.

G. Fogal

/dml

TABLE 1 - PUMPING CAPACITY SHORT TERM REPEATABILITY

TEST RUNS	MEAN*		MAX. DEVIATION FROM MEAN	
	LARGE TUBE	SMALL TUBE	LARGE TUBE	SMALL TUBE
2 - 11	1.216	0.091	0.004	0.001
14 - 23	1.175	0.089	0.012	0.001
26 - 35	1.177	0.089	0.013	0.001
38 - 47	1.130	0.087	0.015	0.001
50 - 59	1.134	0.087	0.009	0.001

*Fluid pumped/pump revolution

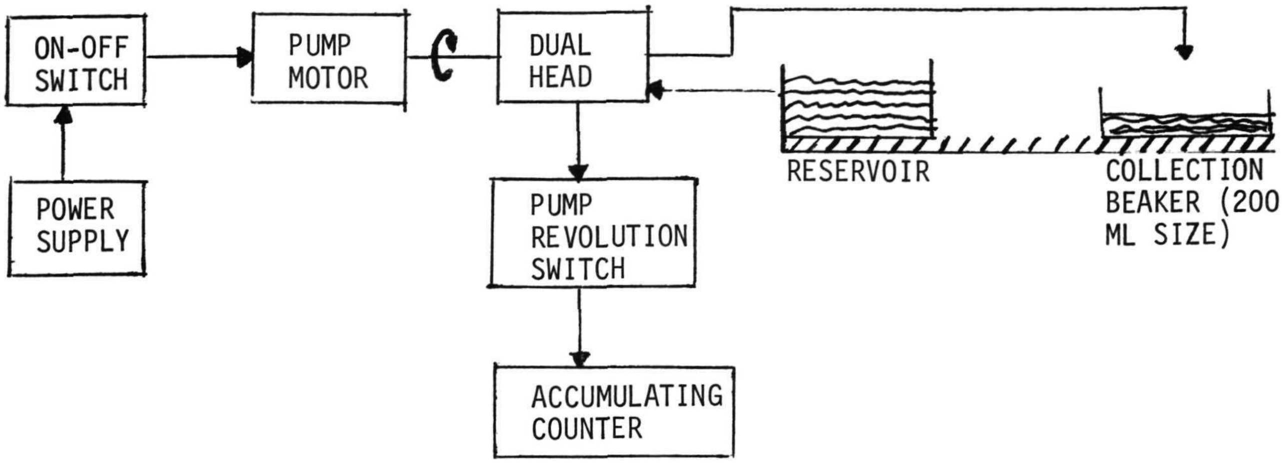

Figure 3. Test Set-up Block Diagram

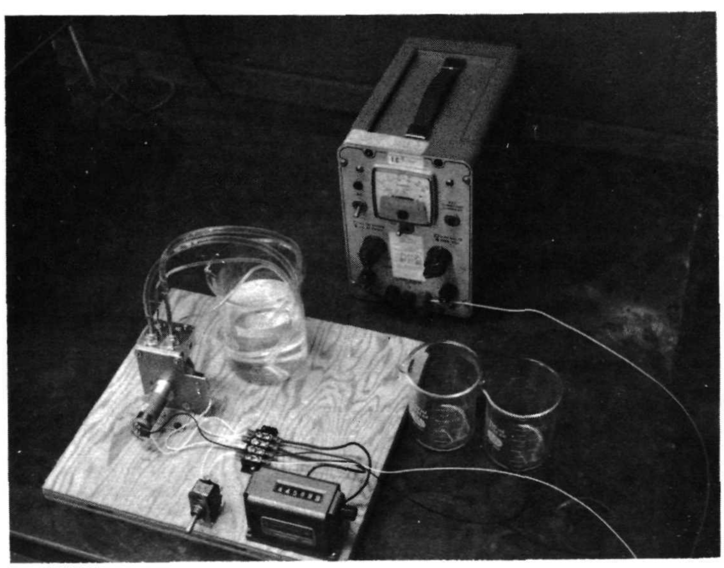

Figure 4. Photograph of Test Set-up

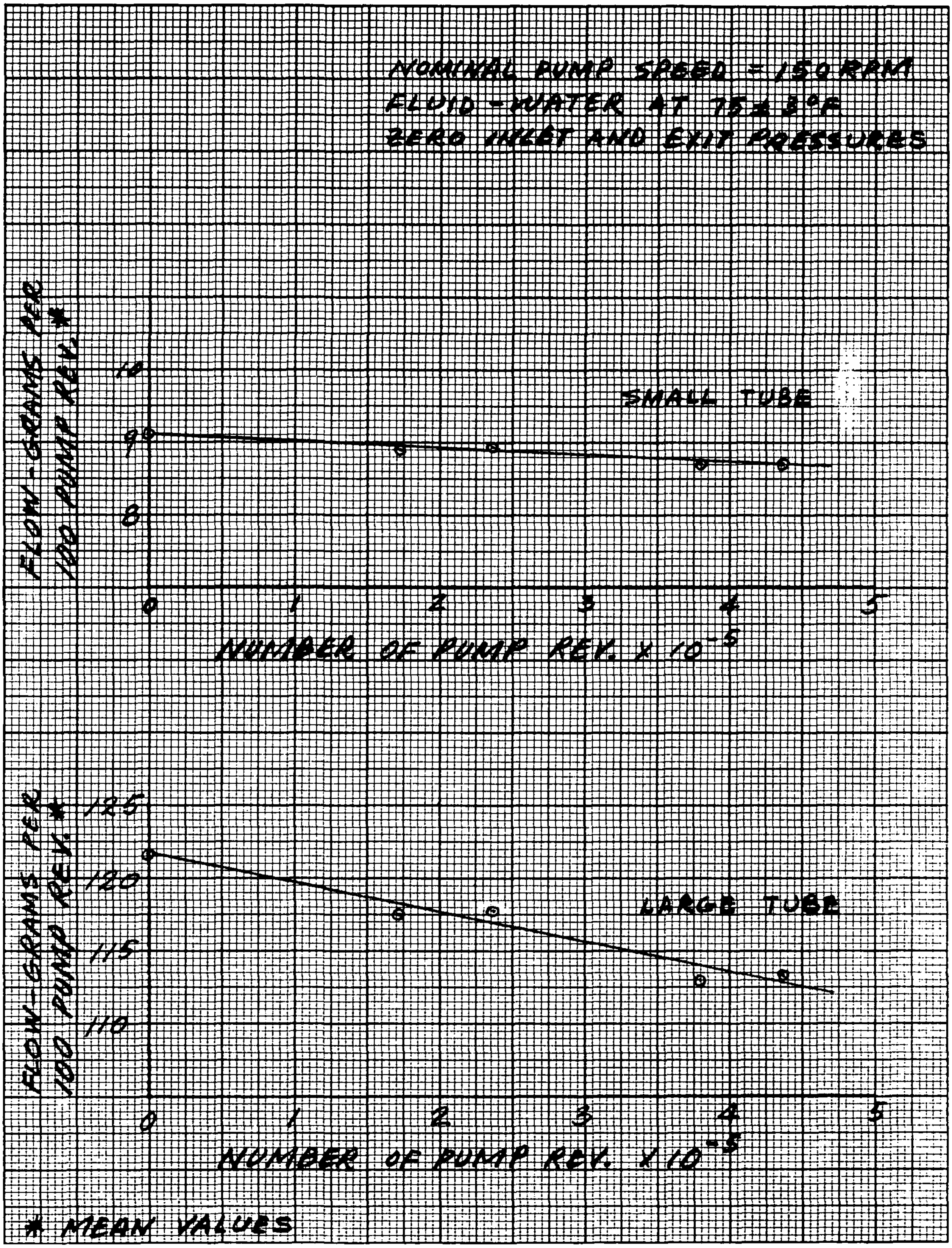

FIGURE 5 - EFFECT OF NUMBER OF PUMP REVOLUTIONS ON PUMPING CAPACITY

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PERISTALTIC PUMP PERFORMANCE EVALUATION

REDUCED DATA

EQUIPMENT: MODIFIED BIOSATELLITE PUMP FROM GE OSVMS BREADBOARD. FLUID - WATER AT AMBIENT TEMPERATURE (75 ± 3°F). NOMINAL PUMP SPEED - 150 RPM.

Run No.	Date	E/I	Number pump rev. X3	Tube 1 a	Tube 1 b	Tube 2 a	Tube 2 b	Tube 3 a	Tube 3 b	Tube 4 a	Tube 4 b	Tube 5 a	Tube 5 b	Tube 6 a	Tube 6 b
1	7/7	0/0	233	PUMP SPEED CHECK. SPEED = 155.3 RPM											
2	7/7	0/0	299			121.2	1.216			9.1	.091				
3			297			120.3	1.215			9.0	.091				
4			298			121.2	1.220			9.1	.092				
5			301			121.7	1.213			9.2	.092				
6			300			121.5	1.215			9.1	.091				
7			301			121.7	1.213			9.1	.091				
8			300			121.4	1.214			9.1	.091				
9			301			121.7	1.214			9.1	.091				
10			300			121.9	1.219			9.1	.091				
11			301			122.3	1.216			9.1	.091				
			MEAN VALUES				1.216				.091				
12	7/7	0/0	510051	RECIRCULATE FLOW											
13	7/8	0/0	224	30 SEC. PUMP SPEED CHECK. SPEED = 149.3 RPM											
14	7/8	0/0	300			117.1	1.171			8.9	.089				
15			300			118.7	1.187			9.0	.090				
16			300			117.7	1.177			8.8	.088				
17			299			117.4	1.178			8.8	.088				
18			301			118.1	1.177			8.9	.089				
19			301			117.4	1.170			8.8	.088				
20			298			116.3	1.171			8.8	.089				
21			302			117.6	1.168			8.9	.088				
22			298			116.5	1.173			8.8	.089				
23			301			117.7	1.173			8.9	.089				
			MEAN VALUES				1.175				.089				

E/I=exit/inlet pressure in psig; a=total fluid pumped,grams; b=fluid pumped/rev.,grams

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PERISTALTIC PUMP PERFORMANCE EVALUATION

REDUCED DATA

EQUIPMENT: MODIFIED BIOSATELLITE PUMP FROM GE USVMS BREADBOARD. FLUID – WATER AT AMBIENT TEMPERATURE (75 ± 3°F). NOMINAL PUMP SPEED – 150 RPM

Run No.	Date	E/I	Number pump rev. x3	Tube 1		Tube 2		Tube 3		Tube 4		Tube 5		Tube 6	
				a	b	a	b	a	b	a	b	a	b	a	b
24	7/8	0/0	192463			RECIRCULATE FLOW									
25	7/8	0/0	223		30 SEC. PUMP SPEED CHECK. SPEED = 148.7 RPM										
26	7/8	0/0	299			117.8	1.182			9.0	.090				
27			299			116.8	1.172			8.9	.089				
28			301			118.2	1.178			9.0	.090				
29			300			118.2	1.182			8.9	.089				
30			300			116.7	1.167			8.9	.089				
31			300			117.4	1.174			8.9	.089				
32			300			118.0	1.180			8.9	.089				
33			300			116.8	1.168			8.9	.089				
34			300			119.0	1.190			9.0	.090				
35			300			117.6	1.176			8.9	.089				
			MEAN VALUES				1.177				.089				
36	7/8	0/0	424037			RECIRCULATE FLOW									
37	7/9	0/0	219		30 SEC. PUMP SPEED CHECK. SPEED = 146.0 RPM										
38	7/9	0/0	302			114.2	1.134			8.9	.088				
39			299			114.1	1.145			8.8	.088				
40			299			113.7	1.141			8.8	.088				
41			299			112.8	1.131			8.7	.087				
42			302			112.5	1.118			8.8	.087				
43			300			113.0	1.130			8.8	.088				
44			300			112.6	1.126			8.7	.087				
45			301			112.7	1.123			8.8	.088				
46			300			112.2	1.122			8.6	.086				

E/I=exit/inlet pressure in psig; a=total fluid pumped, grams; b=fluid pumped/rev., grams

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PERISTALTIC PUMP PERFORMANCE EVALUATION

REDUCED DATA

EQUIPMENT: MODIFIED BIOSATELLITE PUMP FROM GE USVMS BREADBOARD. FLUID-WATER AT AMBIENT TEMPERATURE (75±3°F). NOMINAL PUMP SPEED - 150 RPM

Run No.	Date	E/I	Number pump rev.	Tube 1		Tube 2		Tube 3		Tube 4		Tube 5		Tube 6	
				a	b	a	b	a	b	a	b	a	b	a	b
47	7/9	0/0	299			112.3	1.127			8.7	.087				
			MEAN VALUES				1.130				.087				
48	7/9	0/0	169043			RECIRCULATE FLOW									
49	7/9	0/0	222	30 SEC. PUMP SPEED CHECK. SPEED = 148.0 RPM											
50	7/9	0/0	300			114.0	1.140			8.7	.087				
51			299			113.5	1.139			8.6	.086				
52			301			114.4	1.140			8.7	.087				
53			301			114.0	1.136			8.7	.087				
54			299			112.7	1.131			8.6	.086				
55			300			112.9	1.129			8.7	.087				
56			300			113.0	1.130			8.7	.087				
57			298			113.2	1.140			8.6	.087				
58			299			112.8	1.131			8.7	.087				
59			301			112.9	1.125			8.7	.087				
			MEAN VALUES				1.134				.087				
60	7/9	0/0	132209			RECIRCULATE FLOW - PUMP STOPPED AFTER ABOUT 5 HOURS DUE TO MOTOR/GEARBOX FAILURE.									

E/I=exit/inlet pressure in psig; a=total fluid pumped,grams; b=fluid pumped/rev.,grams

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PROGRAM INFORMATION REQUEST / RELEASE

PIR NO.	*CLASS. LTR.	OPERATION	PROGRAM	SEQUENCE NO.	REV. LTR.
	U	— 1R62	— 71	— 144	

*USE "C" FOR CLASSIFIED AND "U" FOR UNCLASSIFIED

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10/7/71		Urine Sampling and Collection System	

SUBJECT

Peristaltic Pump Tests Results - Third Report

INFORMATION REQUESTED/RELEASED

This third report summarizes the results of tests using "loaded" and "unloaded" pump tubes.

1.0 SUMMARY

Analysis of the test data show a reduction in pumping capacity for large diameter pump tubes as the number of pump revolutions is increased. This change is approximately linear with number of pump revolutions and at 250,000 pump revolutions amounted to about 7.5% for the "loaded" and 13.5% for the "unloaded" pump tubes. No significant reduction in pumping capacity was observed for either the loaded or unloaded small diameter pump tubes. Also the results only compare generally with past tests (of loaded tubes), the change in pumping capacity being greater for large tubes and less for the small tubes.

2.0 DISCUSSION

2.1 Background

Previous peristaltic pump test results are reported by PIR's 1R62-71-123 and 1R62-71-124. The former reports on tests using a Holter Model MC721 commercial pump. Test results indicated a reduction in pumping capacity when comparing pre and post endurance test data. Other data obtained as part of the same series of tests appeared to indicate that this reduction might occur primarily during the first few hours of operation. This possibility was checked by tests using the GE USVMS breadboard peristaltic pump (a flight type version of the commercial pump) as reported in the latter PIR. Results of these tests showed a nearly linear decrease in pumping capacity as a function of number of pump revolutions.

The Holter type peristaltic pump provides a pumping action by the linear stretching of a silastic tube over three equilaterally spaced, free turning rollers. This stretching action minimizes tube damage and thus increases operating life as compared to competitor designs wherein the plastic pump tube is squeezed by a roller against a fixed surface. As normally installed in the pump, the silastic pump tubes are in a stretched (i.e. "loaded") condition. The object of the test reported on herein is to determine the effect of reducing the stretch, i.e. "unloading" the pump tubes, during nonoperation periods.

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G. Fogal

PAGE NO. 1 OF 8

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2.2 Pump Description

A standard six tube Holter peristaltic pump head (identical to that used in PIR 1R62-71-123) was modified so that three of the six tubes could be automatically unloaded, i.e. amount of tube installed stretch reduced, during non-operating periods. Loading and unloading of the pump tubes is accomplished by a solenoid valve controlled air cylinder. The remaining three tubes were leftin the normally installed stretched condition at all times. Figure 1 illustrates this equipment. Each three tube bank consisted of two large and one small diameter tube, the small tube being in the center in both instances. Tube dimensions are shown in Figure 2. The reduction in length (stretch) of the unloaded tubes was about 20% (as compared to their loaded, i.e. operating condition).

2.3 Test Set-Up

The test set-up is the same as that used for the previously reported tests.

2.4 Test Results

The test consist of periodic operation of the pump under zero inlet and exit pressure conditions. The pump was operated continuously with the unloaded tubes placed in their loaded operating position over a 15 min. period five times every 24 hours starting at t = 0, 4, 8, 12, 16 hours and repeating at t = 24 hours. A total of about 250,000 pump revolutions were accumulated over a seven week test period. Water at room temperature was used as the test fluid. Pump speed was set at a nominal 155 rpm.

Figure 3 illustrates the test results. The reduction in pumping capacity for the large tubes is roughly linear with number of pump revolutions. Surprisingly the reduction was less for the loaded tubes than for the unloaded tubes (7.5% as compared to 13.5% at 250,000 pump revolutions. Equally surprising, no difference was found between the loaded and unloaded small tubes.

When comparing the "loaded" tube results only with previous data from previously reported tests, no clear pattern emerges, see Table I.

Table I

Reduction in Pumping Capacity for "Loaded" Tubes

Test Series	% Reduction at 250,000 Pump Revolutions	
	Large Tube	Small Tube
PIR 1R62-71-123	2.5*	7.0*
PIR 1R62-71-124	4.1	2.2
Current	13.5	0.0

*Estimated

Each data point shown on Figure 3 is the average of 10 separate tests wherein the pump was operated for 100 revolutions and the pump discharge weighed. Test data from each individual test is included in Appendix A.

3.0 Conclusions and Recommendations

Reducing the stretch (loading) in the pump tubes during non-operating periods does not appear to have a beneficial effect on reducing pump capacity degradation as the number of pump revolutions increases.

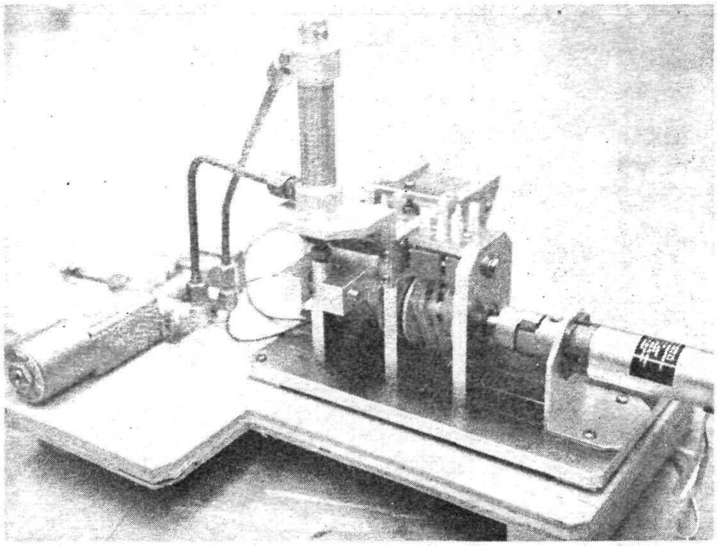


Figure 1 - Modified Holter 6 tube Pump Head with loading/
unloading mechanism and pump drive motor

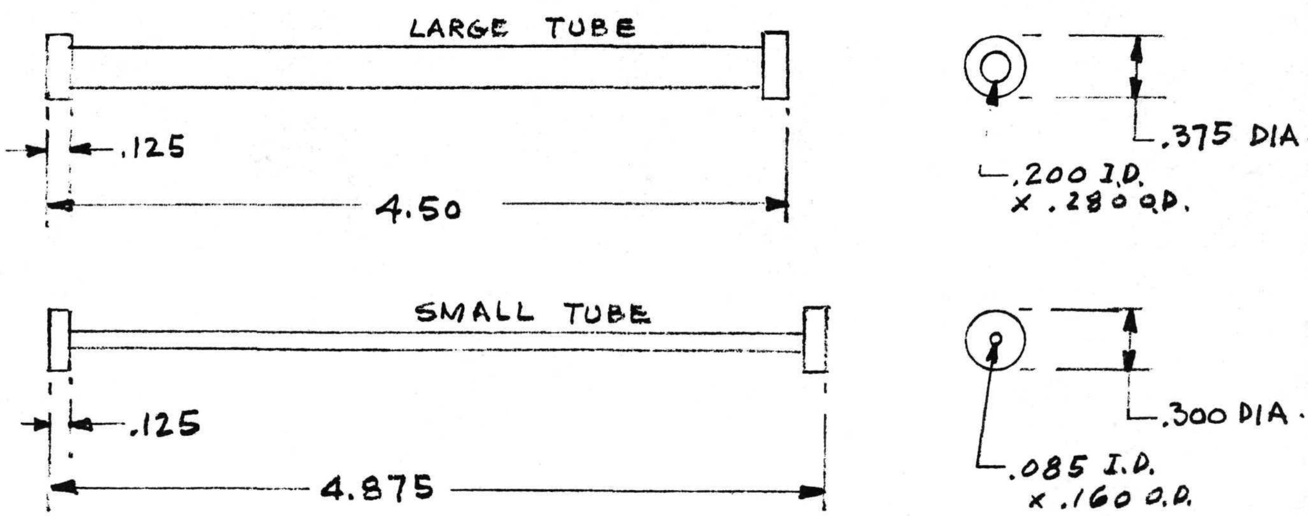
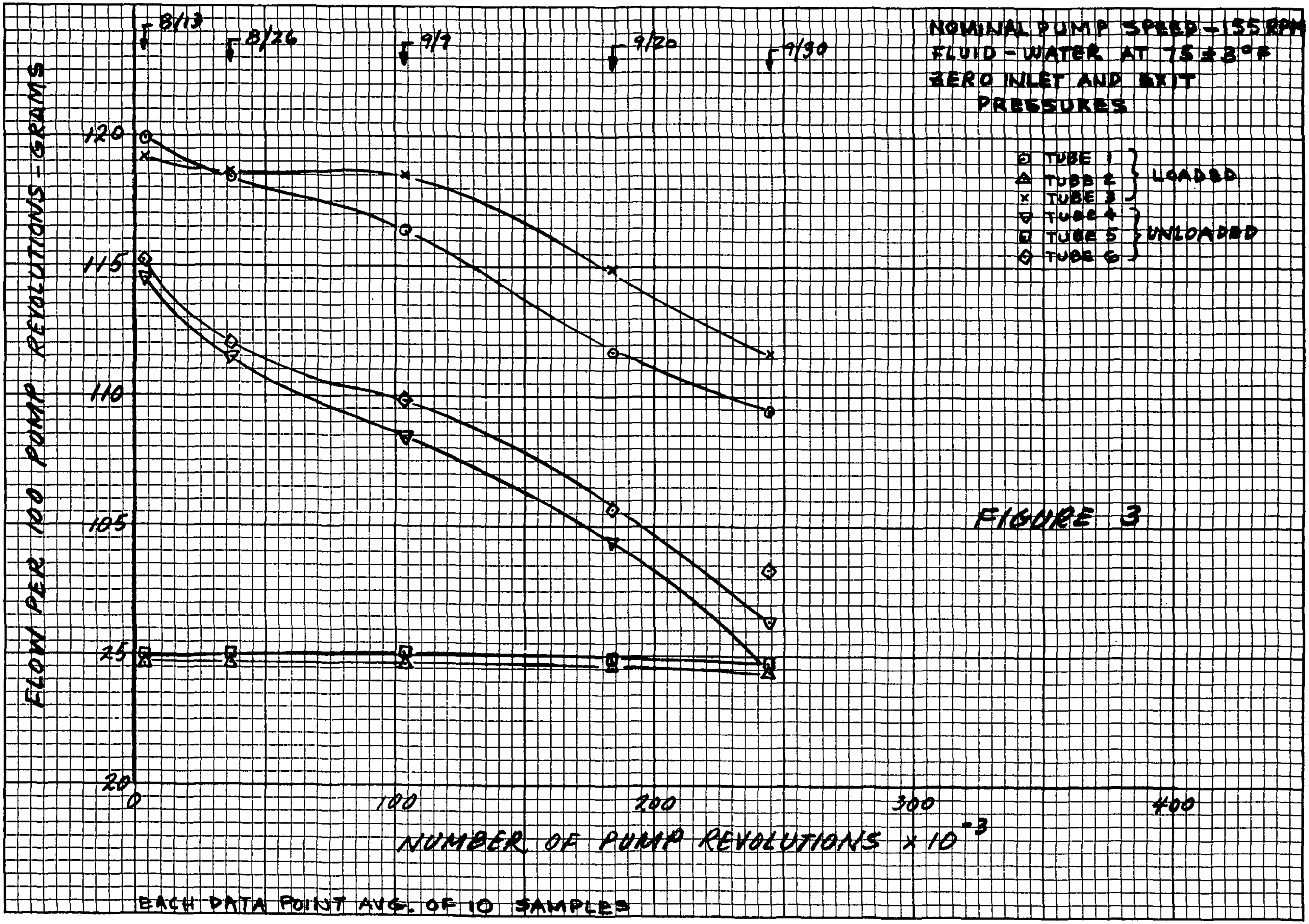


Figure 2 - Pump Tube Dimensions*

* STRETCHED LENGTH ≈ 5.875



NOMINAL PUMP SPEED - 155 RPM
FLUID - WATER AT 75 ± 3°F
ZERO INLET AND EXIT PRESSURES
TUBE 1
TUBE 2
TUBE 3
LOADED
TUBE 4
TUBE 5
TUBE 6
UNLOADED
8/13
8/26
9/9
9/20
9/30
FIGURE 3
FLOW PER 100 PUMP REVOLUTIONS - GRAMS
120
115
110
105
25
20
0
100
200
300
400
NUMBER OF PUMP REVOLUTIONS × 10^-3
EACH DATA POINT AVG. OF 10 SAMPLES

APPENDIX A

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PERISTALTIC PUMP PERFORMANCE EVALUATION

REDUCED DATA

EQUIPMENT: LOADED/UNLOADED TUBE TEST
TUBES 1,2,3 LOADED; 4,5,6 UNLOADED. PUMP SPEED=155 RPM; FLUID-WATER AT 75±3°F.

Run No.	Date	E/I	Number pump rev.	Tube 1		Tube 2		Tube 3		Tube 4		Tube 5		Tube 6	
				a	b	a	b	a	b	a	b	a	b	a	b
1	8/12	0	1500	CHECKOUT TESTING											
2	8/12	0	3040	AUTOMATIC CYCLING											
3	8/13	0	100	216.7		123.0		216.3		210.8		121.6		213.1	
4		0	100	216.4		123.0		216.2		210.8		121.6		213.0	
5		0	100	216.5		123.0		216.4		210.5		121.6		212.8	
6		0	100	216.7		123.0		216.5		211.2		121.6		212.5	
7		0	100	216.6		123.0		216.4		210.9		121.6		213.2	
8		0	100	216.8		123.0		216.6		210.7		121.6		213.3	
9		0	100	216.8		123.0		216.6		210.8		121.6		213.3	
10		0	100	216.6		123.0		216.4		211.1		121.6		213.4	
11		0	100	216.4		123.0		216.3		211.3		121.6		213.6	
12		0	100	216.3		123.0		216.3		210.8		121.6		213.1	
		AVG.		216.6		123.0		216.4		210.9		121.6		213.1	
AVG. LESS TARE				119.9	1.199	24.7	.247	119.1	1.191	114.5	1.145	25.0	.250	115.2	1.152
			5540	TOTAL ACCUMULATED PUMP REVOLUTIONS											
13	8/13	0	0	AUTOMATIC CYCLING											
	8/26		30450												
14	8/26	0	100	215.2		123.0		216.0		208.0		121.6		210.0	
15		0	100	215.1		123.0		216.0		207.7		121.6		209.7	
16		0	100	215.2		123.0		215.8		208.0		121.6		209.9	
17		0	100	215.0		123.0		216.0		207.9		121.6		209.8	
18		0	100	215.2		123.0		215.9		208.0		121.5		209.9	
19		0	100	215.1		123.0		215.8		208.0		121.6		209.9	
20		0	100	215.1		123.0		215.8		208.0		121.6		209.8	
21		0	100	215.0		123.0		215.7		208.0		121.5		210.0	

E/I=exit/inlet pressure in psig; a=total fluid pumped,grams; b=fluid pumped/rev.,grams

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PERISTALTIC PUMP PERFORMANCE EVALUATION

REDUCED DATA

EQUIPMENT: LOADED/UNLOADED TUBE TEST
TUBES 1, 2, 3 LOADED; 4, 5, 6 UNLOADED. PUMP SPEED = 155 RPM; FLUID-WATER AT 75 ± 3 °F.

Run No.	Date	E/I	Number pump rev.	Tube 1		Tube 2		Tube 3		Tube 4		Tube 5		Tube 6	
				a	b	a	b	a	b	a	b	a	b	a	b
22	8/26	0	100	215.0		123.0		215.7		208.0		121.6		209.9	
23		0	100	215.0		123.0		215.7		207.8		121.5		209.7	
			AVG.	215.1		123.0		215.9		207.9		121.6		209.9	
AVG. LESS TARE				118.4	1.184	24.7	.247	118.6	1.186	111.5	1.115	25.0	.250	112.0	1.120
			36990	TOTAL ACCUMULATED PUMP REVOLUTIONS											
24	8/26	0	0	AUTOMATIC CYCLING											
	9/7		67120												
25	9/7	0	100	212.9		123.0		216.0		205.2		124.5		206.7	
26		0	100	213.1		123.0		215.9		205.2		124.6		206.7	
27		0	100	212.9		123.0		215.9		204.9		124.6		206.6	
28		0	100	212.9		123.0		215.9		205.0		124.6		206.6	
29		0	100	213.0		123.0		215.8		204.8		124.6		206.6	
30		0	100	213.0		123.0		215.8		204.8		124.6		206.6	
31		0	100	213.0		123.0		215.7		204.7		124.6		206.7	
32		0	100	213.2		123.0		215.7		204.5		124.6		206.8	
33		0	100	213.2		123.0		215.7		204.4		124.6		206.8	
34		0	100	213.3		123.0		215.7		204.5		124.6		207.0	
			AVG.	213.0		123.0		215.8		204.8		124.6		207.7	
AVG. LESS TARE				116.3	1.163	24.7	.247	118.5	1.185	108.4	1.084	25.1	.251	109.8	1.098
			105110	TOTAL ACCUMULATED PUMP REVOLUTIONS											
35	9/7	0	0	AUTOMATIC CYCLING											
	9/20		77450												
36	9/20	0	100	208.4		122.8		212.2		201.1		124.4		203.7	
37		0	100	208.2		122.7		212.0		200.9		124.4		203.5	

E/I=exit/inlet pressure in psig; a=total fluid pumped,grams; b=fluid pumped/rev.,grams

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PERISTALTIC PUMP PERFORMANCE EVALUATION

REDUCED DATA

EQUIPMENT: LOAD/UNLOADED TUBE TEST
TUBES 1, 2, 3 LOADED; 4, 5, 6 UNLOADED. PUMP SPEED = 155 RPM; FLUID - WATER AT 75±3°F

Run No.	Date	E/I	Number pump rev.	Tube 1		Tube 2		Tube 3		Tube 4		Tube 5		Tube 6	
				a	b	a	b	a	b	a	b	a	b	a	b
38	9/20	0	100	208.4		122.8		212.2		200.8		124.4		203.5	
39		0	100	208.2		122.8		212.1		200.7		124.3		203.6	
40		0	100	208.3		122.8		212.1		200.8		124.3		203.5	
41		0	100	208.4		122.8		212.2		200.8		124.4		203.7	
42		0	100	208.5		122.8		212.3		200.8		124.3		203.6	
43		0	100	208.5		122.8		212.2		200.7		124.3		203.6	
44		0	100	208.4		122.8		212.1		200.5		124.3		203.6	
45		0	100	208.3		122.8		212.1		200.5		124.3		203.5	
			AVG.	208.4		122.8		212.2		200.7		124.3		203.6	
	AVG. LESS TARE			111.7	1.117	24.5	.245	114.9	1.149	104.3	1.043	24.7	.247	105.7	1.057
			183560	TOTAL ACCUMULATED PUMP REVOLUTIONS											
46	9/20	0	0	AUTOMATIC CYCLING											
	9/30		60120												
47	9/30	0	100	205.8		122.7		208.5		198.0		121.3		201.6	
48		0	100	206.2		122.7		209.0		197.8		121.3		201.5	
49		0	100	206.1		122.7		209.0		197.8		121.3		201.3	
50		0	100	206.1		122.7		209.1		197.8		121.3		201.2	
51		0	100	206.1		122.7		209.0		197.8		121.3		201.1	
52		0	100	206.1		122.6		209.0		197.7		121.3		201.0	
53		0	100	206.2		122.7		209.0		197.6		121.3		201.2	
54		0	100	206.0		122.7		209.0		197.6		121.3		201.1	
55		0	100	206.0		122.7		209.0		197.5		121.3		201.2	
56		0	100	205.8		122.7		209.0		197.5		121.3		201.0	
			AVG.	206.0		122.7		209.0		197.7		121.3		201.2	
	AVG. LESS TARE			109.3	1.093	24.4	.244	111.7	1.117	101.3	1.013	24.7	.247	103.3	1.033
			244680	TOTAL ACCUMULATED PUMP REVOLUTIONS											

E/I=exit/inlet pressure in psig; a=total fluid pumped, grams; b=fluid pumped/rev., grams

7.3 PUMP/ACCUMULATOR TEST RESULTS

Appendix 7.2 reports on results of the Peristaltic Pump Tests and notes that because of the potential problems associated with using the dual tube peristaltic pump as the volume measuring element for the system, a precision accumulator was added to accomplish this function. The accumulator also provides the desired 80/20 sample split.

As a key element, tests on the pump/accumulator assembly were conducted to verify its performance. Test details and results analyses are included in GE PIR 1R62-71-150, attached.

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PIR NO.	*CLASS. LTR.	OPERATION	PROGRAM	SEQUENCE NO.	REV. LTR.
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FROM
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Room #U-2612, VFSC Extension - 5499

TO
Distribution

DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
11-1-71		IMBLMS - USCS	

SUBJECT

TEST REPORT

INFORMATION REQUESTED/RELEASED

ATTACHED IS THE TEST REPORT FOR THE DUAL PUMP AND ACCUMULATOR ASSEMBLY FOR THE URINE SAMPLING AND COLLECTION SYSTEM.

THE TESTS WERE PERFORMED IN THE LIFE SYSTEM LAB, ROOM #M-4215, BETWEEN SEPTEMBER 3RD AND OCTOBER 1ST 1971.

cc: R. W. Murray
A. Little (5 copies)
C. Reinhardt
F. S. DiSanto
G. L. Fogal
F. P. Rudek

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TEST REPORT

1.0 SUMMARY

The dual accumulator and pump assembly for the Urine Sampling and Collection System were tested during an accelerated life test of 18,711 cycles at a flow rate of 25 cc/cycle and an extended life test of 28 days at minimum average of flow of 6000 cc's per day.

Urine was used as the circulating medium.

The test results indicate the two components meet and exceed all the system requirements.

The 28 days extended life test included the initial time accumulated during the accelerated life.

