

USAAMRDL-TR- 75-49

12



PRODUCTION SUITABILITY OF AN ELECTROFORM CONDUCTIVE WAX PROCESS FOR THE MANUFACTURE OF FLUIDIC SYSTEMS

Honeywell Inc.
Government and Aeronautical Products Division
Minneapolis, Minn. 55413



November 1975

Final Report for Period 5 November 1973 to 31 January 1975

Approved for public release;
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Prepared for

U. S. ARMY AVIATION SYSTEMS COMMAND
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St. Louis, Mo. 63166

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ADA018874

EUSTIS DIRECTORATE POSITION STATEMENT

The purpose of this three-phase program is to determine the production suitability of the Electroform Conductive Wax process in conjunction with existing conventional production processes for the manufacture of fluidic systems. The Electroform Conductive Wax process was developed to overcome problems of leakage and the inability of duplication associated with current methods used in fabricating fluidic components and systems. Use of this process in the laboratory has produced excellent results; therefore, this program is to demonstrate that fluidic components and systems can be produced in large quantities using production methods, production conditions, and production people with the same excellent results experienced under laboratory conditions. This report on the Phase I efforts describes the design, fabrication, and testing of the components and systems manufactured using the Electroform Conductive Wax process.

Mr. George W. Fosdick of the Systems Support Division served as the project engineer for this effort.

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18. REPORT NUMBER USAAMRDL-TR-75-49	2. GOV'T ACCESSION NUMBER	3. RECIPIENT'S CATALOG NUMBER	
6. TITLE (AND SUBTITLE) PRODUCTION SUITABILITY OF AN ELECTROFORM CONDUCTIVE WAX PROCESS FOR THE MANUFACTURE OF FLUIDIC SYSTEMS	9. TYPE OF REPORT/PERIOD COVERED FINAL REPORT 5 Nov 1973 - 31 Jan 1975		
10. AUTHOR Robert Lewis, Walter Posingies Burton Scott	8. CONTRACT OR GRANT NUMBER(S) DAAJ02-74-C-0012 new		
9. PERFORMING ORGANIZATION NAME/ADDRESS Honeywell Inc. Government and Aeronautical Products Division Minneapolis, Minnesota 55413	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 98L(1)692000.74004		
11. CONTROLLING OFFICE NAME/ADDRESS U. S. Army Aviation Systems Command P. O. Box 209, Main Office St. Louis, Missouri 63166	12. REPORT DATE Nov 1975		
14. MONITORING AGENCY NAME/ADDRESS (IF DIFFERENT FROM CONT. OFF.) Eustis Directorate U. S. Army Air Mobility R&D Laboratory Fort Eustis, Virginia 23604	13. NUMBER OF PAGES 127		
16. DISTRIBUTION STATEMENT (OF THIS REPORT) Approved for public release; distribution unlimited.		15. SECURITY CLASSIFICATION (OF THIS REPORT) UNCLASSIFIED	
17. DISTRIBUTION STATEMENT (OF THE ABSTRACT ENTERED IN BLOCK 20, IF DIFFERENT FROM REPORT)		15a. DECLASSIFICATION DOWNGRADING SCHEDULE	
18. SUPPLEMENTARY NOTES			
19. KEY WORDS (CONTINUE ON REVERSE SIDE IF NECESSARY AND IDENTIFY BY BLOCK NUMBER) Hydrofluidics Production Process Electroforming Conductive Wax			
20. ABSTRACT (CONTINUE ON REVERSE SIDE IF NECESSARY AND IDENTIFY BY BLOCK NUMBER) This is a three-phase program to determine and demonstrate the production suitability of the Electroform Conductive Wax process in conjunction with conventional production processes for the manufacture of fluidic systems. During this phase, Phase I, an integrated amplifier-manifold hydrofluidic stability augmentation system using the Electroform Conductive Wax process was successfully designed, fabricated, and qualification tested, and a pilot production line using the Electroform Conductive Wax process was defined. The pilot production line includes all manufacturing, inspection,			

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and assembly equipment necessary to produce the integrated amplifier-manifold hydrofluidic stability augmentation systems. During Phase II, the pilot production line will be set up and checked out by fabrication and test of these systems. The fabrication and test data is to be analyzed and process modifications are to be accomplished as necessary. During Phase III, a small "proof" production run is to be accomplished, component quality determined, and a Technical Data Package prepared.



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PREFACE

This document is the final report on the first phase of a three-phase program conducted under Army Contract DAAJ02-74-C-0012. The program was administered under the direction of the Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, with Mr. G.W. Fosdick as the project engineer. The work was conducted during the period 5 November 1973 through 31 January 1975.

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SECTION I

INTRODUCTION

Most conventional production techniques are not readily adaptable to the manufacture of fluidic devices with small passageways, intricate configurations, close-tolerance requirements, and the need for sealed circuits. Consequently, the Electroform Conductive Wax (ECW) process was developed. Through various developmental programs, the ECW process has demonstrated the potential to accurately fabricate leakproof fluidic components. The object of this program is to determine the production suitability of the ECW process in conjunction with existing conventional processes for the manufacture of fluidic systems. This is a 30-month program divided into three phases. Phase I is the subject of this report and consists of the following major tasks:

- Design and develop an integrated amplifier-manifold circuit for use in the hydrofluidic yaw axis stability augmentation system (SAS) developed under Contract DAAJ02-72-C-0051 with the Eustis Directorate, USAAMRDL, Fort Eustis, Virginia.
- Perform qualification tests on the SAS system with the integrated amplifier-manifold circuit.
- Design a pilot production line for the fabrication of fluidic components using the ECW process and for the functional testing of the components.

In the remaining two phases of the program, ECW-processed fluidic components will be fabricated and tested, the results will be statistically analyzed, and a technical data package defining the SAS system and ECW process will be compiled.

SECTION II

SYSTEM DESIGN

CIRCUIT DESIGN

The circuit developed under this contract is functionally identical to that developed under Contract DAAJ02-73-C-0046, Hydrofluidic Yaw Stability Augmentation System Operational Suitability Demonstration. A schematic of the integrated circuit is shown in Figure 1. Amplifiers A1 and A3 have a high input impedance and are defined in Figure 2. A high input impedance results from the use of narrow control ports, which have an area only 40 percent as large as that on all other amplifiers in this circuit. Amplifiers A2 and A5 are the standard amplifier configurations, defined in Figure 2 as 10050019-101. This standard configuration has a setback in the region where the control flow impinges on the power flow. Amplifier A4, shown in Figure 2 as 10050019-103, is identical to the standard amplifier except that the setback has been eliminated. Amplifier configurations and their location in the circuit are the same for both the previous operational suitability program and the present producibility program. The only significant circuit difference in these two programs is that the in-line feedback resistors are replaced with resistance bridge networks to eliminate the need for extremely small orifices.

FEEDBACK RESISTOR DESIGN

The configuration of the feedback bridge resistor networks, defined in Figure 3, is electroformed on a baseplate as shown in Figure 4. Each bridge resistor assembly has three legs defined by A, B, and C of Figure 5.

Elimination of small contamination sensitive orifices was the primary objective of this design. Resistor elements are 0.015 inch by 0.015 inch, and as many as five are used in series to make each resistor leg. The unusual geometry on each side of the square restrictor holes is designed to dissipate the velocity head of the flow leaving the restrictor. Figure 5 is an example of a pair of bridge resistors used to provide negative feedback.

