NASA CR-144646

(NASA-CR-144646) DEVELOPMENT OF A HIGH-RESOLUTION AUTOMATIC DIGITAL (URINE/ELECTROLYTES) FLOW VOLUME AND RATE MEASUREMENT SYSTEM OF MINIATURE SIZE Final Report (Quantum Dynamics) 43 p HC $4.00

N76-14807

Unclas

G3/54 06870

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ADVANCED EXPERIMENTAL RESEARCH AND INSTRUMENTATION
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Development of a High-Resolution Automatic Digital (Urine/Electrolytes) Flow Volume and Rate Measurement System of Miniature Size

file w/MSC 14982

FINAL REPORT

CONTRACT NAS 9-14433

For Submittal To:

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

Attention: Dr. John A. Rummel, Mail Code DBd6
Biomedical Research Division

Ms. Rae Chambers, Mail Code BB62(27)
Buyer

Mr. Arc F. Lee, Mail Code BB62/B27
Contracting Officer

Submitted By: Date: 20 August 1975

QUANTUM DYNAMICS, INC.

Dr. Frederick F. Liu, Dipl. Ing., Ph.D., D.Sc.h.c.
President and Scientific Director

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DETAILED DESIGN DRAWINGS

A Set of (8) Blueprints for Detailed
Electro-Mechanical and Electronic Designs

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ADVANCED EXPERIMENTAL RESEARCH AND INSTRUMENTATION

19458 VENTURA BLVD., P. O. BOX 865, TARZANA, CALIFORNIA 91356 • PHONE: AREA CODE 213, 345-6828

OFFICE OF THE PRESIDENT
DR. F. F. LIU. DIPL. ING. PH.D.

25 August 1975

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Biomedical Research Division
Attn: Dr. John A. Rummel, Mail Code DB6
Houston, Texas 77058

Subject: Transmittal of Completed Hardware and Final Report
Contract NAS 9-14433

Dear Sir:

Contract #NAS 9-14433 has been completed in compliance with the instructions contained in the subject contract.

We are shipping:

1. (1) Complete System of the Hardware representing the result of our development of a High-Resolution Automatic Digital (Urine/Electrolytes) Flow Volume and Rate Measurement System of Miniature Size.

2. Ten (10) Copies of Final Report Complete with Detailed Drawings and Test Results in accordance with the specifications and Tasks Assignment of the subject contract.

We respectfully request that cognizant authorities at JSC will evaluate the enclosed report and release the final payment as soon as feasible.

The undersigned will be pleased to answer any questions at your convenience.

Very respectfully yours,

QUANTUM DYNAMICS, INC.

Dr. Frederick F. Liu, Dipl. Ing., Ph.D.
President and Scientific Director

FFL:bja

Enclosures

QUANTUM-DYNAMICS, INC.

ADVANCED EXPERIMENTAL RESEARCH AND INSTRUMENTATION

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No date - Recd w/ Final Tech Report by Dr. Rummel & this copy came from the [illegible]

STATEMENT ON NEW TECHNOLOGY CLAUSE

Contract NAS 9-14433

TO: Dr. John A. Rummel, Mail Code DB6
Ms. Rae Chambers, Mail Code BB62(27)
Mr. Arc F. Lee, Mail Code BB62/B27
NASA-Lyndon B. Johnson Space Center
Biomedical Research Division
Houston, Texas 77058

FROM: Dr. Frederick F. Liu, Dipl. Ing., Ph.D.
President and Scientific Director

Contract NAS 9-14433 was in the nature of a developmental effort. As a result, a High-Resolution Automatic Digital (Urine/Electrolytes) Flow Volume and Rate Measurement System of Miniature Size was fully developed. Of the entire system, the flowmeter design was already subject to prior patents of Dr. F. F. Liu (U.S. Patent No. 3,135,116 and 3,201,988.)

We have also very carefully examined the other items of the system regarding their patentability; these items are:

1. <u>Dielectric Flow Switch</u>

   A large number of patents relating to dielectric sensing methods are well-known as prior arts. Although the present development utilizes advanced techniques for its implementation, and that it may contain novelty; it is our studied opinion that the dielectric flow switch section does not merit a patent application;

2. <u>Digital and Analog Electronic Counting and Measuring Unit</u>

   Although we have applied digital counting and other logic and analog circuits to the subject development; and that a considerable amount of engineering effort was spent in realizing an efficient working system: we are of the opinion that these circuits, although not without certain novelties, may not be patentable due to numerous prior claims of reasonably similar nature.

In compliance with the New Technology Clause, the above finding is respectfully submitted for the evaluation of cognizant authorities at NASA-JSC.

Very respectfully, Date: 25 August 1975

QUANTUM DYNAMICS, INC.

Dr. Frederick F. Liu, Dipl. Ing., Ph.D., D.Sc.h.c.
President and Scientific Director

I INTRODUCTION

Around 1971, Dr. John Rummel of Johnson Space Center, had originated the concept that, in the quantitative analysis of man's physiological rhythms; the circadian patterns of electrolyte excretion during various environmental stresses can be a particularly fruitful area of investigation. In pursuing this conceptual approach, and under Contract NAS9-14433, Quantum Dynamics is assigned the following developmental tasks:

1.1 Design and fabricate one initial flowmeter, the sensor of which will be the approximate size of a wristwatch.

1.2 The detector section will include a high resolution urine flowmeter of compact design, based on the modification and optimization of the well known Quantomics-Liu ULG type flowmeter.

1.3 The detector section will also include a special type of dielectric integrating type sensor which automatically controls, activates, and deactivates the flow sensor data output by determining the presence or absence of fluid flow in the system, including operation under zero-G conditions. The detector should also be able to provide qualitative data on the composition of the fluid.

1.4 A compact electronic system will be developed to indicate flow rate as well as total volume per release or the cumulative volume of several releases in digital/analog forms suitable for readout or telemetry. A suitable data readout instrument will be provided for the present program.

1.5 Conduct appropriate tests such as calibration and statistical analyses of the performance functions required of the flowmeter.

Quantum Dynamics is proud to report to cognizant authorities of NASA-JSC that the mission has been accomplished. A complete set of automatic digital urine volume and flow measurement systems was successfully developed in hardware form. The performance of the resultant hardware, as can be judged from the enclosed test data, must be considered as extraordinary from the standpoint of high precision and operating efficiency: its measurement resolution (one part in 23.56 of a milli-liter or c.c.) exceeds all known records of virtually all known conventional flow instruments.

Yet the significance of the present concept and successful hardware development to space technology may transcend beyond the urine volume measurement. It means that the consumption of any liquid flow, of minute or large amount, can be accurately measured under zero-G conditions. One example is in the determination of the propellant consumption and the impulse of altitude-control pulse rockets using monopropellants. Such consumption rate, as well as the remaining amount of propellant in the tank, is of importance to long-period space flights. Such consumption can now be determined pulse by pulse, while also totalized continuously. From such pulse propellant consumption, the impulse of the altitude-control rocket can also be determined for the benefit of space vehicle maneuvers. Many other similar applications can also be enumerated.

We believe that with the very modest contract support, Quantum Dynamics has justified the confidence of NASA, and has more than fulfilled its contracted objective by developing an advanced system of hardware for the implementation of the important concept originated by Dr. Rummel.

The following Quantum Dynamics personnel have participated in the contract work:

<u>Project Director</u>: Dr. Frederick F. Liu, Dipl. Ing., Ph.D., D.Sc.h.c.

<u>Technical Assistants</u>:

Computerized Configuration Design, Tests and Statistical Analysis:	Arnold E. Liu, Cand. Dr. rer. Nat. Georg-August University Goettingen, Germany
Electronics:	Johnny Lo, Electronic Engineer
Design & Fabrication of Hardwares:	Helmut Trummer, Manager Mechanical Laboratory
Project Secretary:	Brenda Allen

Fig. 1

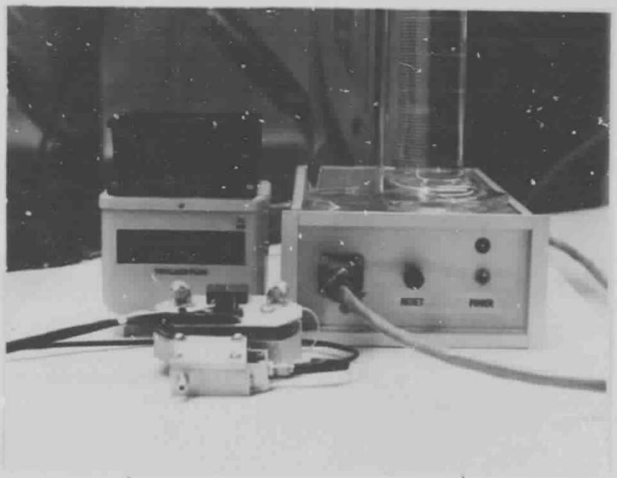
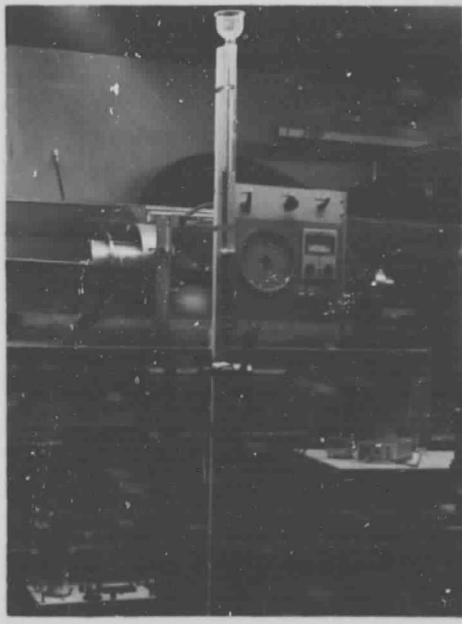


Fig. 2

TEST SETUP



II SUMMARIZATION OF TEST DATA

1. Resolution

   System's flowmeter generates 23.56 pulses per milli-liter (c.c.) of urine flow; or, 0.0423 ML/pulse.

2. Precision and Accuracy (based on calibration and statistical analysis)

   Standard Deviation: 0.47%
   Probable Error: 0.32%

3. Volume Range of Urine Flow Applicable

   Full Volume Range Capability:

   a) 5 to 4200 mL (high volume only limited by the present 5-digit counter) when using direct flowmeter output.

   b) 5 to 99,999 mL when using built-in divided-by-23 programmable counter.

4. Telemetry Analog Output: 1 VDC equivalent to 500 mL
   (from 12-bit DAC) (set 1 VDC at 11,780 count)

5. Urine Flowrate Range

   Flowrate Output: 5 to 500 mL per min.
   0 to 5 VDC.
   (set 4 VDC at 400 mL/min., namely, @ 157 Hz)

6. Power Supply for Urine Flow System

   5 VDC
   +10 and -10 VDC
   +15 and -15 VDC

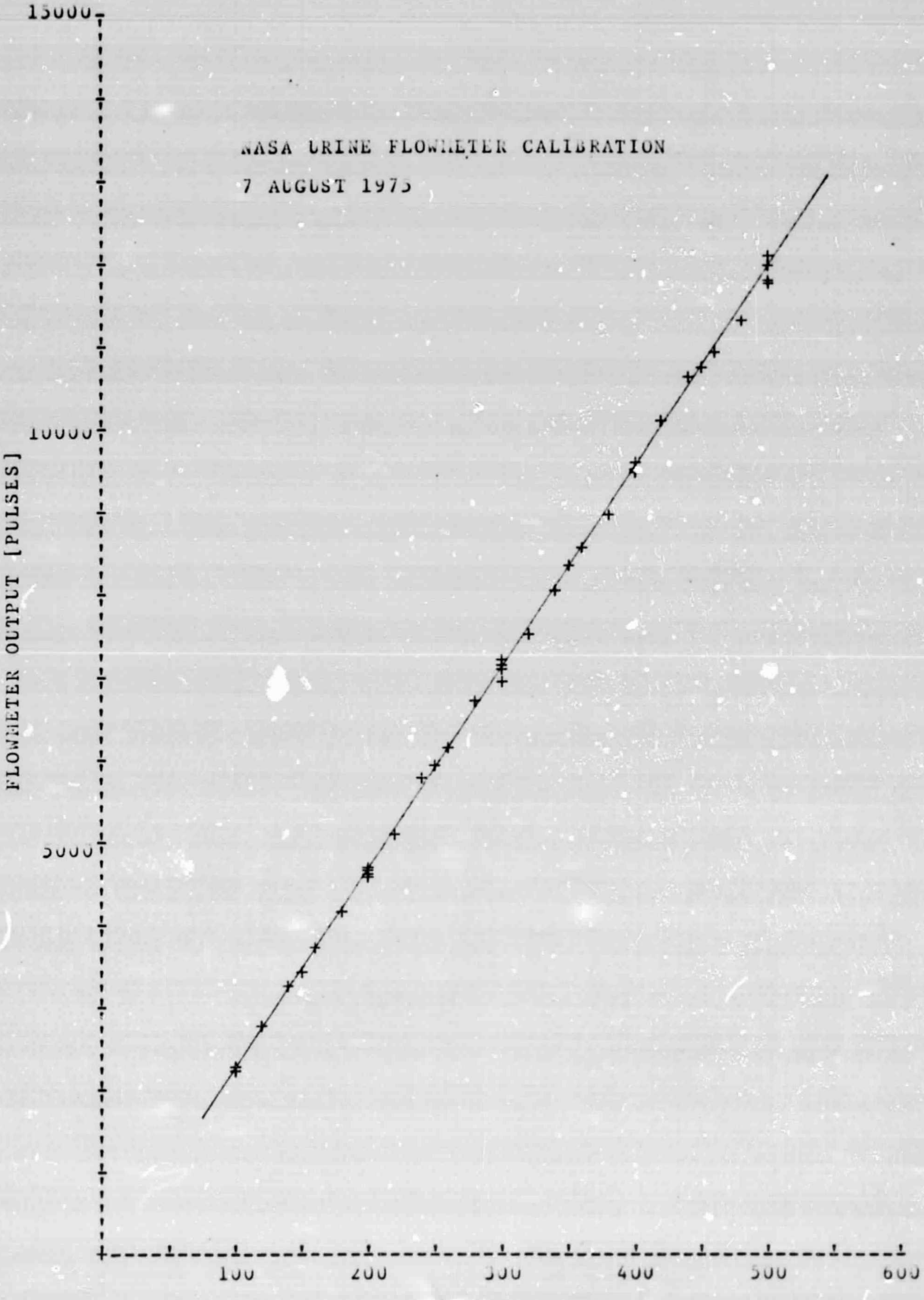

NASA URINE FLOWMETER CALIBRATION
7 AUGUST 1975
15000
10000
5000
FLOWMETER OUTPUT [PULSES]
100
200
300
400
500
600
VOLUME [ML]