2.0 PURPOSE OF TEST

The tests were conducted to verify that the pump-dual accumulator assembly meets the system requirements as revised in Paragraph 3.1.1.2.3.5 of the model requirement specification, i.e.:

2.1 Volume discharge of 25 cc's/stroke divided in two channels of 20 cc's and 5 cc's each.

2.2 Discharge pressure of 2 psig.

2.3 Volume Measurement Increment signal for at least .5 cc volume.

2.4 Volumetric discharge accuracy of ± 1% or better for the assembly.

2.5 Assembly performance to be maintained for at least a 4 weeks period.

3.0 DESCRIPTION OF TEST HARDWARE

The basic test hardware is illustrated in Figure 1 & 2. It consisted of:

3.1 The Dual Roller Pump. This unit is basically the same as that used in the previous USVMS unit except some minor design changes to simplify the tube installation and the rotor design. Also, the small tube was changed to accomodate the new 4:1 pumping ratio (was 10:1) and the motor was changed to an "off the shelf" Globe unit, due to schedule limitations. See Figure 1.

3.2 The Dual Accumulator. The design of this unit is based on the Biosatellite 10 cc's accumulator. The Biosatellite unit consisted of an accumulation chamber with a rolling diaphragm (Bellofram) attached to a moving piston-shaft assembly. Discharge pressure was provided by a set of Negator springs attached at the end of the shaft. Length of travel (& metering accuracy) was controlled by a set of switches designed as an integral part of the housing and shaft assembly.

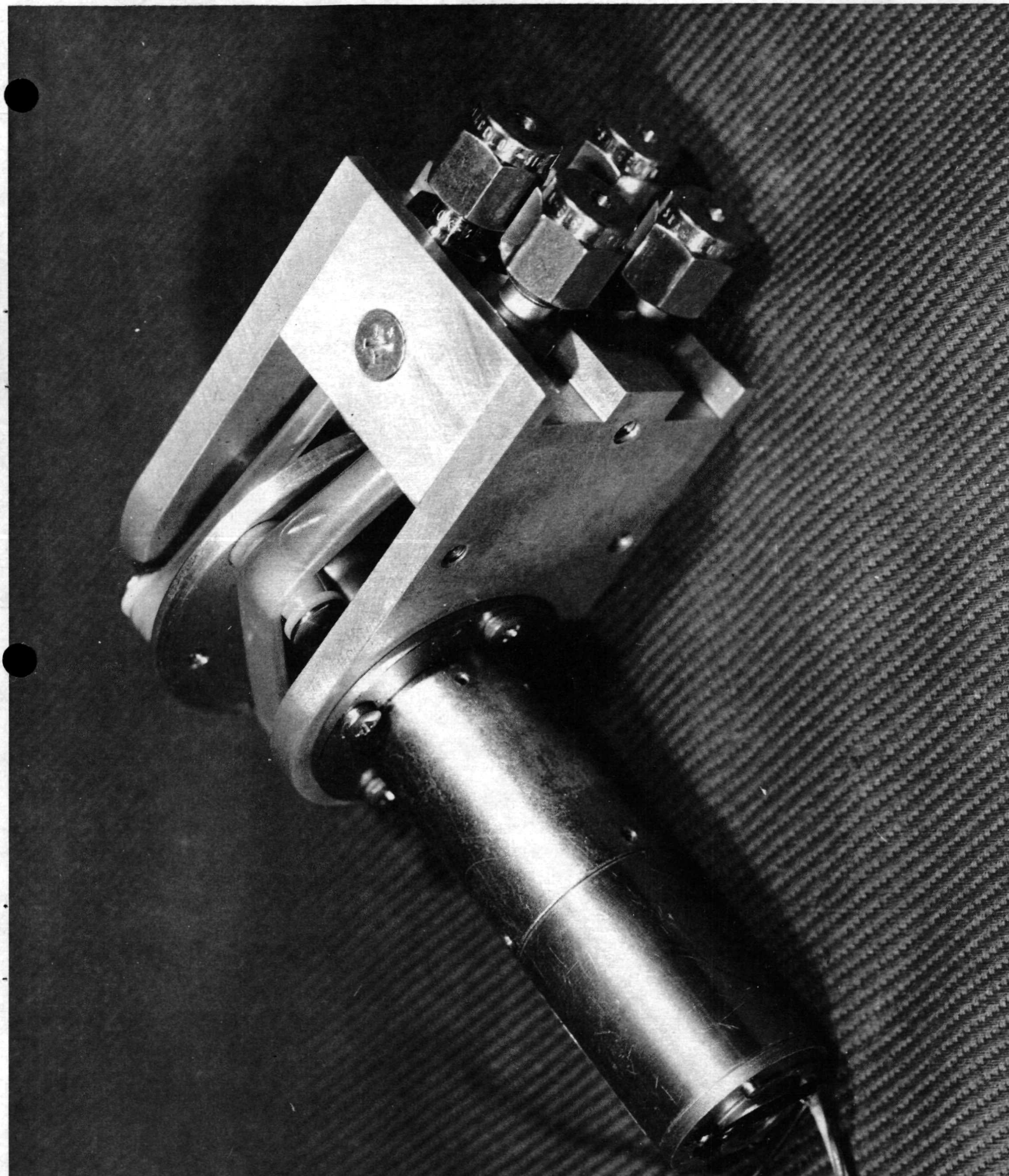


FIGURE 1. ROLLER PUMP

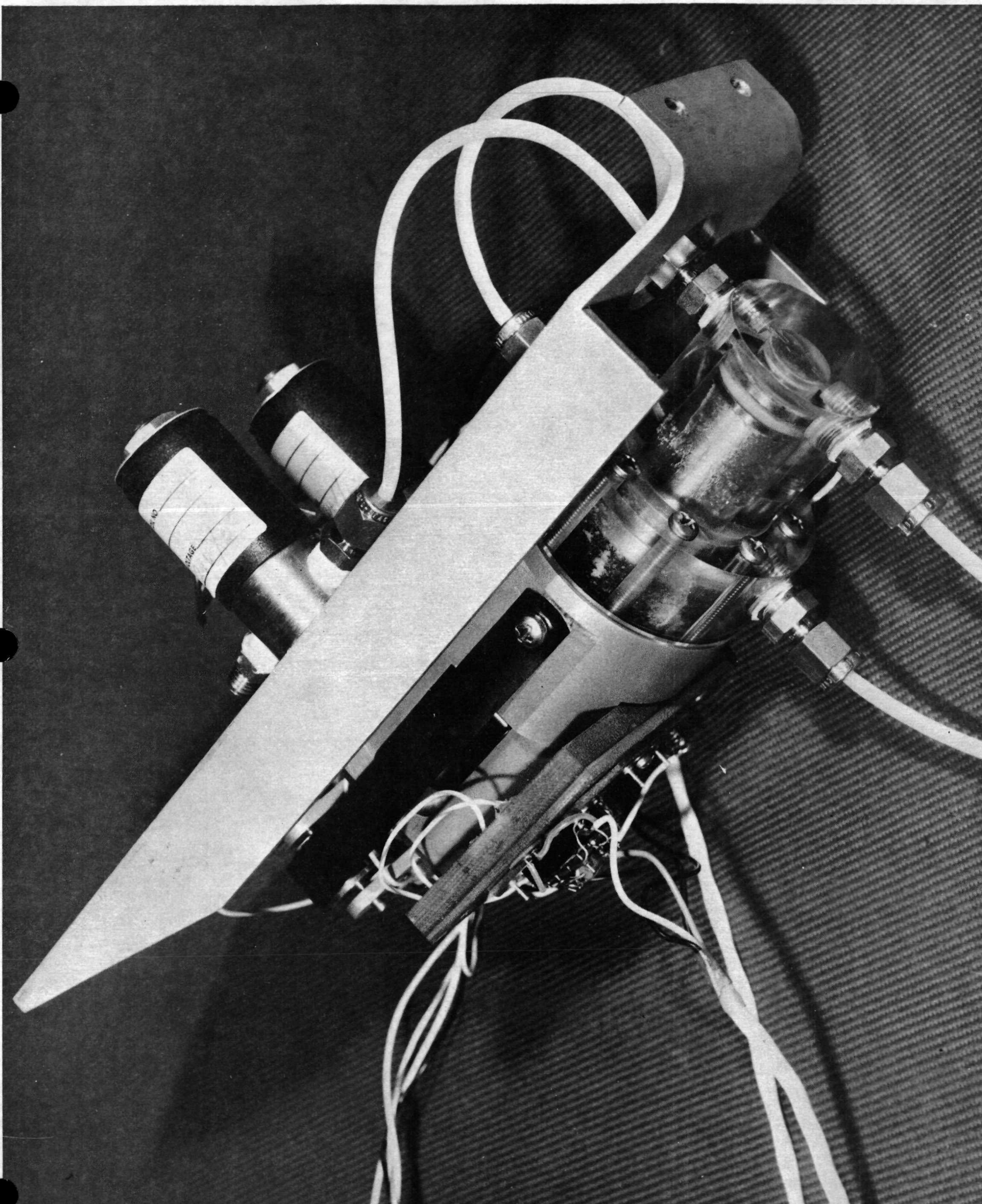


FIGURE 2. ACCUMULATOR ASSEMBLY WITH DISCHARGE VALVES

3.2 The Dual Accumulator (Continued)

The two significant changes in the USCS design are:

The splitting of the single chamber into two separate delivery chambers with a fixed nominal ratio of 4:1. The piston for the small chamber (5 cc's volume) is an integral part of the piston for the large chamber (20 cc's volume). The two chambers are separated by an "O" ring. The extension of the Bellofram piston into the added chamber adds to the mechanical balance of the system and provides a smoother performance than that obtained with the single chamber Biosatellite unit.

The addition of an incremental volume metering signal device. Because of the need to record a partial filling of the accumulator volume an IR emitter and sensor have been added to the accumulator. The emitter is masked by a disk with a series of small apertures which allow the signal to be received in pulses by the sensor as the disk is rotated by linear motion of the shaft. The spacing of the holes (apertures) on the disk allows to detect volumetric increments of about 0.36 cc/pulse.

The dual accumulator with the sensor housing and the discharge valves is additionally illustrated in Figure 2.

3.3 Two Solenoid Discharge Valves, Part No. B2DA1026, manufactured by the Skinner Valve Company, New Britain, Conn.

4.0 DESCRIPTION OF TEST SET UP

The accumulator and the valves were installed and interconnected on the bracket required for the next assembly. The pump was also installed on its next assembly bracket.

Both accumulator and pump brackets were bolted together and attached to a test stand as shown in Figure 3.

A latching relay and a terminal board required for the normal operation of the system were attached to the accumulator bracket.

The inlet to the pump and the outlet from the valves were routed to a common reservoir for recirculation. The reservoir was made from a 2.00 inch I.D. Plexiglas tube sealed at the bottom with a Plexiglas disk and at the top with a rubber stopper with four holes for the teflon tubes used for the outer connections.

5.0 DESCRIPTION OF TEST

The test was divided in two phases.

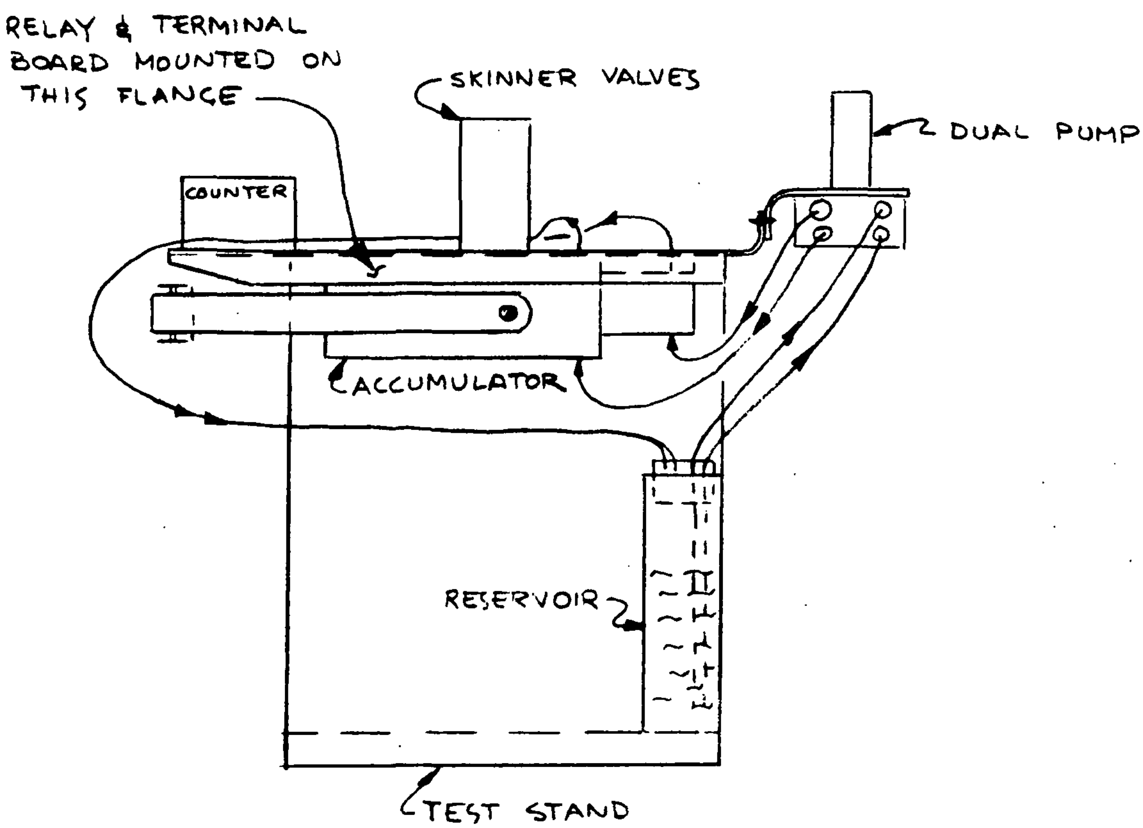


FIGURE 3 - TEST SETUP

5.0 DESCRIPTION OF TEST (Continued)

The first phase was an accelerated life test where the unit was operated over a four days' period for a number of cycles in excess of the requirements for a 28 days, 3 men mission.

Since the discharge volume of the accumulator in 25 cc's the minimum number of cycles is:

$$\frac{28 \text{ days} \times 2000 \text{ cc's/man-day} \times 3 \text{ men}}{25 \text{ cc's/cycles}} = 6{,}720 \text{ cycles}$$

During this phase the actual number of cycles accumulated by intermittent operation was 18,711 or nearly 2.8 times the minimum requirement.

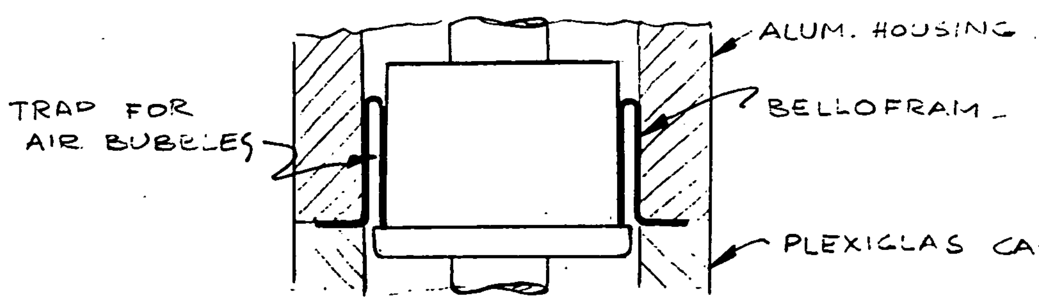
The second phase was an extended life test where the unit was operated daily for a number of cycles equivalent to the pumping required to circulate an average 6,000 cc's or the output of a three men team. Due to time limitation the required 28 days test included the days spent during the accelerated test. This was perfectly valid since no internal changes or disturbances were made to the system in the transition from the accelerated to the extended life test.

5.1 ACCELERATED LIFE TEST DESCRIPTION

Several calibration runs were made to check the volume and discharge pressure before starting the actual test.

The calibration for volume was done by operating the system as an open loop and letting the two accumulator chambers discharge into separate beakers. To minimize errors each run consisted of ten discharge cycles. The collected volume was then weighted on a gram scale. The weight of the two beakers used for the collection of the effluent was corrected (by adding a small weight) and rechecked for every measurement at 50 gm and 100 gm respectively for the collection from the small and large chamber.

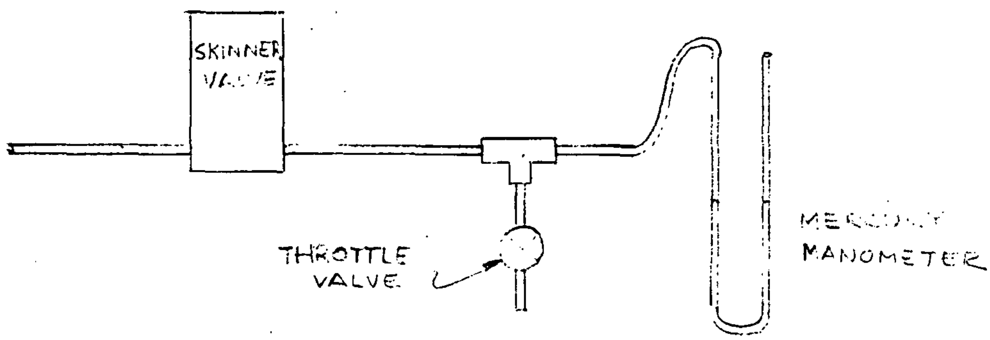
The calibration run were made with the accumulator in the same position as installed. The orientation of the unit is significant in one "g" operation because of entrapment of air bubbles mostly in the Bellofram fold if the unit were to be installed in a vertical position with the Bellofram up.



5.1 ACCELERATED LIFE TEST DESCRIPTION (Continued)

To answer the question as to what would happen in zero "g" if the air were to remain trapped, some calibration runs were made in that configuration. This is nearly impossible since liquid would definitely fill the Bellofram fold because of minimum surface configuration. The test was made to cover an extreme possibility.

The test to calibrate discharge pressure was performed by connecting the discharge line to a mercury manometer through a tee as shown below:



It must be noted that the discharge pressure capability changes as a function of the return stroke. Neither the internal friction or the Negator spring force is really constant. In particular the Negator spring roll-out force is greater than the roll-in so that more pressure is required to fill the accumulator than it can be delivered even if the piston friction is neglected. This means that the presure at the end of the return stroke is always lower than at the beginning of the discharge cycle.

The pressure at the end of the stroke was obtained by letting the fluid escape slowly through the valve shown above and then actually shut off the flow when the piston was as close to the end of the stroke as possible without making electrical contact to start the new cycle.

After the calibration run the water was pumped out of the system and replaced with urine. The system run intermittently for periods of several hours. The urine was changed every day. When a total of approximately 18,000 cycles were accumulated the test was stopped. The urine was pumped out and the reservoir was refilled with water. The calibration runs for both pressure and volume as described above were repeated and recorded.

5.2 EXTENDED LIFE TEST DESCRIPTION

The extended life test was basically the same as the accelerated test except that the number of cycles per day was limited to an average 240 equivalent to a flow of approximately 6,000 cc's of urine. Calibration runs were made before and after the test as described in the previous section. This test was a continuation of the accelerated test. There was no real interruption other than flowing a limited amount of water for calibration. The only change made was the replacement of the Negator springs. This external change was necessitated by a visible crack on the surface of each spring. The springs used were standard units from a spring assortment kit and are only rated for a minimum of 3,000 cycles. Higher rated springs could not be obtained at the time due to schedule limitation. However, based on the evidence of the first set of springs, the springs presently being used should be more than adequate to last over the approximately 7,000 cycles required for a mission. However, it should be pointed out that the springs are easy to replace and the drums that hold them are large enough to take the special units for longer life.

6.0 TEST RESULTS

The test results will be described according to the list of requirements outlined in Paragraph 2.

6.1 DISCHARGE VOLUME

The total discharge volume required from both chambers was set at 25 cc's stroke.

The measured discharge is 25.3 cc's, see tables 1 & 2. This volume can be slightly increased or decreased to any desired value by resetting the "FULL" contact in the back of the accumulator.

The two channel discharge ratio of 4/1 or 20 cc's and 5 cc's for each chamber respectively was checked to be at:

$\frac{202.5}{50.5} = \frac{4.01}{1}$ At the start of the test.

$\frac{203.3}{49.9} = \frac{4.07}{1}$ At the end of the test.

6.2 DISCHARGE PRESSURE

All the measurements on discharge pressure both at the beginning and the end of the test exceed the 2 psig minimum required. The lowest discharge pressure, recorded at the end of the extended life test, was 2.45 psig.

6.3 VOLUMETRIC DISCHARGE SIGNAL

The performance evaluation of this particular requirement is part of the electrical control. The tests, run in conjunction with the electrical system indicated a total of 69 signals per 25 cc's volume or approximately .362 cc, much smaller than the minimum .50 cc required.

6.4 VOLUME DISCHARGE ACCURACY

All the volumetric measurement readings taken during the test fall within the $\pm$ 1% requirement. Disregarding the trapped air configuration readings which were taken just to give an indication of the possible effect of an unlikely condition, all the reading before, during and after the entire test are well within the $\pm$ 1%.

The highest and the lowest volume discharge reading recorded and shown in either Table 1 or Table 2 are 253.7 and 252.75 cc's or a maximum error span of $\pm$ .45 cc from an average value of 253.2 cc/10 strokes. The measured accuracy is then:

$$\frac{\pm .45}{253.2} \times 100\% = \pm 0.17\%$$

Even if we take into account the forced trapped air configuration the maximum variation would be $\pm$ 1.075 cc's (254.9 cc's highest, 252.75 cc's lowest) over an average 253.82 cc's or:

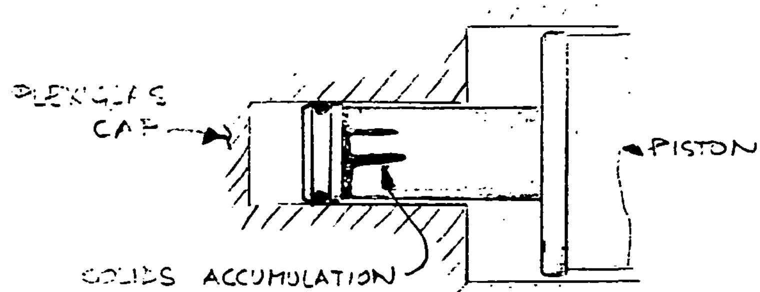
$$\frac{\pm 1.075}{253.82} \times 100\% = 0.42\%$$

6.5 MAINTENANCE OF PERFORMANCE

The unit was operated successfully over an initial accelerated life test spanning a six days period meeting all the system requirements before and after the tests. During this time the total number of cycles accumulated was 18,711. The total amount of urine pumped through the system was approximately 470,000 cc's or the equivalent output of a 3 men, 78 days mission. As noted before, the only incipient failure noted at the end of this portion of the test was related to the Negator springs which had been used much beyond their rated life. The piston remained relatively clean. Whatever solids tended to settle at the bottom of either chamber in between operating cycles, were immediately flushed at the beginning of the next cycle.

The operation during the next phase, i.e. the extended life test, was also faultless.

At the end of the 28th day the total number of cycles was 25,834. Every component of the system had remained in good operating conditions. The only evidence of permanent accumulation of solids was on the surface of the small stainless steel piston shaft. This accumulation had formed early during the test and remained mostly unchanged.



6.5 MAINTENANCE OF PERFORMANCE (Continued)

The only indication of general relative degradation of the system could be observed by monitoring the time required for each pumping and discharge cycle.

At the beginning of the test, when everything was clean and new, the total time for a fill and discharge cycle was approximately 10 seconds or 2.5 seconds discharge time and approximately 7.5 seconds pumping time to fill the accumulator.

Seven days later at the beginning of the extended life test the above times had increased to 2.7 and 8.7 seconds respectively for a total of 11.4 seconds.

At the end of the test the times had increased to 3.2 and 10.4 seconds respectively for a total 13.6 seconds for a complete cycle.

A second indication of degradation was in the appearance of the pump tubes which did show wear. The evidence of wear was much more noticeable on the surface of the large tube. Also the odor of urine became noticeable toward the end of the test. The odor permeated through the silastic material of the tube and could be detected only on close "sniffing" inspection no more than a foot away from the pump tubes.

7.0 DISCUSSION & CONCLUSION

The test results described in the previous section have been summarized in Table 3.

As can be seen all the requirements have been met and exceeded.

The data further substantiates the performance of units of similar configuration used on the Biosatellite system which over period of several years never experienced any failure. The USCS pump-accumulator-valve system is relatively more complex than the Biosatellite equivalent because of the dual pump - dual accumulator arrangement and the addition of the rack and pinion to drive the mask for the volume sensing device. However, except for the addition of the latter, all the design changes have been implemented in such a manner as to improve and simplify the old configuration even though the performance requirements have been increased (e.g. two chamber vs one). The additional piston for the small pumping chamber has been used as a second bearing and alignment surface thus minimizing friction in the Bellofram and shaft bushing. It also minimizes the need to balance the spring force on the piston shaft so that two instead of three springs could be used. The improvement is evidenced in the small difference between maximum and minimum discharge pressure. In the Biosatellite units these pressures averaged between 5.00 and 2.75 psig respectively. The highest pressure recorded in our case is 3.83 psig. This becomes much more significant when considering that the travel (or discharge volume) for the USCS unit is 2.5 times greater.

In reference to the discharge accuracy, it is felt that the percent variation is even smaller than that shown on Table 3. It is to be noted that the maximum and minimum readings were recorded both at the end of the test when difficulty was encountered with the Metler scale. The repeatability of the readings between the Metler and the Tripple beam scale used as a substitute was not as good.

There are two slightly puzzling items that need to be commented upon:

1. Why the exact shift in pumping ratio so that the increase in one chamber equals the decrease in the other?

2. Why the increase in pumping volume when one would really expect a decrease if there is to be any change at all?

The answer to the first question can be found in either internal leakage or the slifting of the "O" ring in its groove, or both. The shifting of, the "O" ring can be caused by the initial unbalance of the flow rate from the pump. The small pump tube (rated at 1/3 flow of the big tube) wants to pump more than the accumulator small chamber can take (regulated by the fixed 4:1 ratio). This causes a pressure unbalance which is reversed on the return stroke of the accumulator. This unbalance effectively shifts the "O" ring and consequently changes the relative volume of the nominal 4:1 chambers. Eventually the flow from the tubes adjusts itself to the capability of the accumulator and the pressure unbalance ceases.

Since the volume changes in question are so small and since the effect is inconsequential to the performance of the system, any further discussion on that would be strictly academic.

The answer to the question of apparent increase, although of microscopic size, may be found in the fact that the initial calibration is done with clean, distilled water in a clean system. In the subsequent calibrations, even though the input was distilled water, the effluent had picked up some of the solids accumulated on the internal walls of the system. In fact flakes of material could be seen swirling in the accumulator chambers during the several calibration tests.

In conclusion the above described tests have fully demonstrated the performance of the dual accumulator. Its addition to the Urine Sampling and Collection System primarily as a fine volume metering device should greatly enhance the capability of the system. This addition, should it be no longer required at a later date, can be easily bypassed by simply letting the two discharge valves operate in a normally open mode while retaining the capability of fine, accurate volume calibration.

TABLE 1
ACCELERATED LIFE TEST RESULTS

1. Calibration of discharge volume before test*

a. Using normal one "g" configuration

RUN #	SMALL CHAMBER	LARGE CHAMBER	TOTAL
1	50.5	202.5	253
2	50.5	202.5	253
3	50.5	202.5	253

b. Using trapped air configuration

RUN #	SMALL CHAMBER	LARGE CHAMBER	TOTAL
1	50.7	204.2	254.9
2	50.5	204.0	254.5
3	50.5	204.0	254.5

c. Returning to normal configuration

RUN #	SMALL CHAMBER	LARGE CHAMBER	TOTAL
1	50.5	202.5	252.9
2	50.4	202.4	252.8
3	50.5	202.6	253.0
4	50.4	202.5	253.0

2. Calibration of discharge pressure before test

At beginning of discharge stroke P= 7.8" Hg (= 3.83 psi) maximum

At end of discharge stroke P= 5.8" Hg (= 2.84 psi) minimum

3. Calibration of discharge volume after test*

RUN #	SMALL CHAMBER	LARGE CHAMBER	TOTAL
1	49.7	203.4	253.1
2	49.7	203.4	253.1
3	49.7	203.5	253.2

4. Calibration of discharge pressure after test

At beginning of discharge stroke P= 6.8" Hg (= 3.34 psi) maximum

At end of discharge stroke P= 5.4" Hg (= 2.65 psi) minimum

* NOTE: All volumetric measurements given in this table are based on 10 cycles.

Also the + volumes quoted are actually weights in grams converted directly to cc's since distilled water was used for calibration.

TABLE 2
EXTENDED LIFE TEST RESULTS

1. Calibration of discharge volume before test **

RUN #	SMALL CHAMBER	LARGE CHAMBER	TOTAL
1	49.9	203.3	253.2
2	49.9	203.3	253.2
3	49.9	203.3	253.2

2. Calibration of discharge pressure before test

At beginning of discharge stroke P= 7.8" Hg (= 3.83 psi) maximum

At end of discharge stroke P= 6.0" Hg (= 2.94 psi) minimum

3. Calibration of discharge volume at end of test **

RUN #	SMALL CHAMBER	LARGE CHAMBER	TOTAL
* 1	49.25	203.5	252.75
* 2	49.3	203.9	253.2
3	49.15	204.2	253.35
4	49.2	204.5	253.7
5	49.25	204.3	253.55

* These two readings have to be disregarded after it was noticed that the metler scale used for all previous readings was drifting badly. The readings were switched to a triple beam scale.

4. Calibration of discharge pressure at end of test

At beginning of discharge stroke P= 6.5" Hg (= 3.19 psi) maximum

At end of discharge stroke P= 5.0" Hg (=2.45 psi) minimum

* * NOTE: All volumetric measurements given in this table are based on 10 cycles.

Also the + volumes quoted are actually weights in grams converted directly to cc's since distilled water was used for calibration.

TABLE 3

SUMMARY OF REQUIREMENTS & TEST RESULTS

ITEM	REQUIREMENT	TEST RESULT
Discharge Volume	25 cc nominal	25 cc adjustable
Dual Flow Ratio	$\frac{4}{1}$	$\frac{4.01}{1}$ to $\frac{4.07}{1}$
Discharge Pressure	2 psig minimum	2.45 psig minimum
Incremental Volume Signal	1 pulse/.5 cc minimum	1 pulse/.362 cc
Volume Measurement Accuracy	$\pm$ 1%	$\pm$ 0.17%
Life Test	4 weeks & 6,720 cycles	4 weeks and 25,834 cycles

7.4 PRESSURE SENSOR TEST PROGRAM

In addition to tests of the peristaltic pump, the contract work statement required pressure sensor tests as follows:

> "Perform tests to determine the accuracy degradation of two selected sensors as a function of number of operating cycles. A minimum of 5,000 switch cycles shall be accomplished over a 6 to 8 week test period using urine as the interface fluid. The configuration exhibiting the best predictability shall be used in the engineering model."

The pressure sensors selected were procured from Dynascience, Inc. and Setra-Systems, Inc. Although neither exhibited vendor performance claims, the Setra-Systems, Inc. sensor functioned best and was selected for the Engineering Model. Details of these sensors and the test program are included in GE PIR 1R62-71-139 (Attached).

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9-9-71		URINE SAMPLING AND COLLECTION SYSTEM	

SUBJECT

PRESSURE SENSOR TEST RESULTS

INFORMATION REQUESTED/RELEASED

This report summarizes the results of tests on the Setra-Systems, Inc., model 230BD and Dynasciences Corporation, model P109D, pressure sensors.

1.0 SUMMARY

Analysis of the data shows that the Setra-Systems pressure sensor is preferred over the Dynascience sensor and will be used in the Engineering Model. However, in both cases, performance was inferior to that claimed by the manufacturer. As a consequence, system measurement accuracy for small volumes may be less than desired.

2.0 BACKGROUND

Termination of the Measure and Sample operating phase for the Urine Sampling and Collection System engineering model is accomplished by sensing that the residual urine volume in the system, as evidenced by the phase separator impellor generated pressure head, has reached a preset valve (equivalent to 50 ml). In addition to high sensitivity and repeatability, compatibility with periodic exposure to urine and a small dead space are key design criteria for the pressure sensor. The latter is desired to minimize cross contamination. Two sensors were selected for possible use in this application, a Setra-Systems, Inc., model 230BD and Dynasciences Corporation, model P109D (See Appendices A and B for detail discription).

As utilized in the Urine Sampling and Collection System, the pressure sensor must predictably havethe same output at the preset pressure valve corresponding to a volume of 50 ml. Subsequent repetitive operation and effect of the urine interface must not significantly degrade this sensing predictability.