Resistance of a sharp-edged orifice has been calculated to be

$$R_s = \frac{\sqrt{\Delta P}}{51.6 A} \quad (1)$$

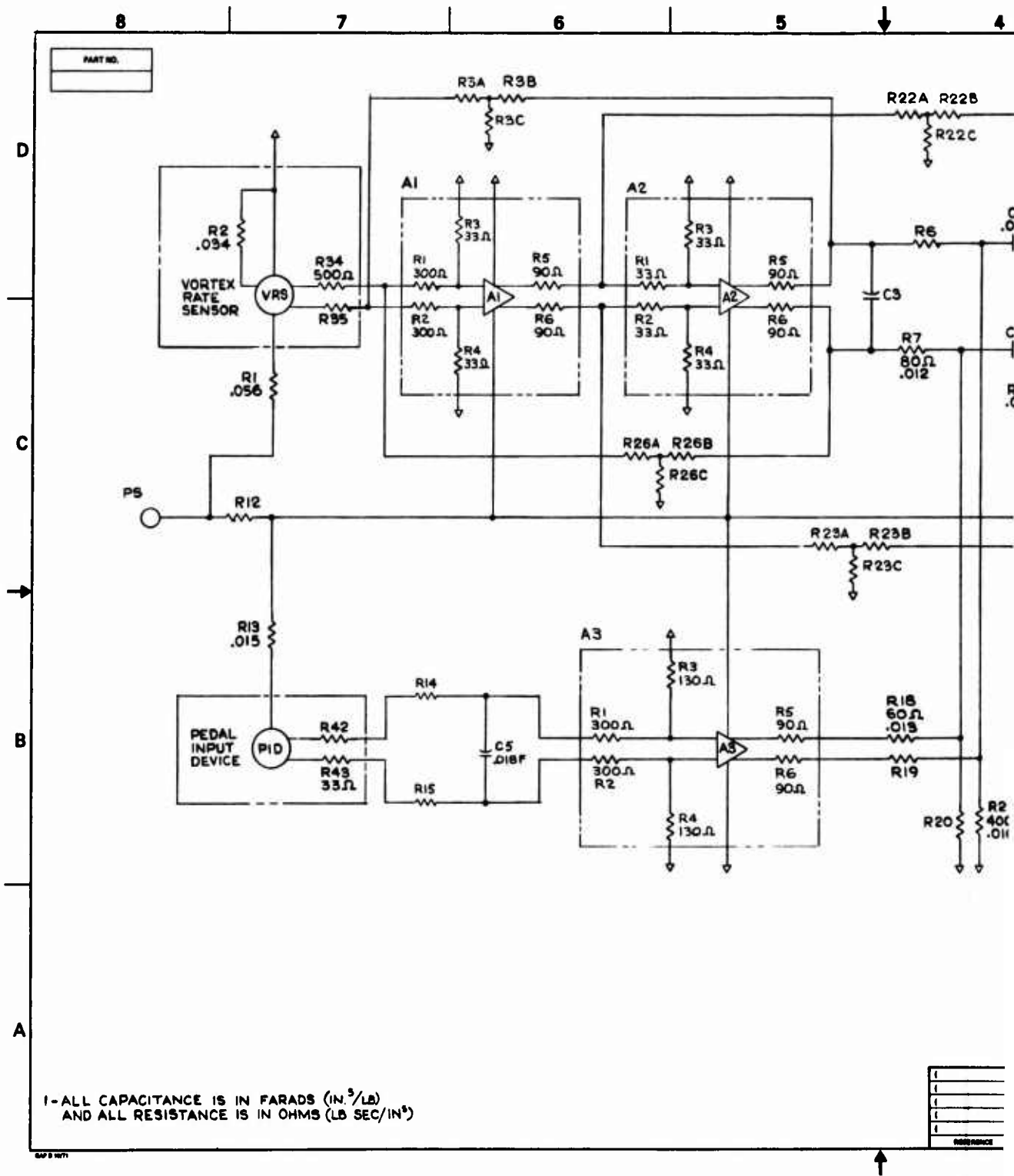
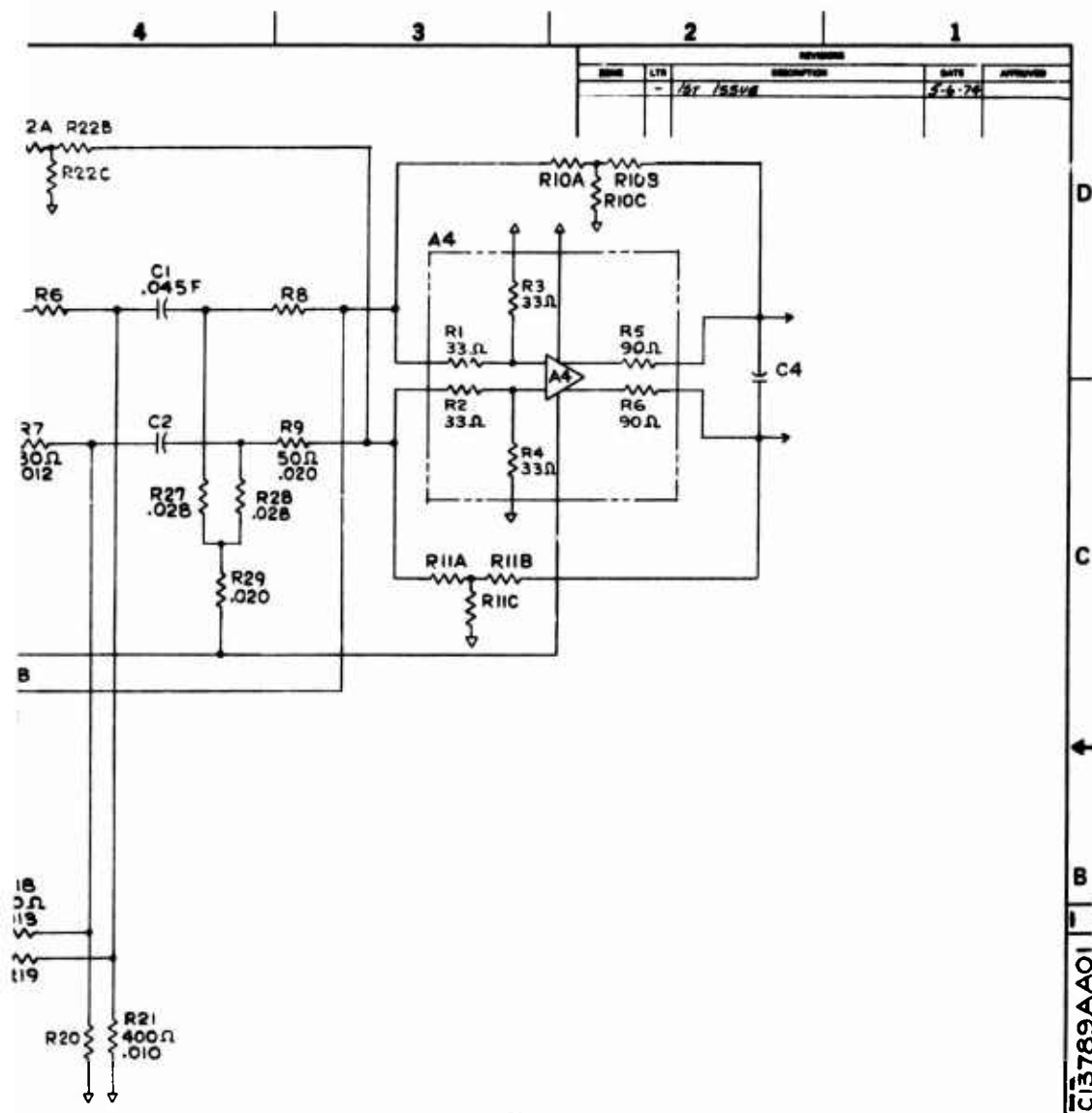


Figure 1. Schematic Diagram of the Yaw Axis Hydrofluidic SAS.



QTY REQD	PART ON IDENTIFY VALUE NO.		HORIZONTAL LINE ON DESCRIPTION		REMARKS		TIME REQD
TOLERANCES UNLESS NOTED OTHERWISE			DRAWERMAN HONEYWELL	DATE 1/28/74	GOVERNMENT AND AERONAUTICAL PRODUCTS DIVISION 2800 FURNACE PARKWAY MINNEAPOLIS, MINNESOTA 55415		
.X 1 .XX 1 .XXX 1			90° FORMED ANGLES 90° 1°		YAW AXIS- HYDROFLUIDIC SAS SCHEMATIC DIAGRAM OF		
MATERIAL			CONTRACT NO. DAAJ02-73-C-0046		SIZE CODE IDENT NO DRAWING NO. D 04580 C13789AA01		
FURNISH-SEE NOTE			SCALE		INSET		