FIG. 3

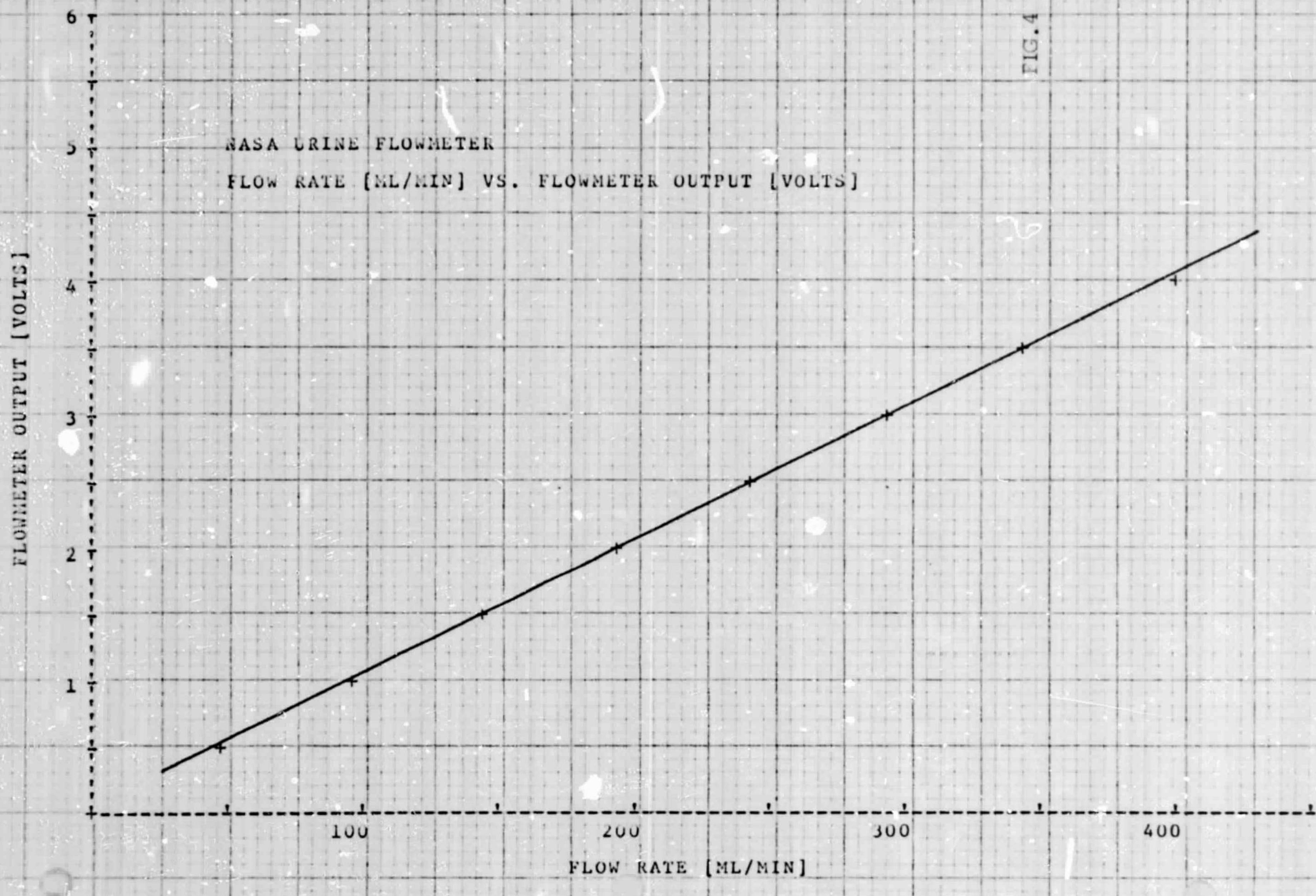

NASA URINE FLOWMETER
FLOW RATE [ML/MIN] VS. FLOWMETER OUTPUT [VOLTS]
FLOWMETER OUTPUT [VOLTS]
1
2
3
4
5
6
100
200
300
400
FLOW RATE [ML/MIN]

FIG.4

NASA URINE FLOWMETER CALIBRATION

PROGRAM # 311

VOLUME (ML)	PULSES	K
500	11792	23.58
500	11981	23.96
500	12096	24.19
500	11760	23.52
480	11300	23.54
460	10929	23.75
450	10739	23.86
440	10624	24.14
420	10091	24.02
400	9515	23.78
400	9595	23.98
400	9508	23.77
400	9472	23.68
380	8966	23.59
360	8563	23.78
350	8341	23.83
340	8048	23.67
320	7514	23.48
300	7134	23.78
300	6938	23.12
300	7097	23.65
300	7215	24.05
280	6705	23.94
260	6147	23.64
250	5927	23.70
240	5775	24.06
220	5085	23.11
200	4691	23.45
200	4578	22.89
200	4604	23.02
200	4654	23.27
180	4160	23.11
160	3718	23.23
150	3433	22.88
140	3254	23.24
120	2774	23.11
100	2273	22.73
100	2229	22.29
100	2278	22.78
100	2227	22.27

$\overline{K}$ = 23.[illegible] PULSES/ML

THE ABOVE CALIBRATION WAS PERFORMED ON 7 AUGUST 1975.

THE PRESSURE DIFFERENCE (VACUUM) USED TO DRAW THE CALIBRATION MEDIUM WAS $\Delta P \approx 1.2 - 1.4$ PSI.

ORIGINAL PAGE IS OF POOR QUALITY

NASA URINE FLOWMETER

VOLUMETRIC FLOW RATE VS. FLOWMETER OUTPUT

FLOW RATE ML/MIN	OUTPUT HERTZ	OUTPUT VOLTS
400.0	157.0	4.000
343.9	135.0	3.500
293.5	115.2	3.000
243.3	95.5	2.503
193.6	76.0	2.000
144.5	56.7	1.500
96.3	37.8	1.000
47.9	18.8	.500

NASA URINE FLOWMETER: STATISTICAL ERROR ANALYSIS

TWENTY (20) TRIALS WERE MADE TO DETERMINE THE TOTAL NUMBER OF PULSES Y_i EQUIVALENT TO A TOTAL FLOW OF 500 ML. THE CALIBRATION DATA Y_i, MEAN VALUE $\overline{Y}$, STANDARD DEVIATION σ AND PROBABLE ERROR PE ARE AS GIVEN BELOW.

i	Y_i	$(Y_i - \overline{Y})^2$
1	11786	1600
2	11906	6400
3	11897	5041
4	11820	36
5	11750	5776
6	11831	25
7	11799	729
8	11748	6084
9	11748	6084
10	11740	7396
11	11778	2304
12	11861	1225
13	11765	3721
14	11850	576
15	11848	484
16	11875	2401
17	11908	6724
18	11843	289
19	11865	1521
20	11897	5041

$\Sigma Y_i = 236515$

$\overline{Y} = 236515/20 \approx 11826$

$\Sigma (Y_i - \overline{Y})^2 = 63457$

STANDARD DEVIATION $\sigma = \sqrt{63457/20} = 56.32$

STANDARD DEVIATION σ (IN %) = 0.47%

PROBABLE ERROR PE = 0.6745σ = 37.98

PROBABLE ERROR PE (IN %) = 0.32%

RESOLUTION = 0.0423 ML/PULSE

III DESIGN APPROACH AND POSSIBLE IMPROVEMENT

An integrated urine flow measurement system has been developed to satisfy the space flight requirement. The unit is efficient and compact with the main urine flowmeter itself no larger than the size of a wrist watch. Its electronic section is based on digital design with 5-digit direct readout of the measured urine volume. However, in view of the telemetry requirement, the stored digital data on urine volume are also transformed into 0-5 VDC analog output by means of a 12-bit digital-to-analog computer. At the same time, the flowrate of urine is also provided in 0 to 5 VDC analog form.

The approach for the system is considered to be among the very few appropriate to space flight and zero-G liquid flow conditions, following a thorough evaluation of the relative merit between various known methods. We, therefore, consider that we have chosen an effective hardware concept to initiate our development effort -- one which has been proven for its dependability under space flight conditions during SKYLAB/Orbital Laboratory Program.

Through necessity, a tremendous amount of developmental effort had been invested by Quantum Dynamics' technical staff, which is way out of proportion to the size and funding of Contract NAS9-14433. Only through the dedication of our contract personnel had we succeeded to develop the present urine flow measurement system which is astounding both in terms of its sophisticated conceptual design and its advanced engineering features.

The only areas of possible improvement, and which should be the subject of future work, is in the flowmeter bearing. This is a very fundamental problem with our technology; and. one should not expect the present limited size contract to solve a fundamental issue. The finest and most sensitive bearings available today are used in the system, and we have optimized the effectiveness of such bearings through new arrangement. Nevertheless, there is still the contamination problem, which even the best stainless steel bearings are not immune after prolonged usage. In any follow-up work, we wish to experiment with a new and promising approach by using a novel external arrangement of bearings which we have conceived only during the last phase of the contract effort, and, which may conceivably represent a further major stride in the technology of automatic space-flight urine measurements.

Of lesser significance in terms of improvement is the further miniaturization of electronic packaging. The present development contract can only permit us to use discrete circuit elements in wired circuits: consequently, to squeeze a 5-digit counter, with its LED readout, a 2-digit programmable counter, a 12-bit DAC, a cryotronic converter, and various logic and control circuits, all into a single small box; and, that the discrete digital/display circuit consumes sufficiently sizable D.C. power: we have to prudently add a cooling fan to insure efficient function. In future work, CMOS type solid state devices packaged in hybrid circuit can cut down the power consumption as well as shrink the size still more. One may not have to use the cooling fan with such units.

IV GENERAL CONSTRUCTION

The integrated Urine Measurement System consists of two (2) main sections: (1) The Miniaturized Flowmeter and Dielectric Flow Switch Section; and (2) The Electronic Urine Flow Data Section. Further sub-divisions of functions can be presented as follows:

A. Flowmeter and Dielectric Flow Switch Section

a. Miniaturized Urine Flowmeter

b. Miniaturized Hybrid (Electronic) Cryotronic Pickup Converter

c. Differential Dielectric Flow Switch integrated with the structure of a.

d. Electronic Dual-Channel Sensing, Comparison and Threshold Control.

B. The Electronic Urine Flow Data Section

a. Cryotronic Converter Interface

b. Programmable Counter and its Enabling and Disabling Control

c. 5-digit Totalizing Digital Counter with LED Readout

d. 2-digit Programmable Counter

e. 12-bit Digital-to-Analog Converter connected to c. for telemetry "VOLUME" output.

f. Diode-Pump Frequency-to-Analog Converter for Flowrate Readout.

The present developmental model, which is based on the use of discrete components, Section B is squeezed into a 3.5" (width) x 3.0" (depth) x 2.5" (height) mini-instrument box. This size can, of course, be further reduced when using custom-made hybrid circuits. A separate D.C. power supply case C, using 110 VAC (wall plug) line power, is provided to facilitate laboratory testing only. However, in actual space-flight applications, this power supply would not be needed, since sections B and A will operate directly from the D.C. power of the vehicle.

Because of our desire to avoid excessive stray capacitances due to the inter-connecting cables: a small section of the electronic circuit is mounted on top of the dielectric switch. In future finalized hardware units, this section can, of course, be suitably enclosed.

To monitor the effective operation of the system, the ON-OFF operation of the dielectric switch is indicated by a LED lamp in the form of a brightly lit-up "dot" located on the right-hand side of the 5-digit LED readout: it appears when urine, or any electrolyte, is passing through the flowmeter, and is being measured by the counter; this dot disappears at the moment when the amount of passing urine in the dielectric switch is either absent, or decreases to such an extent as to be unworthy for further measurement.

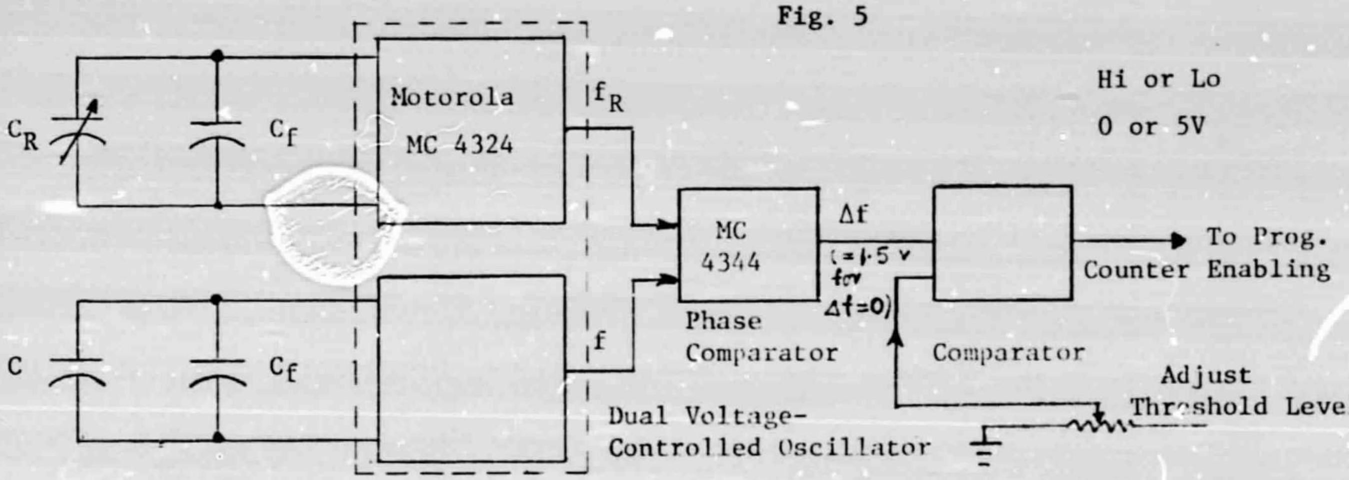
A cooling blower is used with the present development model for prudence sake only; namely, to eliminate any chance that the digital integrated circuits may be overly heated. In future models, we plan to use the CMOS circuit and hybrid circuit constructions: such a blower will not be needed.

Dielectric Switch and Its Sensing Circuit

The function of the Dielectric Flow Switch is to determine the instant of the commencement and termination of the urine flow through the measurement system so that all flow measurements cover only the time period during which the urine is passing through the sensor.

A block diagram of the circuit design of the dielectric sensor switch is shown as follows:

Fig. 5



The urine sensor has capacitance C which, under ambient (air) condition, is set at a value such that $C = C_R$; where C_R is the reference capacitance value of a reference sensor which monitors the dielectric properties of the ambient air, and which is not exposed to urine flow. When necessary, two fixed shunt capacitances C_f are connected to each of the capacitance circuits. Two identical solid-state oscillators (MC 4324) are connected respectively to C_R and C. Under ambient conditions, the frequencies f and f_R of the two oscillator circuits are adjusted to become as close to each other as possible. The frequency outputs of the two oscillators are applied to a phase comparator: the output is adjusted to 1.5 volt. This voltage is applied to a comparator which has, as its other input, an adjustable reference voltage which sets the threshold level for the comparator either to go HI or LO. When $\Delta f = 0$, its output is LO.

When urine enters the measuring sensor section, C immediately deviates from its value due to the change of dielectric medium. As a result, f deviates from f_R, causing the phase comparator to generate a signal which is a function of $\Delta f = f - f_R$. The comparator immediately goes "HI".*

The differential design provides greater stability in the operation of the flow switch; particularly so, in view of the high sensitivity of the dielectric detection and the temperature coefficients of all the capacitors involved.

The Subminiaturized Urine Flowmeter

The design of the flowmeter is based on our computer analysis. The flowmeter principle and its mechanical and electronic design are covered by Quantum Dynamics patents (U.S. Patent No. 3,135,116 and 3,201,988) and the present urine flowmeter is only a miniaturized version of previous designs. The same principle has been used successfully in SKYLAB, APOLLO and LEM programs. The design objective of the present urine flowmeter is to achieve high resolution liquid measurement in a flowmeter of highly miniaturized construction. A complete set of detailed design blueprints are submitted with this report.

The sensing of the flowrate is provided by the angular velocity of a miniature circumferentially propelled turbine as detected by a highly-sensitive dragless cryotronic pickup. The passage of each blade in front of the pickup generates a large pulse, thus during the flow process, a pulse-train is generated; the frequency of which provides an indication of the flowrate. When the number of pulses is continuously being totalized: one obtains the total amount of urine flow for the entire discharge.

*An indicator "spot" light next to the readout will immediately lit-up.

CRYOTRONIC CONVERTER

The principle of operation of the Cryotronic Pickup and its converter is based on the eddy current losses in a metallic object, such as the turbine blade, in proximity with an oscillating tank circuit, and that the distance between them varies in space and time.

Consider a tank circuit composed of an inductance L_1, a capacitance C_1, and series resistance r_1. See Figure 6.