3.0 TEST RESULTS

3.1 Test Procedure

Figures 1 and 2 illustrate the test set-up. The set-up automatically pressure cycled the sensor on a 24 hour repeat cycle. Each 24 hour cycle consisted of 5 short sensor "operating" periods starting at t = 0, 4, 8, 12 and 16 hours with the cycle repeating at t = 24 hours. This sequence was intended to simulate a 3 man SKYLAB application. During each "operating" period, the sensors were subjected to a nominal 50 cycles of pressure loading and unloading (pressure range 0 to 20 inches of urine). This was accomplished by

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☐	☐ DO NOT DESTROY

FORM 1020B REV. (9-70)

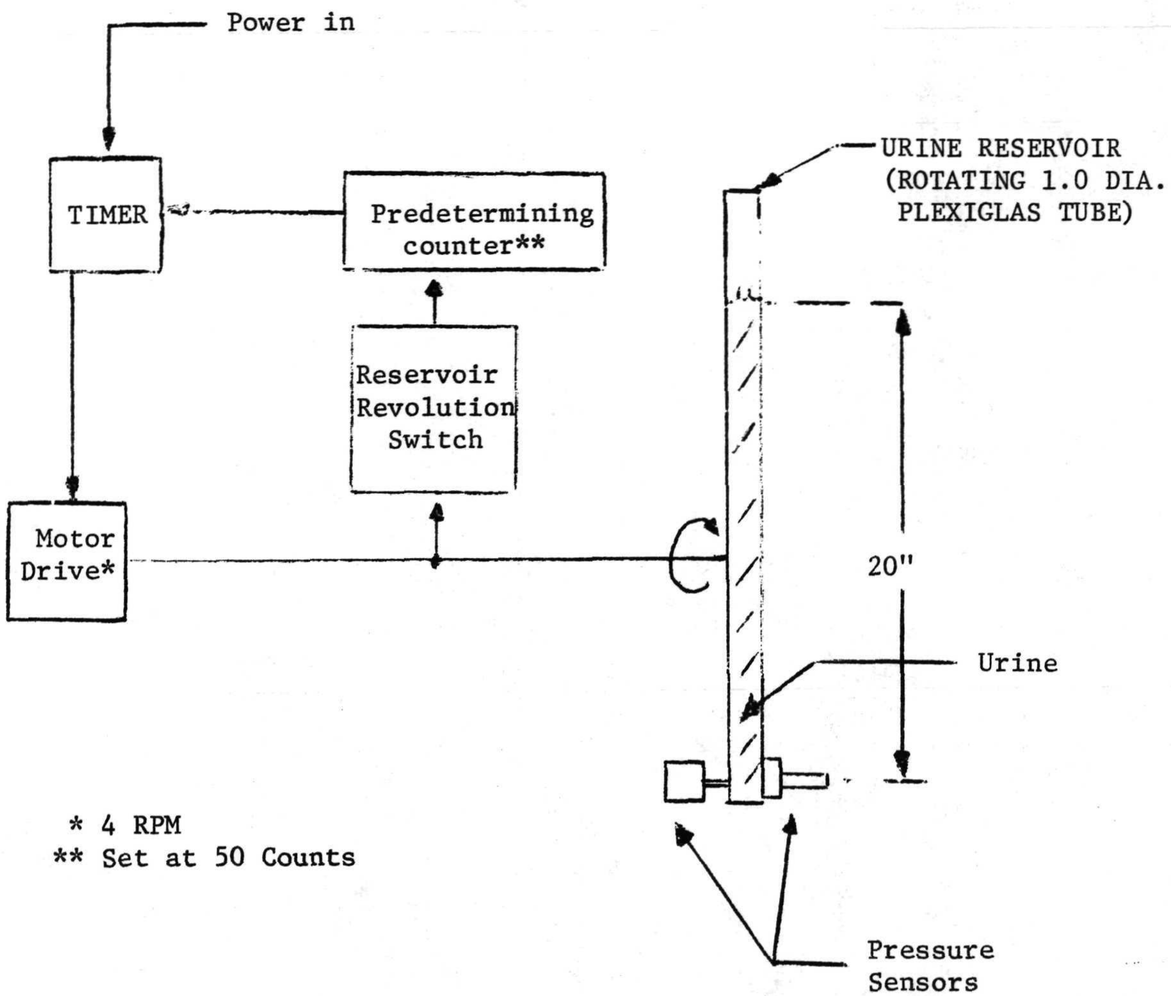


Figure 1 - Test Set-up Block Diagram

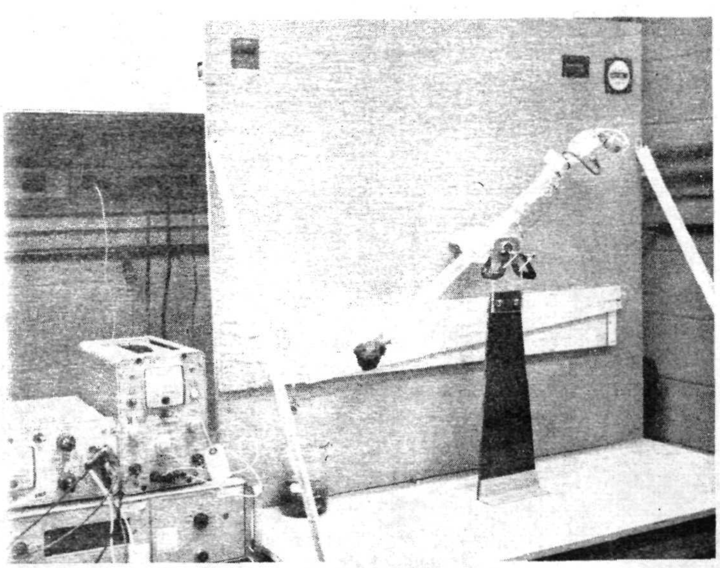


Figure 2 - Photograph of Test Set-up (Controls on Back)

3.1 Test Procedure (Continued)

rotation of the tube (urine reservoir) on which the sensors were mounted. Periodically, the sensors were removed from the urine reservoir and calibration data obtained using a sloped water manometer (10 to 1 scale magnification factor) for applying a known pressure to the sensor. At the same time, the urine reservoir was drained (but not flushed) and fresh urine added.

3.2 Setra-Systems, Inc. Model 230BD

Figures 3 through 6 summarizes the effect of 6 weeks of simulated operational use (10283 pressure cycles). Appendix C is a record of all the data obtained. Note that the data of Figure 3 through 6 are for the sensor delta output (total output at a specific pressure minus sensor output at zero pressure). The zero pressure was found to vary (over a limited range) depending upon the torque applied to the four mounting screws.

Examination of Figures 3 through 6 indicates the following:

(a) Linearity over the entire operating range of 0.1 psid exceeds $\pm$ 2% of FS. (Appendix A states $\pm$ 1%.)

(b) Predictability is well within 2% of FS as shown in Figures 4 through 6, particularily at the low pressure end (which corresponds to the anticipated operating area for termination of the Measure and Sample operating phase.

(c) The application of 10283 pressure cycles of a six week period did not degrade sensor performance.

The deviation from the manufacturers data (linearity/hysteresis) could be due to experimental technique error. However, it should be noted that the minimum resolution of the manometer scale is equivalent to less than a one mv output of the sensor.

3.3 Dynasciences Corporation Model P109D

Figure 7 and Appendix D record results of simulated operational use. Although output (in combination with the model CD10 Carrier Modulator) can be as high as 10 volts, a 2.0 volt span was used due to drift at higher output settings. Figure 7 shows results before and after 1177 pressure cycles during 6 days of simulated operational use. As shown, linearity exceeds $\pm$ 2% FS (Appendix B states $\pm$ 0.5 % FS). Subsequent tests on 8/18 and 8/24 exhibited virtually no correlation with those of Figure 7 (because of excessive drift). Cause of drift is unknown; drift may have been caused by simulated operational use of the sensor or by a malfunction of the carrier modular electronics. To check this latter, a Pace Model CD25 Carrier Modulator was borrowed from the vendor. Drift was not reduced. Further testing was discontinued.

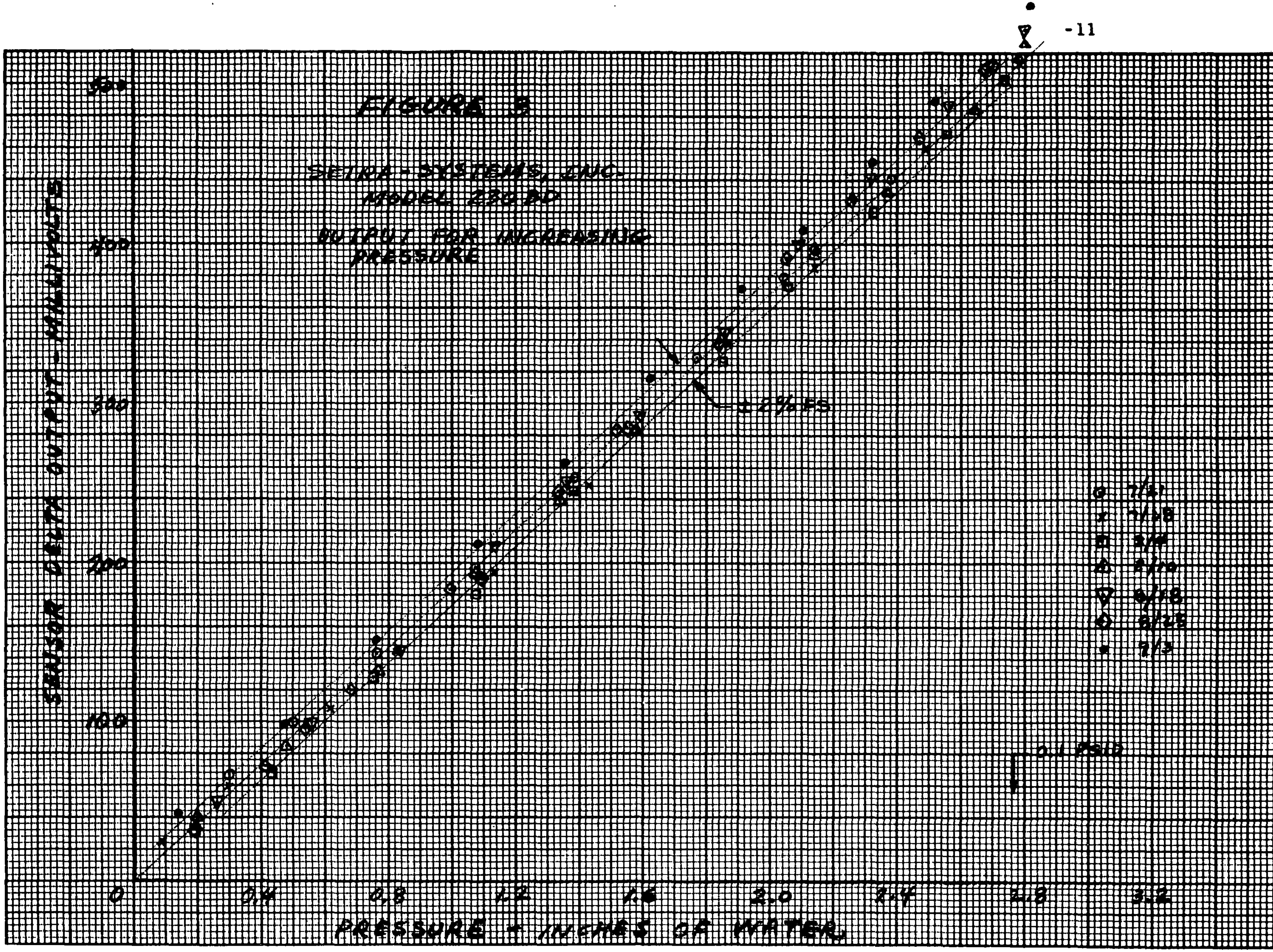
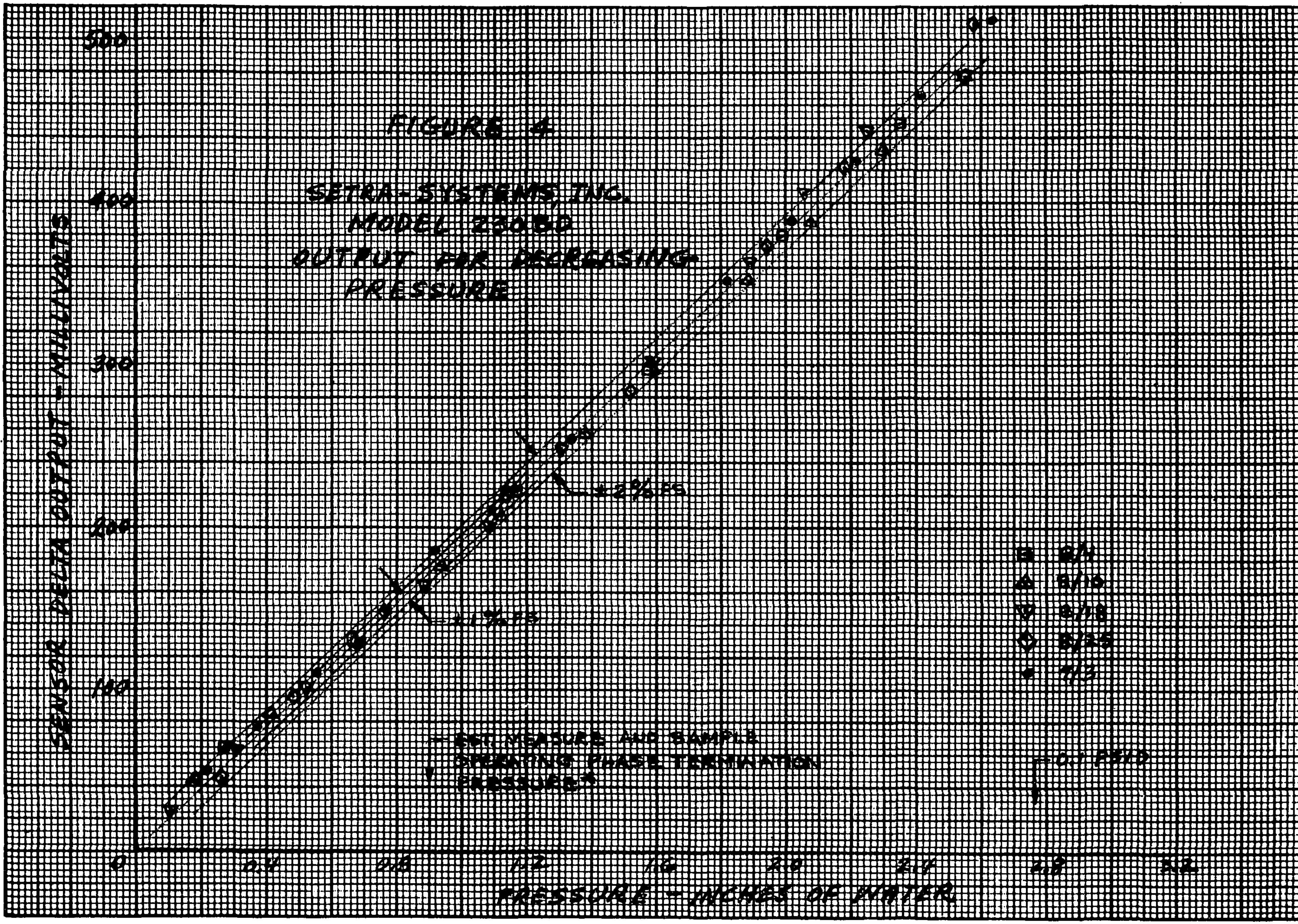


FIGURE 3
SETRA - SYSTEMS, INC.
MODEL 230 AD
OUTPUT FOR INCREASING PRESSURE
SENSOR DELTA OUTPUT - MILLIVOLTS
PRESSURE - INCHES OF WATER
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
100
200
300
400
500
±2% FS
0.1 PSID
-11



-11

* CALCULATED FROM PIR-1R62-71-113

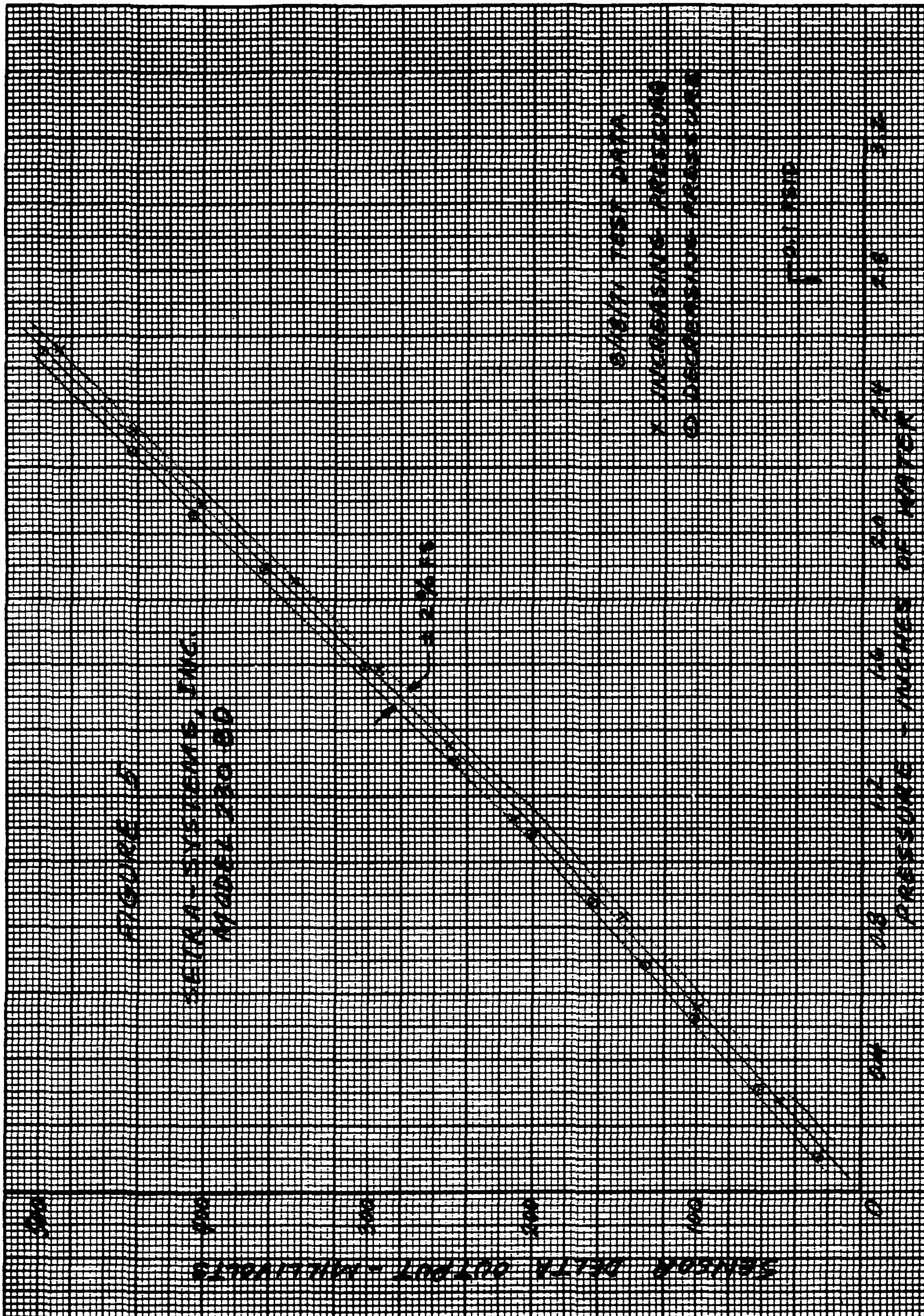
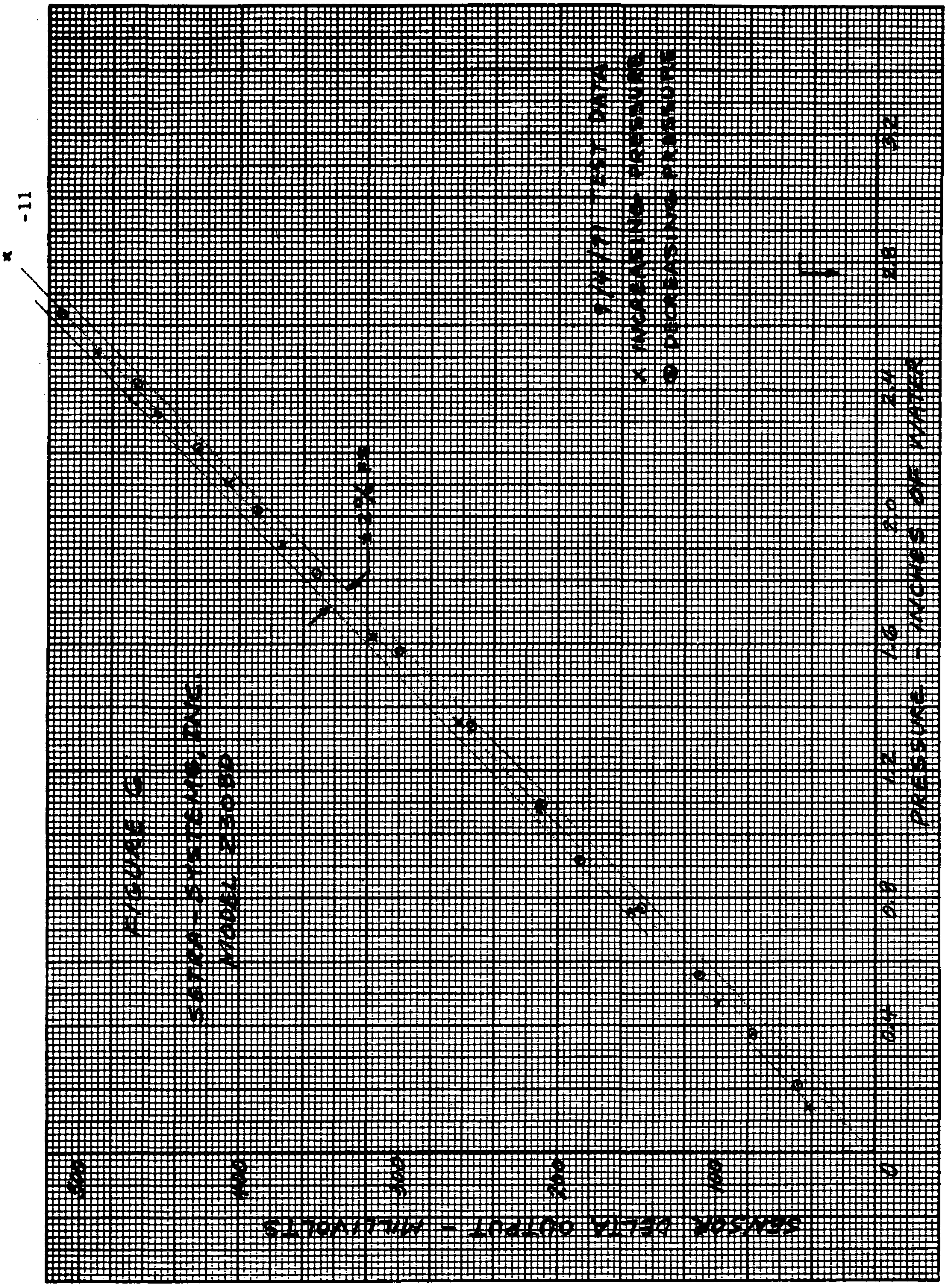


FIGURE 5
SETRA-SYSTEMS, INC.
MODEL 230 BD
±2% FS
8/18/71 TEST DATA
X INCREASING PRESSURE
O DECREASING PRESSURE
0.1 PSID
SENSOR DELTA OUTPUT - MILLIVOLTS
0
100
200
300
400
500
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
PRESSURE - INCHES OF WATER


-11
FIGURE 6
SETRA-SYSTEMS, INC
MODEL 230BD
9/14/71 EXT DATA
x INCREASING PRESSURE
⊙ DECREASING PRESSURE
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
PRESSURE - INCHES OF WATER
100
200
300
400
500
SENSOR DELTA OUTPUT - MILLIVOLTS

-11

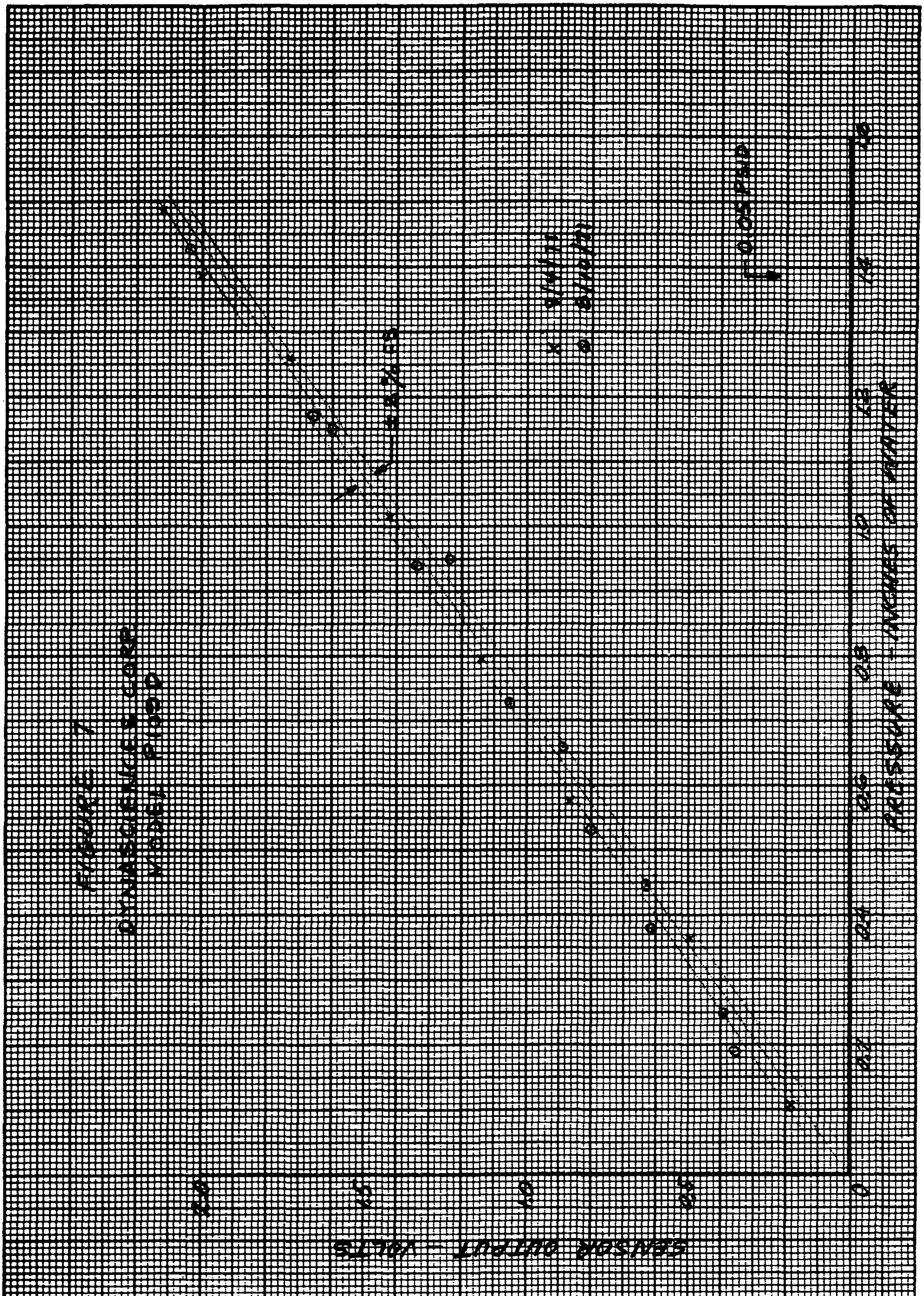
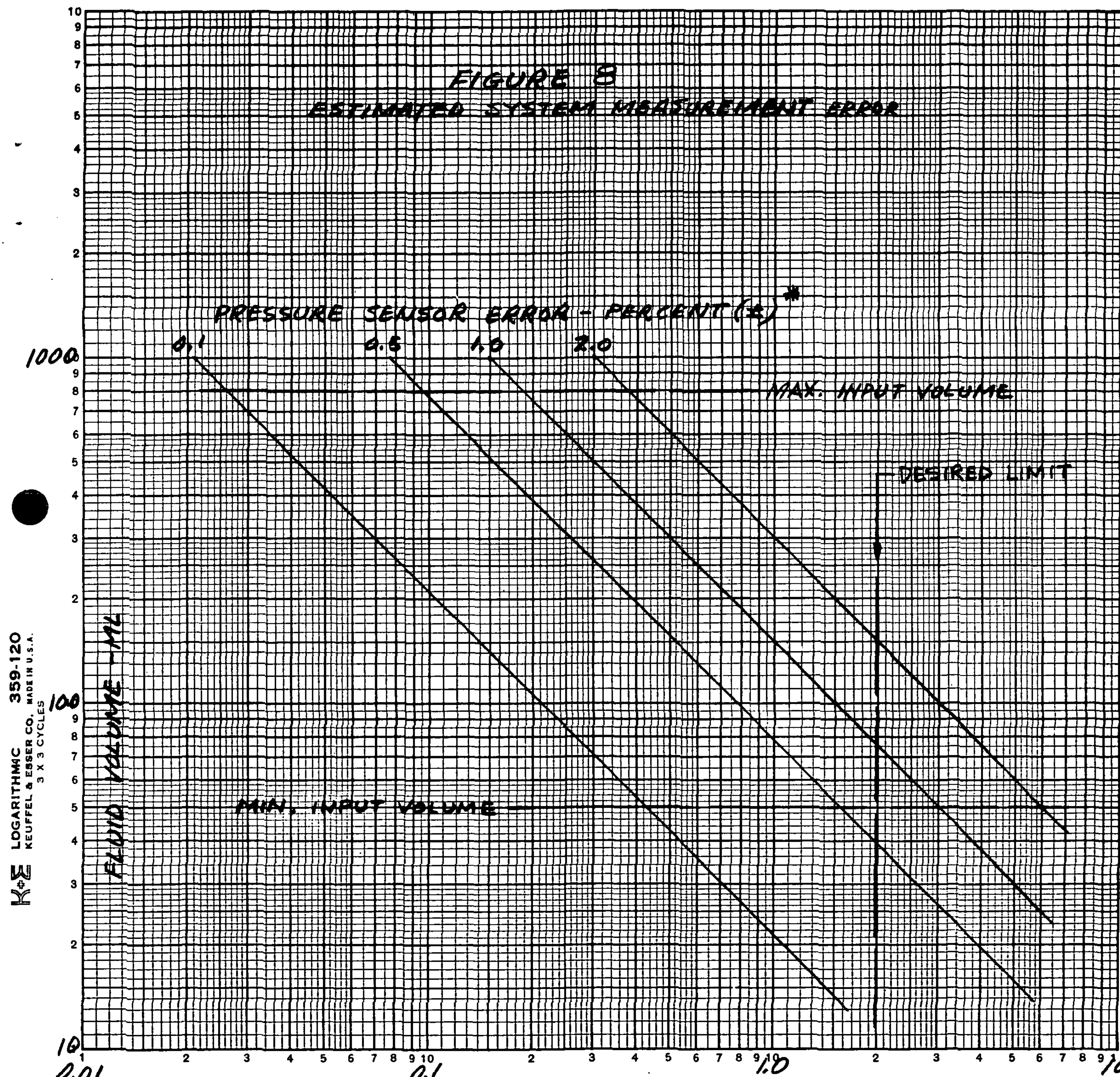


FIGURE 7
DYNASCIENCES CORP.
±2% FS
x 9/4/71
⊕ 8/10/71
0.05 PSID
SENSOR OUTPUT - VOLTS
PRESSURE - INCHES OF WATER
0
0.5
1.0
1.5
2.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

4.0 CONCLUSIONS

Of the two sensors tested, the Setra-Systems sensor is preferred and will be used in the Engineering Model. However, based on the pressure sensor test data and estimated overall system measurement error as a function of pressure sensor error, see Figure 8, the desired overall system accuracy of $\pm$ 2% may not be attainable for the entire 50 to 800 ml volume range.



CALCULATED VOLUME MEASUREMENT ERROR - PERCENT (±)

* SEE PIR 1R62-71-115 FOR OTHER ERROR ASSUMPTIONS.

DESCRIPTION

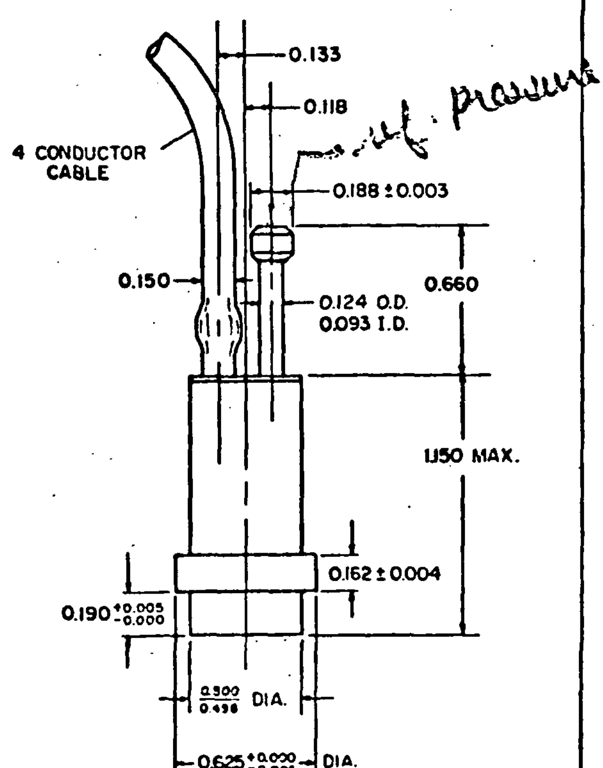
The Model 230 low pressure transducer consists of a thin stretched diaphragm which forms a variable capacitance with an insulated electrode plate located very close to the diaphragm. The built-in electronics utilizes a specially developed switching type integrated circuit to convert the changes of the capacitance due to the pressure variations into a high level d.c. output signal. A unique variable pulse-width modulation system* at a center frequency of approximately 500 KHz is used in the electronic circuit.

The mechanical system used is simple, rugged and almost hysteresis free. The high level, low impedance d.c. output is very convenient to use. Noise introduction and cable matching problems common to some other similar instruments are reduced to a minimum.

*Patents applied for.

FEATURES

- High level d.c. output (1 volt min.) with d.c. excitation.
- Low full scale pressure range (0.2psi) for the 1/2 inch diaphragm size.
- High overload capability (as high as 500x in positive direction).
- Low volume of displacement: 10^{-5} cu.in.
- High natural frequency (5000 Hz) and excellent dynamic response.
- Low gravitational and vibration response (0.0002 psi/g).



Setra Systems
12 HURON DRIVE
NATICK, MASS [illegible]
Telephone (617) [illegible]

..RMANCE SPECIFICATIONS

..anges	
Model 230 UD	0-0.2, 0.5, 1.0, 5.0 psi.
Model 230 BD	0-± .1, ± .25, ± .5, ± 2.5 psi.
Maximum Overload	100 psi, positive direction; 10 x range in negative direction.
Pressure Media	Gases or liquids compatable with type 300 series stainless steel.
Reference Media	Clean dry gas only, 30 psig maximum pressure.
Excitation *	6.0 volts ±10 mv, approx. 20 ma (case is at + excitation potential.
Full Range Output	
Model 230 UD	0-1 volt minimum **.
Model 230 BD	0- ± 0.5 volt minimum **.
Output Impedance	< 400 ohms.
Zero Output	< ± 100 mv at 77F.
Non-Linearity	< ± 1.0% of full range output. (determined by terminal method).
Hysteresis	< .1% of full range output (infinite resolution).
Ambient Operating Temperature Limits	-65F to +250F.
Compensated Temperature Range	0F to +150F.
Thermal Zero Shift	< 2% of full range/100F from 0F to +150F.
Thermal Coefficient of Sensitivity	< 2% of full range/100F from 0F to +150F.
Acceleration Response	< 0.0002 psi/g.
Increase in Volume Due to F. R. Pressure	1 x 10^{-5} cubic inches.
Natural Frequency	5000 Hz minimum.
Output Noise	< 2 mv RMS. —— @ 50KHz
Weight	Approximately 1/2 oz.

ORDERING INFORMATION

Price: $425.00.
Includes the following accessories: protective diaphragm cover, flange mounting ring and "O" ring seal.

Price shown is FOB Natick, Massachusetts, U.S.A. Terms are net 30 days.