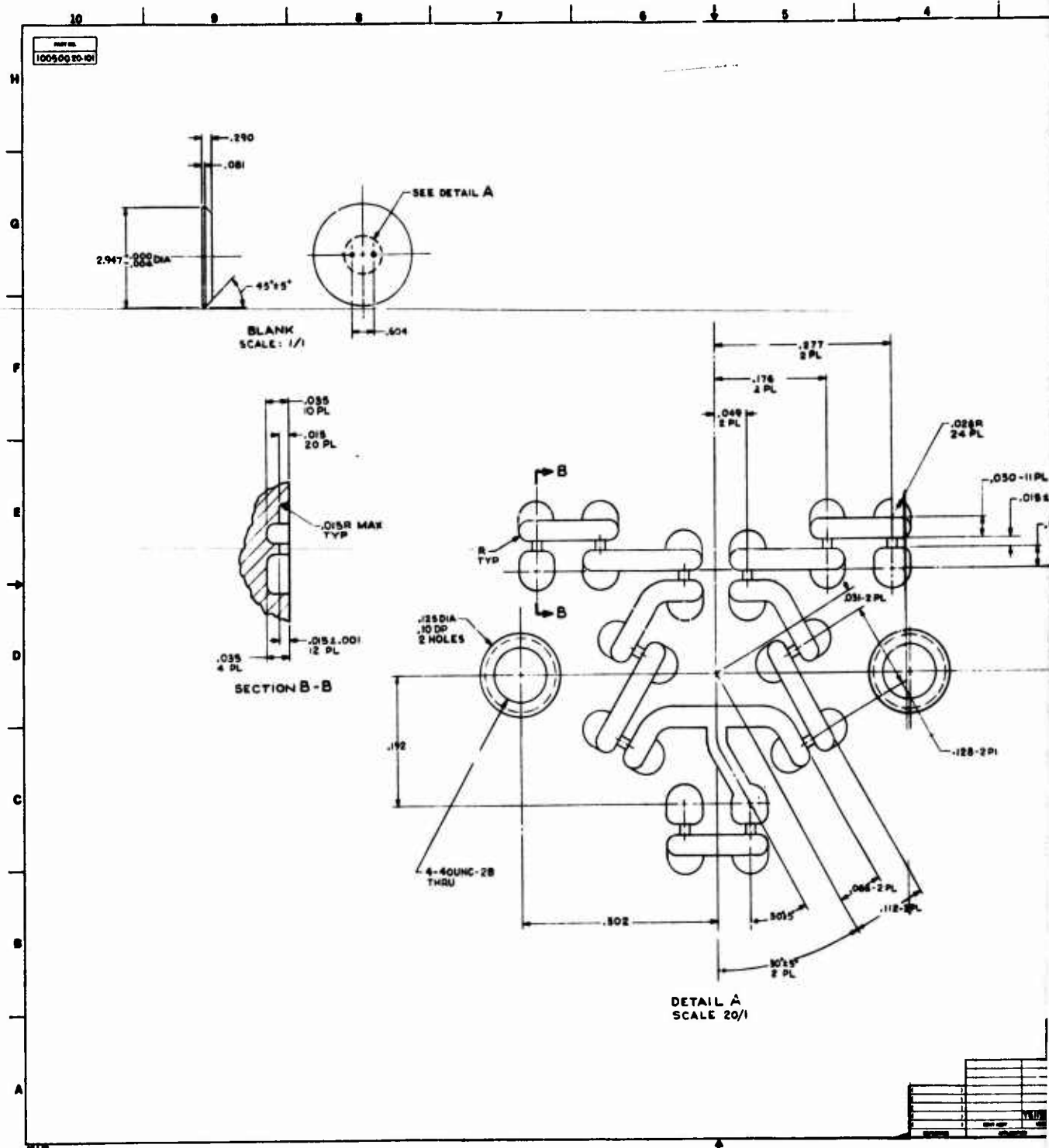
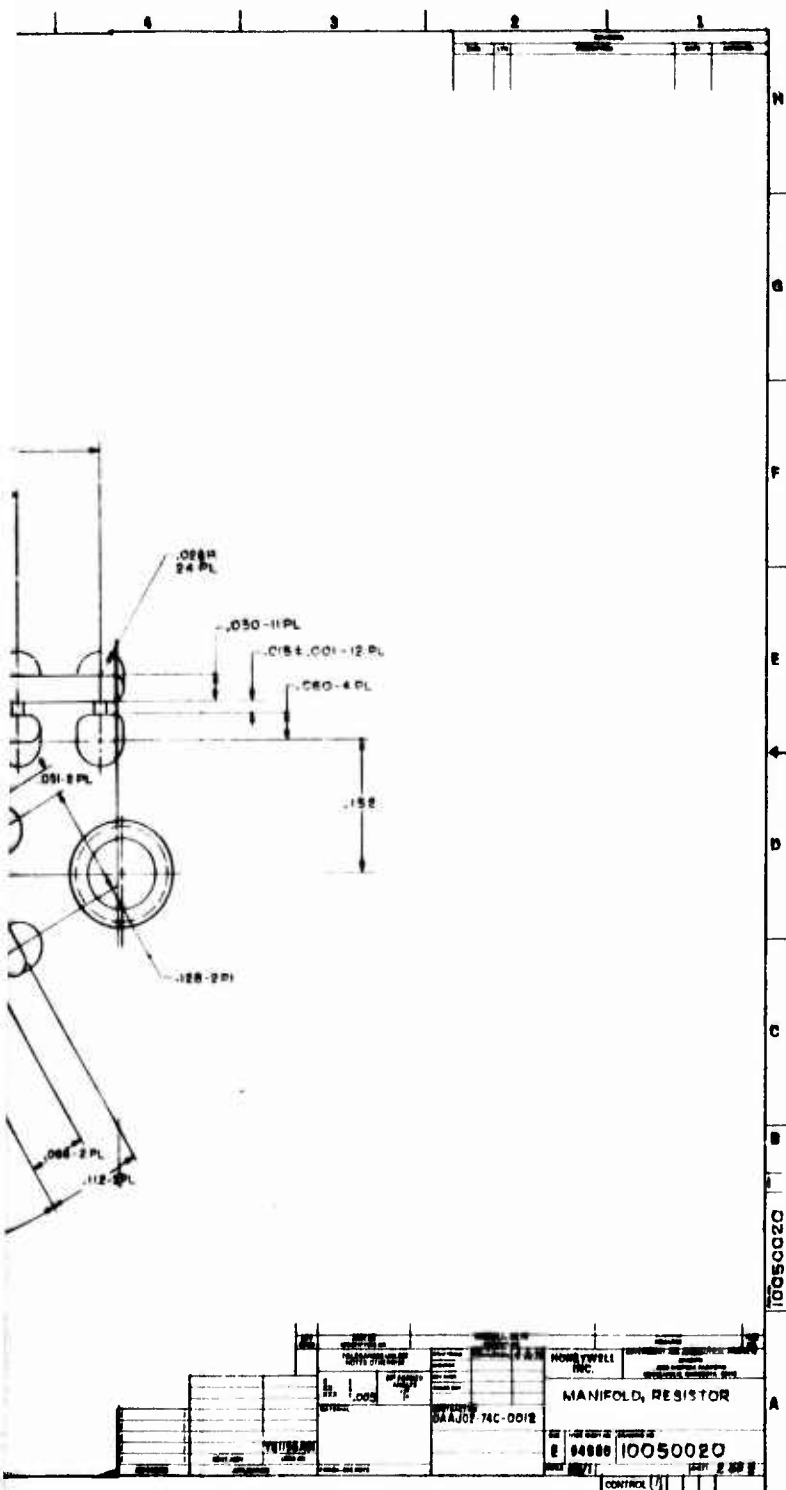


Figure 3. Manifold Resistor.

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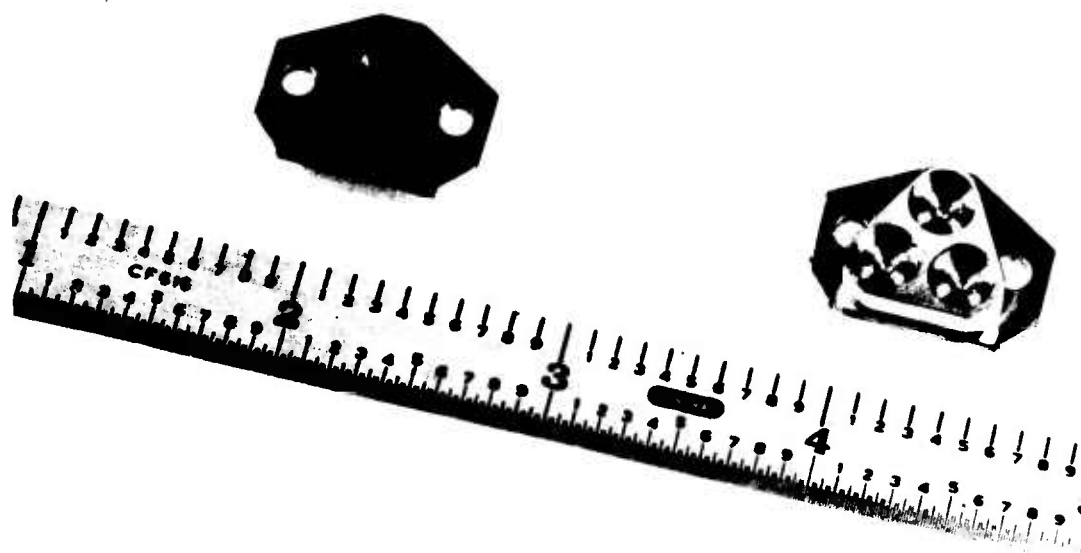


Figure 4. Both Sides of the Resistor Baseplate.

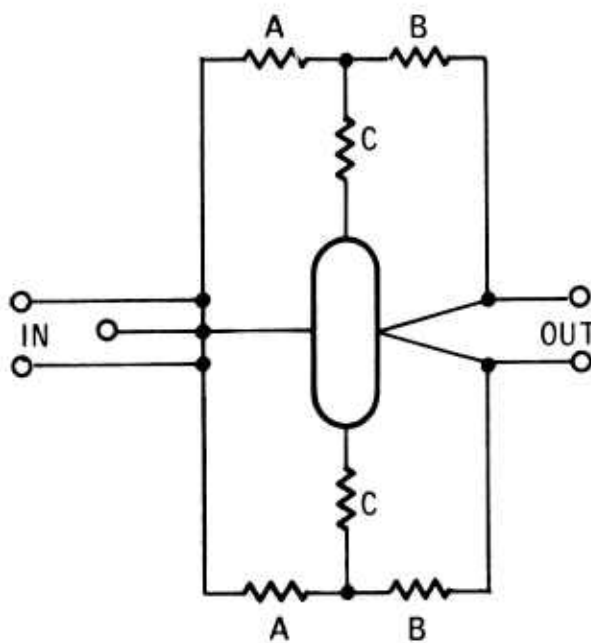


Figure 5. Use of Bridge Resistors as Amplifier Feedback.

where ΔP = pressure drop, lb/in.²

A = area, in.²

R = resistance $\frac{\text{lb-sec}}{\text{in.}^5}$

Resistance of a viscosity-sensitive resistor for rectangular channels is

$$R_v = K\nu \quad (2)$$

where

$$K = \frac{1.325 \times 10^{-6} L}{C^3 W \left(\frac{W}{C+W} \right)^2} \quad (3)$$

L = channel length, in.

C = channel height, in.

W = channel width, in.

ν = fluid viscosity, centistokes

Total resistance is the sum of these two effects and is dependent upon both the pressure drop across the resistor and the fluid viscosity. The following calculations define the resistance of one leg of the bridge when the fluid temperature is 120°F ($\nu = 10\text{cs}$) and the pressure drop across the leg is 1.0 psid. The leg is made up of five resistors, which are 0.015 inch wide, 0.015 inch high, and 0.015 inch long. Resistance of each element is therefore

$$R_s = \sqrt{\Delta P / 51.6 A} = \sqrt{0.2 / 51.6 (0.015)^2} = 38.52\Omega \quad (4)$$

$$R_v = \nu \frac{1.325 \times 10^{-6} L}{C^3 W \left(\frac{W}{C+W} \right)^2} = \frac{10 \times 1.325 \times 10^{-6} \times 0.015}{(0.015)^3 (0.015) \left(\frac{0.015}{0.015 + 0.015} \right)^2} = 15.7\Omega \quad (5)$$

Total resistance for five elements in series is

$$R_t = 5(38.52 + 15.7) = 271.1\Omega \quad (6)$$

54.22 Ω /element

In some cases, R_s is calculated using flow (Q) rather than pressure drop. This equation is

$$R_s = Q / 5325 A^2$$

where A = orifice area, in.²

Q = flow, cis

This second equation for R_s was derived from the definition of point resistance for a sharp-edged orifice, which is

$$R_s = 2\Delta P/Q \quad (8)$$

A mold was fabricated in accordance with Figure 3 with legs A and B having five resistor elements. Leg C used only two elements in series. Five electroformed resistors were tested, and results are presented in Table 1.