Equivalent Circuits of the Tank Circuit and Metallic Object

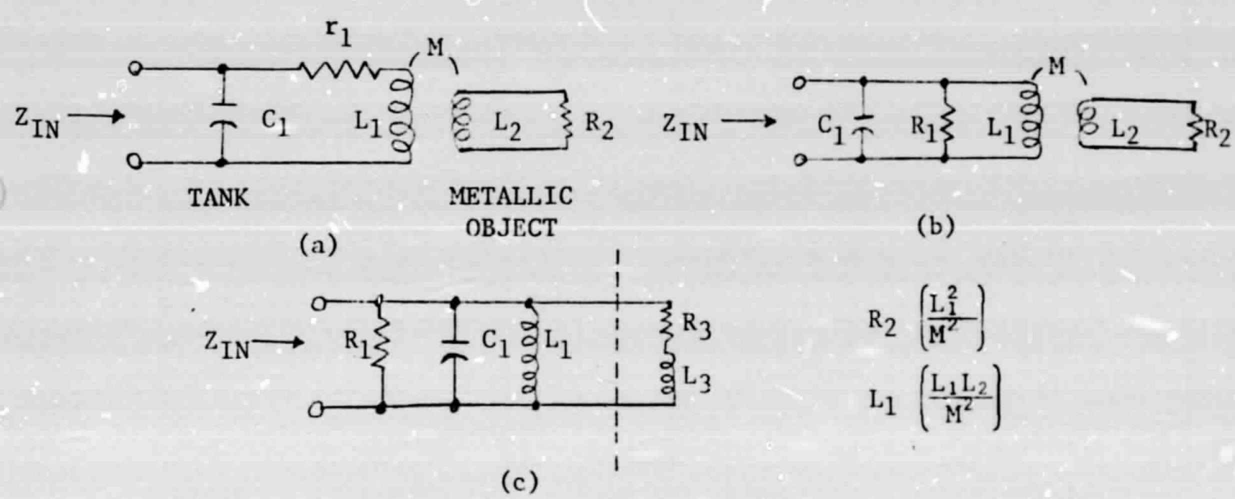


Fig. 6

When a metallic object with inductance L_2 and resistance R_2 comes close to the tank circuit, the input impedance Z_{IN} is affected by the mutual inductance M between L_1 and L_2. When proximity of the metallic object is changed: M, L_2 and R_2 may all vary, but primarily M.

The effect on Z_{IN} due to M can better be understood with the aid of the equivalent circuits shown in above figure. It can be seen that the influence of M on Z_{IN} is equivalent to adding a series R_3 L_3 circuit in parallel with the tank circuit, where:

$$R_3 = R_2 \left(\frac{L_1^2}{M}\right)$$

$$L_3 = L_1 \left(\frac{L_1 L_2}{M^2} - 1\right)$$

Note that R_3 and L_3 and functions of M; therefore Z_{IN} is also a function of M.

When a tank circuit is operating at its natural frequency, its characteristic is purely resistive with resistance R_1. Conversely, if a negative resistance equal to R_1 is placed across the tank circuit, the latter would oscillate at its resonant frequency. In the Cryotronic pickup circuit shown in Figs. the role of such a negative resistance R_N, however, should be visualized in terms of the effect derived from a close-loop control process.

Operational Diagram of Cryotronic Pickup

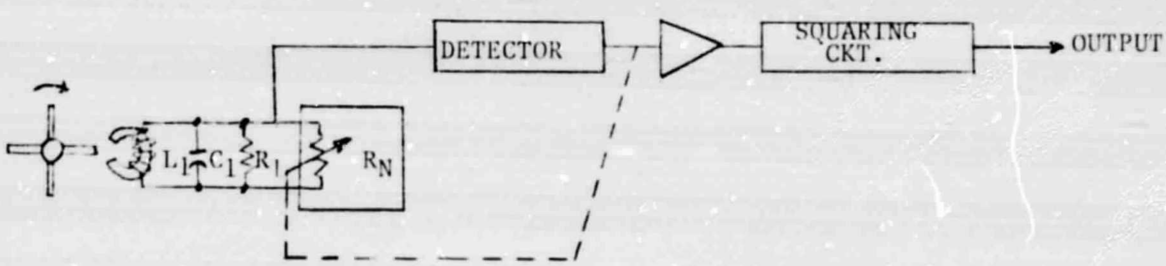


Fig. 7

In other words, the negative resistance R_N is a "created" value controlled by the output of the detector in a manner such that the amplitude of oscillation is maintained at approximately the same fixed value. Its range is automatically adjustable from a few hundred ohms to infinity, and the resistance of the tank circuit is always maintained within this range.

The time constant of R_N is made sufficiently long, so that R_N remains essentially constant for any particular tank circuit, keeping it oscillating near a constant voltage level. Thus, any small change in the impedance Z_{IN} of the tank circuit would cause the amplitude of oscillation to either decrease or increase rapidly.

The passage of the turbine blade would cause such a small change in Z_{IN} (See Fig.).

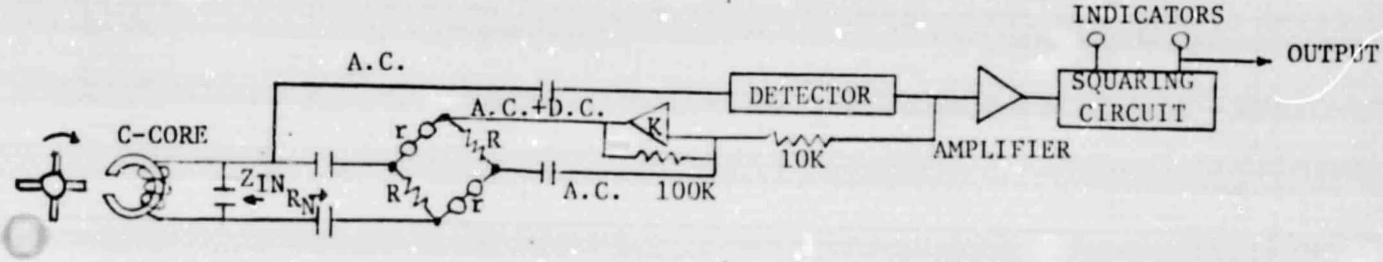
As shown by the block diagram of the cryotronic pickup (Fig.): looking into the circuit one sees the impedance at high frequency as:

$$R_N = \left(\frac{R\cdot r}{R+r}\right)\left(\frac{\frac{R}{K+1}+r}{\frac{K-1}{K+1}(R)-r}\right) \simeq R\left(\frac{r^2}{R^2-r^2}\right)\Bigg|_{k>>1}$$

When $r > R$, then R_N is negative.

Fig. 8

Block Diagram of Cryotronic Pickup



The resistance r is formed by two tungsten filament lamps connected in series, having a relatively long time constant. r can be modulated by varying the rms current through it. Consequently, R_N is produced in such a process. However, in determining the rms current affecting r, the D.C. current through r is predominant over the A.C. current: the D.C. circuit determines the value of R_N while the A.C. circuit provides the power to sustain oscillation in the tank circuit.

Actually, the variation in oscillation amplitude would not materially alter the value of R_N since it has a long time constant; this renders the sensitivity to become very high.

The detector circuit senses the peak-to-peak value of the oscillation, and its averaged output controls the value of R_N. The variation of the detector output is then amplified and squared to become the pulse output of the flowmeter.

The resultant pulse-train output is of 10-volt peak-to-peak square waveform; its frequency is linearly proportional to the volumetric flowrate. This frequency output is then applied to the subsequent pulse counting stages.

The Electronic Urine Flow Data Section

The pulse output of the urine flowmeter is generated by the electronic circuit referred to hereafter as the cryotronic converter. This output is applied to two electronic circuits: one is a 5-digit digital counter for totalizing the total amount of urine discharge; the other is for generating a 0-5 volt d.c. signal which is linearly proportional to the urine flowrate. The digital counting is, of course, controlled by a set of logic gating circuits which, in turn, is actuated or deactuated by the dielectric (urine) sensing switch. The total counter enabling period is thus dictated by discharging period of urine through the flowmeter.

Since there is always a constant of proportionality between the digital indication and the actual amount of urine flow: to provide direct indication of the totalized flow in the preferred quantity, e.g. in cc or milli-liter, a 2-digit programmable counter is used with the present system between the cryotronic converter and the totalizing counter. The programmable counter is used to divide its input frequency digitally by pre-setting the digital logic circuit so that the resultant output frequency can be used to indicate the urine flow in the aforesaid direct milli-liter (or c.c.) units. When the programmable counter is set at 01, the input-output frequency relationship is 1 to 1: the flowmeter generates 23.56 pulses per milli-liter. As shown by the calibration diagram, the relationship between the total pulse counts obtained directly from the flowmeter and the urine flow volume is highly linear. For example, at 400 milli-liter volume; a total of 9424 pulses is generated. Thus, when the programmable counter is set at ÷ by 23, the flowmeter provides approximately 1 pulse per milli-liter.

The present programmable counter was not a contract requirement but was built-in to demonstrate the feasibility of the direct reading concept.

Because the present work is of a highly-crammed low budget developmental nature, geared in our effort to achieve miniaturization; the system only permits a 2-digit programmable counter. In future work, it is possible for Quantum Dynamics to develop a more complicated circuit which divides the flowmeter output frequency directly by 23.56 instead of by 23.

For the high-resolution 1-to-1 counting, a 0 to 5 volt D.C. telemetry (analog) output generated by a 12-bit digital-to-analog converter (DAC) is provided. The DAC is connected to the 3 most significant digits (12 bits). Thus, for the ÷ by 23 Low-resolution operation, this analog output would not be useful.

The following is a tabulation of the digital and (telemetry) analog output in relation to the flow volume:

	HIGH RESOLUTION		LOW RESOLUTION	
VOLUME (mL or CC)	DIGITAL (count)	ANALOG (mV)	DIGITAL (count)	ANALOG (mV)
20	471	40	20	USE NOT RECOMMENDED
40	942	80	41	
60	1413	120	61	
80	1885	160	82	
100	2356	200	102	
200	4712	400	205	
300	7068	600	307	
400	9424	800	410	
500	11780	1000	512	
600	14136	1200	615	
700	16492	1400	717	
800	18848	1600	820	

V TEST AND CALIBRATION

Calibration and Test Set-Up

Volumetric method of calibration is used to determine the performance of the urine flow measurement system as well as to provide data for statistical analyses.

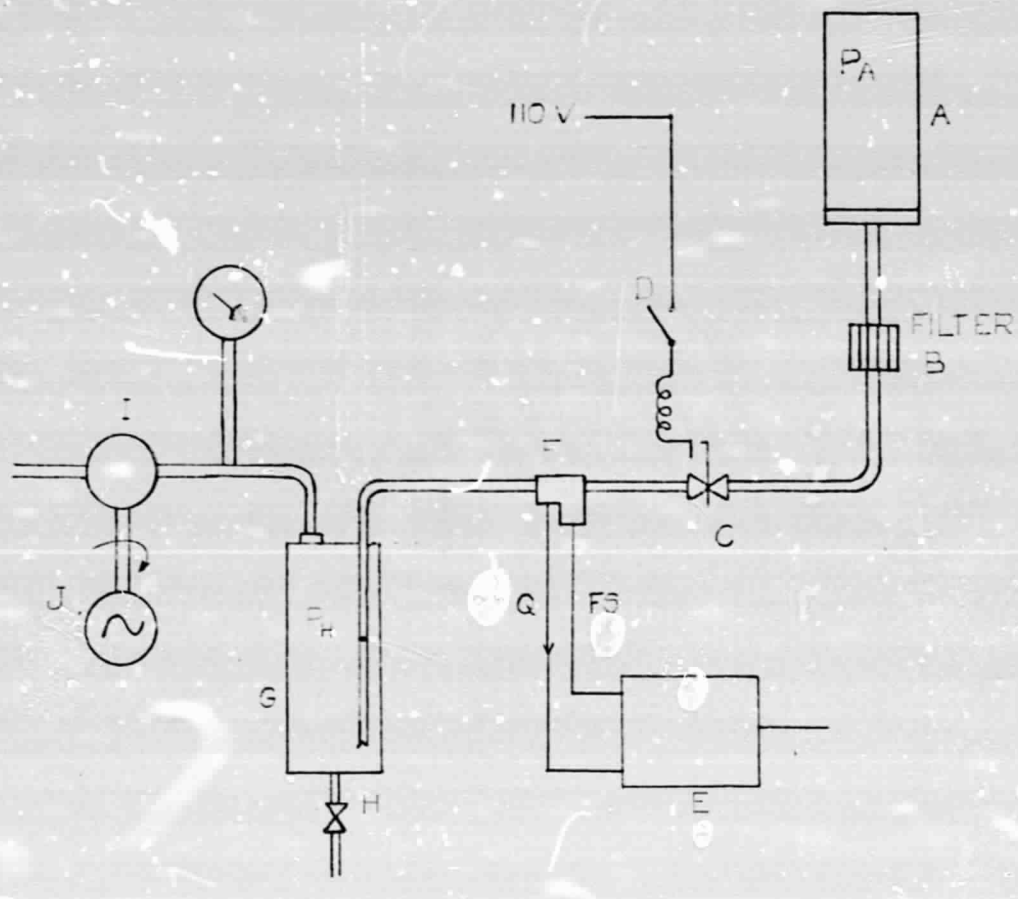


Fig. 9

A precise amount volume of liquid, pre-measured with a set of calibrated cylinders, are stored in a transparent long glass cylinder A which is connected by tubing via a filter B to the urine flowmeter F. Methyl alcohol is used as the calibration fluid. We are interested to simulate, in-so-far as feasible, certain local vaporization, or phase transitional phenomena under downstream evacuation flow process. Hopefully, some degree of approximation of the zero-G liquid flow condition can be achieved.

Between F and A is a 110 VAC operated solenoid operated three-way valve C which is controlled by a switch D. The liquid is allowed to enter F for measurement upon the closure of switch D. This closure is made to commence the calibration process.

To simulate the most likely space flight operating conditions, the liquid is pulled by suction process through F to a receiving tank H. A small vacuum pump I is used for continuous evacuation function. The pump speed is regulated extremely closely by a variable speed motor whose speed can be regulated extremely closely by means of digital speed control.* The initial absolute pressure was monitored. The flowrate of liquid through F, therefore, can be varied over a sufficient range by adjusting the pressure differential between p_A, which is the atmospheric pressure exerted upon the liquid in A on the upstream side; and the rarefied downstream pressure p_H in the receiving tank. By varying the RPM speed of the motor for a number of fixed steps, the same volume of liquid (urine) can be calibrated at different flowrates.

To commence operation: electric valve C is opened. Due to the difference in pressure potential, the liquid commences to flow; when it reaches the dielectric flow switch section of the urine flowmeter, differential in dielectric measurement between the measuring and reference section is developed instantly; thereupon an electronic gate in the programmable counter is enabled which permits the flowmeter's output pulses to enter the electronic counter

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* An Ultra High-Precision N-11-F Aircraft Tachometer Calibrator on loan from Quantum Dynamics is used to provide the pump driving motor.

to be counted and totalized. At the same time, the pulse rate is converted into an analog signal representing the rate of flow in cc per unit time. When the last bulk of liquid leaves the dielectric switch; the electronic gate automatically disables the programmable counter, preventing further transmission and accumulation of the flowmeter output pulses. The totalized count stored in the digital counter then represents the total volume of urine discharge.

The digital readout representing the total volume is then tabulated for a number of tests for calibration and statistical evaluation of the measurement precision.

After each series of tests, the pumping speed is changed so that another set of tabulated data is obtained.

By repeating the test for a number of pumping speeds, the combined analysis is subjected to cross correlation and comparison; precision determination of the calibration factors and other statistical performance data are thus obtained.

VI. OPERATIONAL PROCEDURE

The operational procedure, which is very simple, can be summarized as follows:

1. PREPARATION

A. Cable Connections Between Sensors & Electronic Unit (Small Box)

a) Only two cables need to be connected between the flowmeter: The black mini-coax. cable and its subminiature connectors should be used to connect the flowmeter to the terminal on the box marked FM-IN;

b) The 4-pin connector from the flow switch is to be connected to its mating receptacle on the small box marked To FS;

B. Power Connection:

The main electronic unit is of small size, and is designed to be interfaced eventually with the d.c. power supply of the space vehicle. For the present developmental model, however:

a) a 110 VAC powered D.C. supply is added to facilitate laboratory and test operation. A (D.C.) power cord with a 6-pin connector is used to connect between the (bigger) power supply box and the (smaller) box terminal marked "POWER".

b) a built-in cooling blower is added for prudence sake. This blower will not be needed in the future.