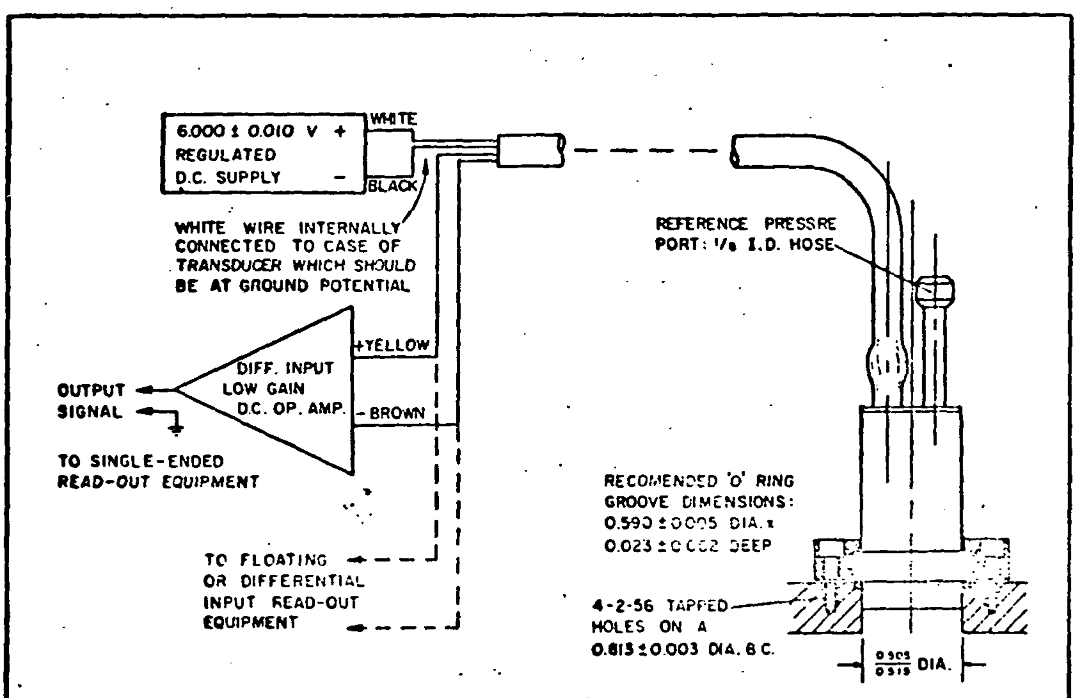
For other special modifications or ranges - consult factory.

* Will not be damaged by excitation up to 8 volts d.c. or reversed excitation current-limited to 250 ma.
NOTE: Observe excitation polarity prior to use.

** Calibrated into a 50K ohm load; operable into load impedances of 1k ohm or greater. The signal common mode voltage is approximately -3 volts referred to the positive excitation terminal.

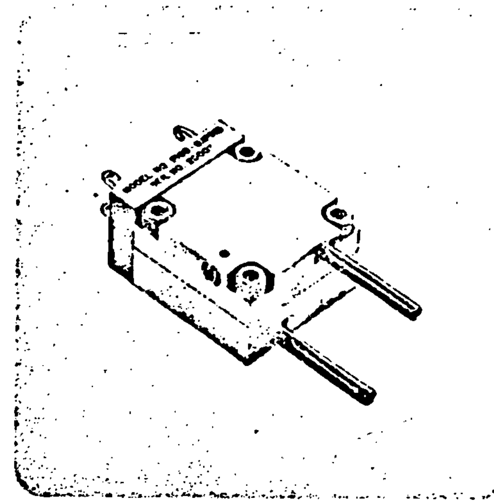
Prices and Specifications subject to change without notice.

INSTALLATION NOTES



FEATURES

- MINIATURE — WEIGHS 3.5 OUNCES.
- RANGES OF ±0.05 TO ±15 PSID.
- HIGH SENSITIVITY.
- ACCEPTS CORROSIVE GASES AND LIQUIDS, BOTH SIDES.
- WIDE DYNAMIC RESPONSE RANGE.
- WITHSTANDS EXTREME SHOCK AND VIBRATION.

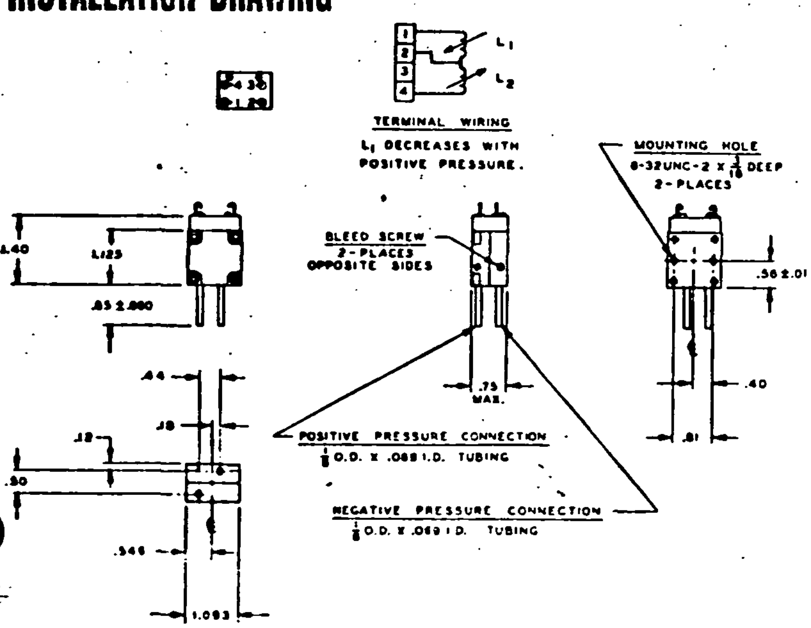


Price: $ 295.00

DESCRIPTION

Model P109D Miniature Sensitive Differential Pressure Transducers operate on the variable reluctance principle and are intended for installations involving minimum space and weight. Corrosive liquids as well as gases may be admitted to either port at pressure levels from vacuum to 15 psi. Pressure difference is applied across the magnetic stainless diaphragm resulting in proportional deflection and consequent change in inductance ratio between two pickoff coils imbedded in the case on either side. The embedded coils are sealed off with a non-magnetic stainless cover so that both pressure cavities present a stainless exposure to the working medium. Full scale pressure results in an inductance change of 5% in each coil, equivalent to a full scale output of 25 mv per volt of excitation in bridge circuit operation. The Model P109D may be used in most carrier systems. When operated with the Model CD32 Miniature Carrier-Demodulator, a DC output of 0-5 volts is delivered to the associated recording or telemetry system. Vent valves facilitate complete liquid filling for dynamic measurement.

INSTALLATION DRAWING



TEST EQUIPMENT SALES COMPANY
4447 NORTH BODINE STREET
PHILADELPHIA, PA. 19140
PHONE 329-1822

P109D-1068-2.5M

7090 DIFFERENTIAL PRESSURE TRANSDUCER

VARIABLE RELUCTANCE

SPECIFICATIONS

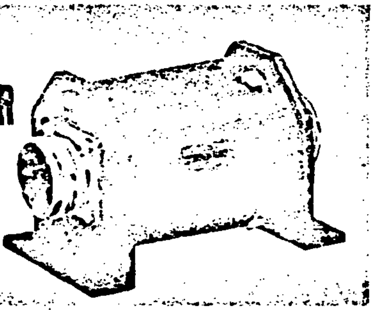
Ranges: ±0.05 to ±15 psi differential.
Linearity: ±½% F.S. best straight line.
Hysteresis: ½% F.S. pressure excursion.
Overpressure: 200% of range in either direction with less than ½% zero shift.†
Line Pressure: 100 psi. maximum.
Output: 25mv/v full scale nominal.
Inductance: 20 mh nominal, each coil, zero balance within 10% full scale.
Excitation: 1,000-20,000 Hz, 15 volts max. at 3,000 Hz. Coils available for 400 Hz and other frequency requirements.
Working Fluids: Corrosive liquids, materials and gases, both sides. Exposure 400 series Stainless standard models. Other materials available on special order.
Temperature: Operational — 65° to +250°F
Compensated — 15° to +165°F

Maximum error (from room temperature) above compensated range: 1 psi and above <3% F.S.
Below 1 psi <5% F.S.
"O" Rings: Buna N — other materials on special order.
Pressure Cavity Volume: 3 x 10 $^{-3}$ cubic inch.
Volumetric Displacement: 3 x 10 $^{-4}$ cubic inch, full scale.
Acceleration Response: Most sensitive axis (across diaphragm).*

Range	Static	Vibratory	Nat. Freq.
±0.05 psid	1%/g	1%/g	3K Hz
±1 psid	0.2%/g	0.2%/g	5K Hz
±15 psid	0.03%/g	0.05%/g	8K Hz

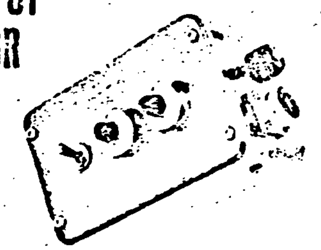
Installation Details: See drawing on front.
Weight: 3½ ounces.
*Acceleration response any axis in diaphragm plane 1% of value listed in table.
†Factory preconditioning for higher overpressures on special order.

MODEL CD32 CARRIER-DEMODULATOR



The Model CD32 Miniature Carrier-Demodulator operates on unregulated 22-32 VDC at 20 ma with Transducers to provide a 0-5 or ±5 VDC full scale output for voltage controlled telemetry and other DC systems. Transducer excitation is 5 Volts at 5 K Hz. Frequency response is flat ±5%, 0-1,000 Hz. Encapsulation in a small, lightweight aluminum case assures reliable performance under extreme shock and vibration. Static acceleration is 100 g. Ambient temperature range is —65°F to +250°F. Weight is 7 ounces and Size is 1½" dia. x 3⅜" overall length.

MODEL CD10 DC OUTPUT CARRIER-DEMODULATOR



A small Carrier-Demodulator, designed for operation on 95-125 Volts, 60-400 Hz at 5 watts, the Model CD10 operates with Variable Reluctance Pressure Transducers in DC systems. Transistorized for reliability, it is compact (may be mounted inside many recorders) and provides an output of 0-10 VDC (0-2.5 ma maximum current) or ±10 VDC full scale. Transducer excitation is 5 Volts at 5 K Hz. Frequency response is flat ±5%, 0-1,000 Hz. Regulated against input voltage variation, it operates reliably over an ambient temperature range of 40°F to 120°F. Long term stability is ±½%. Weight is 34 ounces and Size is 3¼" wide x 3" deep x 5¼" long.

REPRESENTED BY

Design improvements may be made without prior announcement. For Models to meet special requirements, consult our Engineering staff. Collect calls will be accepted for application and engineering assistance.

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PRESSURE SENSOR PERFORMANCE EVALUATION

SENSOR: SETRA-SYSTEMS, INC. MODEL 230 BD

SERIAL NO. 483 RANGE 0.1 PSID

DATE	ACCUM. CYCLES	MANOMETER READING		SENSOR OUTPUT MILLIVOLTS
		SCALE VALUE	INCHES OF WATER	
7/21	0	0	0.0	114.8
		3.0	0.30	181.6
		5.0	0.50	213.5
		7.65	0.765	258.0
		10.7	1.07	311.4
		13.85	1.385	368.1
		17.7	1.77	443.4
		20.4	2.04	493.5
		23.8	2.38	556.1
		27.5	2.75	631.7
7/28	1799	0	0.0	130.
		0.9	0.09	154.1
		3.0	0.30	188.
		6.2	0.62	237.8
		8.25	0.825	272.6
		11.3	1.13	324.0
		14.3	1.43	378.3
		18.7	1.87	466.5
		21.4	2.14	515.3
		24.9	2.49	590.
		27.85	2.785	644.
		0	0.0	131.

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PRESSURE SENSOR PERFORMANCE EVALUATION

SENSOR: SETRA - SYSTEMS, INC. MODEL 230 BD

SERIAL NO. 483 RANGE 0.1 PSID

DATE	ACCUM. CYCLES	MANOMETER READING SCALE VALUE	MANOMETER READING INCHES OF WATER	SENSOR OUTPUT MILLIVOLTS
8/4	3499	0.0	0.0	94.
		1.9	0.19	125.6
		4.35	0.435	161.6
		7.50	0.75	223.2
		10.70	1.07	274.3
		13.80	1.38	339.2
		18.50	1.85	419.6
		20.55	2.055	467.6
		23.25	2.325	514.
		25.50	2.55	563.4
		27.40	2.74	597.
		23.50	2.35	542.4
		19.90	1.99	472.6
		15.70	1.57	390.
		11.70	1.17	316.
		6.60	0.66	224.5
		2.70	0.27	158.6
		0.0	0.0	94.1

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PRESSURE SENSOR PERFORMANCE EVALUATION

SENSOR: SETRA-SYSTEMS, INC. MODEL 230 BD

SERIAL NO. 483 RANGE 0.1 PSID

DATE	ACCUM. CYCLES	MANOMETER READING		SENSOR OUTPUT MILLIVOLTS
		SCALE VALUE	INCHES OF WATER	
8/10	4676	0	0.0	95.3
		2	0.20	135.3
		4.8	0.48	180.
		7.7	0.77	226.5
		10.7	1.07	288.8
		13.35	1.335	334.6
		15.85	1.585	378.6
		18.85	1.885	443.
		21.4	2.14	489.1
		23.7	2.37	527.1
		26.4	2.64	579.2
		28.	2.80	621.
		25.5	2.55	573.6
		23.	2.30	527.
		20.8	2.08	484.7
		18.85	1.885	447.
		15.9	1.59	392.3
		13.75	1.375	353.
		11.25	1.125	303.9
		9.4	0.94	271.
		6.85	0.685	226.2
		4.2	0.42	179.4
		1.8	0.18	138.8
		0	0.0	96.5

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PRESSURE SENSOR PERFORMANCE EVALUATION

SENSOR: SETRA-SYSTEMS, INC. MODEL 230BD

SERIAL NO. 483 RANGE 0.1 PSID

DATE	ACCUM. CYCLES	MANOMETER READING		SENSOR OUTPUT MILLIVOLTS
		SCALE VALUE	INCHES OF WATER	
8/18	6650	0	0.0	98.
		2.6	0.26	147.8
		5.6	0.56	196.7
		8.35	0.835	243.4
		11.3	1.13	309.7
		13.55	1.355	349.
		15.9	1.59	390.8
		18.55	1.855	443.3
		20.9	2.09	498.6
		23.15	2.315	540.2
		25.6	2.56	585.2
		28.	2.8	631.1
		25.5	2.55	596.
		22.5	2.25	541.7
		20.55	2.055	504.
		18.9	1.89	461.4
		15.9	1.59	399.7
		13.05	1.305	346.3
		10.85	1.085	299.3
		8.75	0.875	261.6
		6.85	0.685	230.4
		5.25	0.525	199.4
		3.1	0.31	160.3
		1.05	0.105	124.4
		0	0.0	97.9

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PRESSURE SENSOR PERFORMANCE EVALUATION

SENSOR: SETRA-SYSTEMS, INC. MODEL 230 BD

SERIAL NO. 483 RANGE 0.1 PSID

DATE	ACCUM. CYCLES	MANOMETER READING		SENSOR OUTPUT MILLIVOLTS
		SCALE VALUE	INCHES OF WATER	
8/25	8194	0	0.0	94.3
		1.9	0.19	131.
		4.1	0.41	165.8
		6.85	0.685	213.5
		9.9	0.99	277.6
		13.3	1.33	338.9
		15.5	1.55	378.2
		18.4	1.84	431.8
		20.5	2.05	484.4
		22.55	2.255	522.
		24.65	2.465	561.5
		27.	2.7	606.6
		28.3	2.83	636.4
		25.8	2.58	603.7
		21.8	2.18	514.4
		19.45	1.945	466.
		15.2	1.52	386.
		11.4	1.14	313.5
		7.65	0.765	242.1
		4.8	0.48	189.7
		2.55	0.255	149.
		0	0.0	92.7
		5.4	0.54	189.9
		10.9	1.09	283.4
		15.5	1.55	377.5
		21.45	2.145	490.
		26.7	2.67	605.4
		19.85	1.985	477.
		9.75	0.975	281.
		0	0.0	92.1

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PRESSURE SENSOR PERFORMANCE EVALUATION

SENSOR: SETRA-SYSTEMS, INC. MODEL 230BD

SERIAL NO. 483 RANGE 0.1 PSID

DATE	ACCUM. CYCLES	MANOMETER READING SCALE VALUE	MANOMETER READING INCHES OF WATER	SENSOR OUTPUT MILLIVOLTS
9/3	10283	0	0.0	84.0
		1.4	0.14	126.3
		4.7	0.47	183.3
		7.6	0.76	236.8
		10.8	1.08	295.2
		13.5	1.35	347.0
		16.25	1.625	400.4
		19.1	1.91	455.7
		21.05	2.105	493.0
		23.2	2.32	535.5
		25.15	2.515	574.0
		28.1	2.81	633.5
		26.35	2.635	596.0
		24.15	2.415	548.5
		22.15	2.215	510.3
		20.2	2.02	473.3
		18.2	1.82	436.0
		15.75	1.575	384.2
		13.4	1.34	338.4
		10.9	1.09	293.8
		9.15	0.915	261.1
		7.65	0.765	231.7
		5.55	0.555	194.5
		3.7	0.37	160.6
		2.1	0.21	133.3
		0	0.0	85.2

APPENDIX D

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PRESSURE SENSOR PERFORMANCE EVALUATION

SENSOR: DYNA SCIENCE * MODEL P109D

SERIAL NO. 151351 RANGE 0.05 PSID

* PACE ENG. CO. CARRIER MODULATOR, MODEL CD10

DATE	ACCUM. CYCLES	MANOMETER READING		SENSOR OUTPUT MILLIVOLTS
		SCALE VALUE	INCHES OF WATER	
8/4	0	13.85	1.385	2000.
		0.	0.0	0.
		1.1	0.11	186.
		3.65	0.365	495.
		5.75	0.575	865.
		7.95	0.795	1137.
		10.15	1.015	1423.
		12.6	1.26	1727.
		14.85	1.485	2123.
		13.85	1.385	1970.
		0	0.0	0.
8/10	1177	13.85	1.385	2000.
		0.	0.0	4.
		2.5	0.25	389.
		4.45	0.445	633.
		6.6	0.66	885.
		9.5	0.95	1234.
		11.5	1.15	1600.
		14.25	1.425	2040.
		13.85	1.385	2000.
		11.7	1.17	1662.
		9.4	0.94	1344.
		7.25	0.725	1054.
		5.3	0.53	803.
		3.8	0.38	606.
		1.9	0.19	359.
		0.	0.0	6.

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PRESSURE SENSOR PERFORMANCE EVALUATION

SENSOR: DYNASCIENCE* MODEL P109D

SERIAL NO. 151351 RANGE 0.05 PSID

* PACE ENG. CO. CARRIER MODULATOR, MODEL CD10

DATE	ACCUM. CYCLES	MANOMETER READING SCALE VALUE	MANOMETER READING INCHES OF WATER	SENSOR OUTPUT MILLIVOLTS
8/18	3151	0		
		13.85	1.385	2000.
	NOTE: OUTPUT DRIFT TO 2182 IN ≈ 1½ HRS.			
	RESET ZERO AND SPAN – DIFFICULT BECAUSE OF DRIFT.			
		13.85	1.385	2000
		11.6	1.16	1690
		10.05	1.005	1370
		7.9	0.79	807
		5.95	0.595	504
		4.5	0.45	362
		2.65	0.265	269
		1.2	0.12	172
		0.0	0.0	12
		1.85	0.185	127
		4.95	0.495	318
		6.25	0.625	459
		9.25	0.925	723
		12.25	1.225	1458
		13.7	1.37	1944
		14.6	1.46	2048
		13.85	1.385	1990
		0.0	0.0	+25*
		* DECREASED TO –52 IN 10 MIN.		

PROGRAM: URINE SAMPLING AND COLLECTION SYSTEM

TEST: PRESSURE SENSOR PERFORMANCE EVALUATION

SENSOR: DYNASCIENCE* MODEL P109D

SERIAL NO. 151351 RANGE 0.05 PSID

* PACE ENG. CO. CARRIER MODULATOR, MODEL CD-10

DATE	ACCUM. CYCLES	MANOMETER READING SCALE VALUE	MANOMETER READING INCHES OF WATER	SENSOR OUTPUT MILLIVOLTS
8/25	4695	0	0.0	0 **
		13.85	1.385	2,000
		12.25	1.225	1700
		10.07	1.007	1519
		8.9	0.89	1180
		7.1	0.71	901
		5.9	0.59	781
		4.5	0.45	604
		2.7	0.27	386
		0	0.0	57**

** UNABLE TO HOLD ZERO AND SPAN SETTINGS BECAUSE OF HIGH DRIFT RATE, EVEN AFTER SEVERAL HOURS OPERATION.

7.5 PHASE SEPARATOR TEST RESULTS

Laboratory tests were conducted on the GE USVMS Breadboard model phase separator to obtain data to assist in refinement of the system requirements. The Breadboard phase separator was selected as being reasonably representative in physical size, capacity and operating principle of the phase separator design anticipated for the Engineering Model. Power input and generated dynamic and static pressures for various conditions of phase separator impellor RPM and fluid weight were obtained. Observed asymetrical fluid loading conditions were eliminated by the use of bleed holes in the phase separator impellor blades. Details of these tests are documented in GE PIR 1R62-71-113 and 1R62-71-129 (Attached).

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PIR NO.	*CLASS. LTR.	OPERATION	PROGRAM	SEQUENCE NO.	REV. LTR.
		1R62	71	113	

*USE "C" FOR CLASSIFIED AND "U" FOR UNCLASSIFIED

FROM G. L. Fogal
Life Systems
Room M4214, VFSC, Extension 5636

TO FILE

DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
5/26/71		URINE SAMPLING AND COLLECTION SYSTEM	

SUBJECT

PHASE SEPARATOR TEST RESULTS

INFORMATION ~~REQUESTED~~/RELEASED

1.0 SUMMARY

Using the GE-USVMS Breadboard Phase Separator, power input and generated fluid static and dynamic pressures were measured for various conditions of phase separator impellor RPM and fluid weight.

2.0 TEST PLAN

With the exception of substituting the USVMS Breadboard phase separator in place of the RITE program separator, the test proceeded as outlined in the test plan, PIR 1R62-71-107. The substitution was made for two reasons:

(a) In order to fit the present space available on SKYLAB, system width is limited to 8.0 inches. The USVMS design is a nominal 8 inches in diameter as compared to 10 inches for the RITE phase separator design.

(b) The smaller diameter should result in a smaller residual volume remaining in the phase separator (at least under zero "g" operating conditions).

3.0 DISCUSSION

3.1 Phase Separator Description

The USVMS Breadboard phase separator design uses an enclosed rotating impellor to generate and maintain a fluid vortex to thereby separate the liquid and gas phases by centrifugal action. The USVMS Breadboard phase separator (GE Drawing 201R812) has an eight bladed impellor 6.168 inches in diameter by 3.970 inches wide as illustrated in Figure 3-1.

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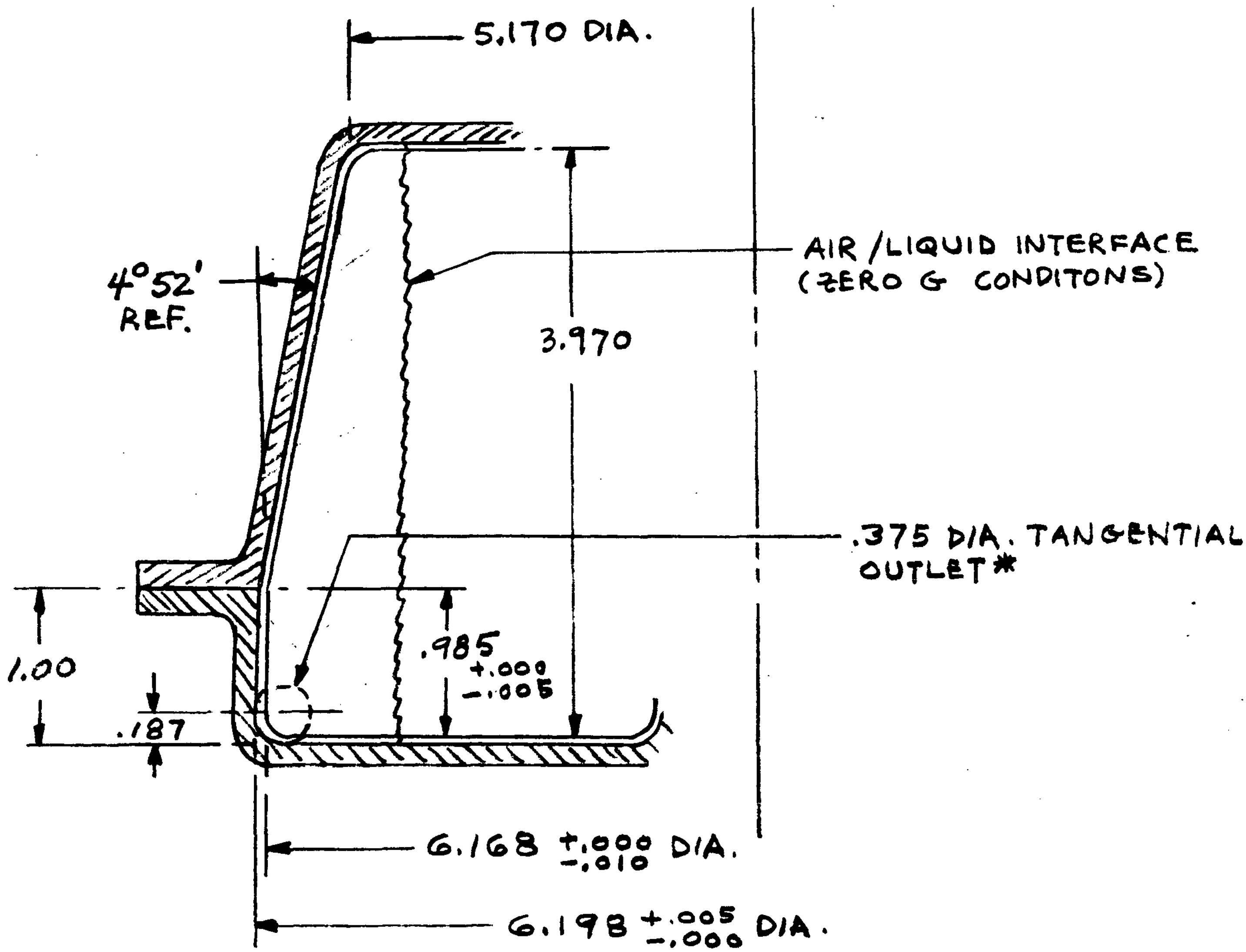


* PRESSURE HEAD STATIC PORT 0.125 DIA. COPPER TUBING BONDED IN PLACE ON SAME CENTERLINE 180° FROM TANGENTIAL OUTLET.

FIGURE 3-1 USVMS BREADBOARD PHASE SEPARATOR IMPELLOR/HOUSING DIMENSIONS (NOT TO SCALE). REF: GE DWG. 201R812

3.2 Pressure Data

Table 3-1 lists the test data and corresponding calculated values used in preparing Figures 3-2 thru 3-8. Impellor RPM was measured with a direct connected tachometer generator (output 2.50 volts per 1,000 rpm). Pressures at the tangential and static outlets were determined by measuring the height of the resulting fluid column at each outlet. Water was used as the fluid. The fluid volume data are corrected for "loss" of fluid from the phase separator to each manometer column.

Referring to Figures 3-2 and 3-3, note that at low fluid volumes (weight), pressure head data (static port outlet) correlates best as a function of Wn instead of the theoretical Wn^2. This anomaly may be caused by the phase separator geometry. The same anomaly may be observed for the velocity head data in Figure 3-4 wherein the weight of fluid should not influence the value of the velocity head.

An additional test was made using a variable capacitance type pressure sensor to monitor the pressure head at the static port (and with the tangential port plugged). A Model 230BD Setra Systems, Inc. pressure transducer was used. Transducer range is 0 $\pm$2.77 inches of water with a full scale output of 0.364 volts. Figure 3-5 is a typical record of the transducer output. The dominate wave has a frequency of 4.48 Hz. At the corresponding impellor speed of 280 rpm, the dominate wave period corresponds to about one revolution of the impellor, a surprising and unexpected result. Superimposed on the dominate wave are the pressure pulses corresponding to the passage of each impellor blade past the pressure head static outlet port (as expected).

TABLE 3-1 USVMS PHASE SEPARATOR DATA

		TEST DATA						CALCULATED VALUES			
RUN NO.	DATE	P_T INCH OF H_2O	P_P INCH OF H_2O	IMP. SPEED VOLTS	NOM. FLUID WT. GMS.	TOTAL POWER INPUT VOLT	TOTAL POWER INPUT AMPS	P_V INCH OF H_2O	W GMS	IMP. SPEED RPM	TOTAL POWER INPUT WATTS
1	5/14	7.	0.8	1.22	50	15.3	0.56	6.2	39.	488	8.57
2	5/14	8.1	1.0	1.52	50	18.5	0.63	7.1	38.1	608	11.65
3	5/14	10.2	1.2	1.78	50	22.4	1.2	9.0	36.1	712	26.9
4	5/14	16.	1.8	1.22	100	19.4	9.7	14.2	80.7	488	18.8
5	5/14	22.	2.1	1.52	100	25.4	1.22	19.9	76.6	608	31.0
6	5/14	24.	2.3	1.70	100	30.	1.32	21.7	75.3	680	39.6
7	5/14	12.0	3.15	0.92	200	16.8	0.87	8.8	184.1	368	14.6
8	5/14	20.	4.3	1.22	200	23.3	1.24	15.7	176.6	488	28.9
9	5/14	33.	5.2	1.52	200	28.9	1.45	27.8	164.8	608	41.8
10	5/14	13.5	4.4	0.92	300	16.6	0.91	9.1	282.5	368	15.1
11	5/14	22.	6.3	1.22	300	25.4	1.35	15.7	274.4	488	34.3
12	5/14	31.	7.8	1.44	300	29.4	1.51	23.2	266.	577	44.3
13	5/14	7.	3.8	0.60	500	12.4	0.91	3.2	488.4	240	11.3
14	5/14	14.	6.2	0.90	500	18.7	1.19	7.8	481.7	360	22.2
15	5/14	24.	9.6	1.22	500	27.0	1.5	14.4	472.	488	40.5
16	5/14	7.7	4.5	0.60	700	14.9	0.85	3.2	687.7	240	12.7
17	5/14	15.5	7.9	0.90	700	20.3	1.2	7.6	679.9	360	24.4
18	5/14	26.5	12.75	1.22	700	27.0	1.52	13.7	669.1	488	41.
19	5/14	6.5	4.05	0.54	700	10.0	0.59	2.45	688.8	217	5.9
20	5/14	6.25	4.0	0.50	800	11.2	0.74	2.25	789.1	200	8.3
21	5/14	14.0	7.8	0.84	800	17.9	0.98	6.2	781.3	336	17.5
22	5/14	30.	15.1	1.26	800	27.2	1.53	14.9	765.5	504	41.6
23	5/14	5.2	0.5	0.80	50	13.1	0.45	4.7	40.7	320	5.9
24	5/14	6.5	0.7	1.22	50	14.6	0.53	5.8	39.5	488	7.7
25	5/14	9.8	0.95	1.78	50	21.3	0.72	8.85	36.5	712	15.3

where

P_T = Total pressure read at tangential outlet.
P_P = Pressure head read at static port outlet.
P_V = $(P_T - P_P)$ = Velocity head
W = Act. Fluid Wt. = Nominal value corrected for "loss"in manometer, i.e. ACTUAL = NOMINAL - $[(3.6 + 0.9\ P_T) + (0.9 + 0.2\ P_P)]$

TABLE 3-1 USVMS PHASE SEPARATOR DATA (Continued)

TEST DATA								CALCULATED VALUES			
RUN NO.	DATE	P_T INCH OF H_2O	P_R INCH OF H_2O	IMP. SPEED VOLTS	NOM. FLUID WT. GMS.	TOTAL POWER INPUT VOLT	TOTAL POWER INPUT AMPS	P_V INCH OF H_2O	W GMS	IMP. SPEED RPM	TOTAL POWER INPUT WATTS
26	5/14	13.0	1.15	2.20	50	27.4	0.94	12.85	33.6	880	25.7
27	5/14	5.3	1.2	0.6	100	9.6	0.51	4.1	90.5	240	4.9
28	5/14	12.0	1.4	0.92	100	14.6	0.8	10.6	84.4	368	11.7
29	5/14	15.8	1.55	1.22	100	21.4	1.01	14.25	81.0	488	21.7
30	5/14	23.0	2.05	1.70	100	27.6	1.27	20.95	74.4	680	35.1
31	5/14	5.8	2.05	0.60	200	10.5	0.57	3.75	189.9	240	6.0
32	5/14	12.0	3.1	0.92	200	17.7	1.4	8.9	184.1	368	24.8
33	5/14	20.3	4.5	1.22	200	23.3	1.14	15.8	176.3	488	26.7
34	5/19	20.5	3.6	1.22	200	20.3	1.06	16.9	176.3	488	21.6
35	5/19	1.9	1.4	0.26	400	4.3	0.24	0.5	393.5	96	1.0
36	5/19	5.0	2.6	0.50	400	7.7	0.38	2.4	390.5	200	2.9
37	5/19	8.6	3.7	0.70	400	11.0	0.55	4.9	387.0	280	6.1
38	5/19	19.0	6.4	1.10	400	18.8	1.0	12.6	377.1	440	18.8
39	5/19	1.9	1.8	0.20	600	3.8	0.27	0.1	593.4	80	1.0
40	5/19	4.1	2.8	0.40	600	6.9	0.37	1.3	591.2	160	2.6
41	5/19	7.8	4.2	0.62	600	10.0	0.53	3.6	587.6	248	5.3
42	5/19	11.8	5.8	0.80	600	13.2	0.69	6.0	583.7	320	9.1
43	5/19	2.4	2.2	0.20	800	4.0	0.27	0.2	792.9	80	1.1
44	5/19	4.5	3.2	0.40	800	7.2	0.40	1.3	790.8	160	2.9
45	5/19	8.8	5.2	0.64	800	12.5	0.58	3.6	786.5	257	7.3
46	5/19	13.4	7.3	0.82	800	13.7	0.73	6.1	782.0	328	10.0
47	5/19	32.5	15.7	1.32	800	24.7	1.33	16.8	763.1	528	32.8
48	5/19			0.20	10	3.8	0.27			80	1.03
49	5/19			0.40	10	6.2	0.32			160	1.98
50	5/19			0.60	10	7.7	0.32			240	2.47
51	5/19			0.80	10	9.3	0.33			320	3.07
52	5/19			1.00	10	10.8	0.34			400	3.67
53	5/19			1.20	10	12.5	0.36			480	4.51
54	5/19			1.40	10	14.0	0.36			560	5.05
55	5/19			1.60	10	15.4	0.36			640	5.55
56	5/19			1.80	10	17.0	0.36			720	6.13
57	5/19			2.00	10	18.3	0.35			800	6.41
58	5/19			2.20	10	20.0	0.37			880	7.4
59	5/19			2.40	10	21.7	0.37			960	8.0

NOTE: Runs 48 to 59 made with both pressure outlets plugged and with residual fluid volume.

TABLE 3-1 USVMS PHASE SEPARATOR DATA (Continued)

TEST DATA								CALCULATED VALUES			
						TOTAL POWER INPUT					
RUN NO.	DATE	P_T INCH OF H_2O	P_p INCH OF H_2O	IMP. SPEED VOLTS	NOM. FLUID WT. GMS.	VOLT	AMPS	P_V INCH OF H_2O	W GMS	IMP. SPEED RPM	TOTAL POWER INPUT WATTS
60	5/21			0.80	450	15.2	0.87			320	13.2
61	5/21			1.00	450	19.2	1.05			400	20.2
62	5/21			1.20	450	22.6	1.22			480	27.5
63	5/21			0.80	650	15.0	0.86			320	12.9
64	5/21			1.00	650	18.3	1.01			400	18.5
65	5/21			1.20	650	22.4	1.20			480	26.9
66	5/21			0.80	800	15.0	0.86			320	12.9
67	5/21			1.00	800	18.2	1.00			400	18.2
68	5/21			1.20	800	22.2	1.18			480	26.2
69	5/21	VARIOUS CONDITIONS USING SETRA SYSTEMS, INC. PRESSURE SENSOR									

NOTE: Runs 61 thru 69 made with pressure outlets plugged.