TABLE 1. PRESSURE DROP OF RESISTOR LEGS AT $Q = 0.021$ CIS AND TEMPERATURE = 120°F			
Resistor	$\Delta P/Q$ Leg A	$\Delta P/Q$ Leg B	$\Delta P/Q$ Leg C
344	262	255	104
345	261	260	107
346	262	259	105
348	266	258	105
349	259	257	105
Average	262.0	257.8	105.2
Average Resistance per Element	52.4	51.6	52.6

Figure 6 is a schematic of the test setup. Pressure transducers measure the drop across legs B and C when the flow through A is zero. These connections were changed to measure the drop across A and B with no flow in leg C during other tests. Flow was determined by measuring the time required to fill a 100-ml graduate. This is an accurate method for measuring flow in the low-flow range of 0.01 cis. Overall instrumentation accuracy may only be 2- to 3-percent of point.

The data of Table 1 show that the restrictors are consistent to within ± 2 percent. This accuracy is better than the projected accuracy of the test equipment; therefore, the true accuracy of the electroformed restrictor fabricated process could be substantially better than ± 2 percent. Data of Tables 2 and 3 summarize pressure drop information at several different temperatures and flows. These data are the average of several tests.

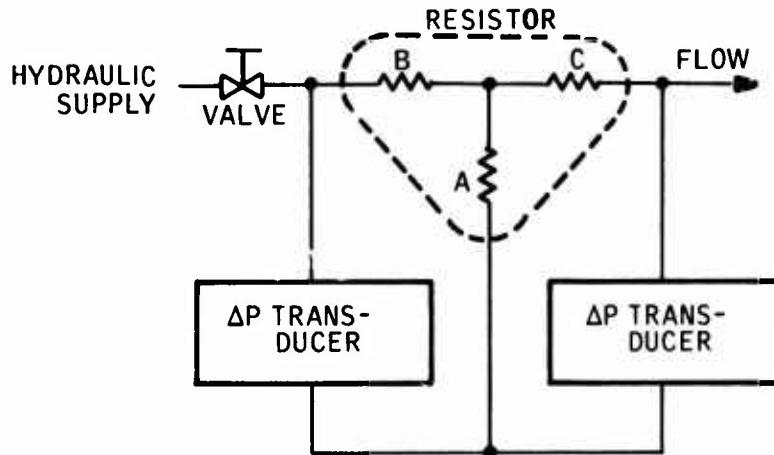


Figure 6. Test Setup for Measuring Flow-Pressure Drop Characteristics of Electroformed Resistors.

TABLE 2. $\Delta P/Q$ AS A FUNCTION OF FLOW FOR TEMPERATURE = 120°F		
Q (cis)	$\Delta P/Q$ (Average A&B)	$\Delta P/Q$ per Element
0.0210	256	51.2
0.0137	193	38.6
0.0065	140	28.0

TABLE 3. $\Delta P/Q$ AS A FUNCTION OF TEMPERATURE AND FLOW				
Temperature	Q (cis)	$\Delta P/Q(B)$	$\Delta P/Q(C)$	$\Delta P/Q$ Element
140	0.0180	220	91	45.0
140	0.0076	129	58	27.4
76	0.1260	249	105	51.0
76	0.0039	180	80	38.0

Performance at 76°F and 120°F is plotted on Figure 7. The curves are extended to show the value of $\Delta P/Q$ that would exist at zero flow where the resistance of a sharp-edged orifice is zero. Resistance is 18.3 Ω at 120°F and 31.8 Ω at 76°F. New 5606 oil has a viscosity of 10 centistokes at 76°F. Resistance of a linear restrictor was previously defined as $R_v = Kv$. K, as determined by test results, is 1.77 at 76°F and 1.83 at 120°F. The calculated value of K was 1.57, representing good correlation with the above test data.

Increase in $\Delta P/Q$ with respect to flow is a result of the sharp-edged orifice component. At 120°F, a flow increase of 0.02 cis increased $\Delta P/Q$ by about 30.2; therefore,

$$R_s = \frac{2\Delta P}{Q} = 60.4\Omega \text{ at } Q = 0.02 \quad (9)$$

$$\text{also } R_s = \frac{Q}{5325A^2} = 3,708 Q \text{ for } 0.015 \times 0.015 = 74\Omega \quad (10)$$

The design value of R_s was 74 Ω as compared to the tested value of 60.4 Ω at this flow condition. Slope of the 76°F line is parallel, indicating the same R_s characteristic.

Performing the calculations and plotting the graphs using the 140°F data emphasizes the fact that a small shift in drawing the slope through the data points can result in a substantial change in calculated constraints. In some cases, a 1-percent error in the measurement of $\Delta P/Q$ for one data point could result in a 5-percent or 10-percent error in the computation of R_s .

Other resistors were fabricated with a different number of elements in each leg to provide flexibility in the development of the integrated circuit.

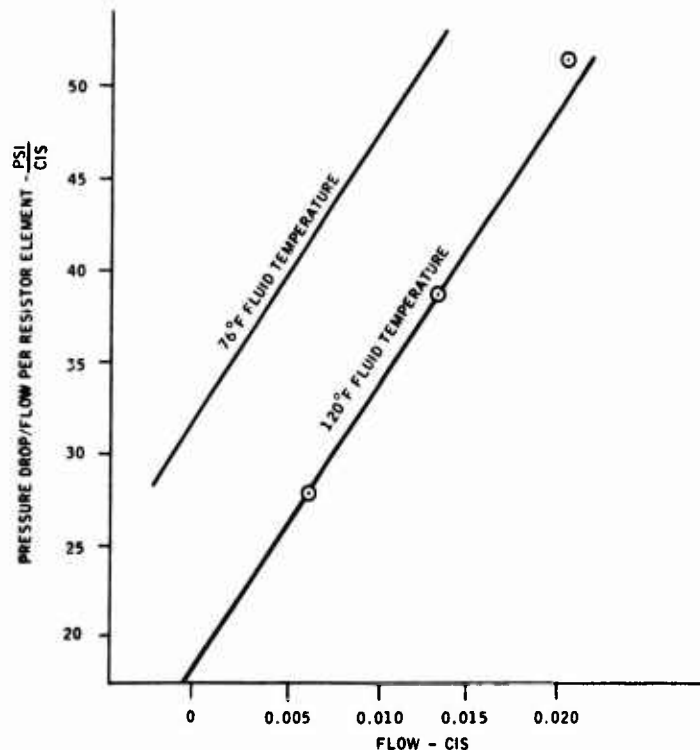


Figure 7. Resistor Pressure Drop/Flow Versus Flow Characteristics.

Nearly all resistor problems were associated with the -4 "O"-ring seals at the bottom of the resistor baseplate. Early in the testing it was discovered that the "O"-ring squeeze was sufficient to completely block the passageway under some conditions. Metal tubing (0.094 inch diameter) was cut into 0.050-inch lengths and was used as backup rings as a temporary fix. A substantial amount of "O"-ring damage resulted from the excessive compression, and contamination was generated from these seals during development testing. Production units will incorporate a permanent fix. The resistor baseplate "O"-ring grooves will be enlarged and -5 "O"-rings will be used.

Only one resistor mold was fabricated during this development phase, but many different resistor configurations were electroformed. This was accomplished after the wax was injected onto the baseplate by manually adding small amounts of wax to the unwanted elements. Using this technique, a leg with five elements could have its resistance accurately reduced in increments of one element. Pairs of resistors were made in six different combinations to provide flexibility for development testing.

Development results on electroformed resistors were excellent. Only a few formulas are required to design a resistor with any linear resistor plus orifice restrictor characteristic. Changes in oil viscosity with use is the largest uncontrolled variable, and it reduces the accuracy of parametric test data on viscosity-sensitive restrictors. Complete systems can tolerate large changes in viscosity, as these effects are largely cancelled by equivalent changes in matching restrictors.

INTEGRATED CIRCUIT (I/C) HARDWARE DESIGN

Control systems fabricated under this producibility program are required to be interchangeable with the YG1143 systems developed under Contract DAAJ02-73-C-0046. The major difference between this YG1158 system and the previous YG1143 system is that the amplifiers and manifolds are electroformed into a single integral unit. By definition, this precludes the use of adjustable resistor blocks mounted between the amplifiers and the manifold. As many of the previous components were retained with the new design as was practical. Rate sensor internal hardware, pilot input device, and flow control were among the components that remain unchanged.

One of the program objectives was to design a single integrated amplifier-manifold circuit to replace the upper and lower manifold assemblies of the previous program. To accomplish this it was necessary to minimize the size of the interconnecting lines. The nominal cross section of the interconnecting lines was selected to be 0.080 inch by 0.080 inch. Using the formulas presented in the resistor design sections of this report, the viscosity-sensitive resistance of these lines is

$$R_y = v 0.13 \Omega/\text{inch} \quad (12)$$

where R_y = resistance, hydraulic ohms.

Equivalent, sharp-edged orifice resistance of these lines is 0.64Ω , when the flow is $0.14 \text{ in.}^3/\text{sec}$. Total resistance for a 2-inch length of channel at a flow of $0.14 \text{ in.}^3/\text{sec}$ and at a temperature of 120°F is about 3.2Ω as compared to 67 ohms for a power nozzle, and 30 to 300 ohms for control ports.

A layout drawing was made to determine the feasibility of compacting all of the required amplifiers and interconnects onto a single plate without exceeding envelope requirements while keeping the lines in the right location to mate with the required rate sensor output, capacitors, etc.