Thus, after the inter-unit cable connections are properly made, one of the first steps is to insert the two electrical plugs to the proper line powered 110 VAC wall receptacle. Turn on the power switch when ready for operation. This switch is located on the front panel of the power supply box.

2. RESOLUTION CONTROL AND DIGITAL VOLUME READOUT

A. High Resolution Operation

For high precision measurement, when high output resolution of 23.56 pulse per mL is preferable, it is recommended that the programmable counter be set at high resolution, namely at

1-to-1 ratio. This is done by setting the small toggle switch (located on the back panel of the (larger) power supply box) upward to "HI" position.

B. Direct mL Low-Resolution Reading

If it is desirable to read-out in 1 count per mL conversion; simply flip the switch mentioned in 2 downward to "LOW". The action completes all the internal digital connections for dividing the flowmeter counter by a factor of 23. Strictly speaking, the division should be 23.56. The present programmable counter is only intended to show this direct-reading feasibility, and is not recommended for precision measurement.

3. SETTING OF VOLUME (TELEMETRY) OUTPUT

A. When the switch is set as described in 2A, in addition to the 5-digit LED readout of volume; the DAC (digital-to-analog converter) is set so that an output of 1.00 VDC, is equivalent to 500 milli-liter volume, namely, when the digital readout is shown as 11780. Thus, 2 millivolt DAC output is equivalent to 1 mL volume. This DAC output is obtained from the BNC output terminal marked "TOTAL FLOW".

B. When the switch is set as described in 2B: divide the digital output by 23. For example, a volume of 500 mL is indicated by digital readout of 512. The DAC output should not be used since it is only connected to the first three (most significant) digits.

4. SETTING OF FLOWRATE OUTPUT

The flowrate output is set internally so that 400 mL/min. flowrate is indicated by 4.00 VDC. More precisely, the precision diode-pump circuit is adjusted to provide 4.00 VDC at an input of 157 hertz. In other words, 1 VDC indicates a 100 mL (c.c.)/min. flowrate.

5. RESET

Prior to each operation, it is advisable to push the RESET button located in the power supply box.

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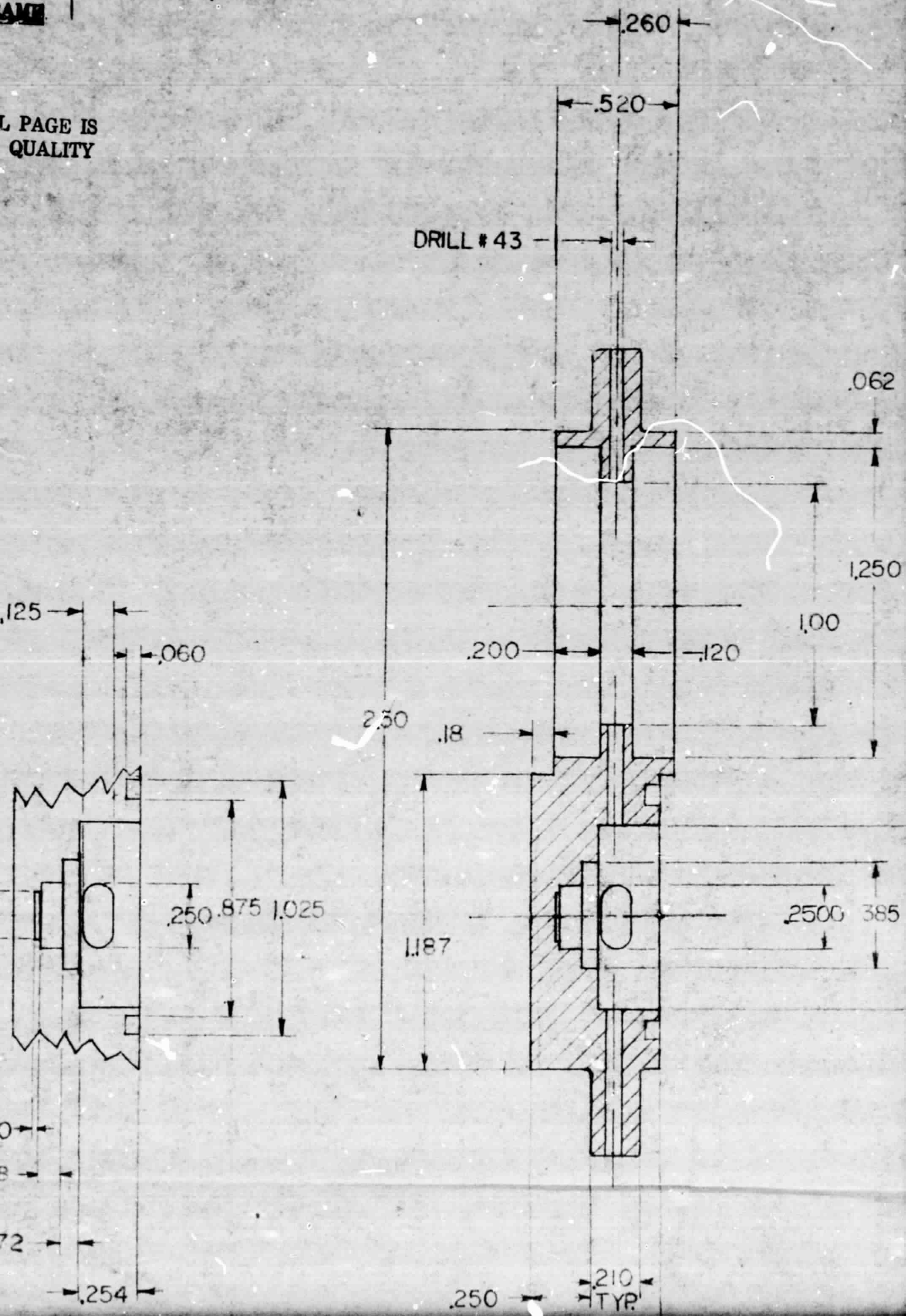

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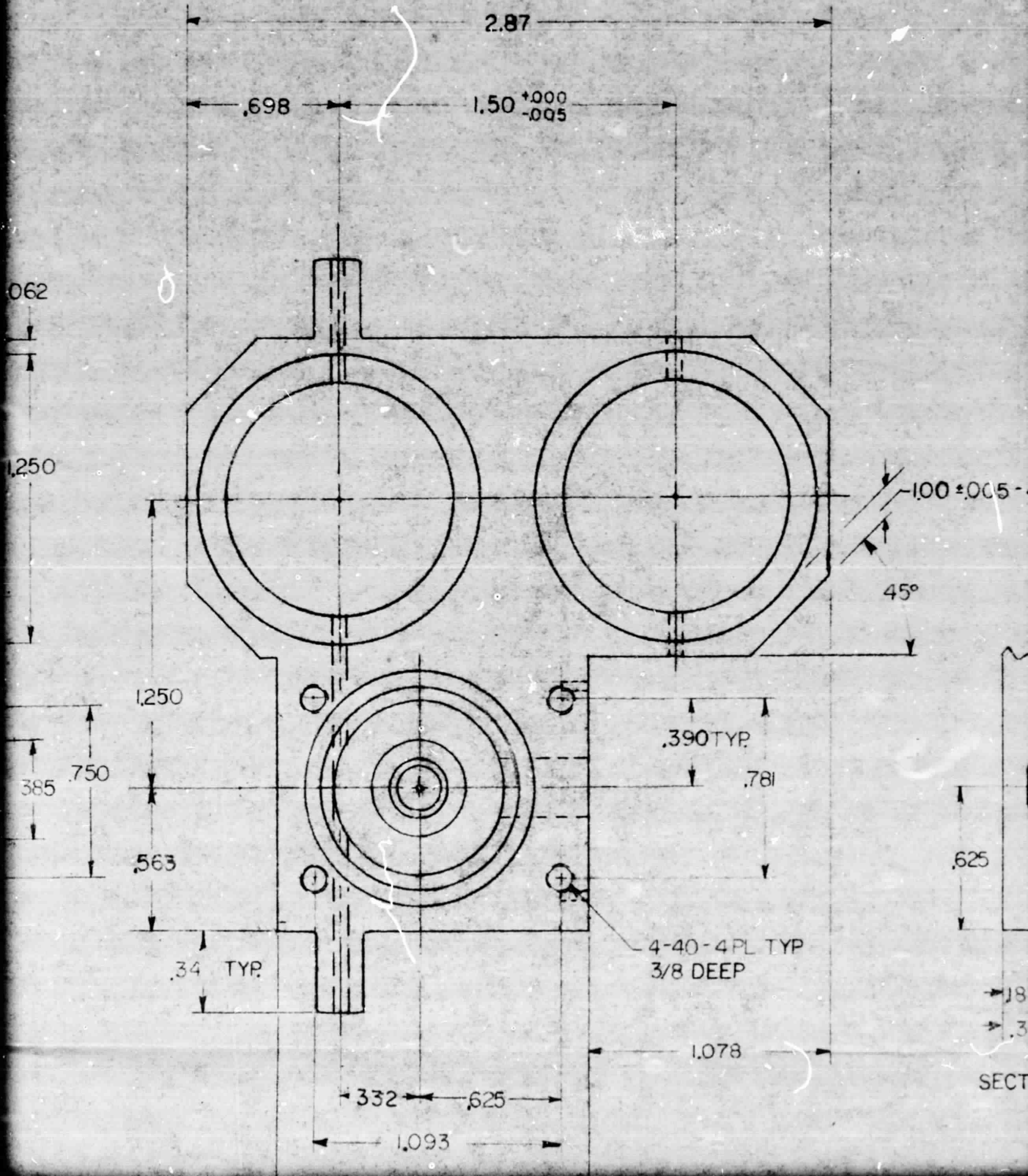

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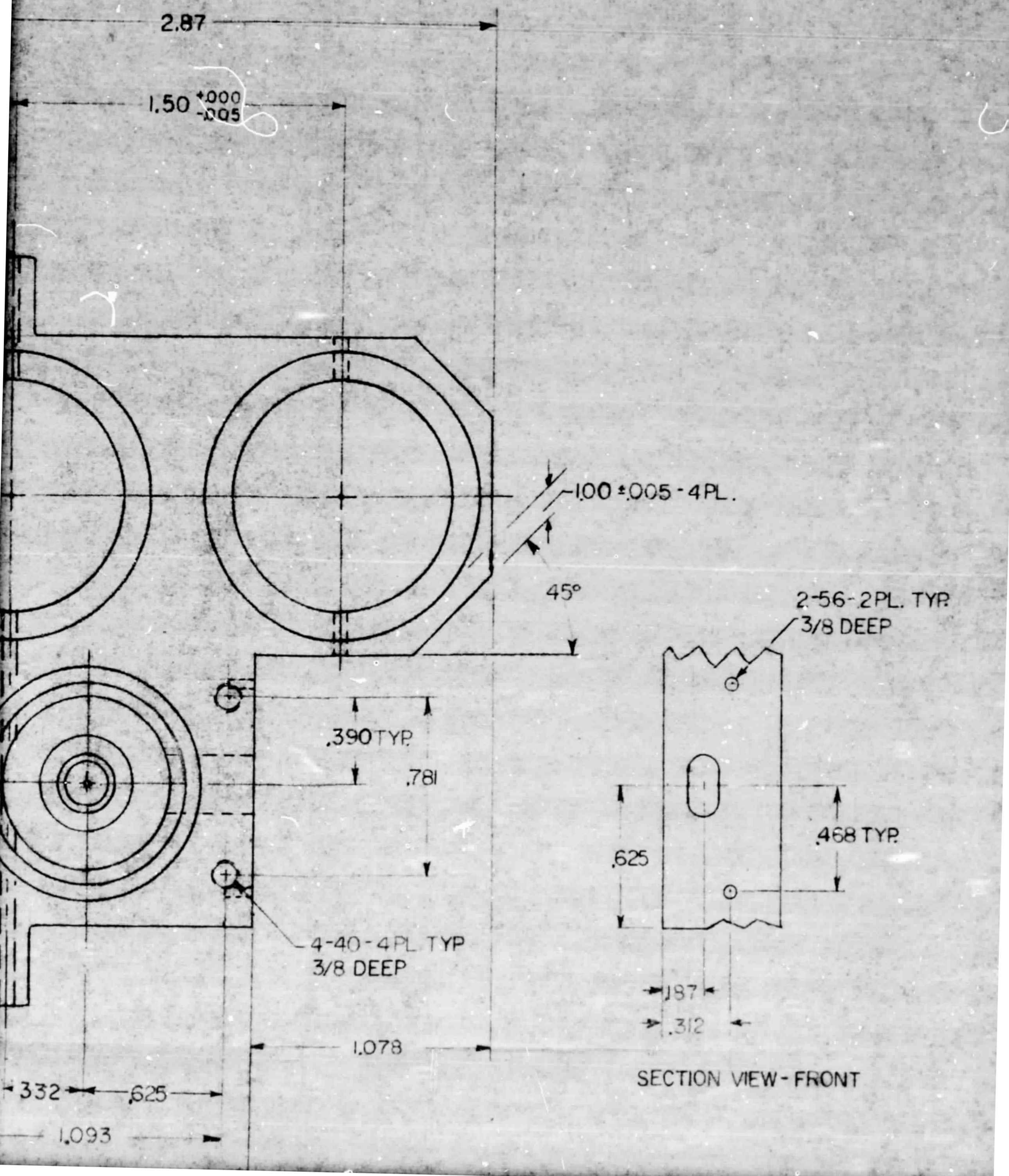