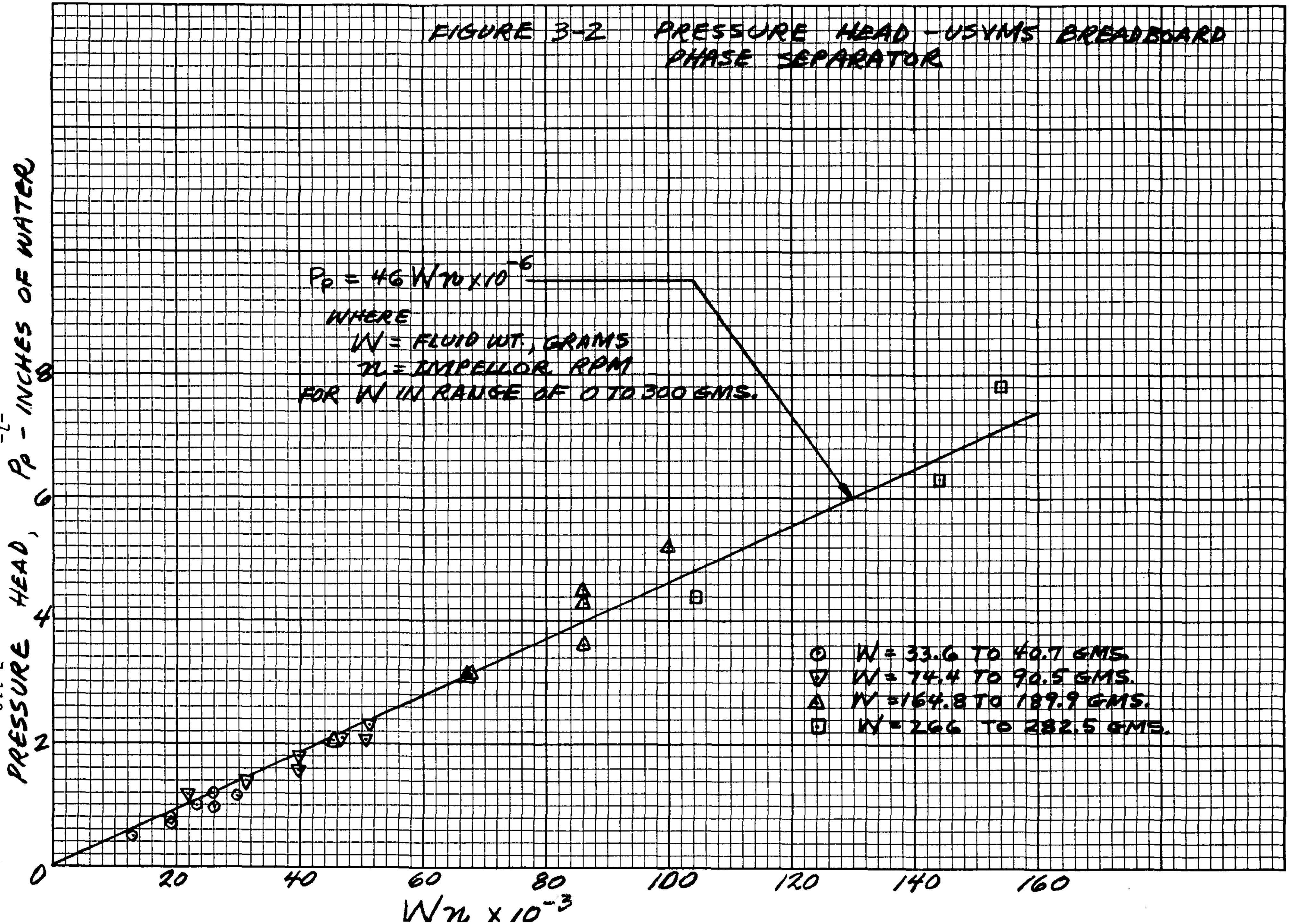


FIGURE 3-2 PRESSURE HEAD - USYMS BREADBOARD PHASE SEPARATOR
$P_p = 46 W n \times 10^{-6}$
WHERE
W = FLUID WT., GRAMS
n = IMPELLOR RPM
FOR W IN RANGE OF 0 TO 300 GMS.
⊙ W = 33.6 TO 40.7 GMS.
▽ W = 74.4 TO 90.5 GMS.
△ W = 164.8 TO 189.9 GMS.
□ W = 266 TO 282.5 GMS.
PRESSURE HEAD, P_p - INCHES OF WATER
0
2
4
6
8
20
40
60
80
100
120
140
160
$W n \times 10^{-3}$

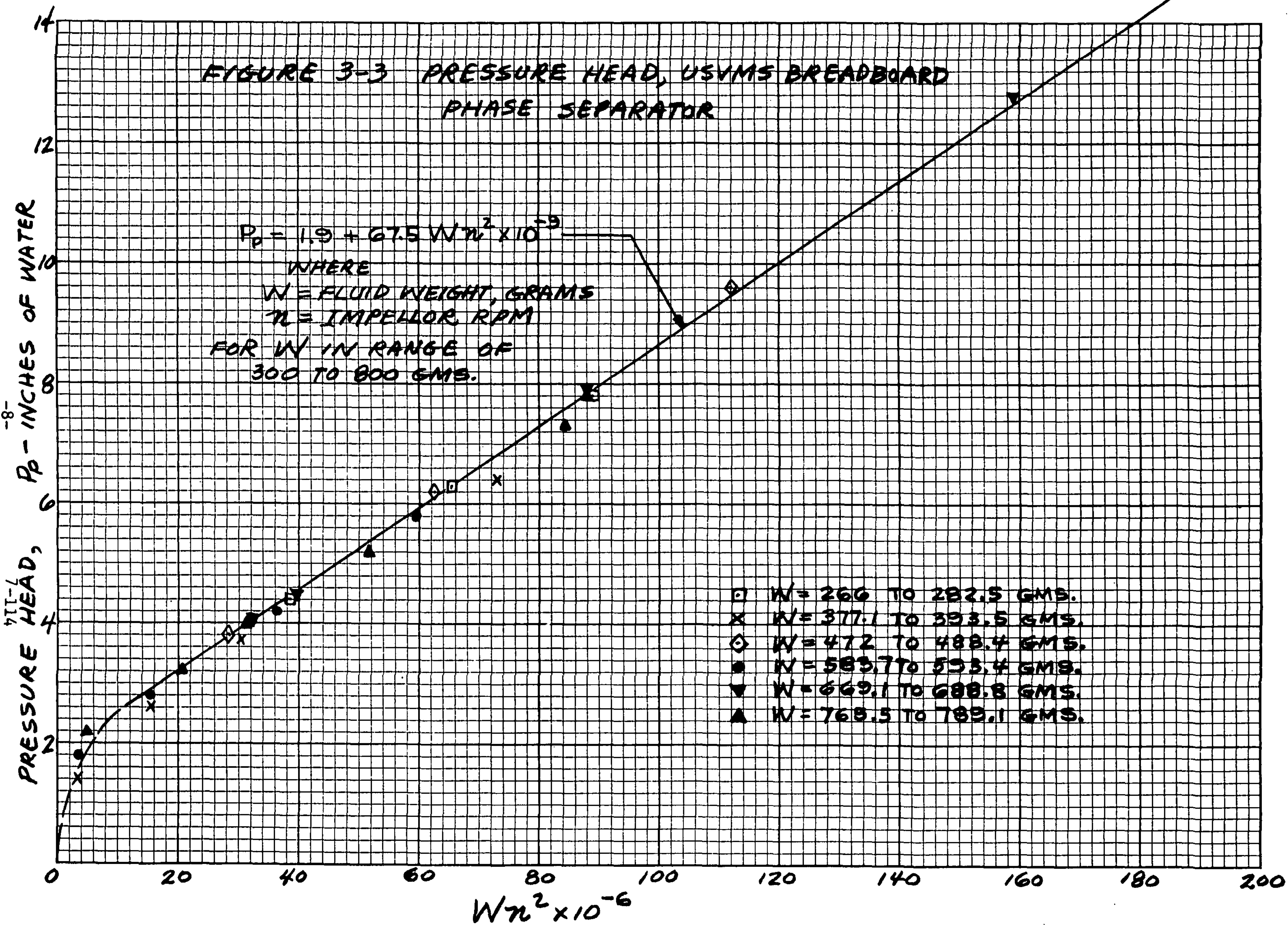


FIGURE 3-3 PRESSURE HEAD, USVMS BREADBOARD PHASE SEPARATOR
$P_p = 1.9 + 67.5\,Wn^2 \times 10^{-9}$
WHERE
W = FLUID WEIGHT, GRAMS
n = IMPELLOR RPM
FOR W IN RANGE OF 300 TO 800 GMS.
W = 266 TO 282.5 GMS.
W = 377.1 TO 393.5 GMS.
W = 472 TO 488.4 GMS.
W = 583.7 TO 593.4 GMS.
W = 669.1 TO 688.8 GMS.
W = 768.5 TO 789.1 GMS.
PRESSURE HEAD, P_p - INCHES OF WATER
$Wn^2 \times 10^{-6}$
0
20
40
60
80
100
120
140
160
180
200
2
4
6
8
10
12
14

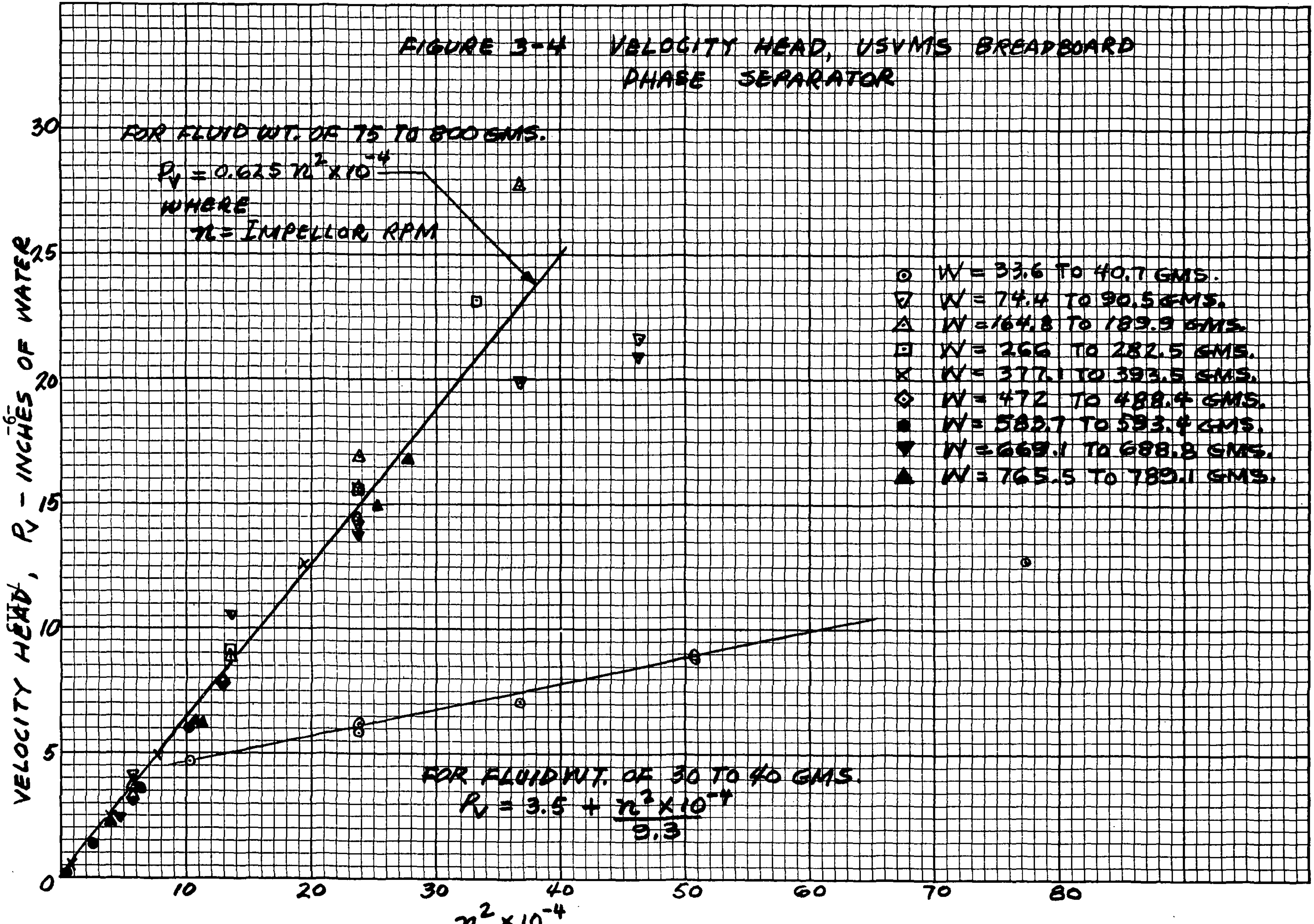


FIGURE 3-4 VELOCITY HEAD, USVMS BREADBOARD PHASE SEPARATOR

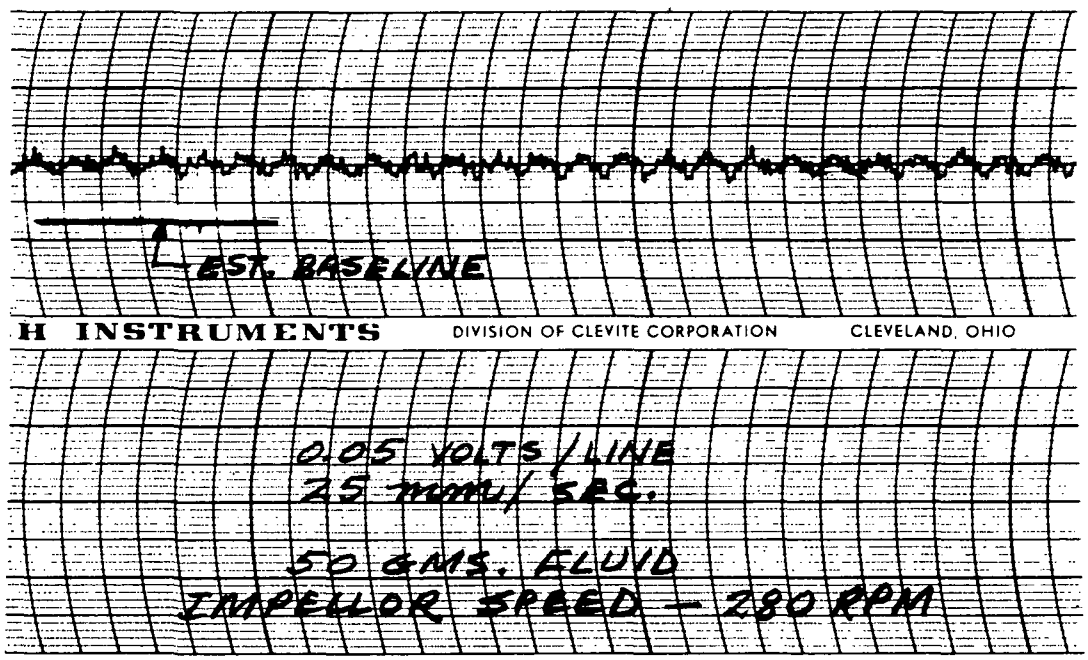


FIGURE 3-5 TYPICAL PRESSURE HEAD SIGNAL USING SETRA SYSTEMS, INC. PRESSURE SENSOR

To determine a possible cause for the above unexpected results, the upper half of the separator housing was removed and operation visually observed for 50 gms of water and an impellor speed of about 100 rpm (higher speeds caused the water to rise over the side of the lower housing). Under these conditions, an apparent imbalance of fluid occurs between the various impellor blades. This imbalance appears to remain stationary in relation to the impellor and thus rotates with the impellor to produce the results shown in Figure 3-5.

Clearance between the housing and impellor blade tips was measured as follows:

BLADE	CLEARANCE
1	.012 inches
2	.013
3	.014
4	.013
5	.0115
6	.013
7	.014
8	.0095

Concentricity was measured and was within $\pm$.001 inches. Marking the "long" blade (No. 8) and visually observing action of the impellor at about 100 rpm, the fluid imbalance appears to be associated with this blade.

3.3 Power Input Data

Total power input as a function of impellor speed squared is plotted in Figure 3-6 and 3-7. No explanation is available for the day to day variations shown. Whether the lack of repeatability is due to variations in wetted surface area (of the housing) or changes in motor/mechanical losses is not evident. Based on past observation, the vortex configuration

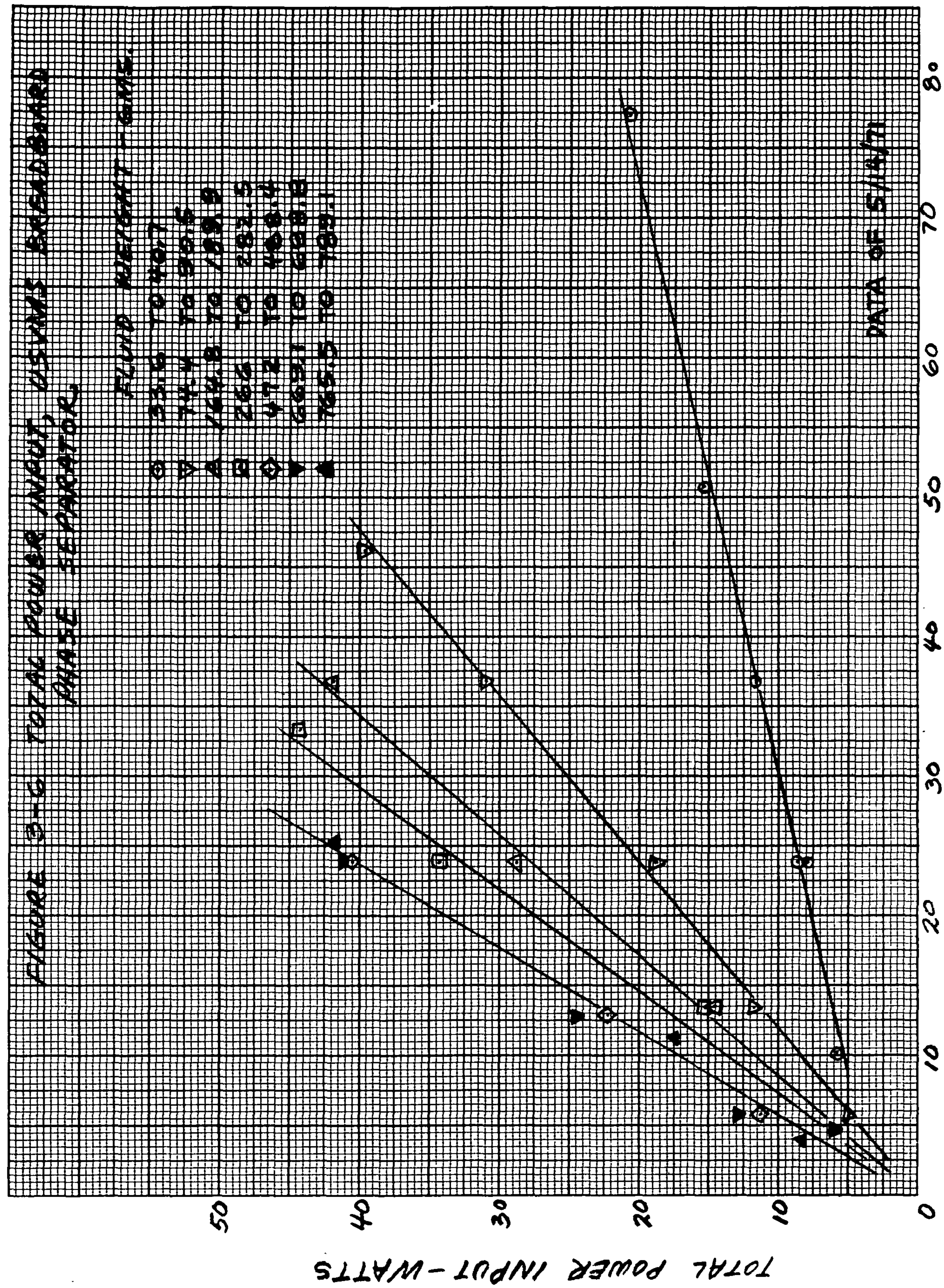
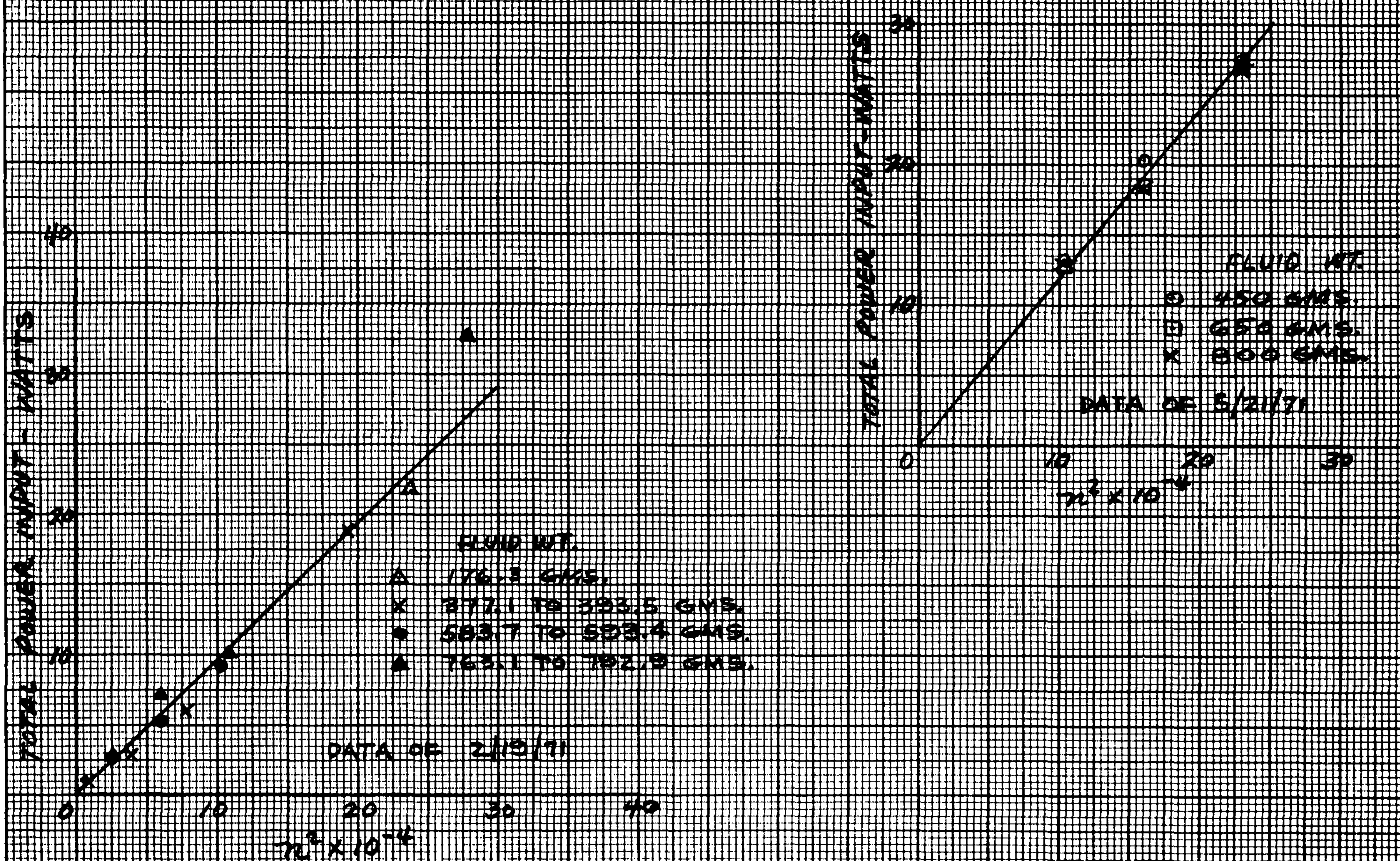


FIGURE 3-6 TOTAL POWER INPUT, USING BREADBOARD PHASE SEPARATOR
FLUID WEIGHT - GMS.
33.6 TO 40.7
74.4 TO 90.6
164.8 TO 189.9
266 TO 282.5
472 TO 488.4
669.1 TO 698.8
765.5 TO 789.1
DATA OF 5/18/71
TOTAL POWER INPUT - WATTS
0
10
20
30
40
50
60
70
80
n² x 10⁻⁴

FIGURE 3-7 TOTAL POWER INPUT, USVMS BREADBOARD PHASE SEPARATOR



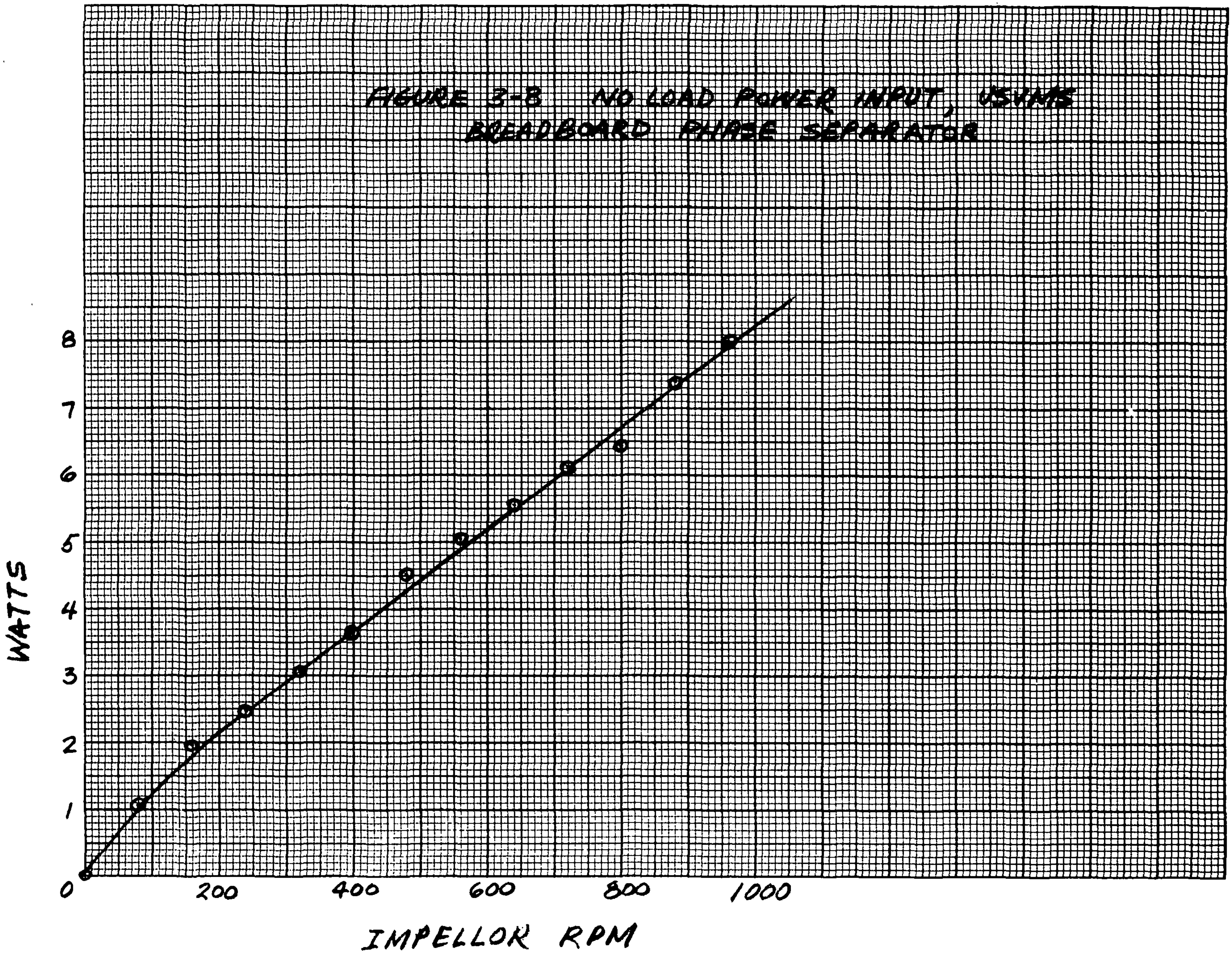


FIGURE 3-8 NO LOAD POWER INPUT, USVMS BREADBOARD PHASE SEPARATOR

appears relatively consistent for a particular impellor speed. Note that the power input appears to be independent of fluid weight (for values over about 400 grams) for the USVMS Breadboard phase separator design.

4.0 RECOMMENDATIONS

Additional tests should be performed to positively determine the cause of the fluid imbalance (Section 3.2 above) as well as the effect of possible corrective actions, e.g., larger clearance, holes in impellor blades, rounded rather than square edged blades, uniform clearance. Although correcting the fluid imbalance is desirable, it should be remembered that the USVMS Breadboard demonstrated excellent measurement accuracy using the phase separator as is.

The USVMS Breadboard pressure switch sensed total pressure at the tangential outlet port. This total pressure is equal to the sum of the velocity head (Figure 3-4) and pressure head (Figures 3-2 and 3-3). Since the velocity head is independent of fluid weight, sensing of the pressure head only is recommended for the URINE SAMPLING AND COLLECTION SYSTEM engineering model.

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DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
7/29/71		Urine Sampling and Collection System	

SUBJECT

MODIFIED PHASE SEPARATOR IMPELLOR BLADES - TEST RESULTS

INFORMATION ~~REQUESTED~~/RELEASED

1.0 SUMMARY

Results of additional phase separator tests indicate a combination of bleed holes and constant impellor blade/housing clearance required to minimize asymetrical fluid loading effects.

2.0 OBJECTIVE

Phase separator test results reported in PIR U-1R62-71-113 indicated an asymetrical fluid loading resulting in both mechanical vibration and static pressure head variations (whose fundamental frequency correspond to impellor rpm). The objective of the subject tests was to explore alternate means of minimizing asymetrical fluid distribution within the phase separator.

3.0 DISCUSSION

3.1 Phase Separator Modifications

Two modifications to the phase separator impellor were made as shown in Figures 1 and 2. As shown in Figure 1, three (3) 5/32 diameter bleed holes were added to each impellor blade. The lower bleed hole center line was located approximately in line with the static pressure port.

In the second modification, shown in Figure 2, the three (3) bleed holes were enlarged to 7/32 diameter and two (2) additional 1/4 diameter holes were added to each impellor blade (for a total of five (5) bleed holes).

3.2 Test Results

Figure 3 through 5 show the results of tests with the three bleed holes (see Figure 1). Figure 6 illustrates the results of tests with five bleed holes (see Figure 2).

Comparatively, the five bleed hole configuration minimized the amplitude of the fundamental frequency caused by asymetrical fluid loading, i.e. the magnitude of asymetrical fluid loading has been reduced, particularily at the critical 50 ml fluid loading condition. In both cases, induced vibration amplitude were also observed to be noticeably reduced as compared to the original no bleed hole condition.

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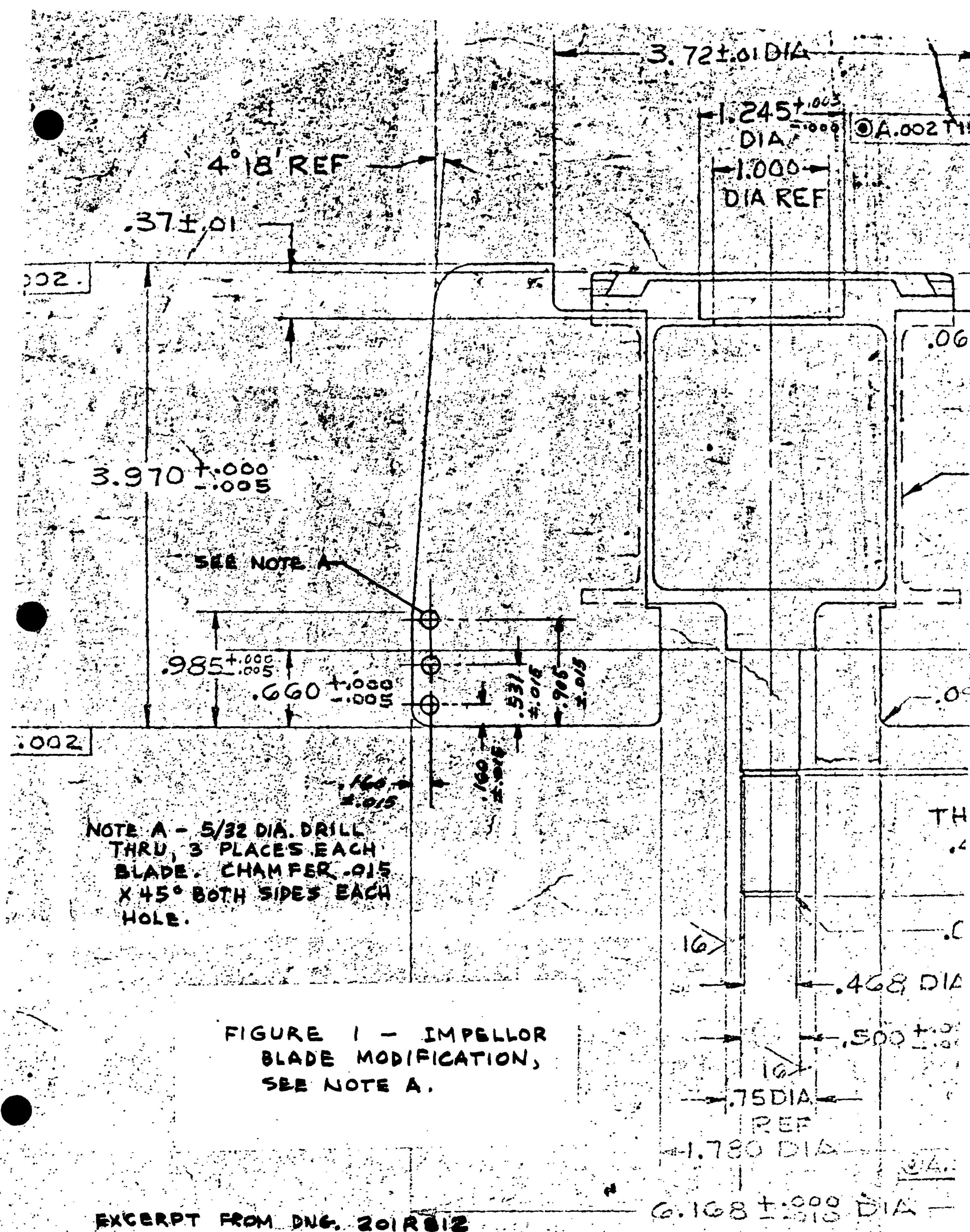

FIGURE 1 - IMPELLOR BLADE MODIFICATION, SEE NOTE A.