Results of this design effort were converted into the detailed design drawings of Figures 8 and 9. The developmental circuit used separate standoffs to interface between the integrated circuit and the housing. Production units will use electroformed standoffs, simplifying assembly and reducing the number of required "O"-ring seals.

The housing, shown in Figure 10, is almost identical to the YG1143 design except for some hole location changes made to accommodate the integrated circuit configuration.

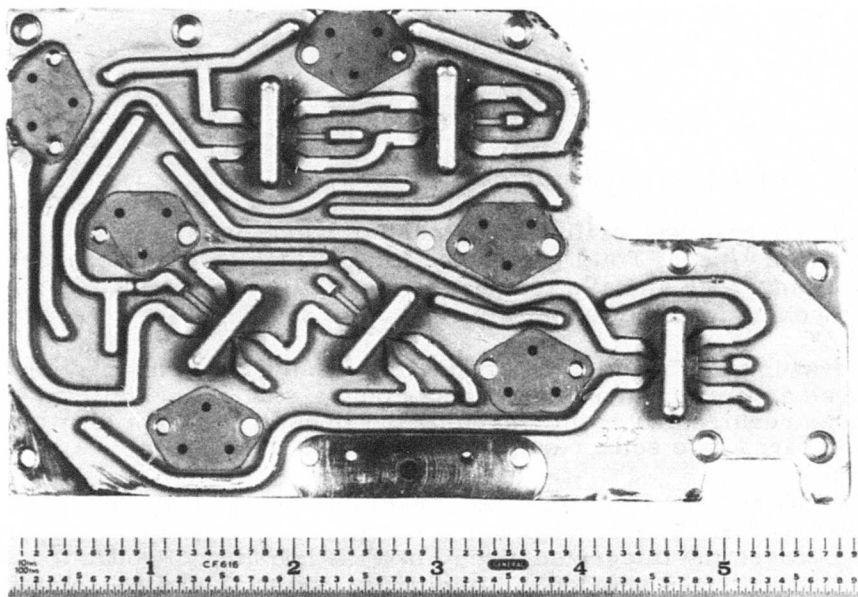


Figure 8. Integrated Circuit - Top View.

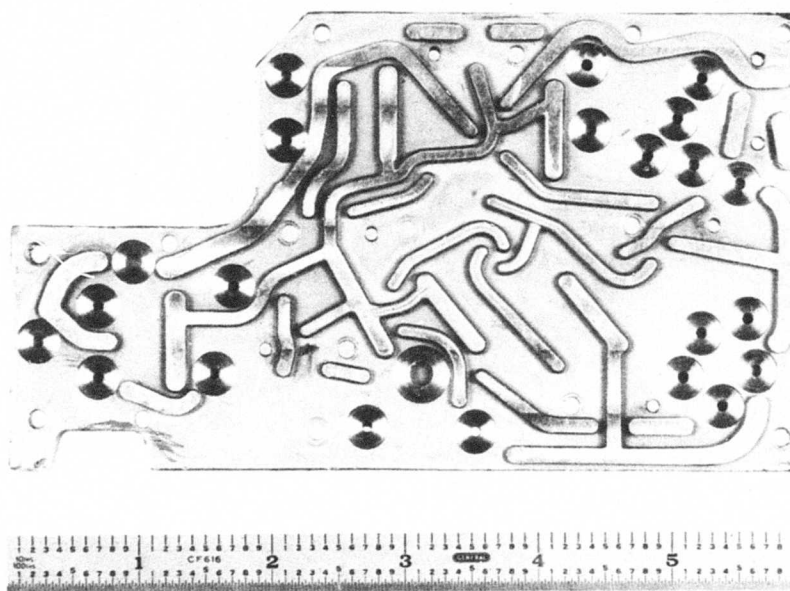


Figure 9. Integrated Circuit - Bottom View.

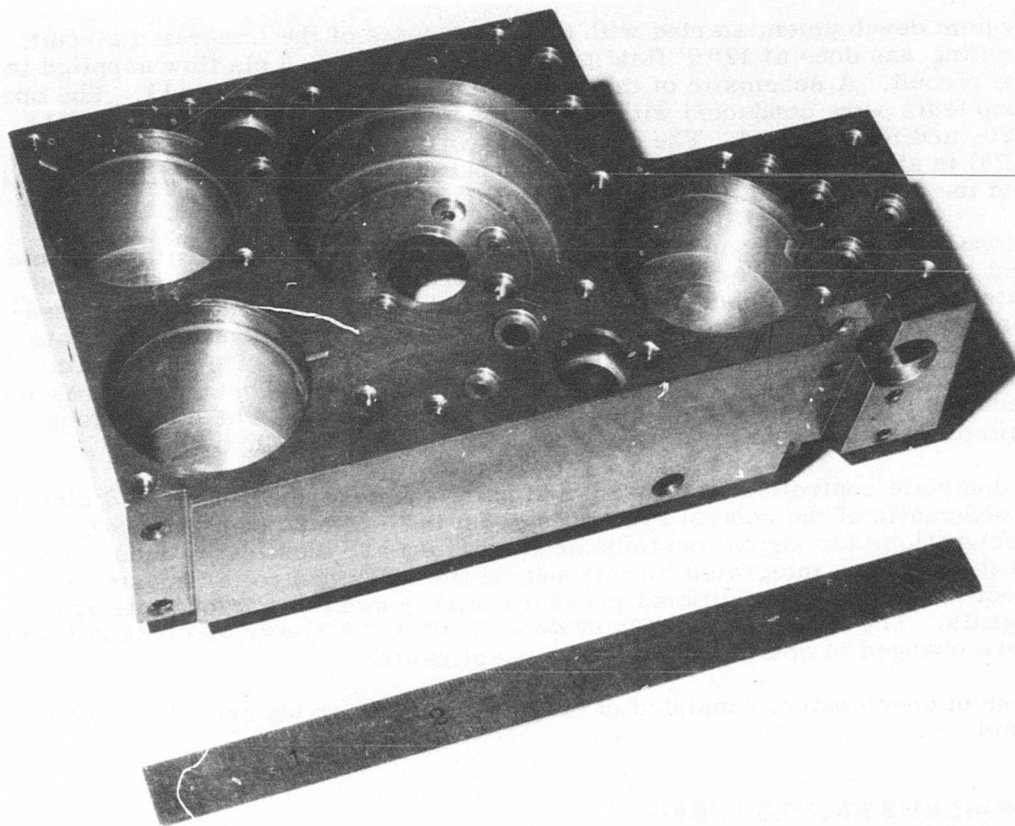


Figure 10. Photo of Housing.

SECTION III

SYSTEM DEVELOPMENT

DEVELOPMENT SEQUENCE

System development started with open-loop tests of the integrated circuit. Testing was done at 120°F fluid temperature with a 0.8 cfs flow supplied to the circuit. A schematic of this test setup is shown in Figure 11. The open-loop tests were conducted with restrictors R3, R26, R22, R23, R10, R11, R20, and R21 blocked. The open-loop gain of the rate sensor circuit (ΔP_2 to ΔP_3) is shown in Figure 12, the pilot input circuit (ΔP_7 to ΔP_3) in Figure 13, and the driver circuit (ΔP_4 to ΔP_6) in Figure 14.

Closed-loop test data on the integrated circuit was obtained with the same test setup, but the previously blocked restrictors were connected and the rate sensor output impedance was simulated. Figure 15 shows the closed-loop gain of the rate sensor circuit (ΔP_1 to ΔP_3) using the simulated rate sensor output impedance. Figure 16 shows the through-rate signal gain (ΔP_1 to ΔP_6) from the rate sensor to the final output. This gain represents about 15 percent of the total high-passed output signal. The closed-loop gain of the pilot input circuit (ΔP_7 to ΔP_3) is shown in Figure 17.

A complete controller was assembled using the described integrated circuit. A schematic of the control system is given in Figure 28 of Appendix C. Designations for signal locations and resistors are identical to those used on the previous integrated circuit schematic. The controller housing was modified to provide additional pressure taps to monitor various internal signals. The sizes of feedback resistors, load resistors, and bias resistors were changed to obtain the desired system gains.

System development consisted of obtaining suitable gains and of solving problems.

PROBLEMS ENCOUNTERED

Feedback Resistor "O"-Rings -- Problems of signal blockage and of generation of contamination associated with the use of -.004 size "O"-rings were discussed in the feedback restrictor design section of this report. Use of larger -.005 "O"-rings is expected to eliminate these problems.