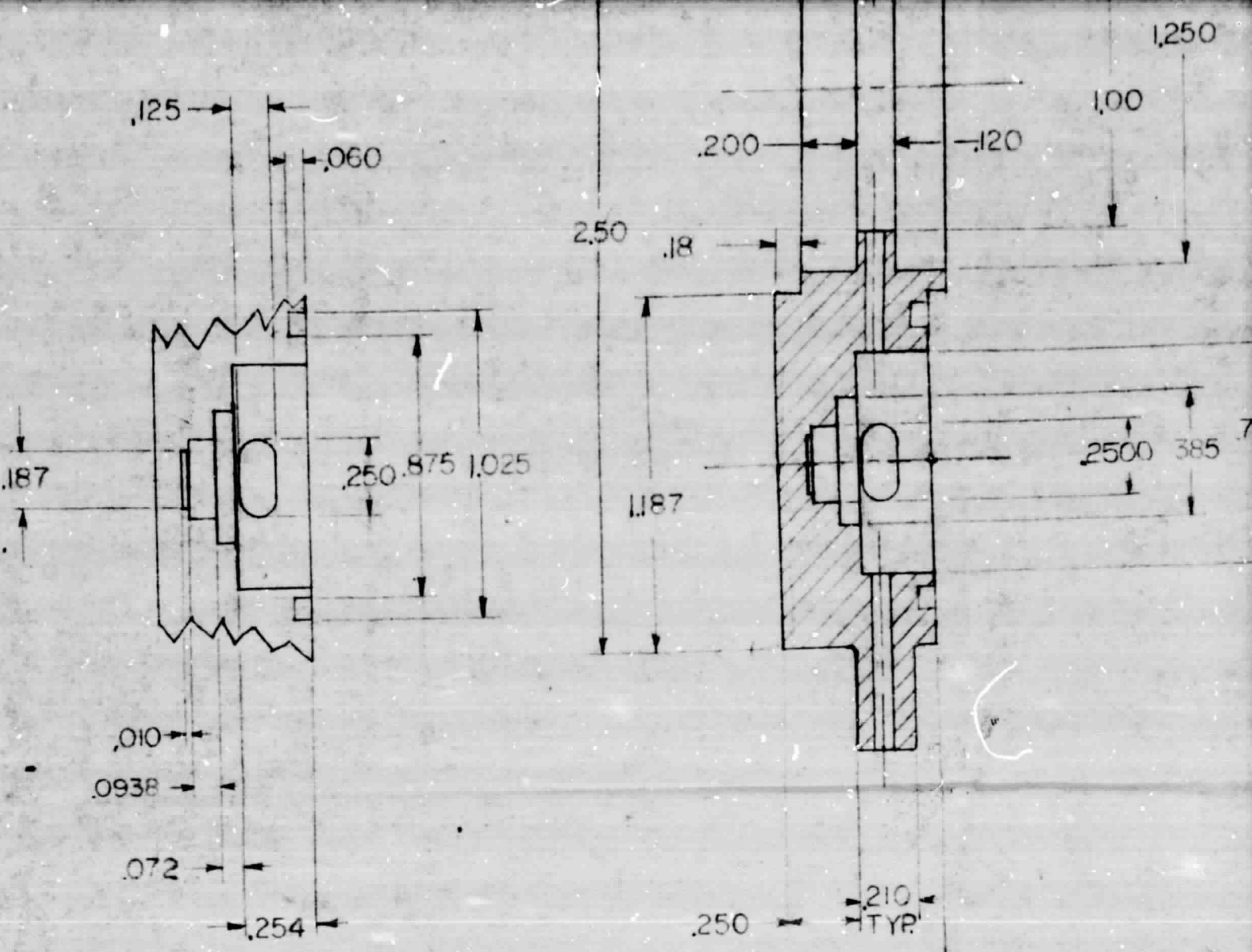

SECTION VIEW - SIDE

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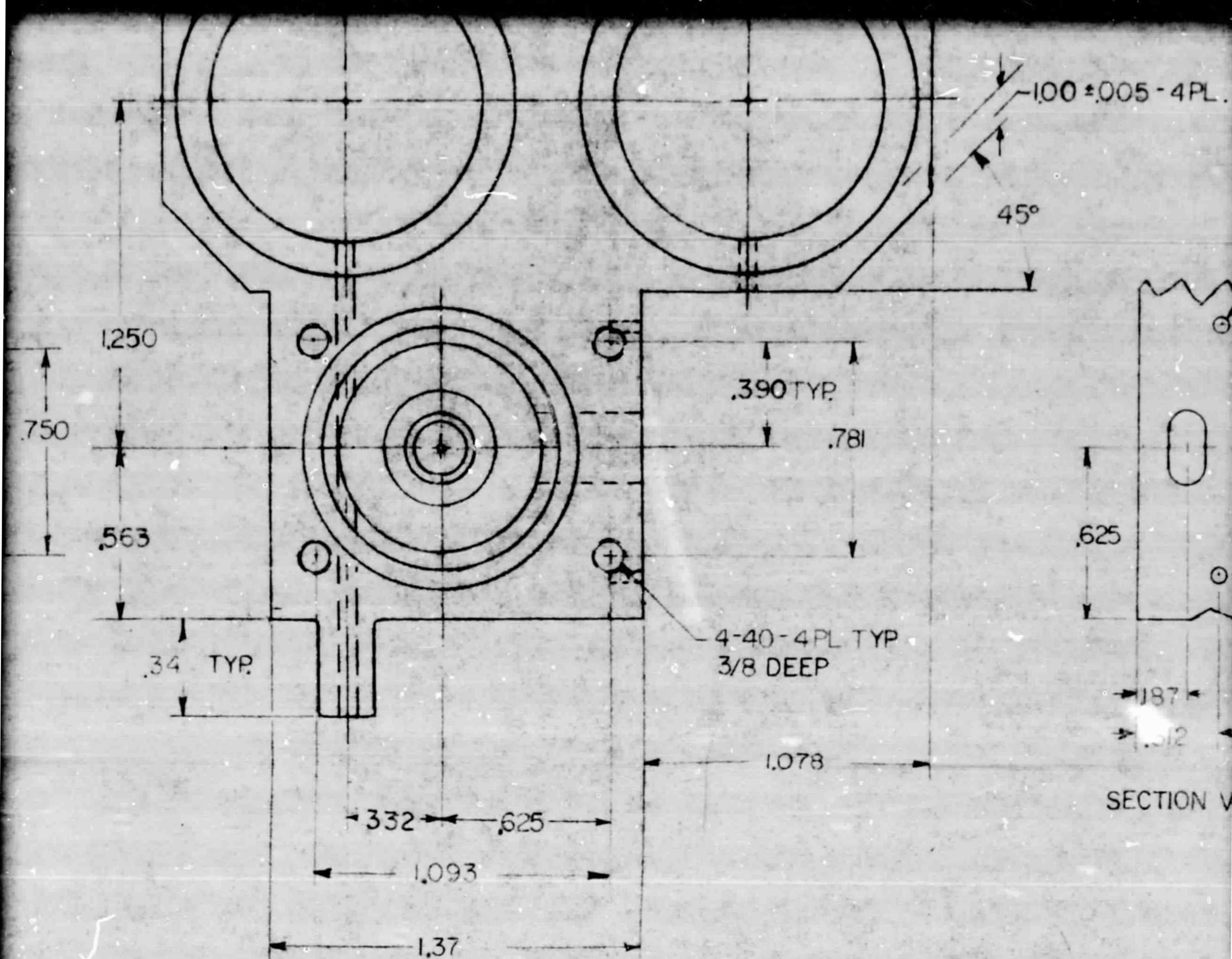
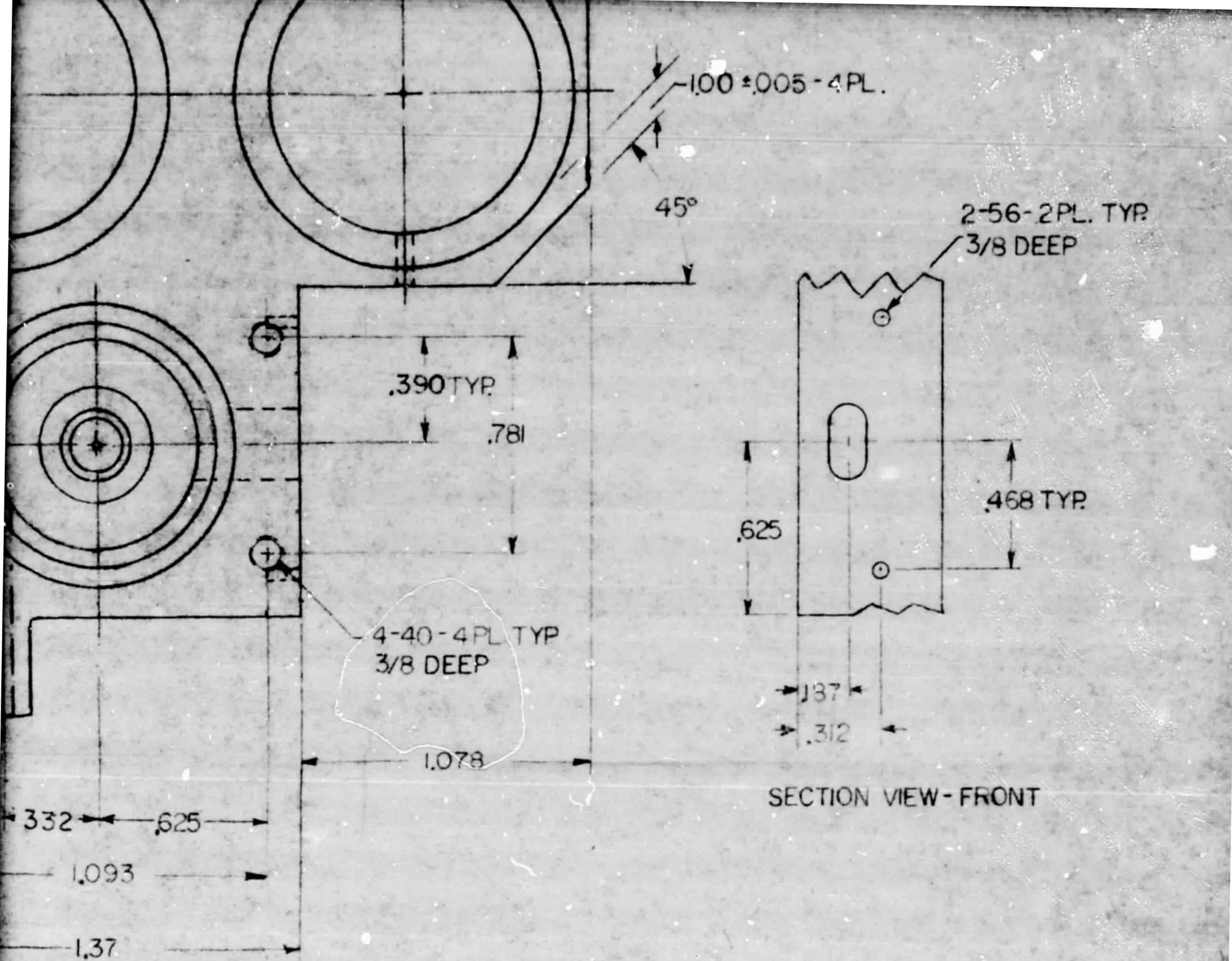


1		BODY	AL.ALLOY 7075
REQ'D	PART NO.	DESCRIPTION	MATERIAL

TOLERANCES EXCEPT AS NOTED			
DECIMAL X ±.1 XX ±.01 XXX ±.001	FRACTIONAL ± 1/32	ANGULAR ± 0° 30'	QUANTUM D ADVANCED EXPERIMENTAL RESEARCH TARZANA, CA
SCALE–			NAME URINE, VERY SMALL P.W. FLOW METER
DRAWN BY AL SOLOMON	DATE		
CH'K'D BY–	DATE		

FOLDOUT FRAME 5



FOLDOUT FRAME 6

1		BODY	AL. ALLOY 7075 ANODIZE PER-MIL-A-8625B	
REQ'D	PART NO.	DESCRIPTION	MATERIAL	SIZE

TOLERANCES EXCEPT AS NOTED

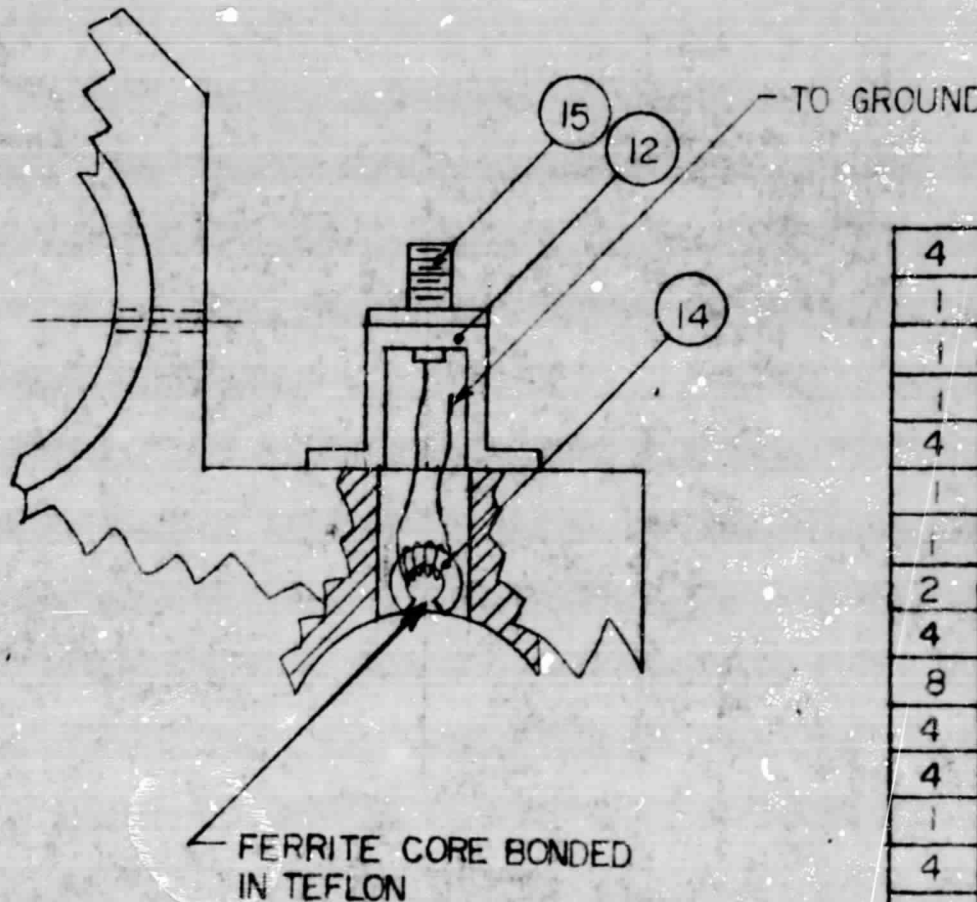
DECIMAL	FRACTIONAL	ANGULAR
X ± .1 XX ± .01 XXX ± .001	± 1/32	± 0° 30'

QUANTUM DYNAMICS

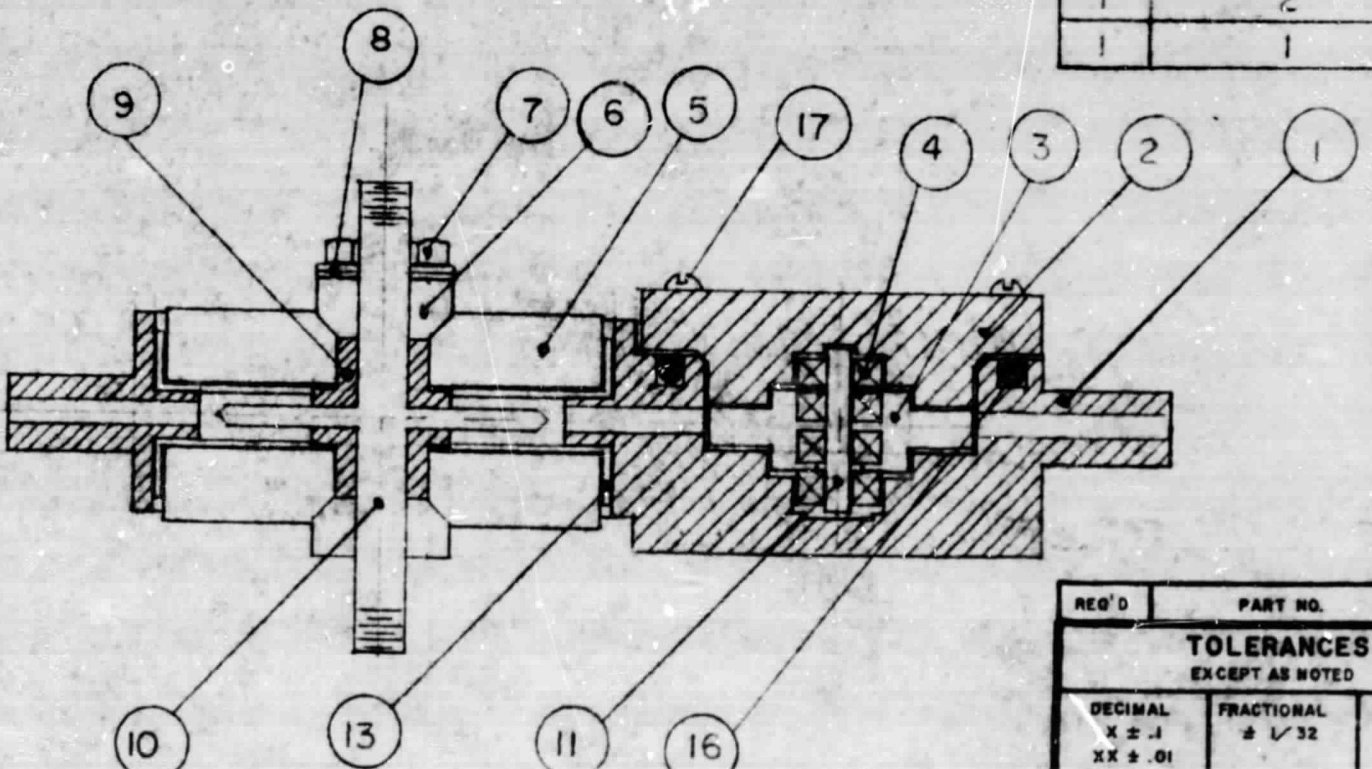
ADVANCED EXPERIMENTAL RESEARCH AND INSTRUMENTATION

TARZANA, CALIF.

NAME | DWG. NO.