EXCERPT FROM DWG. 201R812

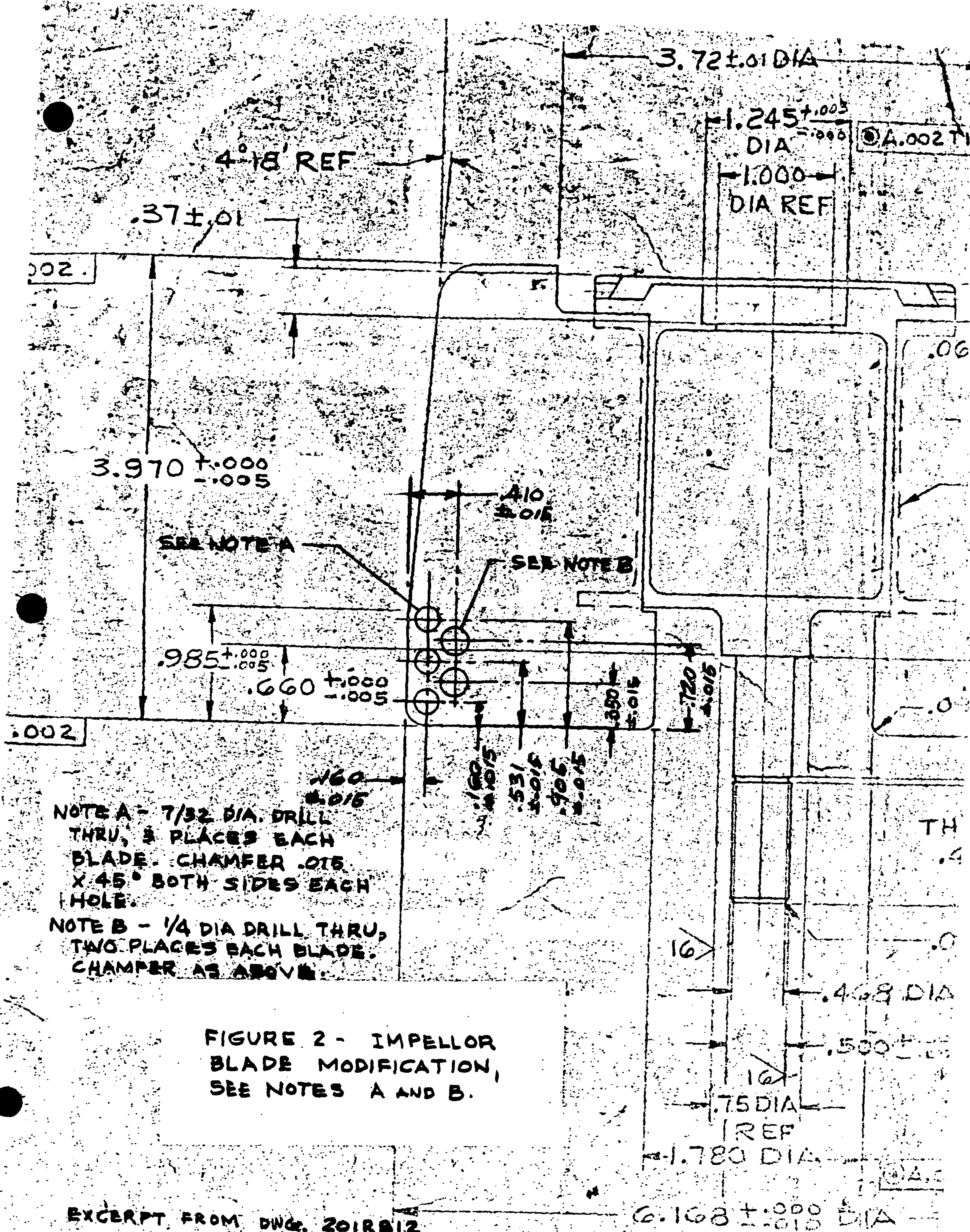

FIGURE 2 - IMPELLOR BLADE MODIFICATION, SEE NOTES A AND B.

EXCERPT FROM DWG. 201R812

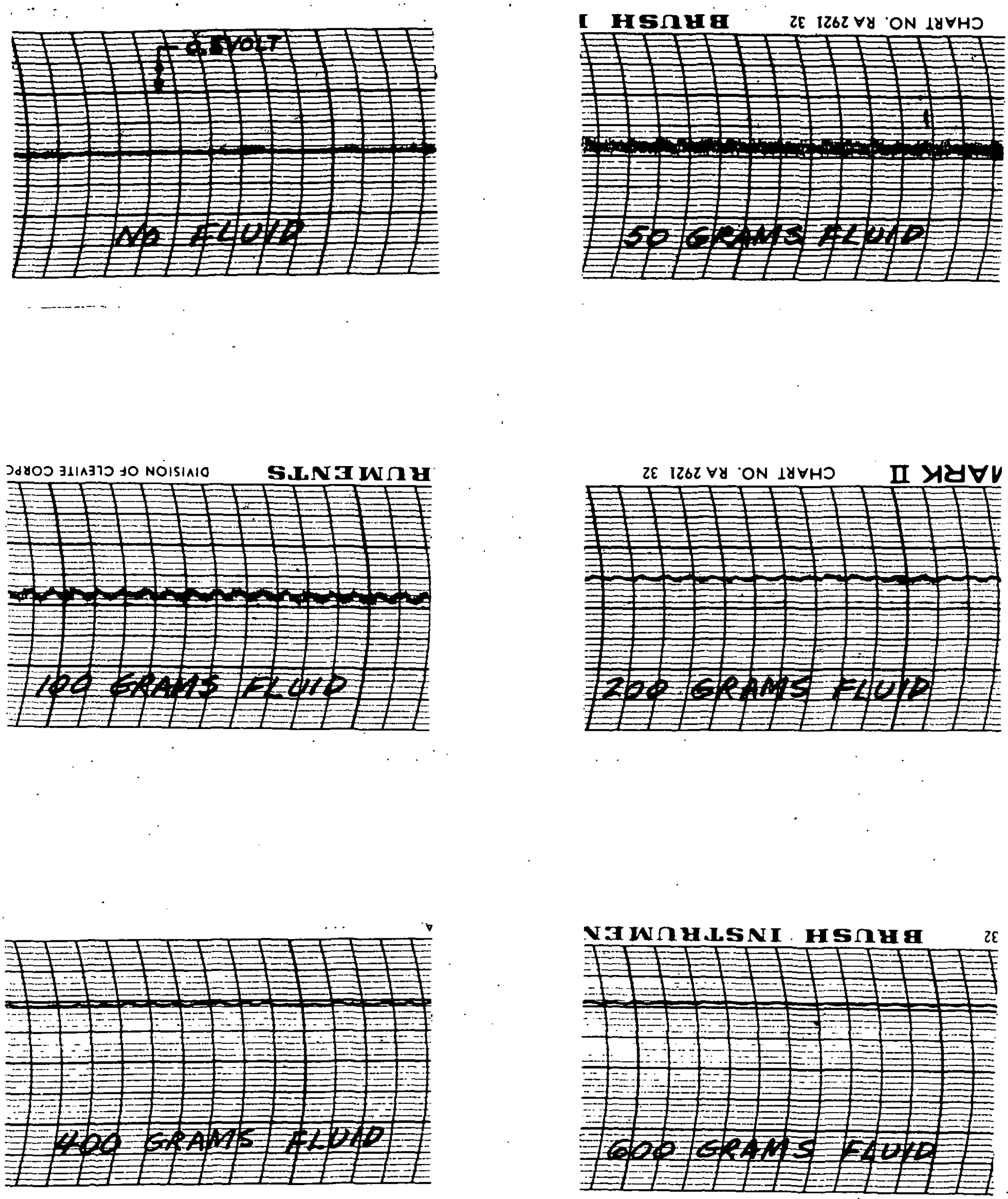

FIGURE 3 - PHASE SEPARATOR IMPELLOR SPEED 400 RPM
(CHART PAPER: 25 MM/SEC.; 0.1 VOLT/LINE)

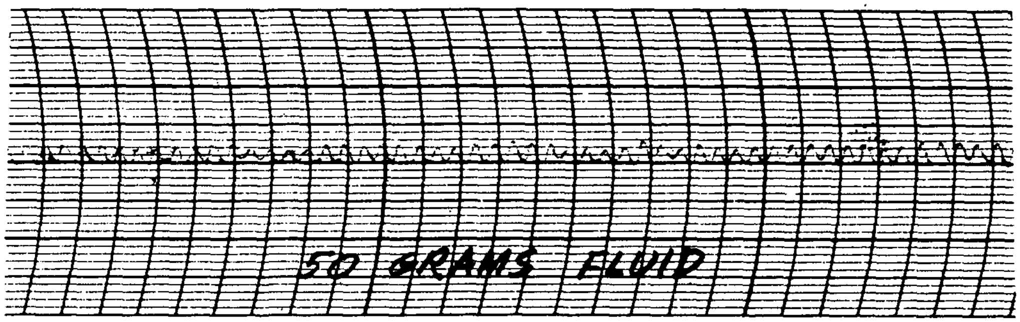

FIGURE 4 - PHASE SEPARATOR IMPELLOR SPEED 400RPM
(CHART PAPER: 125 MM/SEC.; 0.1 VOLT/LINE)

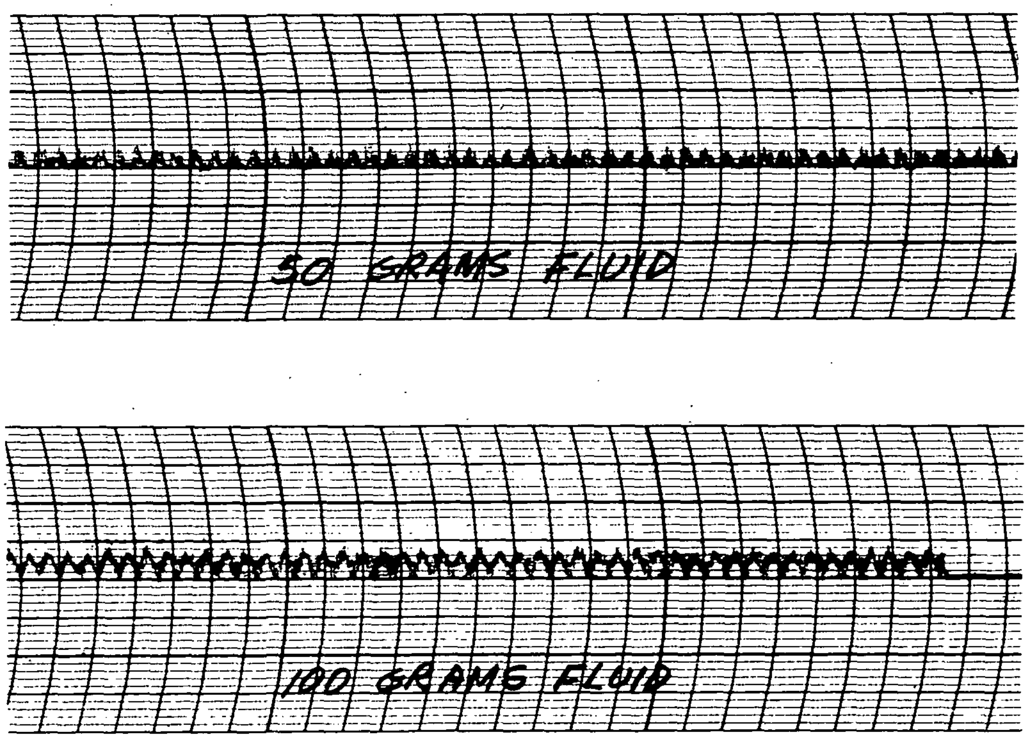

FIGURE 5 - PHASE SEPARATOR IMPELLOR SPEED 600RPM
(CHART PAPER: 25 MM/SEC.; 0.1 VOLT/LINE)

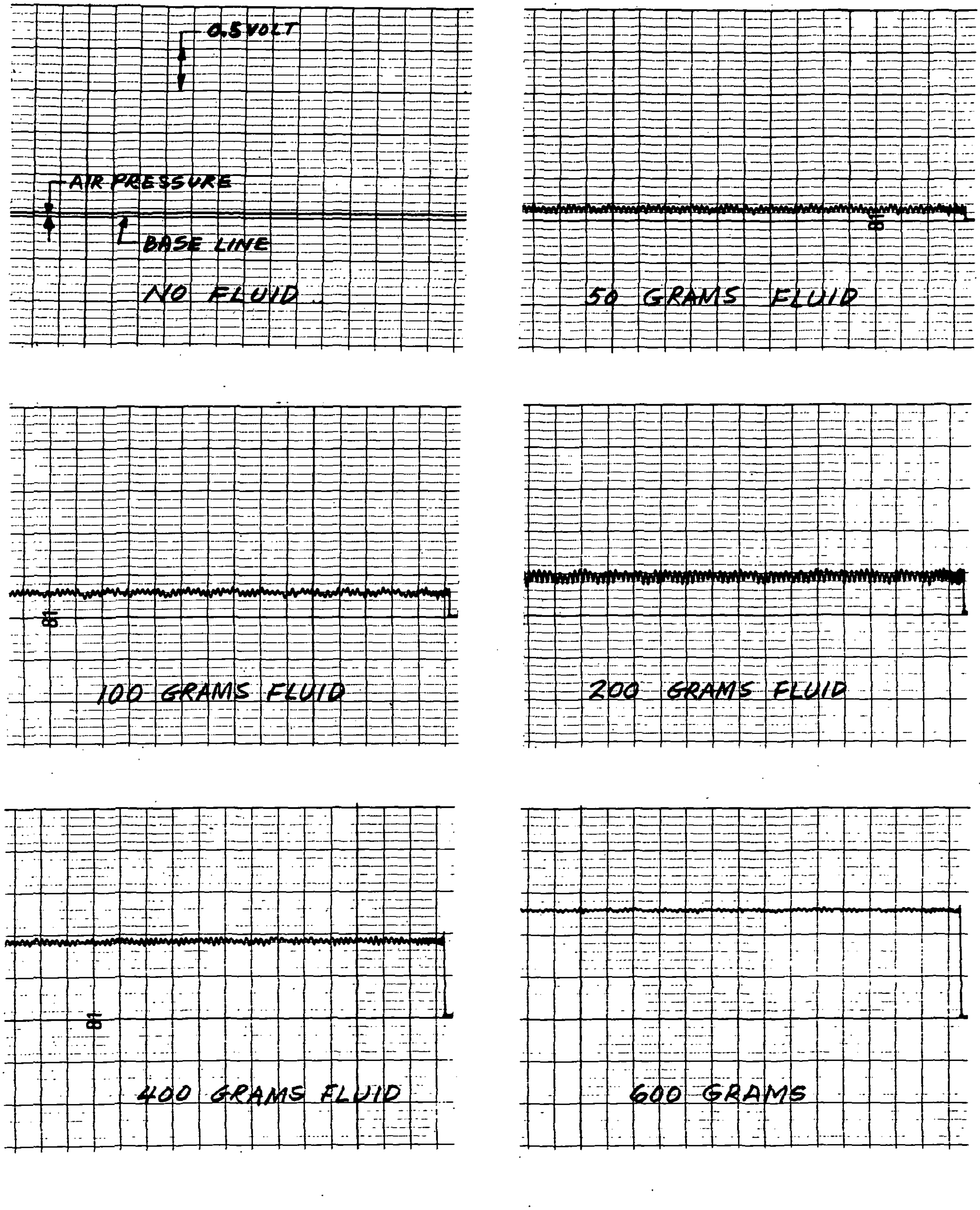

FIGURE 6 - PHASE SEPARATOR IMPELLOR SPEED 400 RPM
(CHART PAPER: 50 MM/SEC.; 0.1 VOLT/LINE)

3.2 Test Results (Continued)

Pressure sensor output for the 5 bleed hole configuration is shown in Figure 7. The sensor calibration curve, Figure 8, was used to convert output to inches of water. Note that for low fluid weights, the addition of the bleed holes had little effect on the static pressure. Figure 3 data, for the 3 bleed hole configuration, is consistant with the above.

4.1 CONCLUSIONS AND RECOMMENDATIONS

(a) The addition of bleed holes will minimize but probably not eliminate asymetrical fluid loading.

(b) A combination of bleed holes and impellor blade length control (i.e. constant spacing between impellor blade tip and housing) is recommended for best minimization of asymetrical fluid loading.

(c) In the critical cut-off range (around 50 grams), the bleed holes have little effect on the resulting static pressure.

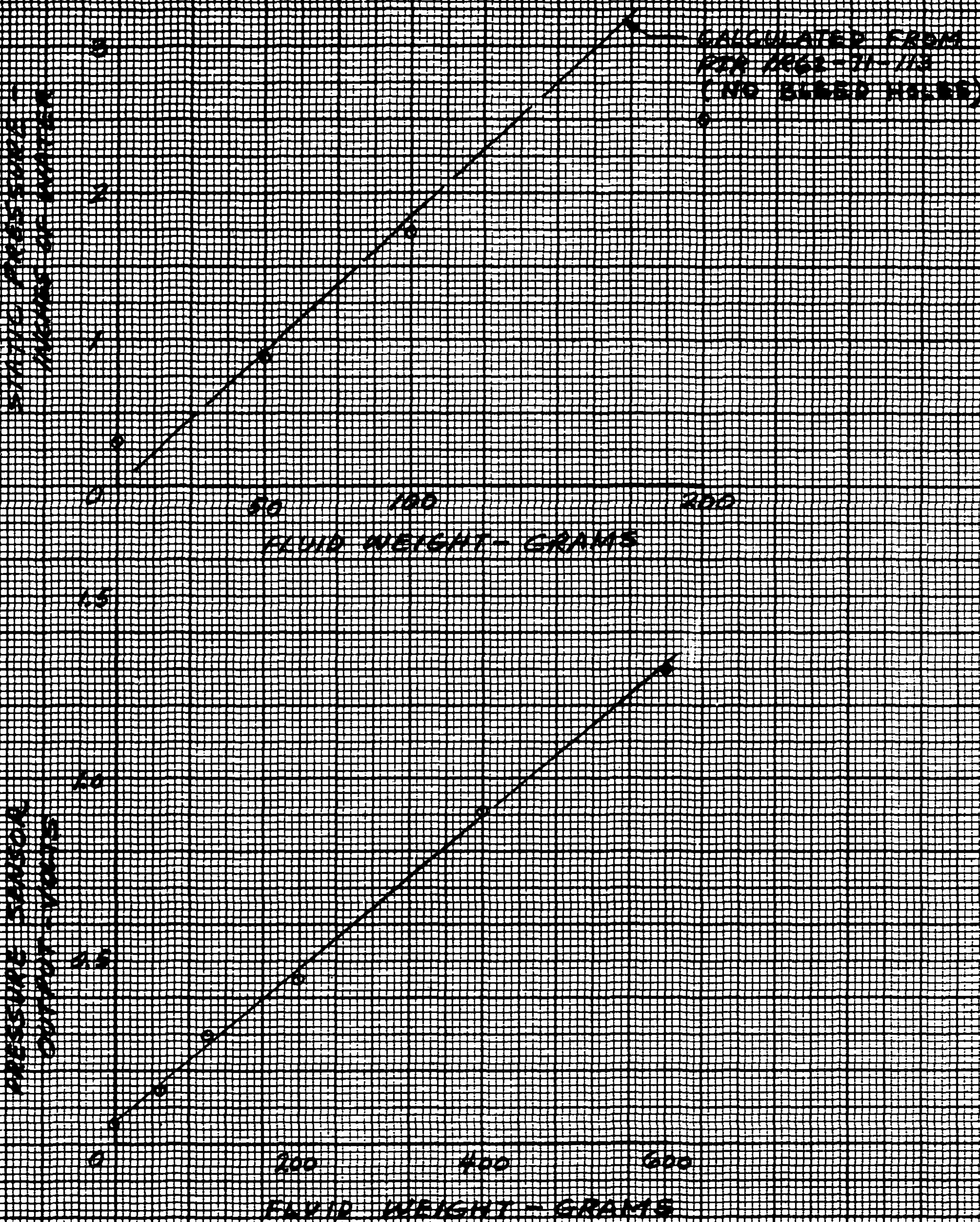

FIGURE 7 - REPLOT OF FIGURE 6 DATA

SEE FIGURE 2 FOR BLEED HOLE CONFIGURATION

-11

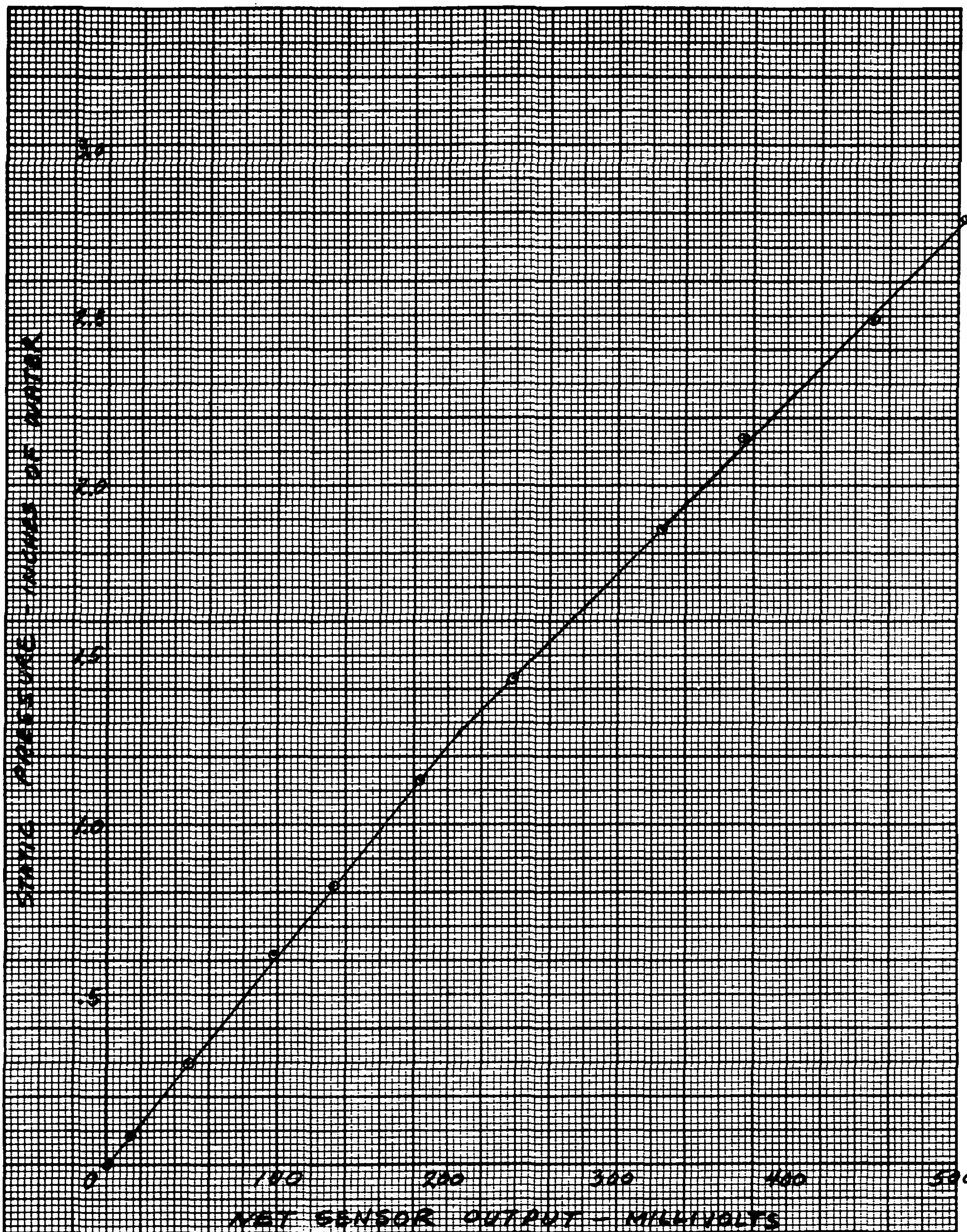

FIGURE 8 - PRESSURE SENSOR CALIBRATION

7/28/71

7.6 MICROBIOLOGICAL SURVEY

The Urine Sampling and Collection System as presently configured does not include a flush or equivalent capability for microbiological and cross-contamination control. The addition of this capability was deferred as a potential add-on for later development phases. This delay permitted examination of the current design to assess the magnitude of the microbiological/cross-contamination control problem. GE PIR 1R61-71-129 (attached) reports on this general problem area.

GENERAL ELECTRIC
MISSILE AND SPACE DIVISION
PHILADELPHIA

PROGRAM INFORMATION REQUEST / RELEASE

PIR NO.	*CLASS. LTR.	OPERATION	PROGRAM	SEQUENCE NO.	REV. LTR.
	U	— 1R61 —	71 —	129	

*USE "C" FOR CLASSIFIED AND "U" FOR UNCLASSIFIED

FROM	TO
M. G. Koesterer, Microbiologist Medical and Life Sciences	G. L. Fogal Life Systems

DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
10/29/71		Task 1.0 IMBLMS B4	

SUBJECT

MICROBIOLOGICAL CONSIDERATIONS FOR THE URINE SAMPLING & COLLECTION SYSTEM(USCS)

INFORMATION REQUESTED/RELEASED

1.0 INTRODUCTION

Biowaste products such as urine are, or can become, highly contaminated and/or can support the growth of microbes indigenous to man, as well as other opportune contaminants. Contamination control must be exercised in the normal collection, processing, and storage of such products, as well as under emergency modes of operation.

Microbial contamination control must be considered for several reasons:

a. To eliminate chemical and microbial cross-contamination of samples, the contemplated experiments require the obtaining of unaltered samples and maintaining them in an unperturbed condition for either in-flight or post-flight analysis. Since microbial action is usually the cause of sample change, this infers that samples will be taken and handled in sterile apparatus and preserved under conditions which inhibit their growth.

b. To prevent chemical and microbial contamination of the environment.

   1. To protect the health and safety of the crew by means of the ambient environment, as well as transfer of contamination between crew members or re-contamination of each crew member.

   2. To prevent spread of nutritive and non-aesthetic materials and micro-organisms which could result in deterioration of hardware.

1.1 CONTROL OF SYSTEM AND SAMPLE CONTAMINATION

The above considerations then define the requirements from a contamination point of view in a system such as the Urine Sampling and Collection System (USCS):

a. The system must be capable of total containment of all materials (solids and liquids) and release only gases which are safe. Removal of any micro-organisms aerosolized in the system and any toxic or objectionable odors from these gases would be required.

b. The system must be capable of being maintained in a chemically and microbiologically safe condition for use and sampling.

S. Gottlieb
A. A. Little (5)
R. W. Murray
F. S. DiSanto
J. Mangialardi

PAGE NO. ____ OF ____

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FORM 1020 H REV. (9-65)

1.2 CONTROL OF CONTAMINANTS TO THE ENVIRONMENT

In addition to the considerations for maintaining control of the contaminants to the sample, the aspect of controlling or not releasing microbial and/or chemical contaminants to the vehicle atmosphere and the sanitation of the man/equipment interfaces are also prime considerations in operating a system such as the USCS.

The possible sources of contamination are:

a. The transport air used to convey the biowaste (urine in this case) into the collection assembly

b. The crew member with his indigenous and altered (discard) microflora from both the genitalia and his hands, and

c. The urinal unit itself.

The following sections discuss the status of control measures for these parameters as they exist for the engineering model of the USCS.

1.3 REVIEW AND EVALUATION

Therefore, as a result of acknowledging these requirements, a review of the USCS was performed and a preliminary evaluation made as to how each functional component or operation would meet those requirements. It would be well to analyze the objectives of the experiment protocols also, in an attempt to determine whether the system must indeed be sterile (completely free of all viable micro-organisms) or whether a high degree of decontamination would suffice. Obviously, if it is determined that the system be sterile, this would require positive application of a procedure and agent to accomplish the complete destruction of all viable micro-organisms. In realizing that no such requirement has as yet been defined, both possible approaches have been considered in this study. As a result of the review performed, recommendations have been generated for systems modification and assessing the engineering model in a future phase of the overall USCS program.

2.0 REVIEW OF USCS HARDWARE

In reviewing the contamination control aspects of the USCS engineering model and its operation it is obvious that

a. The unit does retain approximately 25 ml volume of the urine or other fluid processed in the phase separator. The lines after air purging appear to be void of any residual fluid. The residual retained does represent a problem in that if left for any length of time it will support the growth of micro-organisms and this would allow for gross alteration of the chemical constituents.

b. The unit equipped with a single urinal with the future addition of a disposable liner could suffice for a single crew member; but consideration of use by more than one crew member indicates some cross-contamination potential.

c. The hardware selected appears to be compatible to a chemical decontamination and even a steam flush.

Other aspects of the USCS engineering model are discussed in other sections of this report in light of the specific contamination or contamination control problem identified. A brief discussion of the above points is presented here because they do represent the major area of concern.

2.1 RESIDUAL VOLUME

It has been ascertained that the currently designed phase separator will retain approximately 25 ml of urine or other fluid being processed. It is possible to reduce this in the future by design. However, in a preliminary examination of the problem that such a residual would present, it has been determined that the carry over of the entire 25 ml (which probably won't occur with an average of 375 ml per micturation and 7.4 micturations per day per man) wouldn't affect the composite sample to any great degree. First, the residual would remain in the phase separator an average of about 3 hours at a reasonably ambient temperature (decreasing from body to ambient). This doesn't allow for much alteration of a relatively clean (microbiol) sample.

Secondly, once removed to the sample container, it will be chilled and preserved even more efficiently. In fact, alteration is more likely to occur in the sample container where solids, etc., will drop out of solution due to lowering the temperature.

Thirdly, the 25 ml residual will be deluted by the next micturation collected in the phase separator (average 20:400 or 1:20) and then only a fraction of that (20%) is shunted to the sample container.

Based on the above analysis, the residual would not appear to produce a significant effect on the ultimate sample to be preserved.

2.2 SINGLE VERSUS MULTIPLE MAN USAGE OF USCS

The guidelines under which the USCS was designed and built were:

a. For individual usage.

b. For pooling of representative urine samples of each micturation over a 24 hour period.

If a single individual uses the system, it is capable of collecting the representative sample from each micturation and no reason is obvious that the composite 24 hour sample would not be representative, with only minor fluctuations in certain chemical constituents (such as steroids) due to the physiological activity. A single user does not present a cross-contamination problem and addition of a disposable urinal liner for each 24 hour period, with a flush rinse (containing a germicide) once during that time period appearing adequate for control of the contamination in the system and/or recontamination of the individual user. Such an approach acknowledges a small urine residual present in the phase separator with some alteration and carry over of altered products to the 24 pooled sample.

2.3 AEROSOL FORMATION AND CARRY OVER BY TRANSPORT AIR

Based on a simple comparison of color [1] of a solution of distilled water through which transport air had been bubbled both while the phase separator was operating and quiescent, with diluted samples of the same urine, it appears that less than 1 part per million of urine is aerosolized and carried over. It is recommended that tests using aqueous based dye or some other measure be performed to verify this on some future aspect of the program.

3.0 CONTAMINATION CONTROL

3.1 CLEANING/DECONTAMINATION

The system must be thoroughly cleansed in order to avoid carry-over and cross-contamination from sample to sample. Physical cleanliness is also a prerequisite for effectively decontaminating or sterilizing the system. The real value of effective cleansing is twofold and is necessary if any potential inorganic or organic residues are present.

The possible approaches which could be used to clean and decontaminate or sterilize, if required, include:

a. Aqueous based cleansing solution

b. Hot water (no additives) flushing

c. Steam flushing

a. and b. above could be augmented by adding a germicide and application of ultrasonic or mechanical agitation.

Since such a choice was not evaluated due to the limitations on the current contracted phase, it remains that choice of a cleansing/decontamination process should be evaluated during the next phase.

---

1 Standard Color Units Test - Taylor Water Analyzer

Limited experience from preliminary microbiological studies on the previous GE prototype (Urine Sampling and Volume Measuring System) indicate that small volume flushes appear adequate to remove traces of residual chemicals and viable micro-organisms from the hardware of the actual nature of the USCS. However, only a thorough testing program during some future phase will allow a critical evaluation of the cleansing method and decontamination agent selected.

However, as a result of the small preliminary effort expended, the following factors have been identified for consideration before an appropriate cleaning procedure can be defined:

a. Choice of appropriate cleaning agent and amount for the cleaning method selected.

b. Choice of appropriate germicide for inclusion in cleansing solution (if this approach is chosen)

c. The most efficient cleaning method based on the system configuration

d. Choice of appropriate rinse agent and volume required to remove any residuals of the cleaning and/or germicide added

e. Consideration and assessment of other factors such as time, solution temperature, agitation, soil (type and level) and compatibility with the material of construction.

One of the goals in the next phase should be to analyze the available options and decide on the most practical technique.

3.2 HARDWARE STERILIZATION

If indeed sterilization, i.e., the absolute destruction of all living forms, is required in order to assure that any residual viable micro-organisms are destroyed, a positive means of achieving that state must be implemented. There is no need to recite all the basic theory of sterilization herein, but it should be iterated that any sterilization process is usually based on calculating a treatment (including some safety factor) severe enough to destroy a high level of the type of organism most likely to be present in the system. In the light of this, it is presumed that sterilization (rather than decontamination) would require some agent (chemical or heat) which is significantly more effective that the usual germicides considered capable of producing a high degree of decontamination.

For purposes of sterilizing the USCS, then it is conceivable that sterilization could be achieved by either of the following methods:

a. Application of a thermal process. Moist heat would be the method of choice. The use of a dry heat or irradiation process has not been ruled out, but experience and the recycle times estimated would make them secondary choices. The basis for the steam or chemical agent methods are discussed in the following subsections.

b. Utilization of any of several chemicals, singly or as additives to rinse or flush solutions.

3.2.1 Thermal Sterilization Approach

The conditions necessary for effective steam sterilization are similar, whatever the scale or method of application. The required temperature (pressure) must be achieved in all parts of the equipment and air must be thoroughly purged from the system. Air pockets prevent the free access of steam and readily result in failure to achieve sterility. Superheated steam should be avoided, since this is less effective than saturated steam. The system must be subjected for the appropriate time, dependent to a degree upon the probability of sterility required.

The use of low pressure, low-temperature steam in conjunction with high-vacuum systems (to effectively remove air or other gases) is a highly effective disinfectant process (Kalsey, 1965). Large scale fermentation equipment is usually sterilized by a flow of saturated steam under pressure, and after sterilization, aseptic conditions are maintained by sealing valves, glands, etc., with steam (Richards, 1968). Williams and Grana (1968) have shown the effectiveness and practicality of steam at not less than 100^{o}C. for 30 minutes to sterilize a spacecraft water management subsystem, including the water processing circuit, evaporators, and associated plumbing.

The use of hot water or steam flushes have been commonplace in the dairy and beverage industry for years. A flush of 70^{o}C. steam will kill vegetative organisms in 30 minutes and most bacterial spore forms in slightly longer time periods, (Alder, 1963).

It is feasible: (a) to determine whether the USCS is compatible to steam and capable of utilizing saturated steam under some pressure (0-15 psig) depending upon safety considerations, etc.; and (b) showing such a process adequate to attain a sterile condition, if such is required. Only further analysis during some future phase of the program will determine the practicality of this versus other feasible methods.

3.2.2 Chemical Sterilization Approach

Chemical agents are practical for the sterilization of waste management and biomedical sampling and hardware for manned spacecraft. A variety of liquids or gaseous agents have been shown to be effective for such purposes. The use of gaseous agents has an attendant disadvantage over liquids in that the candidates are all much more toxic, or combustible, and require tighter systems for containing them. A special safety program would be required to assure that no release to the cabin atmosphere could occur because of the potential for a catastrophe.