Standoffs -- Developmental hardware used two "O"-rings and a replaceable mechanical standoff for each fluid connection between the integrated circuit and the housing assembly. This configuration was difficult to assemble. At times, the mechanical standoffs would cock, preventing a good seal and,

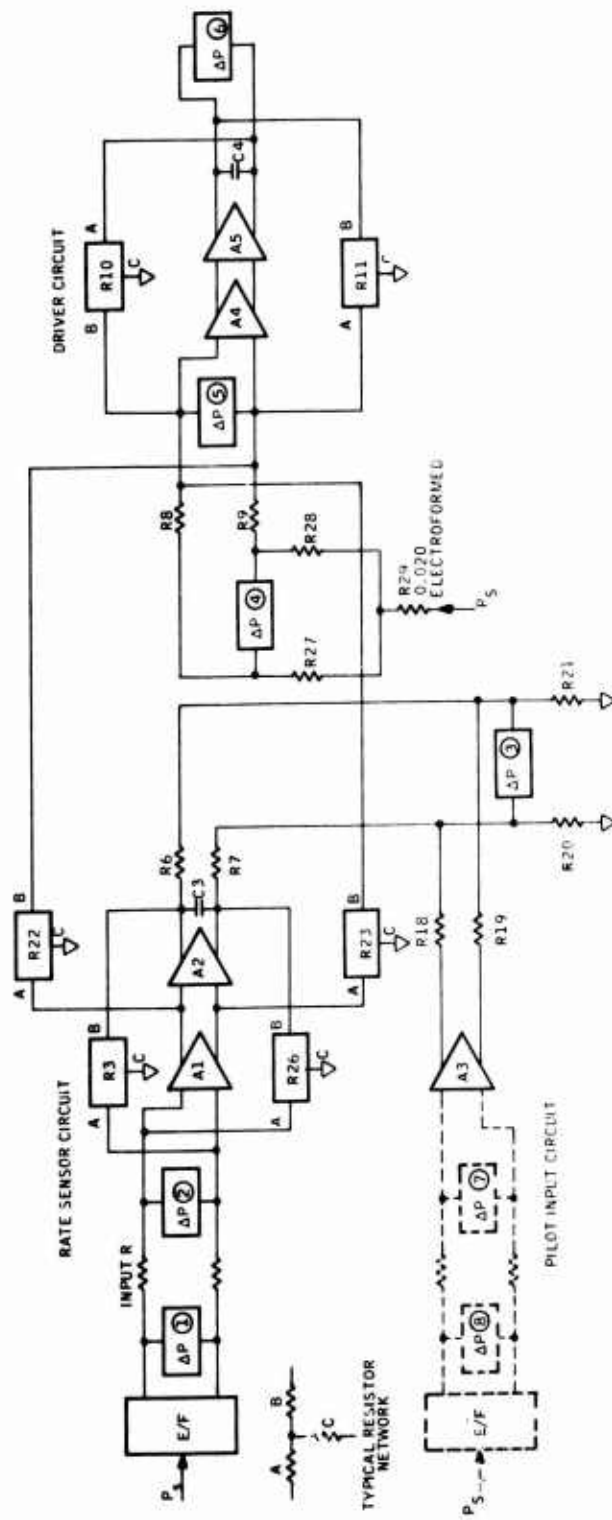


Figure 11. Integrated Amplifier Circuit Test Setup.

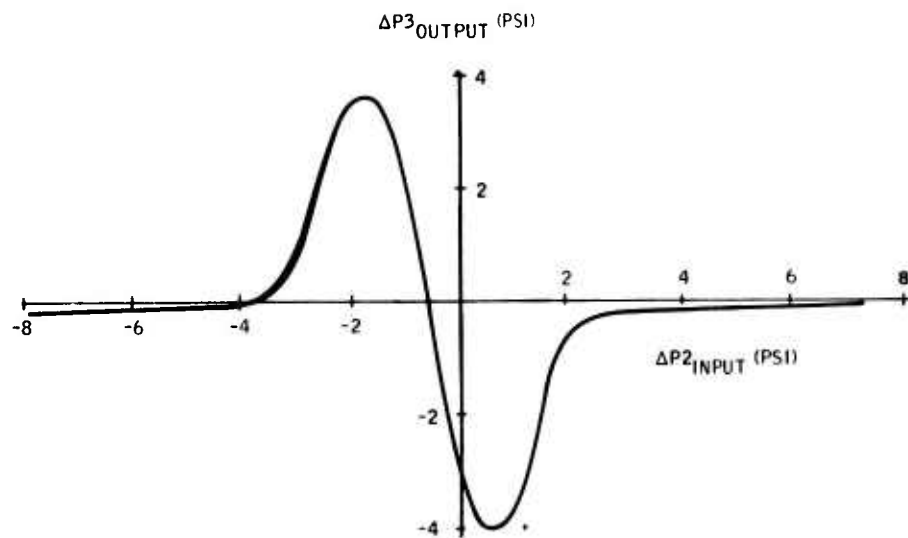


Figure 12. Rate Sensor Circuit Open Loop-Gain.

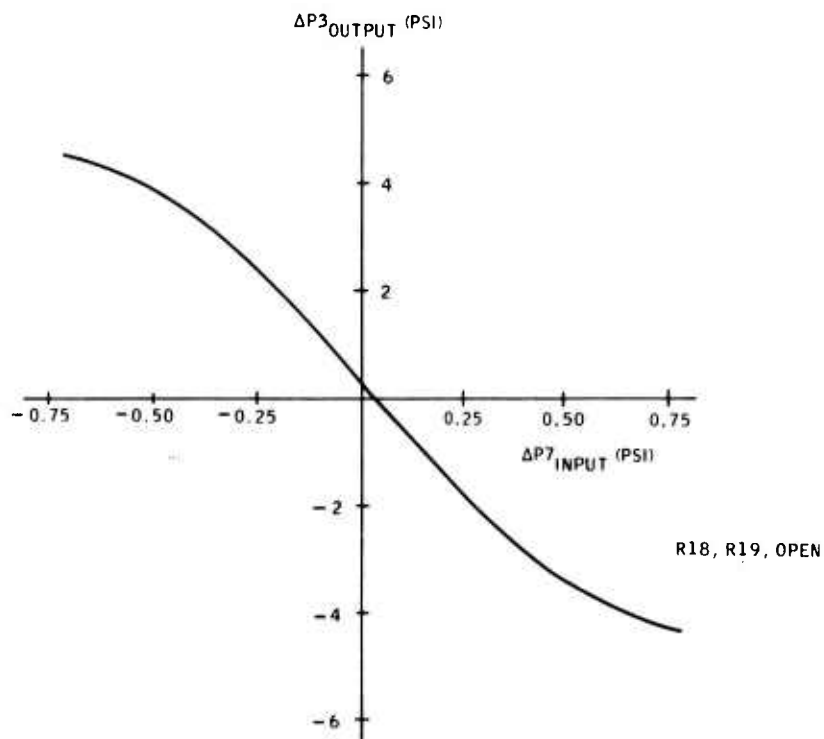


Figure 13. Pedal Input Circuit Open-Loop Gain.

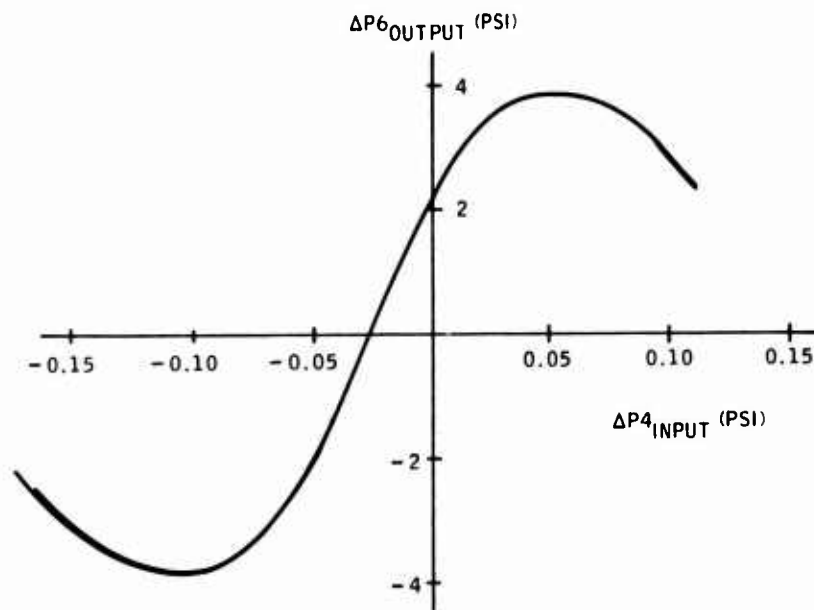


Figure 14. Driver Circuit Open-Loop Gain.

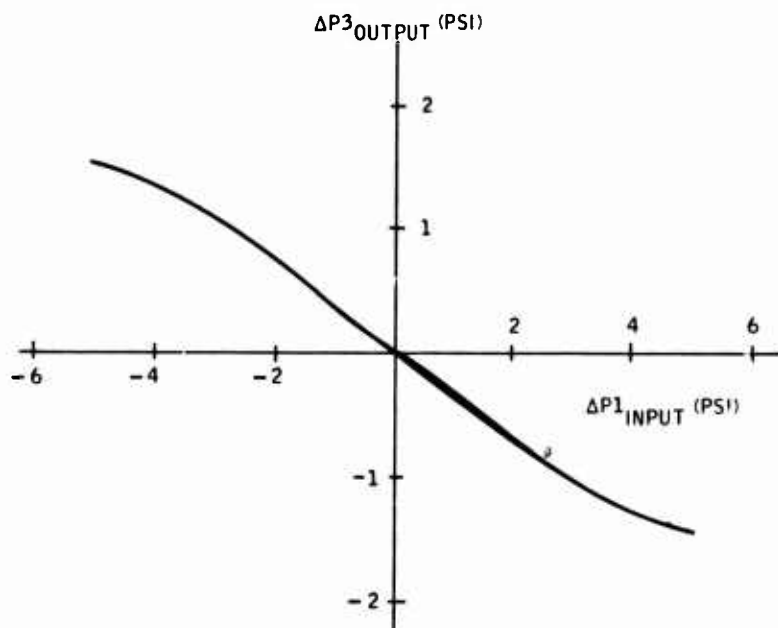


Figure 15. Rate Sensor Circuit Closed-Loop Gain.