REQ'D	PART NO.
4	17
1	16
1	15
1	14
4	13
1	12
1	11
2	10
4	9
8	8
4	7
4	6
1	5
4	4
1	3
1	2
1	1



TOLERANCES
EXCEPT AS NOTED

DECIMAL	FRACTIONAL
X ± .1 XX ± .01 XXX ± .001	± 1/32

SCALE–

DRAWN BY– M. SOLOMON DATE

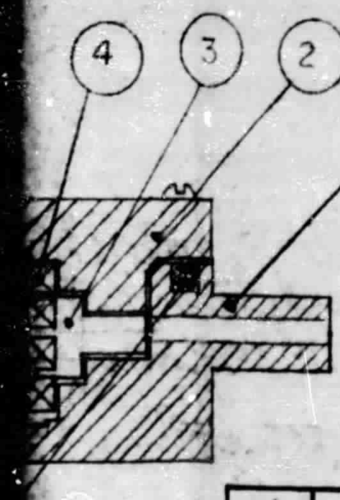
CH'K'D BY– DATE

APPROVED– DATE

FOLDOUT FRAME 2

- TO GROUND

REQ'D	PART NO.	DESCRIPTION	MATERIAL	SIZE
4	17	4-40 SCREWS	STANDARD	
1	16	RUBBER "O" RING		
1	15	CONNECTER	GRFF 3050-0001 6941	
1	14	FERRITE RING	FERRITE	
4	13	INSUL-RING	TEFLON	
1	12	CON-MOUNT	AL. ALLOY 7075 ANO-MIL-A-8625B	
1	11	SHAFT	303 STAINLESS STEEL	
2	10	ELECTRODE	303 STAINLESS STEEL	
4	9	SPACER	TEFLON	
8	8	WASHER	6-32 STANDARD	
4	7	NUT	6-32 STANDARD	
4	6	WASHER	TEFLON	
1	5	DISK	ALUM.	
4	4	BEARING	USE RMB = R2508X-A7	
1	3	BLADE	303 STAINLESS STEEL	
1	2	COVER	AL. ALLOY 7075 ANO.-MIL-A-8625B	
1	1	BODY	AL. ALLOY 7075 ANO.-MIL-A-8625 B	



TOLERANCES EXCEPT AS NOTED			QUANTUM DYNAMICS ADVANCED EXPERIMENTAL RESEARCH AND INSTRUMENTATION TARZANA, CALIF.	
DECIMAL X ± .1 XX ± .01 XXX ± .001	FRACTIONAL ± 1/32	ANGULAR ± 0° 30'		
SCALE–			NAME URINE, VERY SMALL P.W. FLOW METER (ASSEMBLE) NASA Q580	DWG. NO. QD0093/DS
DRAWN BY M. SOLOMON	DATE			
CH'K'D BY–	DATE			
APPROVED–	DATE 8/11/75			SHEET OF

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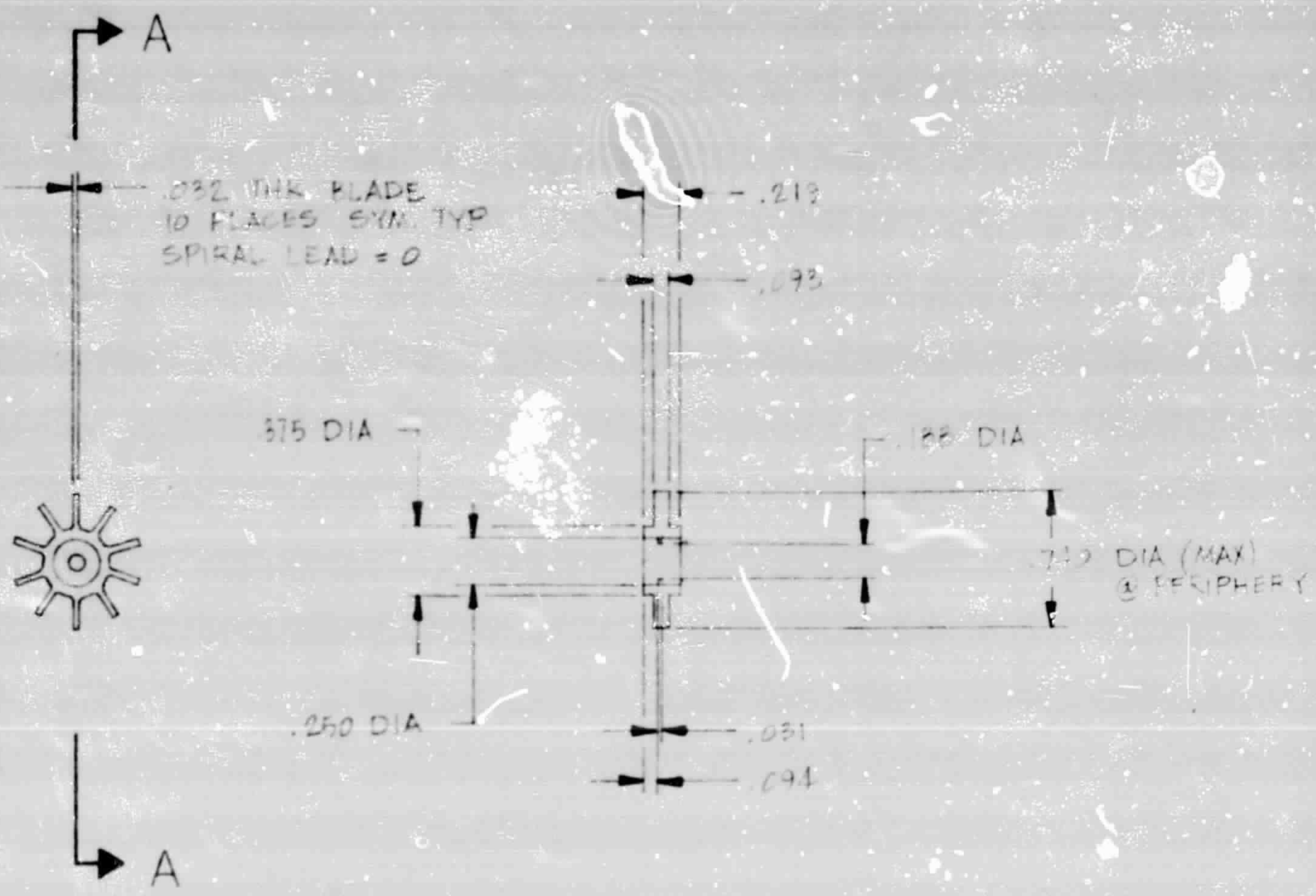

SECTION A-A

1		BLAD
REQ'D	PART NO.	

TOLERANCES EXCEPT AS NOTED		
DECIMAL X ± .1 XX ± .01 XXX ± .001	FRACTIONAL ± 1/32	ANGULAR ± 0° 30'
SCALE–		
DRAWN BY A. SOLOMON	DATE	
CH'K'D BY–	DATE	
APPROVED	DATE 8/14/75	

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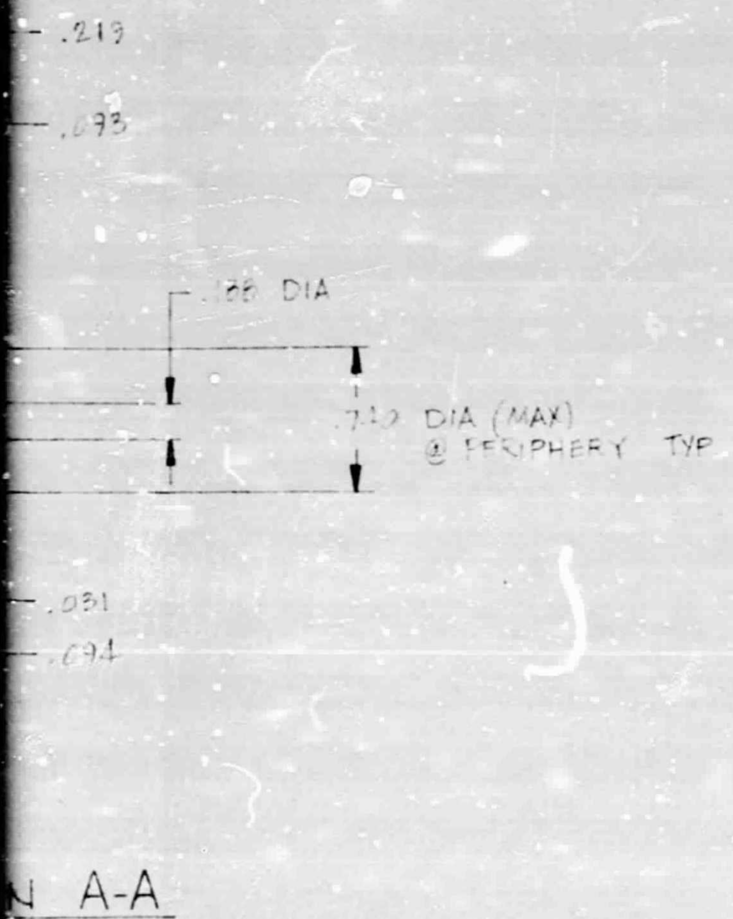

1		BLADE	USE RMB BEARING = R2508X-A7	
REQ'D	PART NO.	DESCRIPTION	MATERIAL	SIZE

TOLERANCES EXCEPT AS NOTED			QUANTUM DYNAMICS ADVANCED EXPERIMENTAL RESEARCH AND INSTRUMENTATION TARZANA, CALIF.	
DECIMAL X ± .1 XX ± .01 XXX ± .001	FRACTIONAL ± 1/32	ANGULAR ± 0° 30'		
SCALE–			NAME URINE, VERY SMALL P. W. FLOW METER	DWG. NO. QD0093/DS-4
DRAWN BY H. SOLOMON	DATE			
CH'K'D BY–	DATE		NASA Q580	SHEET OF
APPROVED [signature]	DATE 6/11/25			

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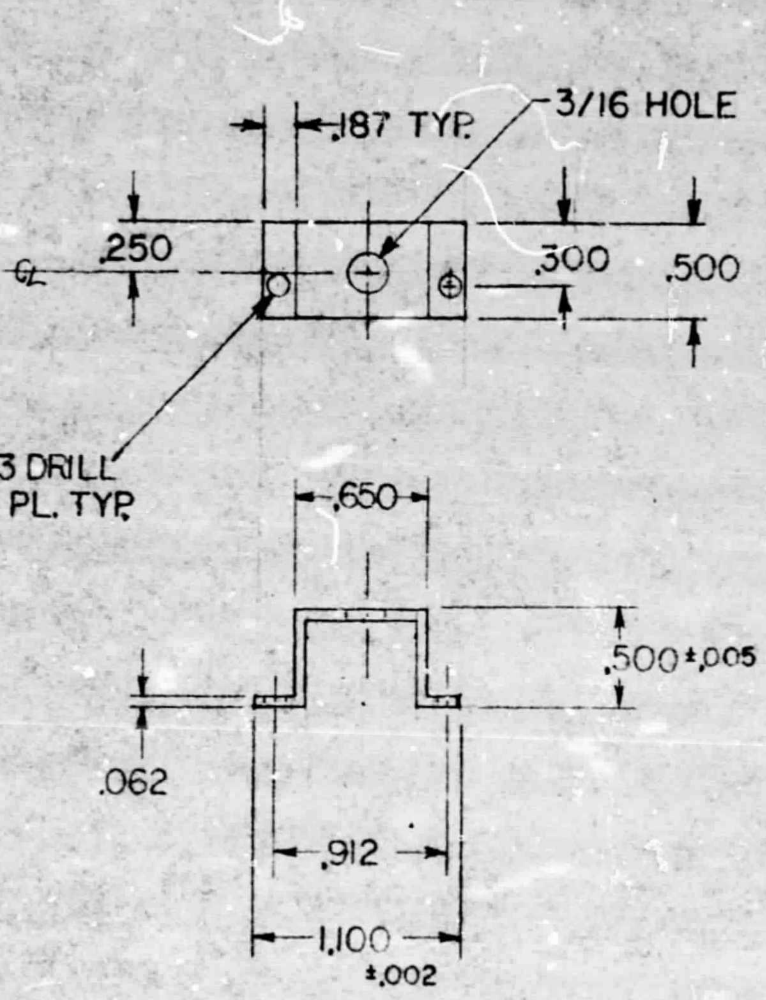

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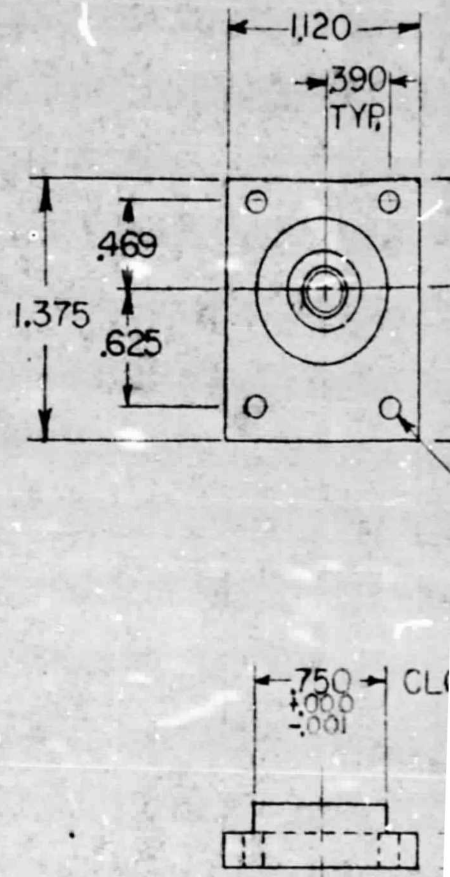

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XXX ±
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APPR'D

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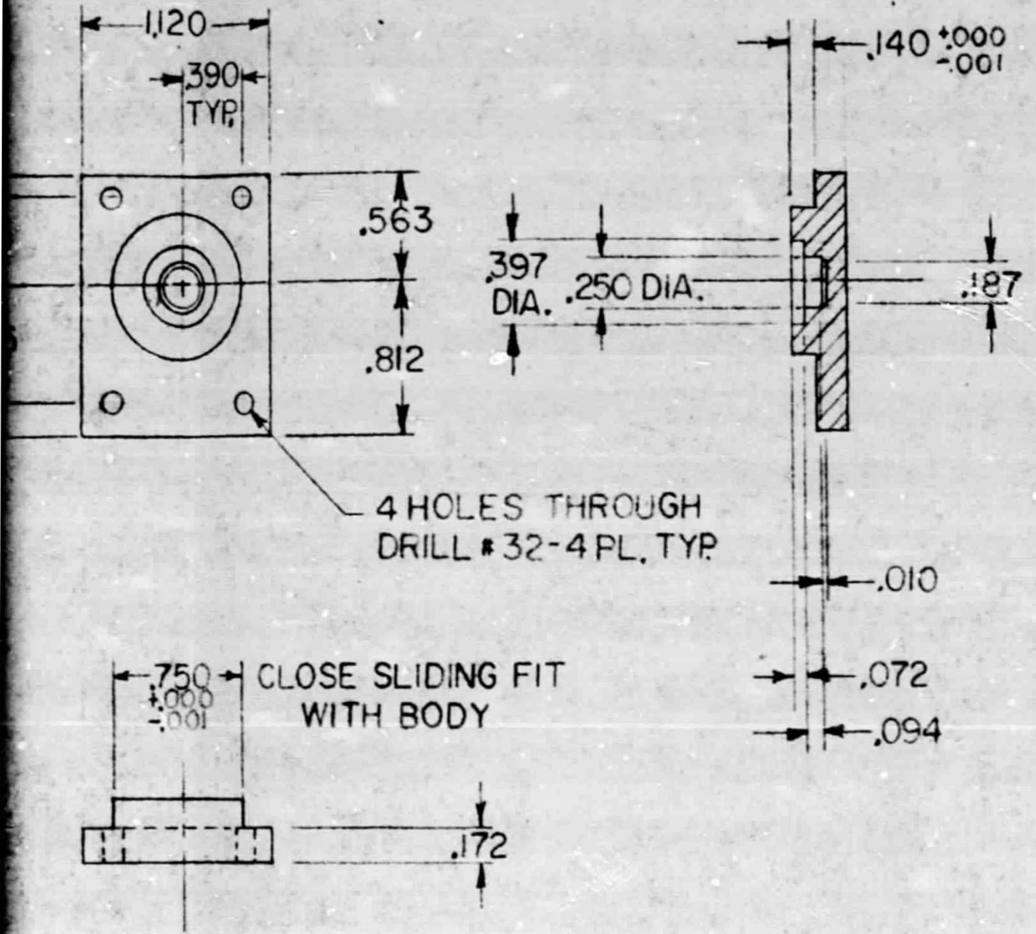

COVER

REQ'D	PART NO.	DESCRIPTION	MATERIAL	SIZE
1	2	COVER	AL ALLOY 7075 ANO-MIL-A-86258	
1	12	CON-MOUNT	AL ALLOY 7075 ANO-MIL-A-86258	

TOLERANCES
EXCEPT AS NOTED

DECIMAL	FRACTIONAL	ANGULAR
X ± .1 XX ± .01 XXX ± .001	± 1/32	± 0° 30'

SCALE–
DRAWN BY M. SOLOMON DATE
CH'K'D BY– DATE
APPROVED DATE 3/11/75

QUANTUM DYNAMICS
ADVANCED EXPERIMENTAL RESEARCH AND INSTRUMENTATION
TARZANA, CALIF.