Liquid compounds or solutions, preferably aqueous based ones, do lend themselves to practical, safe, effective processes when used either alone or as additives to rinses or flushes. Use throughout the treatment period requires no precautions other than reliable containment and metering. Liquid compounds appear compatible with previous prototype models of waste handling and volume measurement systems and should conceivably be compatible to the USCS also. Means for providing a reservoir, an automated dispensing system, would have to be added to the design of the current model. Choice of an agent would have to be part of a future phase for this program.

This approach, although highly feasible and the most easily adapted to the current USCS model, should be compared with the thermal approach for overall effectiveness and reliability in the light of the overall requirements (yet to be defined) for the system.

3.3 TRANSPORT AIR STERILIZATION

Cabin air is required to provide zero gravity transportation of urine into the liquid/gas separator. Any organisms aerosolized or entrained in the transport air coming from the phase separator will be mechanically removed by the microbially retentative filter through which that air is forced before it is vented or recirculated to the cabin environment. Microorganisms can be removed by use of mechanical filters. The filter chosen [1] will be a composite odor and bacterial filter. It has 0.08 micron pores, and is capable of removing up to 98 percent of the particles greater than 0.008 micron and 100 percent greater than 0.08 micron. The filter itself is pleated with an annular space between the inner bacterial filter and the outside well which is filled with activated charcoal to absorb odors. It is sized so that a minimal pressure drop occurs at rated blower output and capacity should allow for normal degradation over a nominal mission without affecting its efficiency for sterilization of the air or performance of the transport air blower.

It remains to be evaluated by testing on some future phase under operating conditions for its ability to retain organisms even if wetted due to any water vapor in the transport air. If an extra measure to avoid this is required, it is possible to either add a metallic wool depth filter upstream of the bacterial filter to remove any dropletes carried over in the transport air or apply a heater to keep the dew point up and avoid condensation on or in the filter material.

3.4 URINAL DECONTAMINATION

The interfaces with the crew and hardware are an area of prime concern as regards either cross-contamination between crew members by direct contact or contamination through the atmosphere, or re-contamination of the same crew member. The urinal can be equipped with replaceable liners so that each man has his own. This could minimize contamination transfer by two of the three modes mentioned. However, some method of sanitation will be required to minimize transfer of contaminants entrained in the urinal hardware or lines.

---

[1] Petrosorb Ultipor 9, Aircraft Porons Media, Inc., Subsidiary of Pall Corporation, Glen Cove, L.I., New York 11542

In past programs, several approaches have been considered: ultraviolet irradiation, thermal treatement with dry heat, liquid rinses, and use of disinfectant wipes. Manufacturing the unit out of or plating with a biocidal material has also been considered.

The most practical at this time would be to incorporate a wiping of the surface with a pre-moistured disposable wipe and flush with a rinse containing a germicide. The wiping will remove any accumulation of waste material, urine, skin oils or secretions, and other debris from the urinal and the rinse would flush the lines clean.

In order to incorporate these some additional design and testing will be required because the USCS engineering model, although apparently compatible with such procedures, does not have them implemented in the current design.

3.5 CREW MEMBER SANITATION (PERSONAL HYGIENE)

Some positive means for minimizing transfer of indigenous body contaminants to the system, primarily the urinal, hand holds, etc., can be expected. It really does not fall into this discussion per se and should be handled under Personal Hygiene. However, it must be considered for interface and testing purposes.

4.0 TESTING

After incorporation of all of the recommended adjuncts to the USCS engineering model, or the next generation unit, only thorough testing of the system and assessment of the results will allow verification of its adequacy in meeting the sampling and the safety objectives. As part of that test program, analyses should be performed on the following parameters:

a. Verification of safe operation of the system by microbiological testing of all potential modes or sources of contaminants.

b. Quantitative and qualitative tests on the representativeness of the compounds in the urine sample compared to the starting material.

c. Degree of cleanliness and sterility of the system by utilizing known challenges. (high levels of chemical and microbial contaminants)

d. Estimate the ability of the subsystem to control cross-contamination from sample to sample using simulated (pure biochemicals and specific strains and levels of bacteria)

e. Determination of the sensitivity, accuracy, and repeatability of the system for each type of material of interest, using suitable control speciments.

5.0 RECOMMENDATIONS

Based on the above review of the USCS program and the engineering model (and forerunners) the following logical steps are recommended for any future program to further develop the USC System:

a. Evaluate and analyze the degree of contamination control required (i.e., highly decontaminant or sterile)

b. Outline possible approaches (techniques, agents, volumes, etc.) to accomplishing the degree of cleansing, decontamination or sterility required

c. Perform trade-off study on possible approaches versus system, material and sampling objectives elucidated

d. Test the selected method by applying microbial and chemical challenges and assessing experimental results

e. Modify method(s) selected, as required to meet the objectives

f. Implement selected, tested and proven method in next generation of USCS hardware.

6.0 SUMMARY

In summary, the major sources and modes of microbial (and to a large degree, chemical) contaminants and their potential transfer modes have been identified and considerations offered to control them. The present engineering model has not been designed to include all of them, although it would not be difficult to adapt and implement them relatively easily. Recommendations have been made concerning development of the next generation unit and the bases which should be considered in the testing program to verify the adequacy of the provisions considered for controlling contamination.

7.0 REFERENCES

a. Alder, V.G., 1963, "Low temperature steam disinfection (of wool blankets)", Nursing Times - 59 1234.

b. Kelsey, J.C., 1965, "Sterilization and Disinfection Techniques and Equipment", Journal of Medical Laboratory Technology - 22, 209-215.

c. Richards, J.W., 1968, "Introduction to Industrial Sterilization", Academic Press, New York, New York, 183 pp.

d. Williams, J.R., and Grana, D.C., 1968, "Microbiological Studies on a Water Management Subsystem for Manned Space Flight Paper 680718, Aeronautic and Space Engineering Manufacturing Meeting, October 7-11, 1968, Society of Automotive Engineers, Inc., 2 Pennsylvania Plaza, New York, New York.

7.7 LIST OF DRAWINGS

Title	GE Drwg. No.
Mechanical	
Urine Sampling and Storage System Assembly	ER47D224700
Phase Separator	ER47D224730
Housing, Inlet Side	ER47D224731
Housing, Motor Side	ER47D224732
Impellor	ER47D224733
Inlet/Outlet	ER47C224734
Shaft and Space Sleeve	ER47B224735
Adapter Plate	ER47C224736
Urinal	ER47C224737
Storage Container	ER47C224738
Hose	ER47C224739
Urine Pump Assembly	ER47C224740
Yoke	ER47C224741
Rotor	ER47B224742
Enclosure Detail	ER47D224746
Structure Detail	ER47D224747
Storage Compartment	ER47D224748
Filter Mounting Plate	ER47C224749
Accumulator Assembly	ER47C224750
Cap	ER47C224751
Housing	ER47C224752
Piston	ER47B224753
Contact	ER47B224754
Accumulator	ER47C224755
Sensor Housing	ER47C224756
Electrical	
Power Distribution Block Diagram	ER47B224720
Programmer Block Diagram	ER47C224721
Electronics - Input Switching	ER47C224722
Electronics - Volume Counting	ER47C224723
Electronics - Time Circuits	ER47C224724
Programmer Control Logic Wiring List	ER47A224725
Electronics - Card 1	ER47C224726
Electronics - Card 2	ER47C224727
Electronics Subassembly Connector Wiring	ER47C224728
Electronics - Pulse Sensor Schematic	ER47C224729
USCS Wiring Diagram	ER47D224776

7.8 OPERATING INSTRUCTIONS

The Urine Sampling and Collection System Engineering Model represents a fully automated approach to urine collection, volume measurement and sampling. System operation requires the following user actions prior to and during use:

Step 1: Set-up

a. Connect 26 VDC supply cable (includes ground lead) to 26 $\pm$2 VDC supply.

b. Connect coolant line (coolant flow 130 lbs/hour at 36 $\pm$ 3^{o}F inlet temperature).

c. Connect dump port to waste drain or other as desired.

d. Install sample container in refrigerated compartment.

Step 2: Start-up

a. Actuate power "ON" switch.

Step 3: Calibrate (as required; see Section 5.0 for additional information.)

a. Actuate "START" switch

b. Inject a known quantity of fluid into the system via the urinal. A test volume of 200 ml is recommended (average micturation volume found in 4 man - 90 day simulator test).

c. Replace urinal and actuate "SAMPLE" switch.

d. Compar e the injected test volume with measured volume as shown on digital meter at termination of the cycle.

e. Adjust residual compensation value and repeat (b) through (e) until test volume and measured volume are essentially identical.

Step 4: Sample

a. Install fresh sample container in refrigerated compartment (if desired).

b. Actuate "START" switch.

c. Remove urinal and urinate into urinal.

d. When micturition complete, replace urinal. If urinal hose not fully elevated, as when used in a standing position, elevate hose momentarily to ensure that all the urine enters the phase separator (this action not required when operating in a zero gravity environment).

e. After urinal is replaced, actuate "SAMPLE" switch.

f. Record volume displayed on the digital volume meter at the end of the cycle.

Step 5: Next Sample(s)

a. Repeat Step 4.

Step 6: Shut-Down

a. Place power switch in "OFF" position.

b. Remove sample container.

7.9 COMPONENT DATA SHEETS

Component data sheets as available are included in this section in the following order:

1. Analogic Corp. 3-1/2 Digit Digital Panel Meter
2. Rotron Mfg. Co., Model R/201 blower
3. Pall Aircraft Porous Media, Retrosorb Ultipor Cartridge
4. Inland Motor Corp. Torque Motor and Tachometer Generator
5. National Semiconductor Current Drivers

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TECHNICAL DATA AN2510

3½ digit digital panel meter

ANALOGIC®

- 3-1/2 digit display (including 100% overrange
- Standard F.S. input ranges, including 100% overrange: 199.9mV; 1.999V (other ranges available)
- 0.05% accuracy
- Only 2"H x 2.75"D x 3.5"W (19.25 cubic inches)
- -10°C to +60°C operating range
- 1000 megohms input impedance
- Automatic polarity indication
- DTL/T²L compatible BCD outputs
- Sample rate to 100/second
- Low power dissipation circuitry (<4 watts) is completely enclosed
- Unipolar or bipolar
- Built-in power supply
- Low cost

Description

Automatic 100% overrange and polarity indications, and positive unambiguous display blanking beyond 100% overrange (overload), are standard in the AN2510 Digital Panel Meter. All BCD, A/D converter logic, and counter outputs are available for external use simultaneously with display operation. In addition, the AN2500 has both internal repetitive and external triggering capability at rates up to 100 measurements per second.

A true instrumentation-type input amplifier permits high impedance measurement of floating differential voltages or currents. Low power circuitry dissipates only 3.5 watts, allowing total enclosure in a Lexan® case for maximum environmental protection - yet the built-in power supply has sufficient reserve to power external circuitry.

Ratiometric input is available as an option, as are current sources for input offsetting or resistance measurements.

The design of the AN2510 has been examined in the most minute detail in the process of an exhaustive worst-case error budget analysis. Total performance is guaranteed by features such as: (1) a unique tracking differential front end; (2) precision zener reference having certified stability better than 0.002%/°C; (3) a conversion technique which guarantees presence of all possible codes and dead bands smaller than one-tenth of one count, providing a resolution capability actually suitable for a 4-1/2 digit unit; (4) a stiff, fully regulated built-in power supply, and (5) rigorous 100% inspection, burn-in, and vibration test procedure.

Specifications

Electrical performance

Input ranges (including 100% overrange):
Standard: 199.9mV F.S. or 1.999V F.S.
Special: Consult Factory Representative

Accuracy (@ 23°C):
Better than 0.05% of reading ± one count

Configurations (for standard input voltage ranges):

Model	Bias Cur. (nom)	Offset Cur. (nom)
AN2510-1A (Bipolar)	15nA	3nA
AN2510-2A (Unipolar)	15nA	-
AN2510-1B (Bipolar)	300nA	50nA
AN2510-2B (Unipolar)	300nA	-
AN2510-1C (Bipolar)	2nA	4nA
AN2510-2C (Unipolar)	2nA	-

Conversion speed:
8 milliseconds (nominal) per complete conversion

Recommended conversion rate (factory adjusted to 2/second):
Absolute maximum for digital output use:
100/second
For unambiguous visual display:
2/second (suggested)

Conversion mode:
Each conversion is totally independent of previous measurement, and responds to step input in one conversion cycle.

Display:
Configuration: 3 digits, plus "1" overrange
Polarity indication: Automatic (+) or (-) indicator
Decimal point: 3 point positions, externally selectable by grounding appropriate connector pins.
Overrange indication: Display blanks beyond 100% overrange

Temperature coefficient:
Better than 0.004%/°F

Sample rate control:
Internally preset repetitive; externally variable repetitive; or Hold and Read on command

Recalibration interval:
60 days

Common mode rejection:
70dB to 60Hz (1kΩ source unbalance)

Common mode voltage:
Floating: ±300V DC, or 300V P-P AC
When output BCD codes are utilized:
± 3.5V DC, or 3.5V P-P AC

Input overload protection (max. input without damage):
199.9mV F.S. models: +15V; -10V
1.999V F.S. models: +15V; -10V

Electrical interface

Power requirements:
115V AC @ 50-60Hz, <4 watts

Digital logic levels (standard DTL/T^{2}L practice):
Upper level: 3.5V ±1V
Lower level: 0.25V ±0.25V
Output signals: Capable of sinking 5mA (lower level) and sourcing 100μA (upper level)
Input signals: Present loads of 1.6mA (lower level) and 10μA (upper level).

Digital input commands:
Trigger input: Positive ≥1.5μsec width and <25μsec fall time. Unit is reset by return to lower level
External blank input: Upper level causes blanking of three least significant digits of display.

Digital outputs:
BCD output: Three BCD 8-4-2-1 digits plus "1" overrange (13 lines)
Overload output: Upper level. Occurs upon input >1999 counts
End of conversion: Reset to upper level by trailing edge of TRIGGER command. EOC indicated by transition to lower level and remains until next TRIGGER command.
Polarity: Positive analog input yields upper level. Polarity data available at beginning of conversion and remains on terminal until rise of next TRIGGER command pulse.

Physical

Size and configuration:
See outline drawing

Mounting capabilities:
With bezel: Through front panel
Without bezel: Flush with rear of panel

Connectors (specify separately):
30 pin, 0.156" spacing, Viking 2V K150/1-2 or equivalent

Repairability:
Repairable down to component level

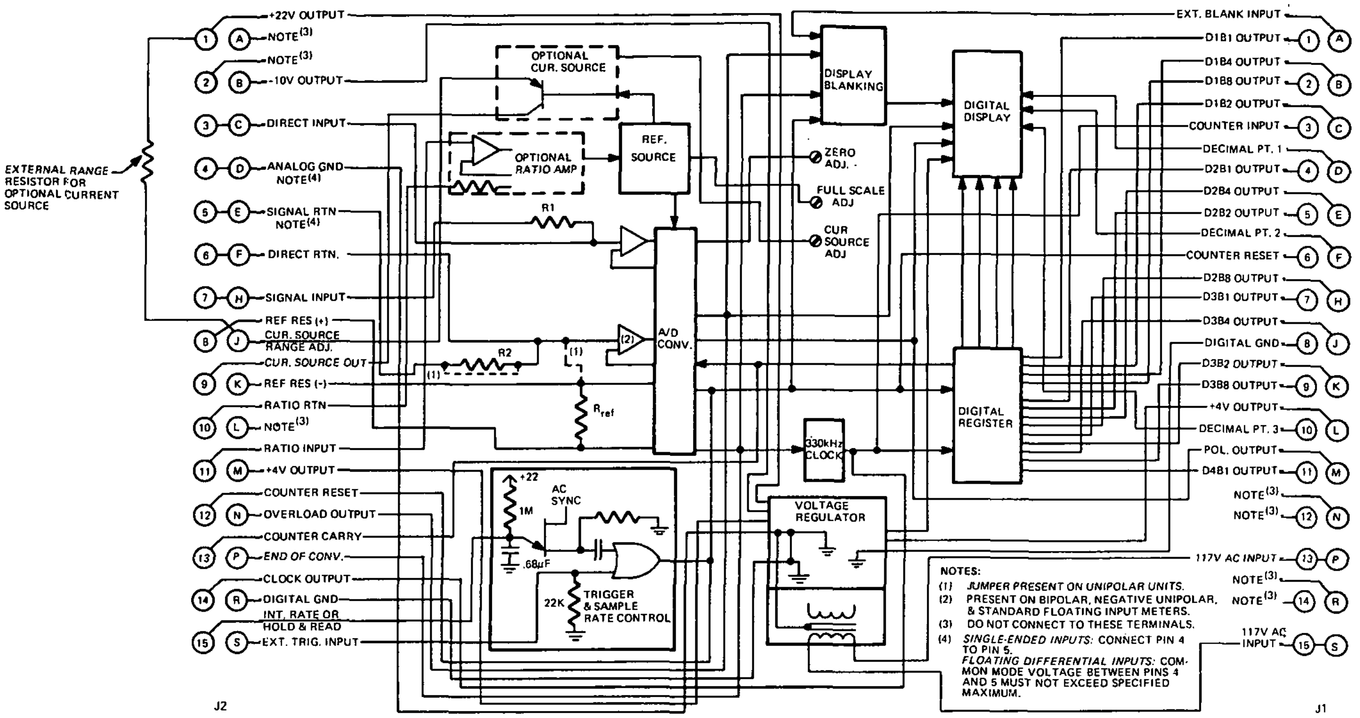
Environmental

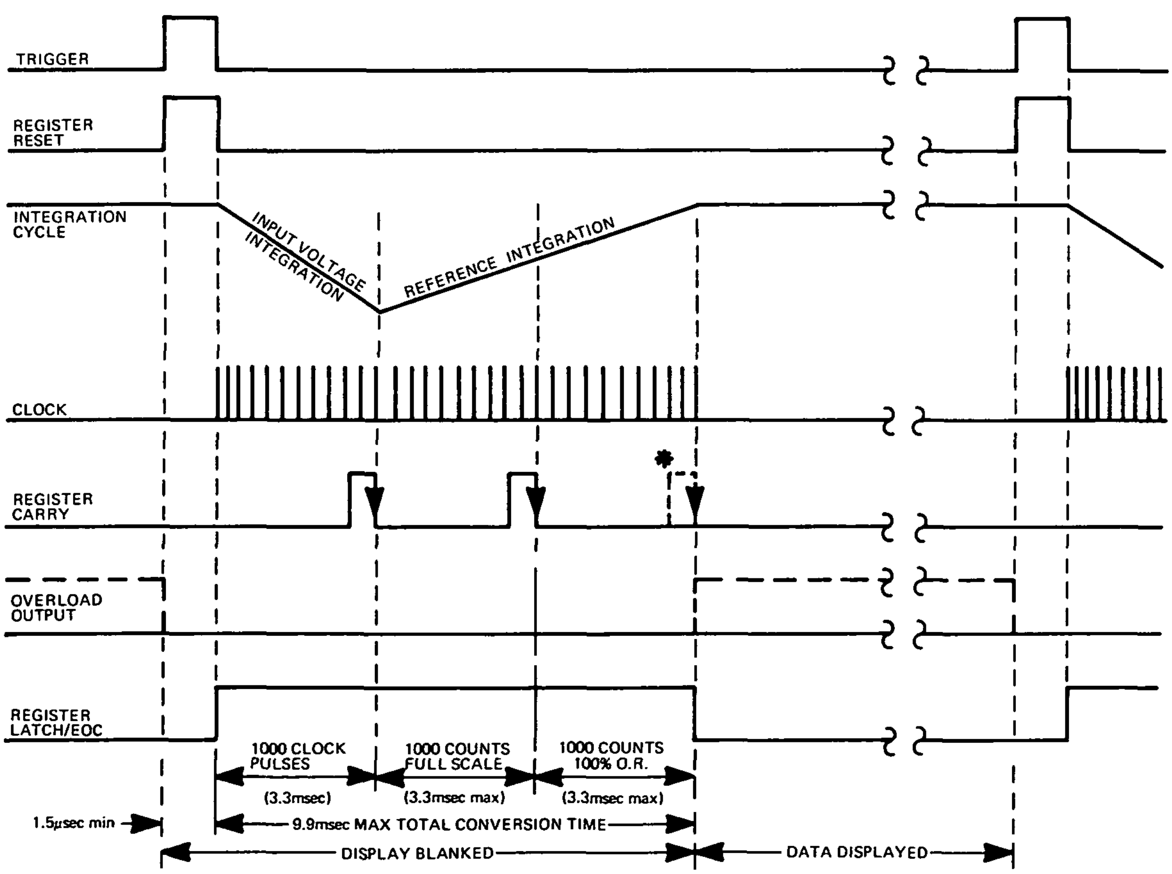
Temperature range:
Operating: -10°C to +60°C
Non-operating: -15°C to +85°C

Calculated MTBF:
50,000 hours

Humidity:
0 to 95%, non-condensing

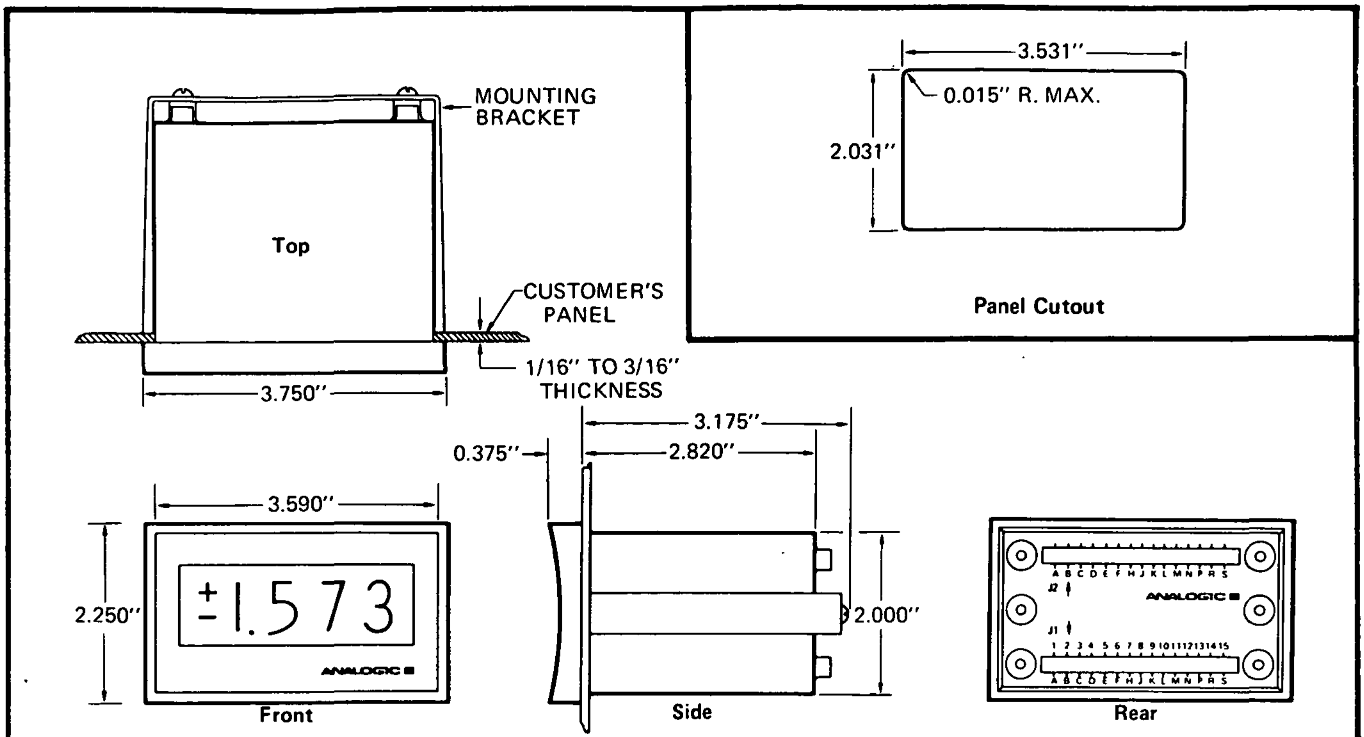
Logic diagram and pin connections for AN2510 DPM





* REGISTER CARRY pulse shown occurs only when input exceeds 1999 counts, causing OVERLOAD output to go high at EOC plus blanking of display and decimal points.

Timing diagram for AN2510 DPM



Outline Dimensions

How to order

Simply specify:

Model AN2510 –□ □–□–□–□–□

Input waveform:

For:	Enter:
Bipolar	1
Unipolar	2

Nominal bias current:

For:	Enter:
15nA	A
300nA	B
2nA	C

Full scale input range (incl. 100% overrange):

For:	Enter:
199.9mV	01
1.999V	1
Special (specify separately)	00

Ratiometric input:

For:	Enter:
1V ref.	R1
10V ref.	R10
Special ref. (specify separately)	00
Omit	RX

Current source for offset:

For:	Enter:
1mA	C1
Special (specify)	C00
Omit	CX

Internal power supply:

For:	Enter:
Standard 115V AC, 50/60Hz	A
Special (specify separately)	00

Example: Model AN2510-1 A-01-R1-CX-A designates a bipolar unit with 199.9mV F.S. input and 15nA input bias current, including 1V reference for ratiometric input and standard power supply.

NOTE:
Variations of the standard AN2510 are available at extra charge. Please consult with the factory office or the Analogic representative in your area is your special requirements include any of the following:

- Special input ranges
- Other power supply input values
- Extreme environmental survival
- Custom configuration

Compatible Analogic products

AN650 Digital Set Point Control: The AN650 Digital Set Point Control is fully compatible with the AN2510 DPM. Front panel controls consist of a polarity switch to select limits in either the positive or negative region, and three 0 to 9 thumbwheel switches plus a fourth 0/1 thumbwheel "overrange" switch to dial any limit over a ±1999 count range. A full 10 position switch may be optionally specified for the overrange switch to permit control up to ±9999 counts when a full four digit range is desired. The AN650 is housed in a panel mounting case identical to that of the AN2510.

CATALOG SHEET	I-5900
REPLACES	40201-1B

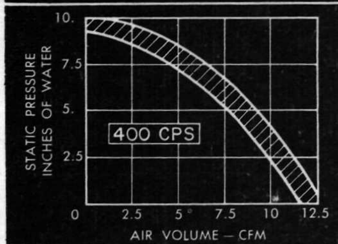
YELLOW LABEL

BLOWERS

RADIAL

MODEL R

TYPE 201



TYPE CHARACTERISTIC
$N_S = 11,000$

ROTRON®

- HIGH PRESSURE-TO-VOLUME RATIO
- SIZE: 3½" x 3 5/16" x 4 13/32" APPROX. • WEIGHT: 1.7 LBS.
- 400 CPS, 1 PHASE OR 3 PHASE, 115 OR 200 VOLTS
- MULTIPLE MOUNTING ARRANGEMENTS
- BUILT TO APPLICABLE MILITARY SPECIFICATIONS

MODEL R/201

WHERE TO USE

The Model R Type 201 blower is a single-stage, radial-wheel blower with a specific speed characteristic of 11,000. It is consequently recommended where a high pressure-to-volume ratio is required and where small physical size and light weight is essential. It is, therefore, ideally suited for airborne applications where high shaft speeds may be obtained from the aircraft's 400 CPS power source. The most important current application is in a cargo compartment smoke detection system aboard commercial transport aircraft. For lower pressure-to-volume ratios, see Rotron Model D centrifugal blowers or, where pressures higher than those obtainable with the Model R Type 201 are mandatory, refer to Rotron's larger Model R Type 3501, Model M and Model L multistage blowers.

ADAPTORS AND MOUNTING

The Model R Type 201 blower may be fitted with a nozzle type inlet rim suitable for a simple hose connection. The outlet flange can be attached to any flat surface or cabinet wall.

Mounting may be accomplished from the blower outlet flange or from mounting flats at the top and bottom of the motor. On request the inboard motor endbell can be tapped to offer a fourth mounting alternative.

MOTOR

The induction motor is either three-phase or permanent split-phase capacitor type and is available with either A, F, or H insulation. The anodized case, which totally encloses the motor, is finned for maximum heat dissipation resulting in a minimum winding temperature rise. The motor operates on double-shielded, precision ball bearings which are greased for life and are carefully aligned for quiet, trouble-free operation. The case and shaft are of die-cast aluminum and stainless steel respectively. A compact screw-type terminal block is fitted integrally into a recess in the motor case so that hookup cables can be run directly to the motor. Motors meet applicable military specifications for ground, sea and airborne service. See applicable Catalog Sheet in Section C, "MOTORS." U. S. Patent Design 174,148. Other U. S. Patents Pending.

ROTATION AND BLAST

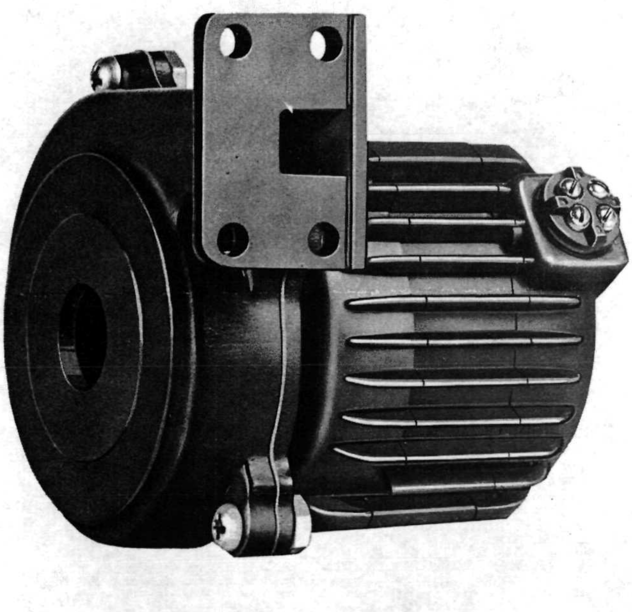
The Type 201 blower is supplied for CCW rotation only. Direction of blast, however, may be rotated at 90° increments to any of four possible choices. The drawing that follows shows a 3 o'clock blast.

MATERIALS AND FINISH

The blower housing consists of a two-piece aluminum casting anodized and finished in dull black. The blower wheel is aluminum and anodized. The motor case and shaft are of die-cast aluminum and stainless steel respectively. The motor case has a black anodized finish. All finishes meet applicable military specifications.

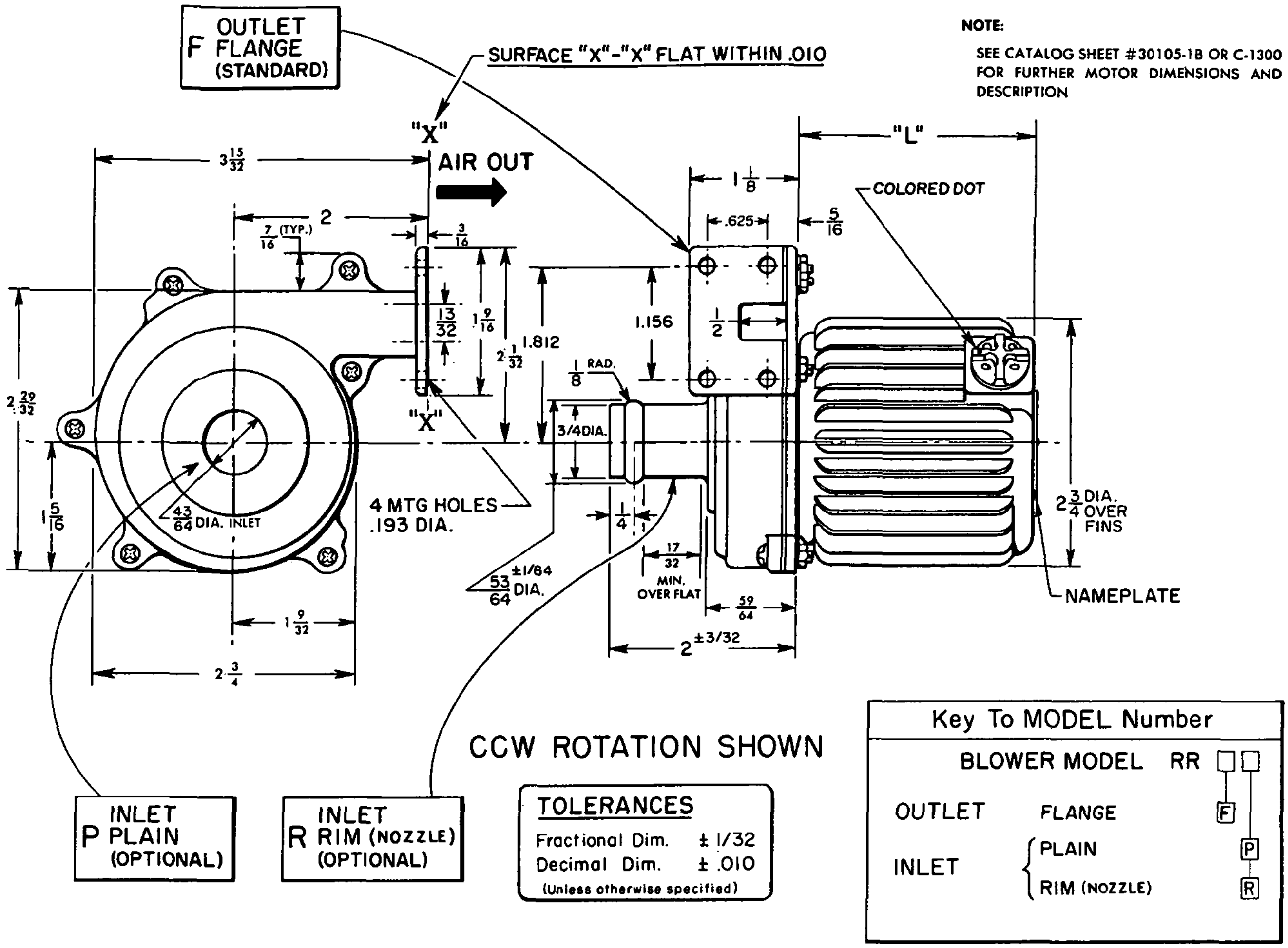
ORDERING INFORMATION

- **Select model, type and motor series number from Type Chart.**
- **Consult Rotron for special inlet, outlet or mounting arrangements.**



ROTRON MANUFACTURING CO., INC.

HASBROUCK LANE, WOODSTOCK, N. Y.



SHAFT SPEED

Figures given in this TYPE CHART as well as on the nameplate are nominal only and generally refer to MAXIMUM CFM air delivery (Maximum Load) at sea level at nominal line voltage and frequency.

HOOKUP

The first suffix letter immediately following the motor SERIES number listed in the accompanying TYPE CHART refers to the applicable wiring diagram found on Catalog Sheet C-1000, Section C, MOTORS. Wiring hook-up is dependent upon motor rotation only.

CAPACITORS

Running capacitors indicated in this TYPE CHART are not normally supplied by Rotron. Their values should preferably be held within a tolerance of ±10%, especially for 400 CPS and variable frequency motors. In selecting capacitors, due attention should be given to variations in capacity ratings with high and low ambient temperatures. Unless otherwise indicated in this TYPE CHART, Working Voltage ratings are 220 VAC for 115 Volt lines and 330 VAC for 230 Volt lines. Oil-impregnated, canned, paper dielectric capacitors are recommended.