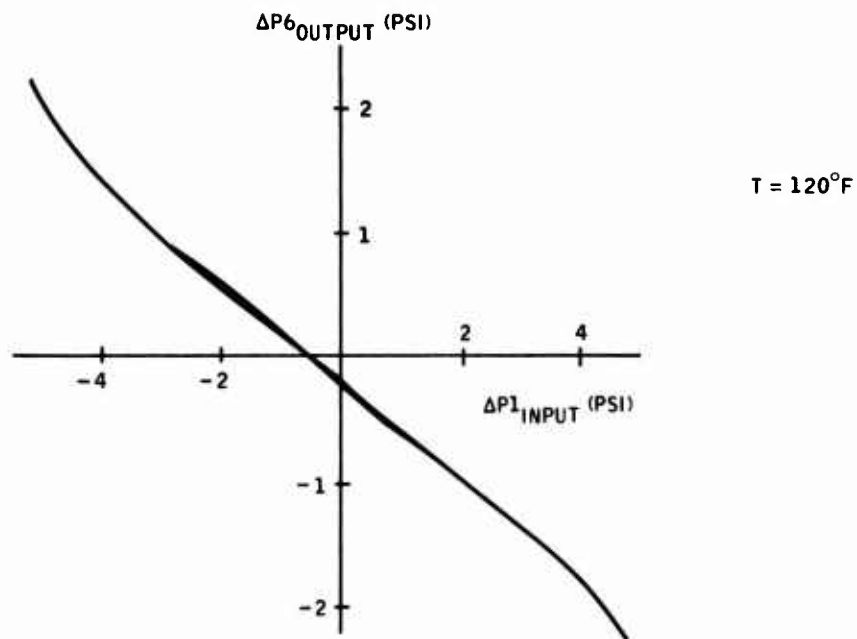


Figure 16. Rate Sensor Through-Rate Gain.

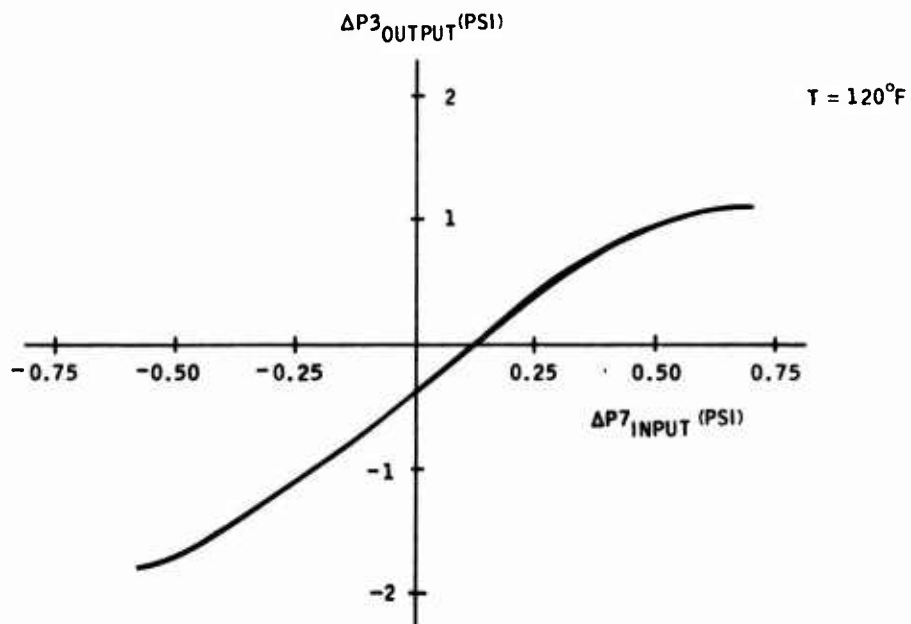


Figure 17. Pedal Input Circuit Closed-Loop Gain.

therefore, would require reassembly. Production units will use integral electroformed standoffs which require only one "O" - ring and which will eliminate the misalignment problem. Present experience with electroformed standoffs on other programs indicates that they do not affect system performance.

Rate Sensor Pickoff -- Rate sensor null offset of 30 degrees per second or more was a significant problem. A restriction or bias can be introduced to compensate this offset at one temperature; however, the offset usually changes as a function of fluid temperature, and matching the compensation over the operating temperature range is difficult. Reducing rate sensor null offset also reduces the amount of null shift with temperature. A rate sensor pickoff was fabricated with four pickoff ports, and it demonstrated substantially better performance than the previous two-port configuration. The improvement seems to be a result of shorting out any pressure difference existing across the rate sensor sink due to misalignment. Also, the output impedance of the pickoff is substantially reduced.

Pilot Input Device -- The pilot input device (PID) consists of a sleeve, spool, and associated linkage. Installation of the sleeve into the controller housing was designed to be accomplished by a press fit. Leakage was a major problem with this configuration; and a press fit and a shrink fit did not give a leak-tight configuration even when the sleeve was lightly plated to increase the interference. This problem was solved by incorporating radial grooves around the outside of the sleeve at each end and by using epoxy to provide an oil-tight seal.

During qualification tests, the PID output experienced a large null shift, which was found to be caused by a mechanical slippage. The fork and operating shaft were pinned together to prevent reoccurrence of this problem. Appendix C, Development and Evaluation Lab Engineering Test Report. Paragraph 4.3 explains the problem in more detail.

Removal of Wax from Electroformed Circuits -- Removal of conductive wax from electroformed components had been a problem in previous programs. In this producibility program, hot solvent (above the melting point of the wax) was pumped through the circuit and/or components. There were no indications of residual wax in any components during the development program.

Nonlinear Bellows -- Specifications for fluidic capacitors require that they be linear within ± 20 percent over a range of ± 2 psid. Bellows procured to this requirement were found to have the characteristics shown in Figure 18. These bellows do have a linear range, but it is necessary to bias the fluidic circuit to ensure that the bellows operate in compression by an amount equal to 2 psid. This compromise did make development more difficult. Electroformed linear (about centers) bellows have been ordered for later phases of this program.

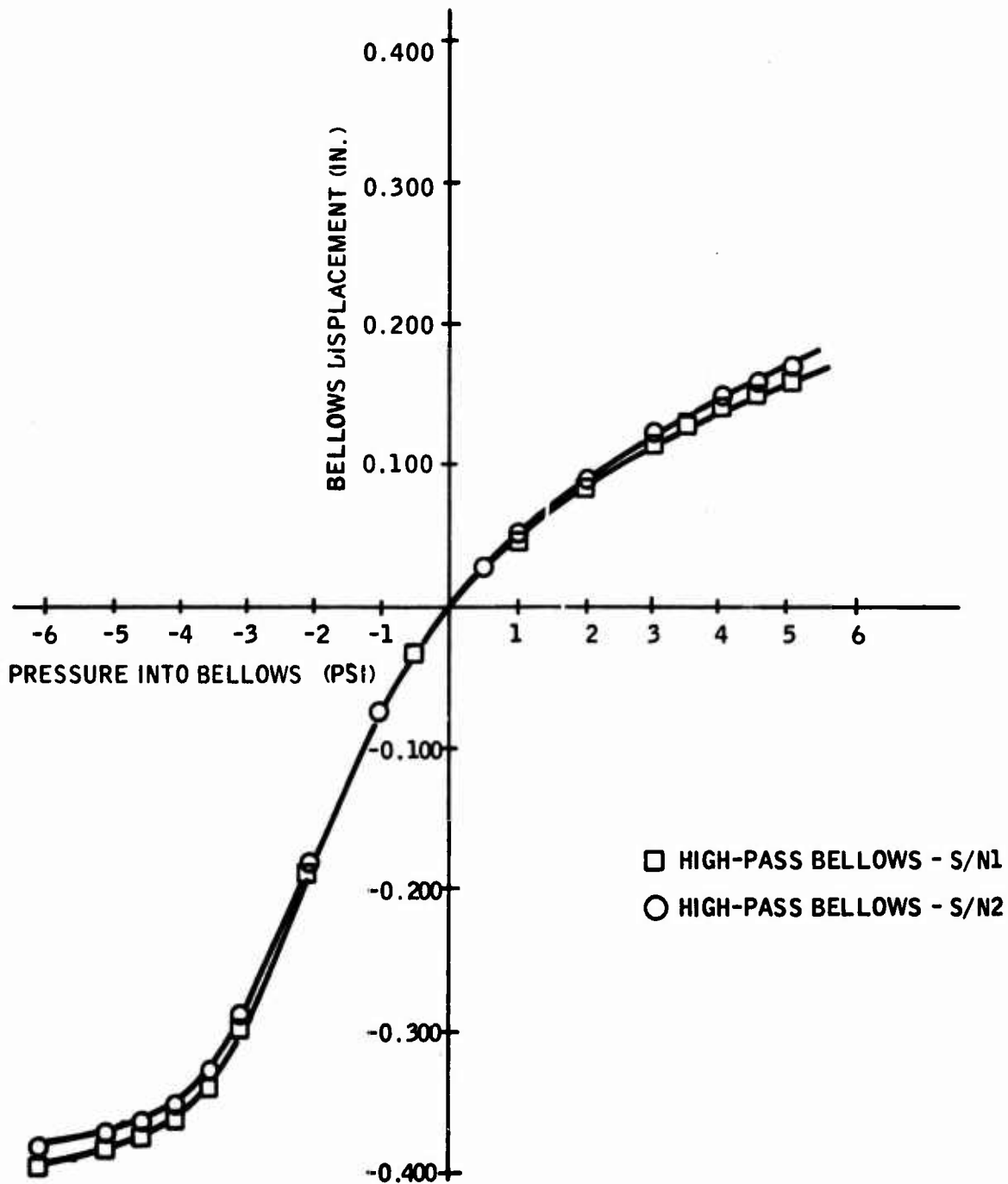


Figure 18. High-Pass Bellows - Pressure Versus Displacement.