NAME
URINE, VERY SMALL P.W.
FLOW METER (PARTS)
NASA Q580

DWG. NO.
QD0093/DS

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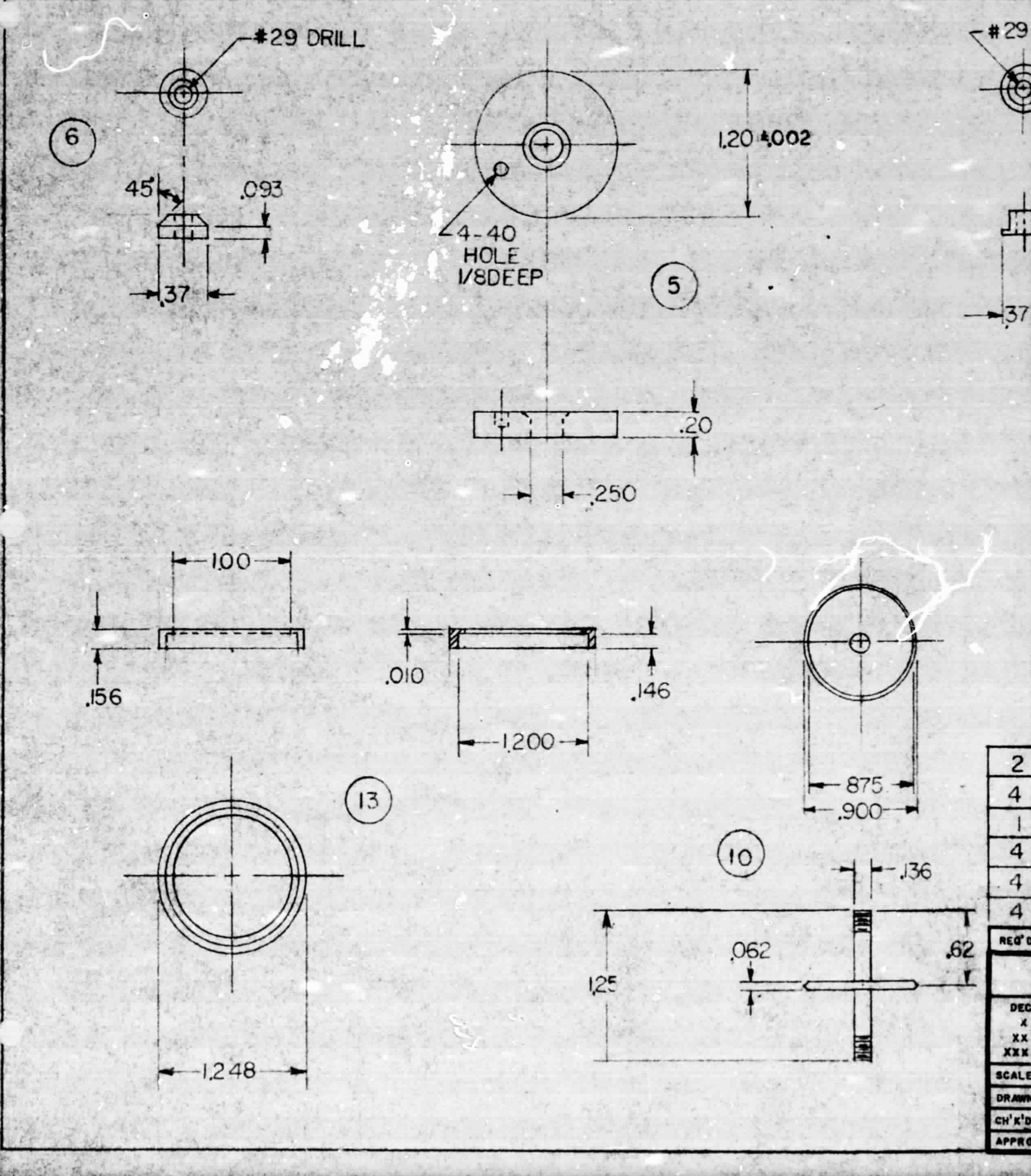

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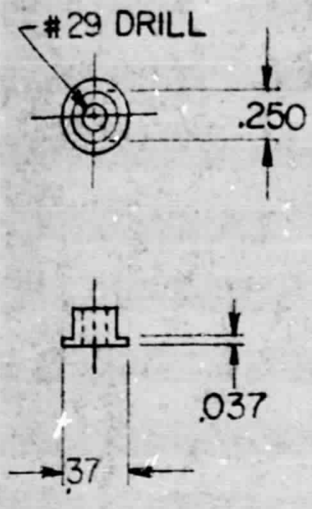

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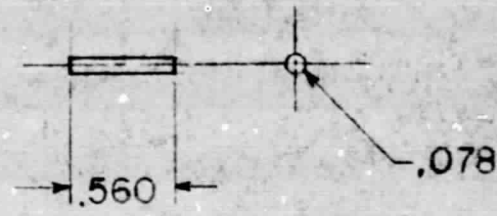

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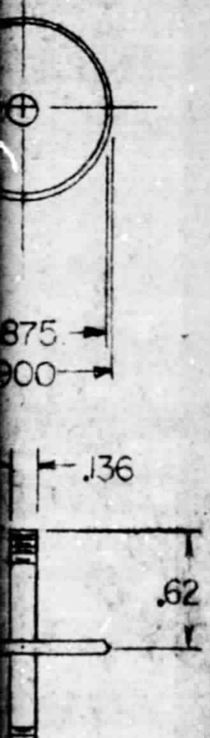

REQ'D	PART NO.	DESCRIPTION	MATERIAL	SIZE
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4	13	INSUL-RING	TEFLON	
1	11	SHAFT	303 STAINLESS STEEL	
4	9	SPACER	TEFLON	
4	5	DISK	ALUM.	
4	6	WASHER	TEFLON	

TOLERANCES EXCEPT AS NOTED		
DECIMAL X ± .1 XX ± .01 XXX ± .001	FRACTIONAL ± 1/32	ANGULAR ± 0° 30'

QUANTUM DYNAMICS
ADVANCED EXPERIMENTAL RESEARCH AND INSTRUMENTATION
TARZANA, CALIF.

SCALE–	
DRAWN BY M. SOLOMON	DATE
CH'K'D BY	DATE
APPROVED	DATE 2/11/73

NAME: URINE, VERY SMALL R. W. FLOW METER (PARTS)
NASA Q580

DWG: 30093/DS
SHEET | OF

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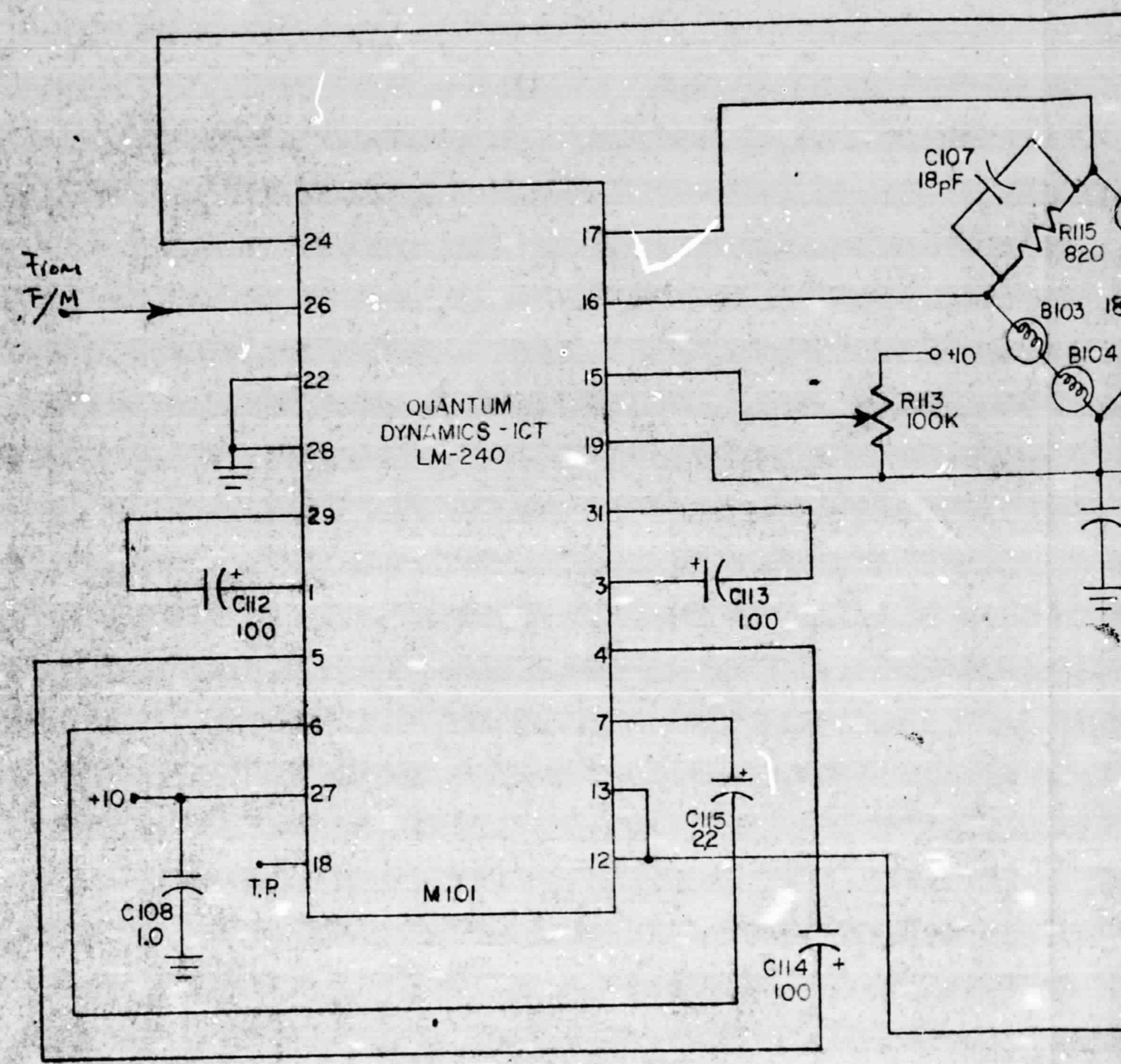

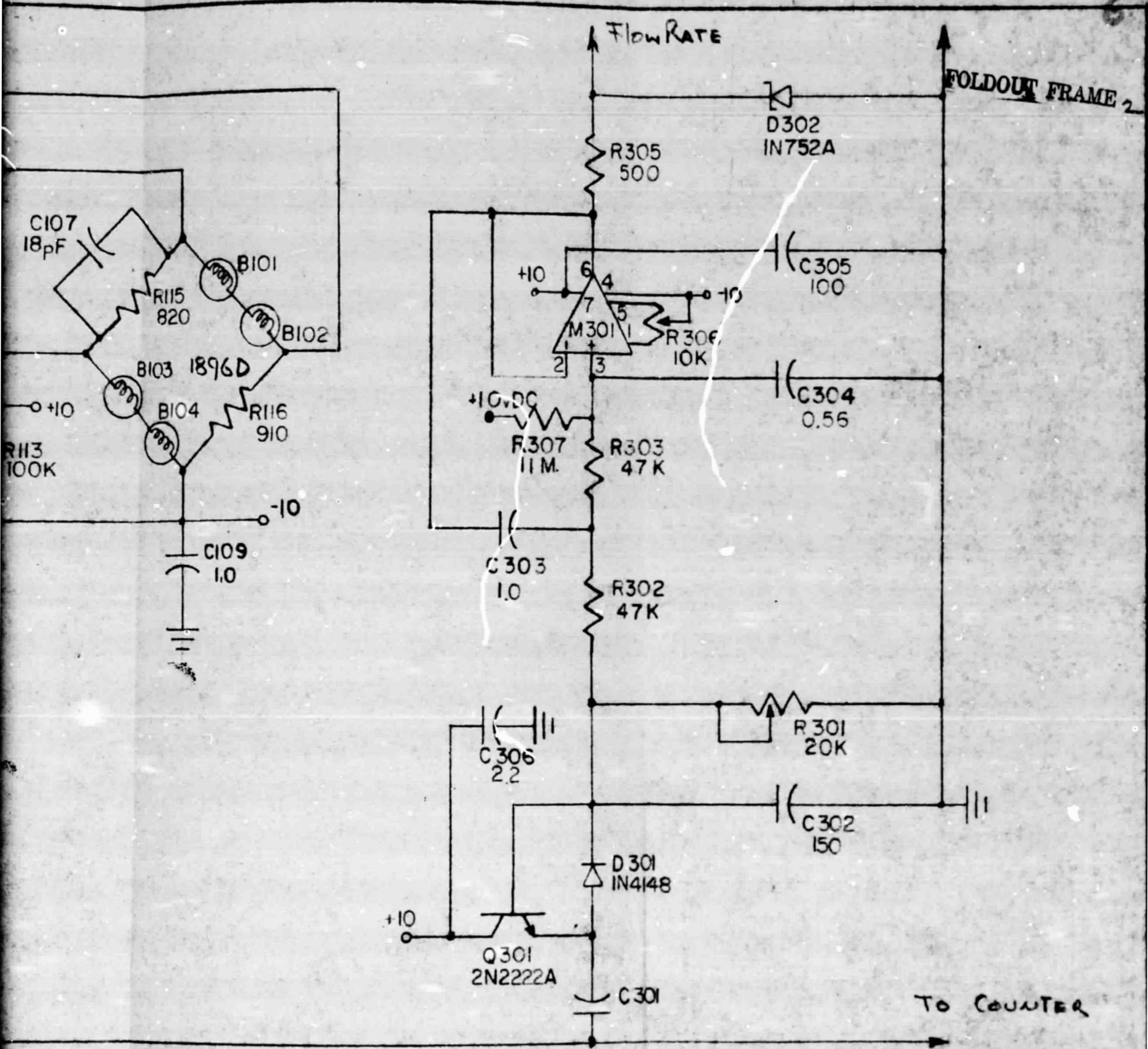

REQ'D	PART NO.	DESCRIPTION	MATERIAL	SIZE

TOLERANCES
EXCEPT AS NOTED

DECIMAL	FRACTIONAL	ANGULAR
X ± .1 XX ± .01 XXX ± .001	± 1/32	± 0° 30'

QUANTUM DYNAMICS

ADVANCED EXPERIMENTAL RESEARCH AND INSTRUMENTATION
TARZANA, CALIF.