THREE PHASE MOTORS

For optimum reliability three phase 3-wire ("J") connections are preferable to three phase 4-wire ("Q") connections where neutral wire is brought out. The source impedance of a three phase power supply may be unbalanced causing circulating currents in the motor windings through the neutral connection. This could lead to overheating and possible motor failure due to causes not attributable to motor design or quality. Also in the event of a temporary line failure (open) the circulating current would be considerably lower in the remaining branches adding a degree of safety under abnormal power supply conditions.

The fourth terminal post on 3-wire ("J") designs is a dummy.

DIMENSIONS

For dimensions and tolerances, refer to the outline drawing.

For details of motor dimensions refer to Catalog Sheet 30105-1B or C-1300 in Section C, Motors.

AIR DELIVERY

Figures in the AIR column of this TYPE CHART represent actual amount of air moved at sea level standard atmospheric conditions per AMCA* code, Bulletin #210. The figures are for free-delivery at no static pressure (P_s). Maximum P_s figures listed in this TYPE CHART apply to complete cut-off or no-delivery state. The CFM and MAXIMUM P_s figures therefore serve only as a preliminary performance guide, and should NOT be construed as indicating that the MAXIMUM CFM figure is obtainable at the MAXIMUM P_s figure.

WATTAGE AND CURRENT

Figures in this TYPE CHART are nominal only, for nominal line voltage and frequency. They are representative of typical production unit tests and must not be construed as maximum or minimum values. In case of variable frequency motors, they apply to 400 CPS. Where more than one voltage is stated, amperage figures apply to the lower voltage.

* AMCA — Air Moving and Conditioning Association, Inc., 2159 Guardian Bldg., Detroit 26, Mich., is the successor to NAFM, National Association of Fan Manufacturers, Inc.

BEARING SHELF LIFE

Rotron military quality motors are built to operate under humidity conditions as specified in MIL-E-5272. When stored under high humidity conditions, however, the bearings will deteriorate. It is therefore strongly recommended that the fans and blowers not be subjected to more than six months of inoperative shelf life in humid climates and not more than one year in dry climates. Units properly packaged in sealed containers with a desiccant may be expected to withstand longer shelf life.

MOTOR INSULATION

This TYPE CHART lists the NEMA classification for electrical insulation. Motors with a different class of insulation may generally be supplied. To obtain the maximum allowable winding temperature for any unit, add the maximum ambient temperature, (°C), to the winding rise temperature obtained from the performance graphs immediately following this page. Limiting total winding temperatures are 105°C for Class A, 155°C for Class F, and 180°C for Class H insulation.

MODEL R BLOWER — TYPE 201

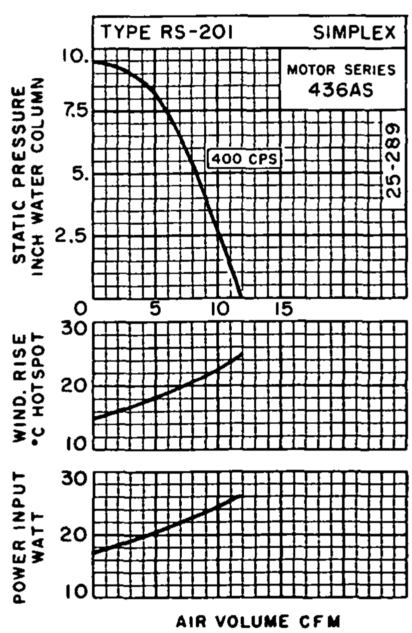
BLOWER	MOTOR		ELECTRICAL									AIR		MECHANICAL	
Type	Frame	Series	Volt	Phase	CPS	Cap.* Mfd.	Nominal RPM	Insul. Class	Full Load Watts	Line Amps. (At Lower Volt.)	Locked Rotor Amps. (At Lower Volt.)	Max. CFM	Max. S. P. at No Del.	Approx. Wt. Lbs.	Dimensions "L"
RS-201	TA2	436AS	115	1	400	0.15	19500	H	26	0.23	0.39	12	9.5	1.75	2 15/32
RS-201	TA1	289JS	200†	3	400	—	21000	H	35	0.13	0.41	13	9.8	1.25	1 31/32

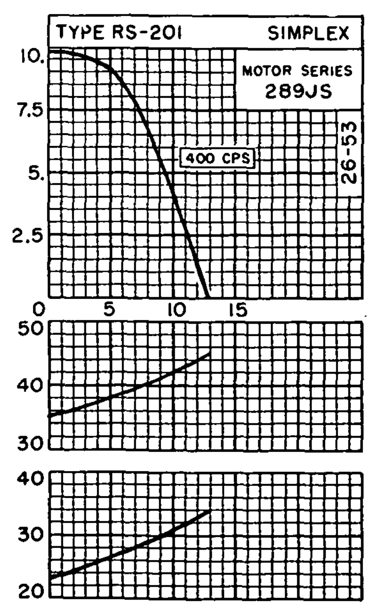
* Running Capacitors are not normally supplied by Rotron.
† For 3-phase motors all voltages are phase to phase.

ACCURACY

Curves at right represent results of measurement of a typical sample and should be taken as nominal. Rotron will advise tolerance for a specific application. Allowance should be made for the effect of "channeling" of ball bearing grease.

IMPORTANT: Before placing order or requesting a quotation, see Key to Model Number and paragraph "Ordering Information" on this Catalog Sheet for COMPLETE product "call out" information requested.





ADSORBENTS

PETROSORB® EPOCEL CARTRIDGES

Combines a high grade activated carbon with a 3 micron (98%) rated filter element. Petrosorb units remove taste, odor, and color, (when due to organic matter in solution) from water and other fluids; also removes organic vapors from gases.

PETROSORB® ULTIPOR* CARTRIDGES

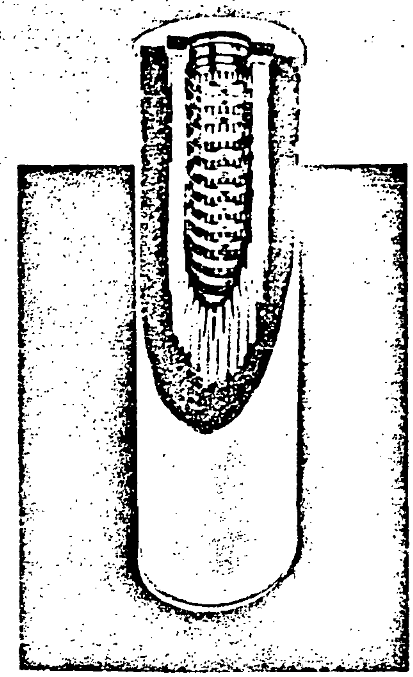
Combines a high grade activated carbon with a nominal .45 micron or a .15 micron rated filter element.

Petrosorb Ultipor.9 units very effectively remove oil vapor from compressed air and other gases; taste, odor, and color from liquids. Petrosorb Ultipor.15 units remove taste, odor, and color, when due to dissolved organic or colloidally suspended matter, and in addition removes all incident bacteria.

DESICCANT EPOCEL® CARTRIDGES

Cartridges contain an efficient desiccant, which has a capacity of 600 grains of water vapor, and will provide approximately 475 scf of clean dry air which has been compressed to 80 psi or more at 70°F or less. Air is simultaneously filtered to .07 microns (98%) and .9 microns absolute. Effluent dewpoint is –70°F or better if operated at the flow rate recommended in table below.

*Patent Pending



Adsorbent cartridges, dimensionally interchangeable with the filter cartridges in this bulletin, consist of a 30 cubic inch annular bed of adsorbent contained between an outer perforated cylinder and a high area corrugated EPOCEL or ULTIPOR filter "core" on the downstream side.

SELECTION GUIDE TO ADSORBENT CARTRIDGES–TABLE 4

SPECIAL OPTIONS	Add Letter
100% Test for absolute rating	A
Buna N. Gaskets	No Letter Required
Viton A Gaskets	H
Cartridge to be used in competitive housing	M

CARTRIDGE P/N

		MCS 1001 CE ☐ PETROSORB EPOCEL	MCS 1001 CV ☐ PETROSORB ULTIPOR.9	MCS 1001 CW ☐ PETROSORB ULTIPOR.15	MCS 1001 CM ☐ DESICCANT EPOCEL 3
EFFECTIVE FILTER AREA (SQ. FT.)		1	1	.9	1
MINIMUM DIRT CAPACITY PER MIL-F-25682 (GRAMS)		3	10	33⑥	30
LIQUIDS	98% REMOVAL RATING (MICRONS)	3	.45	.15	3
	100% REMOVAL RATING (MICRONS)	23	3	.35	23
GASES	98% REMOVAL RATING (MICRONS)	.07	.008	.001	.07
	100% REMOVAL RATING (MICRONS)	.9	.08	.015	.9
TYPICAL APPLICATIONS	① BLACK FIGURES: RATED FLOWS, LIQUIDS GPM/CARTRIDGE GASES SCFM/ CARTRIDGE				
FLUID ④	TYPE OF SERVICE	② YELLOW FIGURES: MAX. CLEAN PRESS. DROP OF CART., PSI			
AIR-SCFM ③ AT 100 PSIG	NORMAL CONDITIONS	15	15	10	3.5
		.05	1.2	7	.1
	VERY DIRTY CONDITIONS	8	8	5	3.5
		.05	.6	3	.1
WATER	VISUALLY CLEAR, DEIONIZED AND OTHER RELATIVELY SOLIDS-FREE WATER	1	1	.25	..
		.3	.6	2	..
	SLIGHTLY TURBID	.5	.4	.25	..
		.5	.25	2	..
	TURBID, ALGAE PRESENT	.2	.1	.1	..
		.06	.1	1	..

NOTES: ① Rated flow figures are intended as guides only, to yield reasonably long cycles between cartridge replacements, and are not intended as substitutes for tests to determine service intervals for critical or unusual applications. ② Clean pressure drop figures are for the cartridge only. See footnote 4, Table 7 for computation of assembly drop. ③ Rated flow (SCFM) for air at pressures other than 100 PSIG are obtained by multiplying by factors given in table under footnote 4, page 5. ④ For other fluids contact Pall Corp. ⑤ Dirt capacity of Ultipor.15 element measured per MIL-F-25682 (USAF) except using water instead of hydraulic fluid.

TYPE NO.

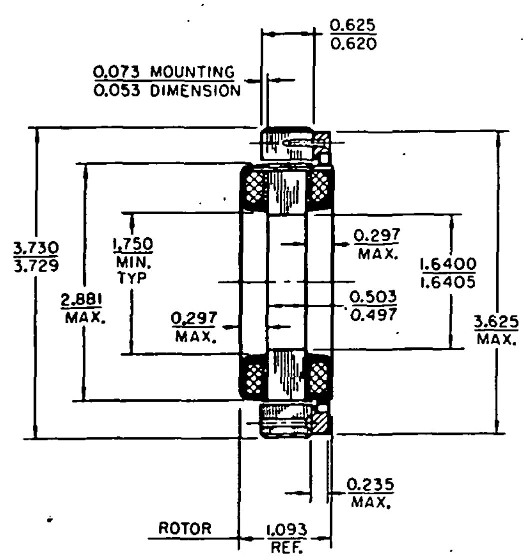
T-2955 0.85 lb-ft

MOTOR SIZE CONSTANTS	UNITS	SYMBOL	VALUE
Peak torque	lb-ft	T_P	0.85
Motor constant	lb-ft/$\sqrt{watt}$	K_M	0.097
Electrical time constant	milli-sec	τ_E	1.6
Mechanical time constant	milli-sec	τ_M	17.7
Power input, stalled, at peak torque (25°C)	watts	P_P	77
Viscous damping coefficients: Zero impedance source	lb-ft/rad/sec	F_O	0.013
Infinite impedance source	lb-ft/rad/sec	F_I	0.5×10^{-3}
Motor friction torque	lb-ft	T_F	0.013
Ripple torque, average to peak	percent	T_R	5
Ripple cycles per revolution	cycles/rev	—	41
Ultimate temperature rise per watt	deg C	TPR	5.0
Max permissible winding temperature	deg C	—	105
Rotor moment of inertia	lb-ft-sec²	J_M	2.3×10^{-4}
Max power rate	lb-ft/sec²	$\dot{P}$	3100
Max theoretical acceleration	rad/sec²	α_M	3700
Max no load speed	rad/sec	ω_{NL}	67
Motor weight	lb	—	1.5

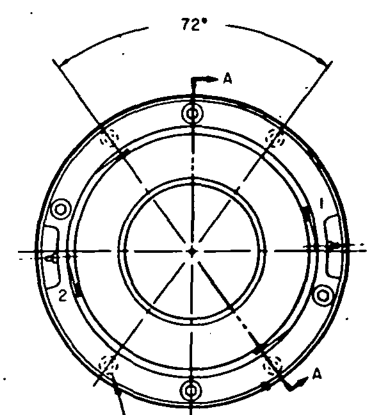
The motor winding constants shown here are typical and are not meant to indicate the *complete range available. For information on* motor windings not shown please contact your local representative or the factory.

The type T-2955 is a frameless DC permanent magnet torque motor. It is shipped as three unmounted components — rotor, brush ring, and permanent magnet field. When installed, it is required that the structure with which the circumferentially oriented field is in direct contact must be non-magnetic. The rotor-to-field eccentricity should not exceed 0.004 inches. See installation section for detailed installation instructions and specific precautions. Brush life will normally exceed 10^7 revolutions. Rotor hubs and field adapters are supplied to customer specifications.

			WINDING DATA FOR MODELS T-2955-A THRU T-2955-H							
DING CONSTANTS	UNITS	SYMBOL	A	B	C	D	E	F	G	H
DC resistance (25°C)	ohms	R_M	1.8	2.7	6.7	10.3	16.2	41.7	105	170
Volts at peak torque (25°C)	volts	V_P	12.2	14.9	22.8	28.2	34.5	56.7	89.2	114
Amps at peak torque	amps	I_P	6.8	5.5	3.4	2.74	2.13	1.36	0.85	0.67
Torque sensitivity	lb-ft/amp	K_T	0.125	0.155	0.25	0.31	0.40	0.63	1.0	1.27
Back EMF	volts/rad/sec	K_B	0.17	0.21	0.34	0.42	0.54	0.85	1.36	1.73
Inductance	milli-hys.	L_M	2.7	4.1	11	17	27	68	0.18	0.28



SECTION A-A



0.125-0.130 DIA. THRU COUNTERSINK 82° TO 0.230 MIN. DIA. (4) HOLES SPACED AS SHOWN ON 3.468 B.C.

TP-1005

INLAND MOTOR
Radford, Virginia
TORQUE MOTOR STANDARD TEST FORM

Customer Number ________ Inland Model TT-2911-B Date 8-24-71

Serial Number 71 H621-1 Job Number 26955 Tester J. E.

Peak Test Current (Ampere) 3.40 Low Test Current (Ampere) 0.90

1. A. Visual OK ✓ B. Brush force grams —, —, —, —

2. Megger reading 10K Meg. ohms. 3. Dielectric VAC 500 3A. Megger reading 10K Meg. ohms

4. Resistance: Rm. temp 75 °F. Volts 6.2, 6.7, 6.3, 6.7, 6.7
   Conv. factor 1.111 Ohms 6.9, 7.45, 7.0, 7.45, 7.45

5A. Check for proper rotation ✓

5B. Stabilization performed 3.40

6. Performance (Units: OZ at 3.0 inch radius)

	Max.	Min.
a.	58.0	54.0
b.	53.0	49.0
c.	16.5	15.5
d.	13.0	12.0
e.	58.0	54.0
f.	53.0	49.0
g.	16.5	15.5
h.	13.0	12.0

7. Sensitivity: (Conversion factor to LB-FT/Amp is .01565)

i. $\frac{a(max) + b(min)}{2 \times \text{peak test current}}$ X Conv. factor = .248

j. $\frac{c(max) + d(min)}{2 \times \text{low test current}}$ X Conv. factor = .248

k. $\frac{e(max) + f(min)}{2 \times \text{peak test current}}$ X Conv. factor = .248

l. $\frac{g(max) + h(min)}{2 \times \text{low test current}}$ X Conv. factor = .248

8. Ripple (Conversion factor to OZ-IN is 3.0)

m. $\frac{b(max) - b(min)}{2}$ X Conv. factor = 6.0 ____ %

n. $\frac{d(max) - d(min)}{2}$ X Conv. factor = 1.5 ____ %

o. $\frac{f(max) - f(min)}{2}$ X Conv. factor = 6.0 ____ %

p. $\frac{h(max) - h(min)}{2}$ X Conv. factor = 1.5 ____ %

9. Linearity: q. i/j = 1.0
   r. k/l = 1.0

10. Shorted turns: Amps = .153

11. Friction: Amps = .115 ~~Static: oz. — in.~~ CW .115 ~~Static: oz. — in.~~ CCW

12. Inductance: Volts —— Amps .90 Degrees 60 HZ
   a. Henrys = .0110
   b. L/R = .00141 Eff. Ro = 7.8 Ω Bridge G.R. 1633A

TACHOMETER GENERATOR TYPE NO. TG-2916

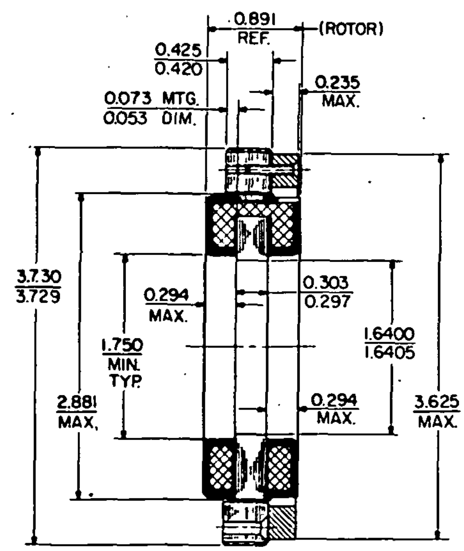
0.89* volts/rad/sec (max.)

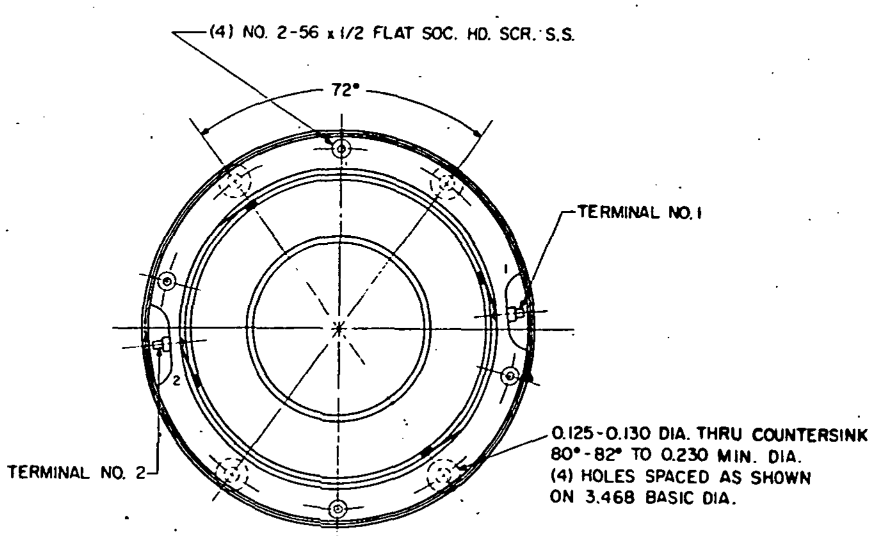
The type TG-2916 is a frameless DC permanent magnet tachometer generator. It is shipped as three unmounted components — rotor, brush ring, and permanent magnet field (stator) with keeper. This keeper must not be removed until rotor is fully in place. When installed, it is required that the structure with which the circumferentially oriented field is in direct contact, be non-magnetic. Rotor to field eccentricity should not exceed 0.002 inches. See installation section for detailed installation instructions. Commutator is gold-plated; brushes are of silver graphite. Brush life will normally exceed 10^8 revolutions. Rotor hubs and field adapters are supplied to customer specification.

TACHOMETER GENERATOR SIZE CONSTANTS	UNITS	SYMBOL	VALUE
Tach generator friction torque	lb-ft	T_F	0.014
Ripple voltage, average to peak	percent	E_R	2.0
Ripple cycles per revolution	cycles/rev	—	71
Rotor moment of inertia	lb-ft-sec²	J_M	2.1×10^{-4}
Tach generator weight	oz	—	17.5

TACHOMETER GENERATOR WINDING CONSTANTS	UNITS	TOL	SYMBOL	WINDING DATA FOR MODEL TG-2916					
				A*	B	C*	D	E	F
DC resistance (25°C)	ohms	±12.5%	R_T	265	41.5	420			
Voltage sensitivity	volts/rad/sec	±10%	K_G	0.71	0.28	0.89			
Inductance	henries	±30%	L_M	0.032	0.005	0.051			
Min load resistance	ohms	nom	$R_{L\,(min)}$	25K	4K	42K			
Max operating speed	rad/sec	nom	ω_{max}	150	380	119			
Volts @ max operating speed	volts	nom	V_{max}	106	106	106			

*Special Winding





TITLE TACHOMETER-GENERATOR STANDARD TEST FORM

Standard Tachometer-Generator Final Test

ISSUE: 6

SHEET NO. 3 OF 3

MODEL NO. 71-2911-B JOB NO. 26955
CUSTOMER NO. ___ DATE 8-27-71
SERIAL NO. 71H621-1 TESTER J.E.

ITEM			TEST
		Polarity	✓ OK
1.		Visual Inspection	✓ OK
2.		Stabilization Performed	✓ OK
3.		Brush Force	— — Grams
4.	A.	Insulation Res. @ 500 VDC	150 Megohms
	B.	Dielectric Strength @	500 VAC (rms) ✓ OK
	C.	Insulation Res. @ 500 VDC	150 Megohms
5.		D-C Res. Ohms	38.7 read 38.7 corrected to 75°F
		— Wheatstone Bridge	✓ Volt Amp method
6.	A.	Inductance	9.3 Milli-Hys
	B.	Time Constant (L)/R	.240 Milli-Seconds
7.	A.	Sensitivity	.292 Volts/Rad/Sec
		High Test Speed	10.47 Rad/Sec
	B.	Sensitivity	.292 Volts/Rad/Sec
		Low Test Speed	1.047 Rad/Sec
8.		Linearity (7A)/7B	1.0
9.		Unfiltered Ripple	2.5 Percent
10.		Load Impedance (from TL)	4.0 K Ohms
11.		Ripple Frequency, cps	71 cps @ 1 rev/sec
12.		Max. Speed-Nom. Design Limit	— Rad/Sec 860 RPM

NO.	ECN. NO.	DATE	APP'D	NO.	ECN. NO.	DATE	APP'D	NO.	ECN. NO.	DATE	APP'D
6	26634	12/11/69	GAY								

Current Drivers

NH0006/NH0006C current driver

general description

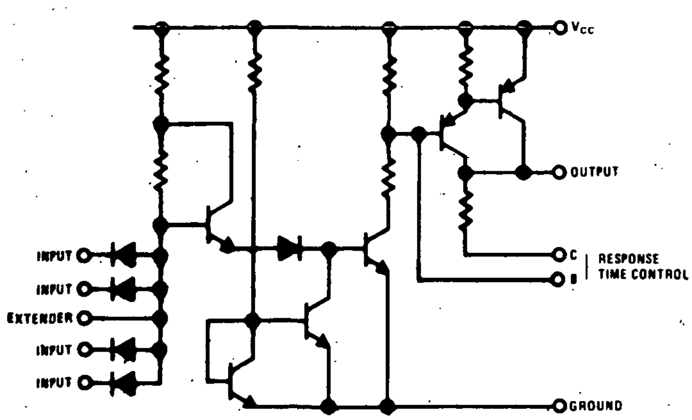
The NH0006/NH0006C is an integrated high voltage, high current driver designed to accept standard DTL or TTL logic levels and drive a load of up to 400 mA at 28 volts. AND inputs are provided along with an Expander connection, should additional gating be required. The addition of an external capacitor provides control of the rise and fall times of the output in order to decrease cold lamp surges or to minimize electromagnetic interference if long lines are driven.

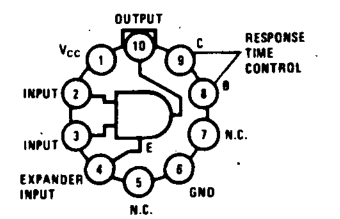
Since one side of the load is normally grounded, there is less likelihood of false turn-on due to an inadvertent short in the drive line.

Some important design features include:

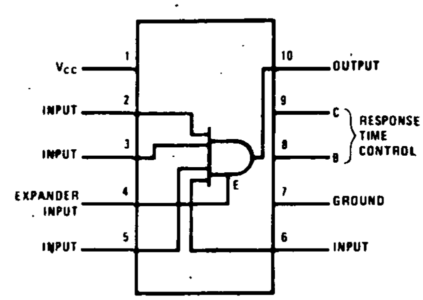
- Operation from a Single +10V to +45V Power Supply.
- Low Standby Power Dissipation of only 35 mW for 28V Power Supply.
- 1.5A, 50 ms, Pulse Current Capability.

schematic and connection diagrams



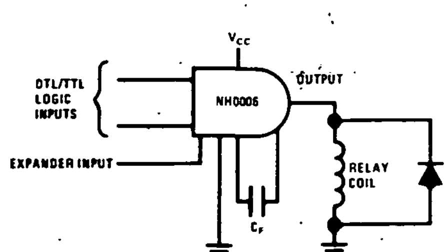


TOP VIEW

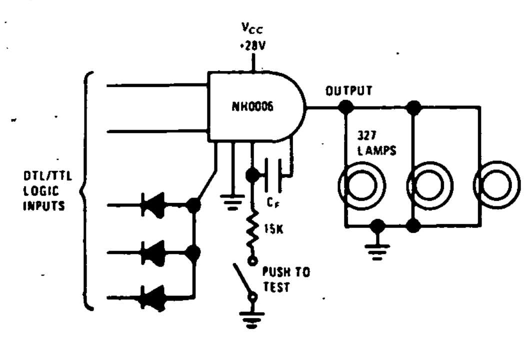


typical applications

Relay Driver

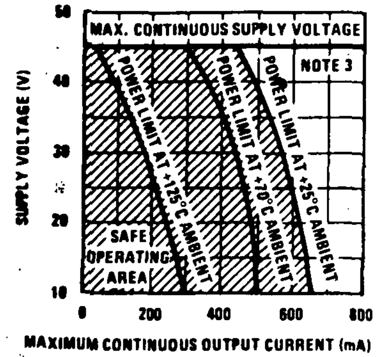


Lamp Driver with Expanded Inputs

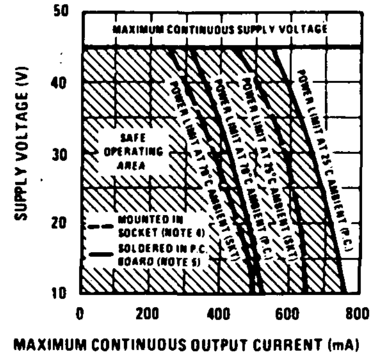


typical performance

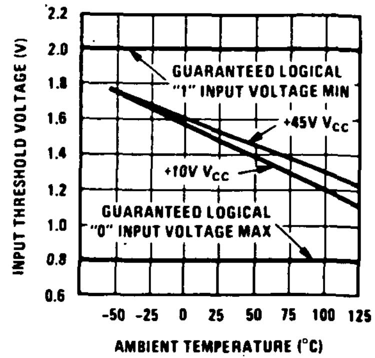
Maximum Continuous Output Current For TO-5



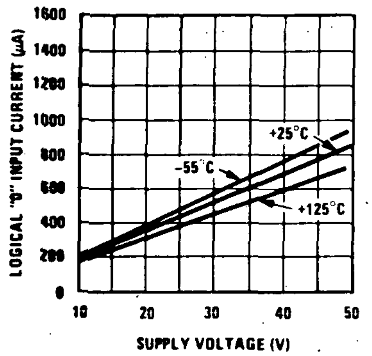
Maximum Continuous Output Current For Molded DIP



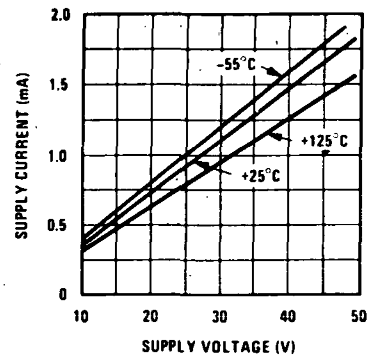
Input Threshold Voltage vs Temperature



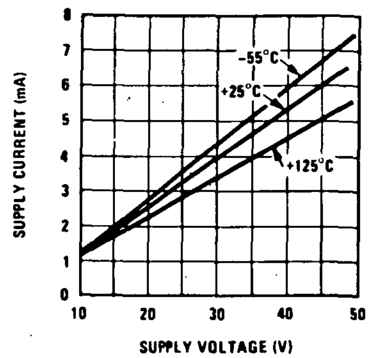
Logical "0" Input Current



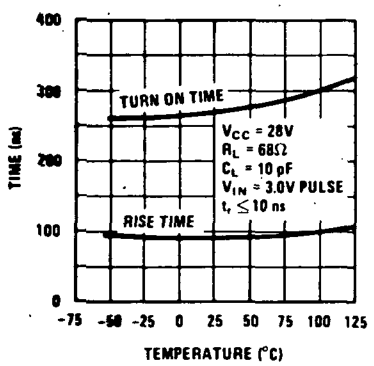
"OFF" Supply Current Drain



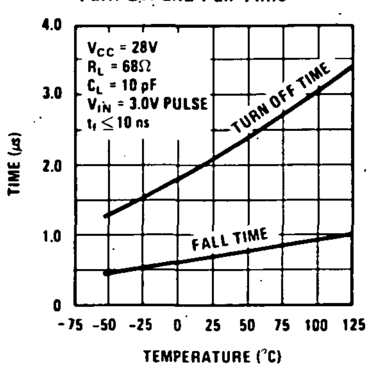
"ON" Supply Current Drain



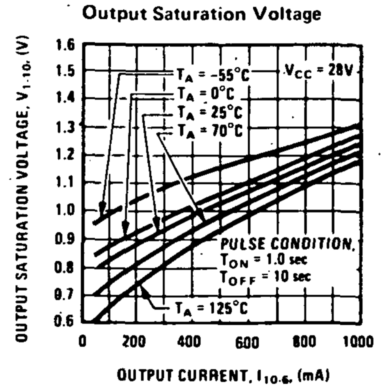
Turn On And Rise Time



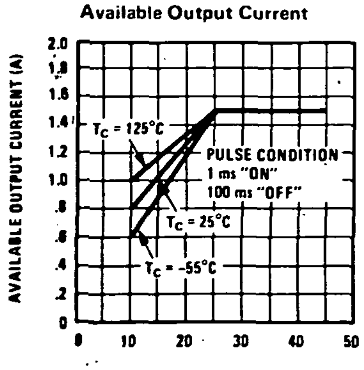
Turn Off and Fall Time



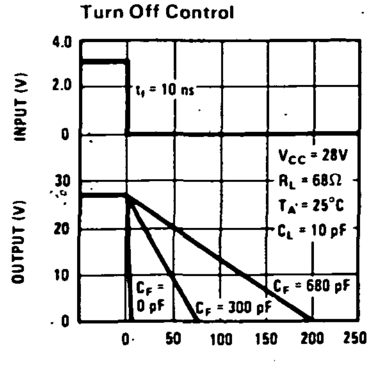
Output Saturation Voltage



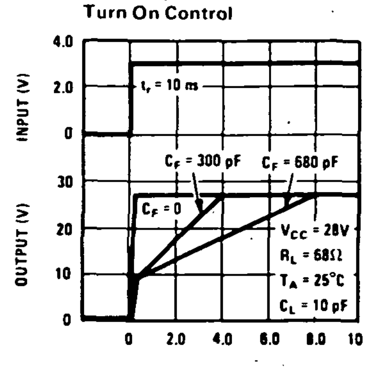
Available Output Current



Turn Off Control



Turn On Control



absolute maximum ratings

Peak Power Supply Voltage (for 0.1 sec)	60V
Continuous Supply Voltage	45V
Input Voltage	5.5V
Input Extender Current	5.0 mA
Peak Output Current (50 ms On/1 sec Off)	1.5A
Operating Temperature	
NH0006	-55°C to +125°C
NH0006C, NH0006CN	0°C to +70°C
Storage Temperature	-65°C to +150°C

electrical characteristics (Note 1)

PARAMETER	CONDITIONS	MIN	TYP (Note 2)	MAX	UNITS
Logical "1" Input Voltage	V_{CC} = 45V to 10V	2.0			V
Logical "0" Input Voltage	V_{CC} = 45V to 10V			0.8	V
Logical "1" Output Voltage	V_{CC} = 28V, V_{IN} = 2.0V, I_{OUT} = 400 mA	26.5	27.0		V
Logical "0" Output Voltage	V_{CC} = 45V, V_{IN} = 0.8V, R_L = 1K		.001	.01	V
Logical "1" Output Voltage	V_{CC} = 10V, V_{IN} = 2.0V, I_{OUT} = 150 mA	8.8	9.2		V
Logical "0" Input Current	V_{CC} = 45V, V_{IN} = .4V		0.8	1.0	mA
Logical "1" Input Current	V_{CC} = 45V, V_{IN} = 2.4V		0.5	5.0	μA
	V_{CC} = 45V, V_{IN} = 5.5V			100	μA
"Off" Power Supply Current	V_{CC} = 45V, V_{IN} = 0.8V		1.6	2.0	mA
"On" Power Supply Current	V_{CC} = 45V, V_{IN} = 2.0V, I_{OUT} = 0 mA			8	mA
Rise Time	V_{CC} = 28V, R_L = 82Ω		0.10		μs
Fall Time	V_{CC} = 28V, R_L = 82Ω		0.8		μs
T_{on}	V_{CC} = 28V, R_L = 82Ω		0.26		μs
T_{off}	V_{CC} = 28V, R_L = 82Ω		2.2		μs

Note 1: Unless otherwise specified, limits shown apply from -55°C to 125°C for NH0006 and 0°C to 70°C for NH0006C/NH0006CN.

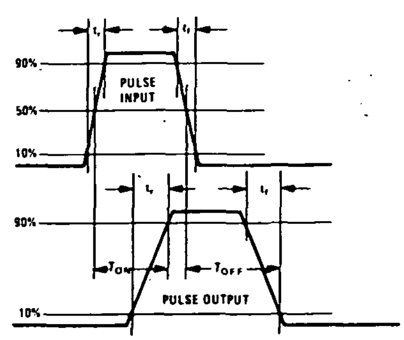
Note 2: Typical values are for 25°C ambient.

Note 3: Power ratings for the TO-5 based on a maximum junction temperature of +175°C and a θ_{JA} of 210°C/W.

Note 4: Power rating for the NH0006CN Molded DIP based on a maximum junction temperature of +150°C and a thermal resistance of 175°C/W when mounted in a standard DIP socket.

Note 5: Power rating for the NH0006CN Molded DIP based on a maximum junction temperature of +150°C and a thermal resistance of 150°C/W when mounted on a 1/16 inch thick, epoxy-glass board with ten 0.03 inch wide 2 ounce copper conductors.

switching time waveforms



GENERAL ELECTRIC

Space Division

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