SCALE–
DRAWN BY M. SOLOMON DATE
CH'K'D BY– W... DATE
APPROVED– DATE

NAME
CRYOTRONIC CONVERTER

DWG. NO.
QL-580-01

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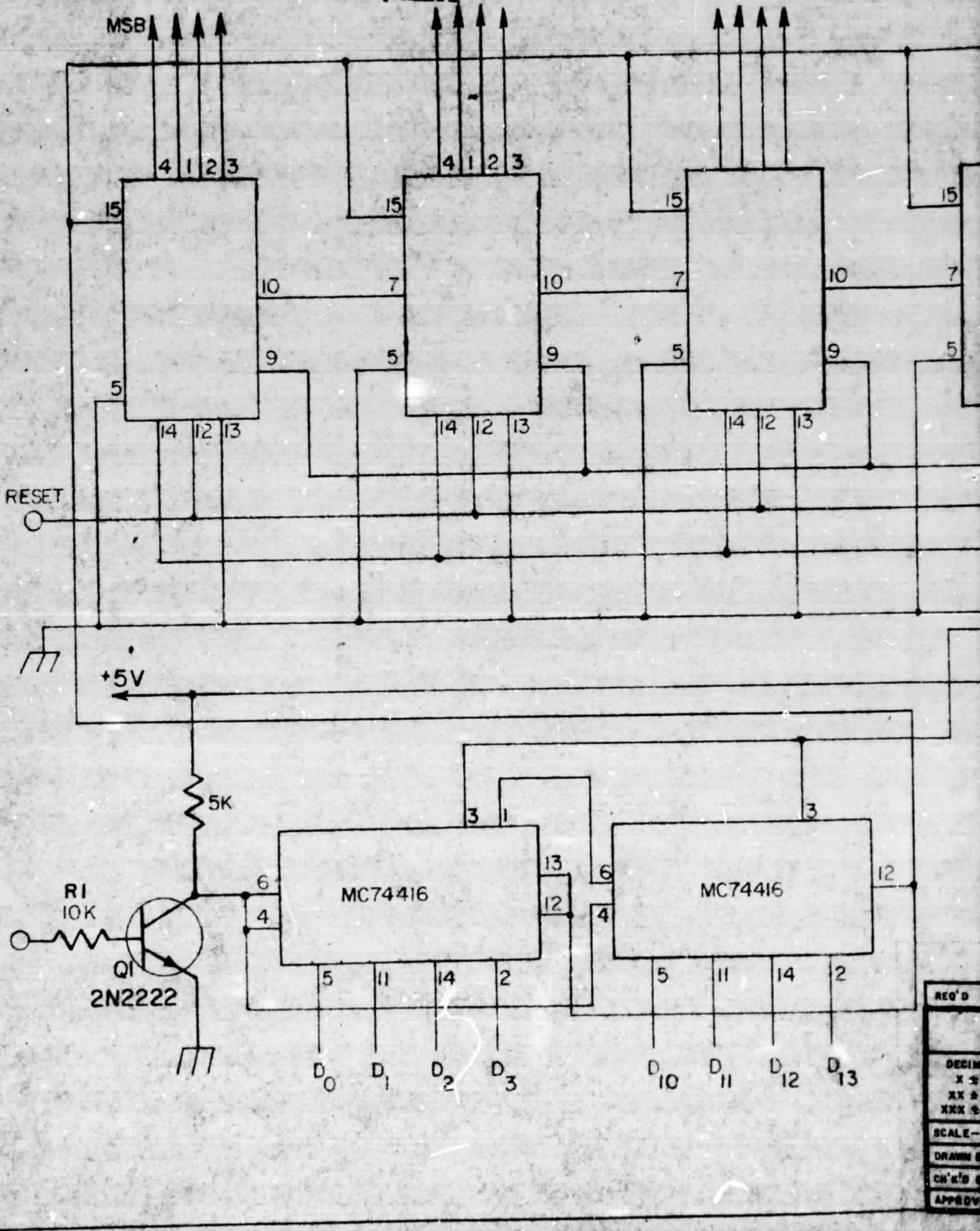

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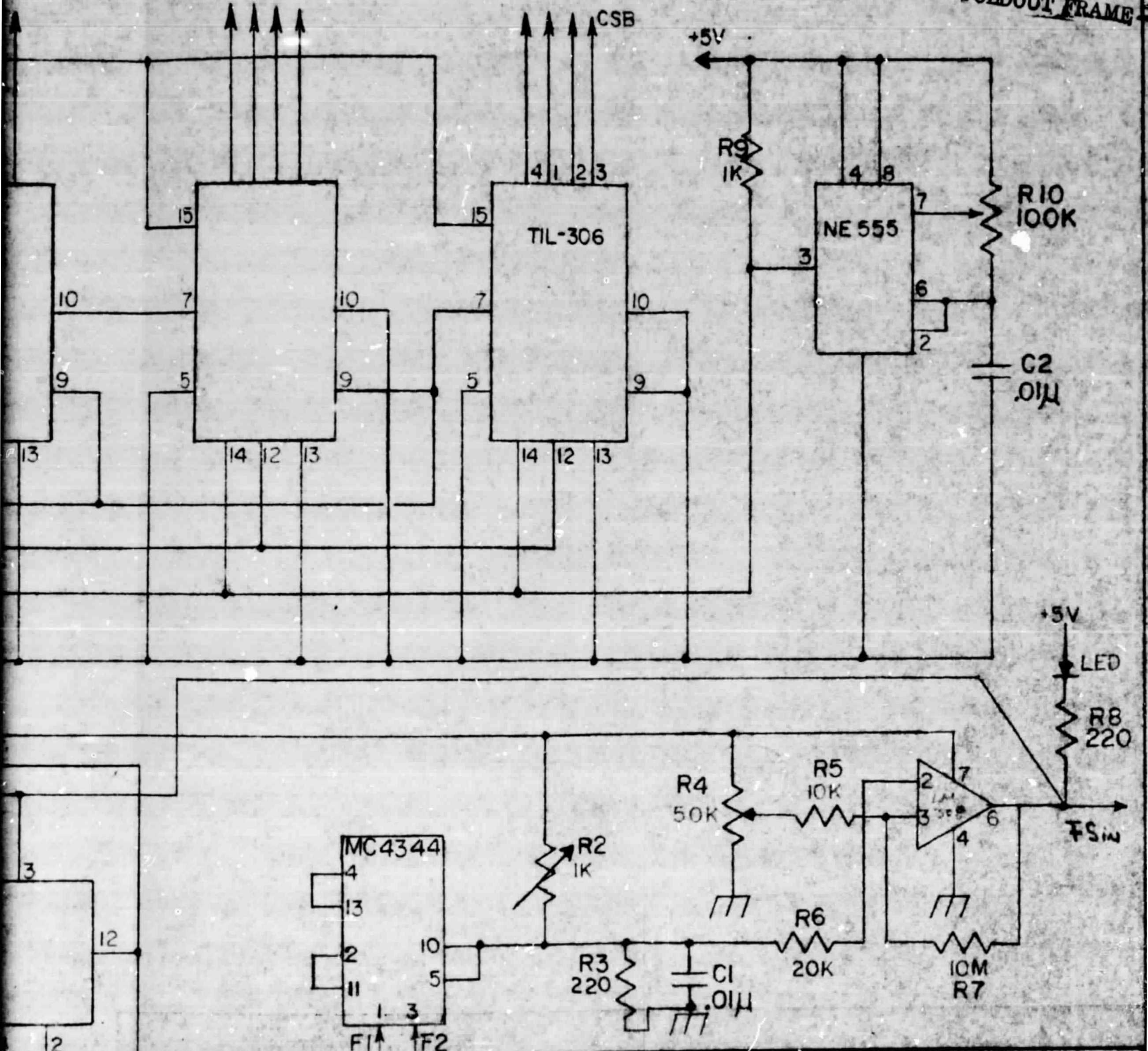

REQ'D	PART NO.	DESCRIPTION	MATERIAL	SIZE

TOLERANCES
EXCEPT AS NOTED

DECIMAL	FRACTIONAL	ANGULAR
X ± .1 XX ± .01 XXX ± .001	± 1/32	± 0° 30'

QUANTUM DYNAMICS

ADVANCED EXPERIMENTAL RESEARCH AND INSTRUMENTATION
TARZANA, CALIF.

SCALE-
DRAWN BY- M. SOLOMON DATE
CH'K'D BY- [illegible] DATE
APPROVED- DATE

NAME: COUNTER/SW CONTROL

DWG. NO. QL-580-01

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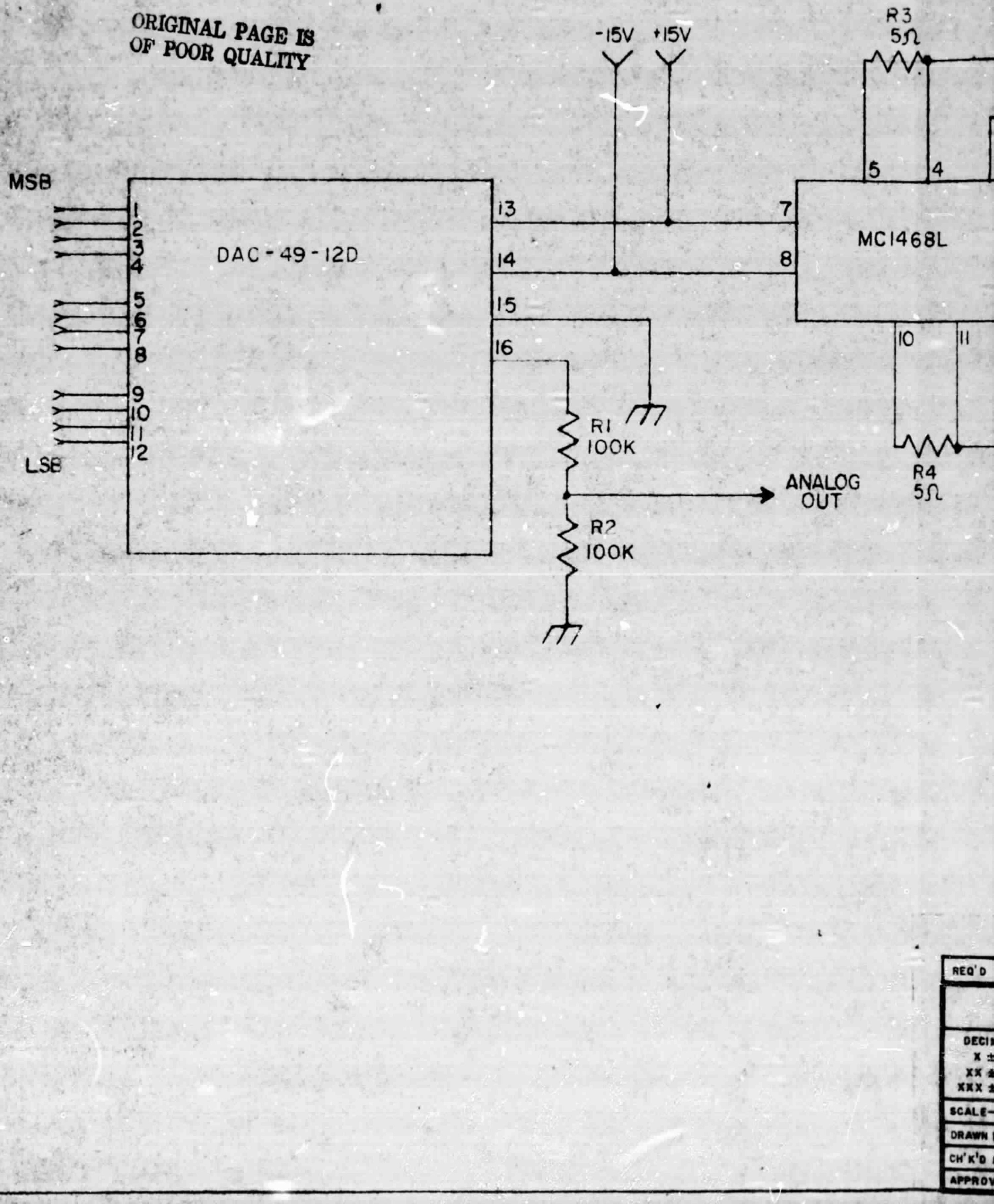

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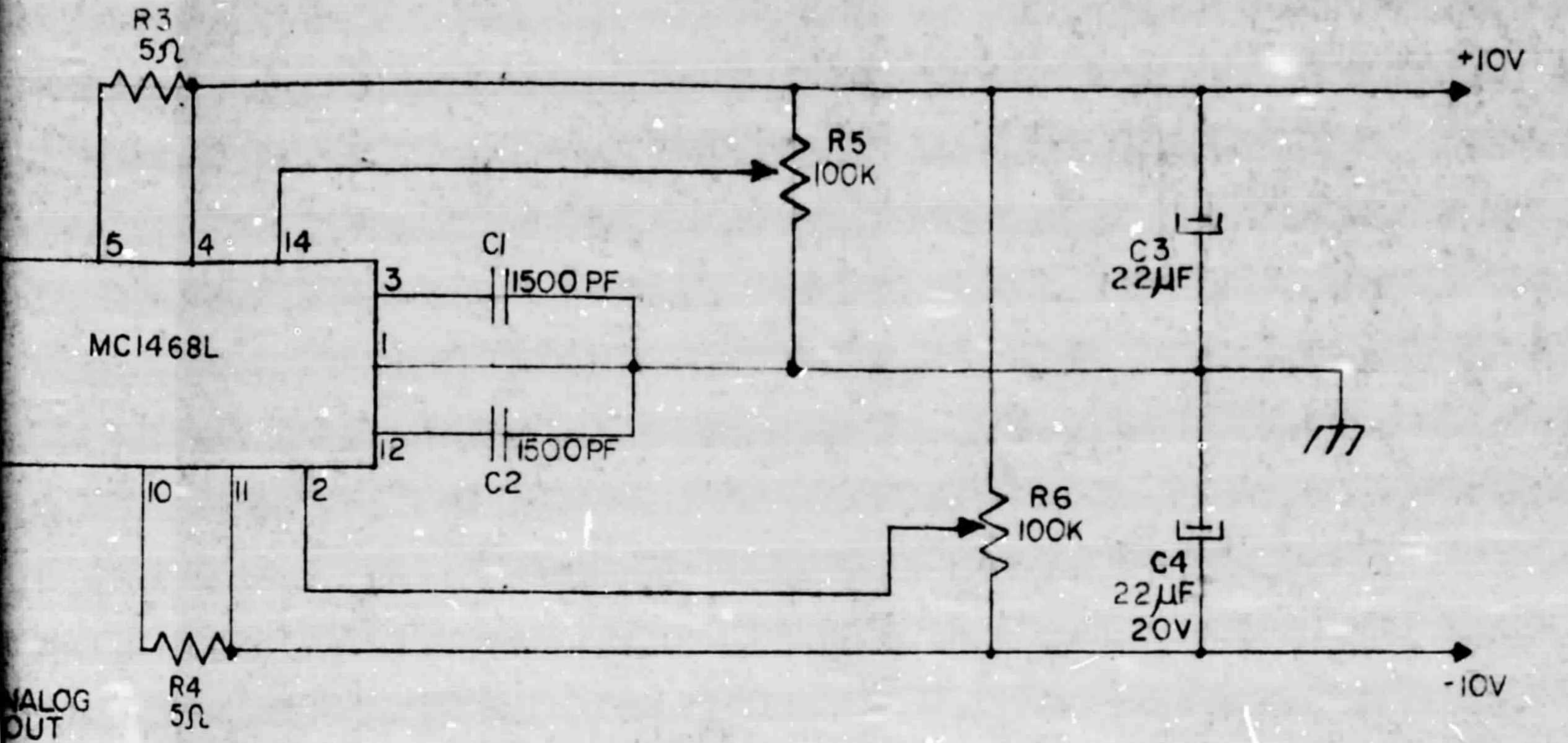

REQ'D	PART NO.	DESCRIPTION	MATERIAL	SIZE

TOLERANCES
EXCEPT AS NOTED

DECIMAL	FRACTIONAL	ANGULAR
X ± .1 XX ± .01 XXX ± .001	± 1/32	± 0° 30'

QUANTUM DYNAMICS
ADVANCED EXPERIMENTAL RESEARCH AND INSTRUMENTATION
TARZANA, CALIF.

SCALE–
DRAWN BY– M. SOLOMON DATE
CH'K'D BY– W.H. DATE
APPROVED– DATE

NAME: DAC/±10V REG

DWG. NO. QL-580-01

SHEET OF