Electroformed Manifold Design Problems -- Two views of the integrated circuit are shown in Figures 19 and 20. Amplifiers shown on the top view are the rate sensor cascade (two amplifiers), the output driver cascade (two amplifiers), and the PID amplifier. Bridge-type resistors use return pressure as a ground reference, and pressure drops in the return manifold result in a slightly different pressure between the two reference ports for the rate sensor cascade feedback resistors. If space permitted, the ideal configuration would be for these two ports to be joined together before they connect to the return manifold. A null offset of about 0.5 psid in the output of the rate sensor cascade resulted from this differential. This offset is almost within acceptable limits; however, mismatched feedback resistors were needed to eliminate most of this effect. Present plans call for elimination of feedback on the rate sensor cascade in later phases of this program, and therefore this problem will not exist.

Summing -- Signals are summed together in several locations on the integrated circuit. Resistance of a sharp-edged orifice is directly proportional to the differential pressure across it, and at zero ΔP , it has zero resistance; therefore, characteristics of summing junctions vary substantially when the input signal levels change. The most difficult area is the summing junction between the rate sensor cascade and the PID amplifier. For example, when PID is displaced to its extreme, the pressure downstream of R7 (Figure 1) increases by 0.5 psi and the pressure downstream of R6 (Figure 1) decreases by 0.5 psi. During development testing, the pressure drop across R7 (Figure 1) decreased to zero under these conditions, causing a substantial change in the rate loop gain characteristics. Increasing the physical size of R20 and R21 (Figure 1) reduces the pressure downstream of all summing resistors and minimizes the change in resistance with signal level. This solution can be implemented more easily with linear capacitors, as it is not necessary to maintain a bias upstream to maintain linear capacitance. Changes in these bias levels can also increase or decrease the input impedance to the high-pass capacitors, thereby changing high-pass time constant.

Range -- It is important to maintain sufficient range in all areas of the circuit under normal operation. Under high-temperature conditions, the amplifier ranges decrease; therefore, obtaining a full ± 2 -psid range at the output of the driver cascade is difficult. Supply pressure can be increased, but this also increases system noise. Because most of the system noise comes from preamplifier stages, it is desirable to operate the preamplifier stages at a low pressure for minimum noise and the output amplifier at high pressure for increased range. The present circuit configuration is not capable of operating in this manner, but the circuit will be modified in production units to provide a higher supply for the output stage.

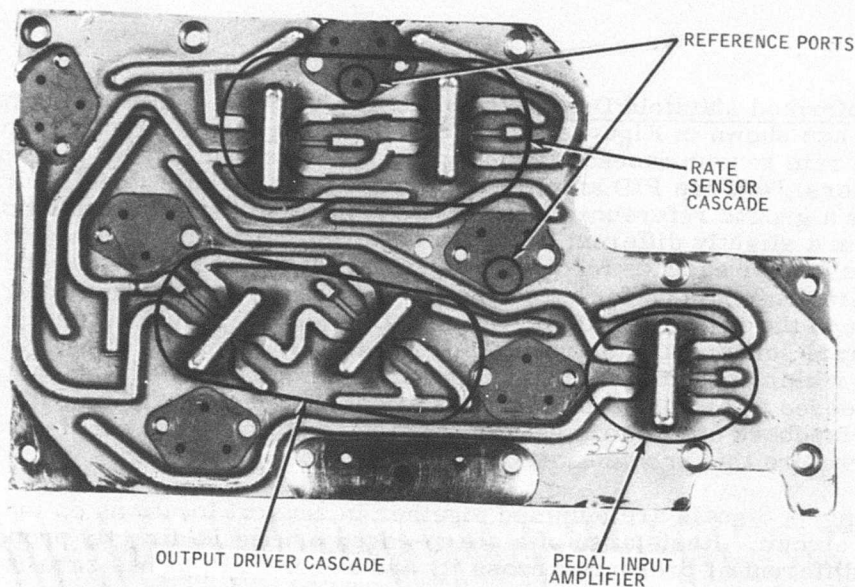


Figure 19. Integrated Circuit - Top View.

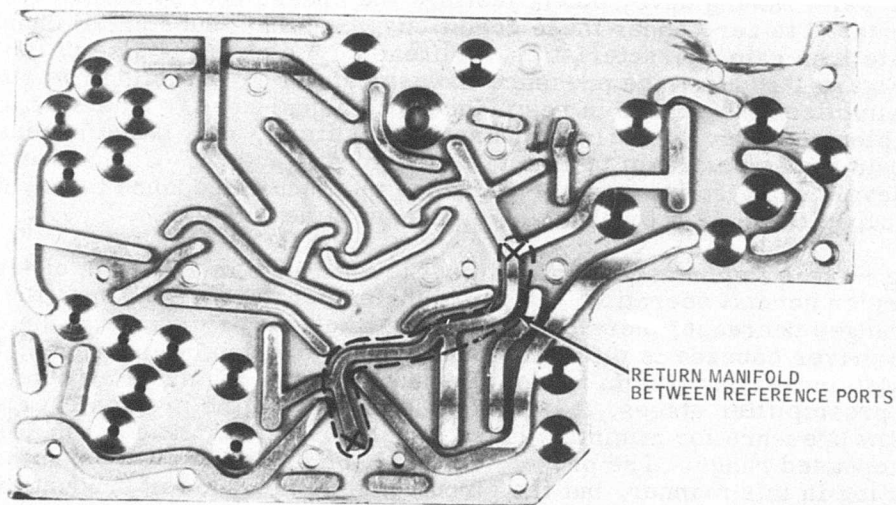


Figure 20. Integrated Circuit - Bottom View.

Noise -- Noise is the biggest problem associated with the design of fluidic flight control systems. Many of the rate sensor and amplifier design changes are directed to reduce system noise. Noise can also be reduced by improved manifolding techniques and by operating amplifiers at a lower supply pressure. Some of these changes introduce new problems of reduced range or of gain changes as a function of fluid temperature. A discussion of modifications introduced in this program to reduce system noise follows.

A four-port pickoff provides a higher-loaded scale factor requiring less pre-amplification, thereby reducing noise. Four ports in place of two also provides some cancellation of pickoff-generated noise. Use of a four-port pickoff did not result in a substantial noise improvement during the development phase, however, because of other noise generation.

High-frequency noise in excess of 100 Hz cannot be detected by the X-Y plotters used in development testing. A brief investigation was conducted using an oscilloscope to isolate the causes of this noise. It is suspected that the lag capacitors are in a configuration that does not properly attenuate this high-frequency noise. Much of it appears to be associated with the rate sensor cascade and its feedback. Eliminating the preamplifier feedback would substantially reduce this noise. The servoactuator will not respond to the high-frequency noise, but it does have other detrimental effects: it can induce subharmonics, drive later stages into saturation, and induce turbulent flow into the final stages.

Output manifold noise can reflect throughout the system. In the original system configuration, the rate sensor return flow passed through the integrated circuit manifold (return channel), generating an intolerable level of system noise. The rate sensor return port was moved to the bottom rate sensor cover (separate from integrated circuit return), eliminating this source of noise.

Power-supply orifices have generated noise in previous systems. A screen was placed downstream of the power-supply restrictor to the integrated circuit (Figure C-1 of Appendix C) to reduce system noise, but it also reduced amplifier supply pressure. When the supply pressure was increased, the noise returned to its original level. Test results indicate that noise generated from the power supply restrictor in the manifold is insignificant, but small orifices located close to an amplifier power inlet generate excessive noise.

Gain change as a function of temperature was found to be greater than desired for a typical stability augmentation application. This characteristic can be improved by optimizing the relative supply pressure to each stage and by reducing the number of amplifiers. The developmental integrated circuit did not have provisions for making those changes; however, experience on the operational suitability program (Contract DAA J02-73-C-0046) has demonstrated a satisfactory gain versus temperature characteristic.

Changes in the production phases of this program are expected to demonstrate an equivalent improvement.

Based on the discussed developmental problems, the following changes will be made:

- Use a four-port rate sensor pickoff
- Eliminate the feedback on the rate sensor cascade
- Use linear (over center) high-pass bellows
- Operate preamplifier stages at a lower pressure
- Pin the PID linkage fork to its shaft
- Place the system return on the rate sensor bottom cover rather than on the integrated circuit output
- Use electroformed standoffs on the integrated circuit
- Use -005 "O"-rings on electroformed resistors

Implementation of these changes should result in a system with performance superior to that now being flight tested in the Operational Suitability program.

SECTION IV

QUALIFICATION TEST

Qualification tests were conducted in accordance with the Environmental Test Plan given in Appendix A. System performance requirements are defined in detailed specification DS24470-01, given as Appendix B. Honeywell requested and received approval (reference contract modification P00002) to conduct these tests without an actuator, as AMRDL was unable to supply a unit as required in the contract. Consequently, the test results are presented in units of psi/deg/sec instead of inches of servo/deg/sec. To convert the test results into units compatible with the detailed specification, the test results should be multiplied by the servoactuator scale factor of 0.15 inch/psi. The Development and Evaluation Laboratory Test Report describing the qualification test is given as Appendix C. The report is complete; only a few observations will be noted in this section.

It should be noted that the oil viscosity after use at 120°F was equivalent to new oil at 143°F, and viscosity at 180°F was equivalent to new oil at 210°F. Operation over a temperature range from 90°F to 150°F, which is equivalent to a range from 110°F to 180°F with new oil, is compatible with requirements for an OH-58 helicopter. Noise at 150°F (180°F new oil) is slightly high but would be reduced if an actuator were used. Gain and response variations of the rate and PID loop over the range of 46°F to 180°F are shown in Figures C-3 and C-5 of Appendix C. Gain remained relatively constant for amplitudes from $\pm 2^\circ/\text{sec}$ to $\pm 15^\circ/\text{sec}$, indicating good linearity, minimum hysteresis, and very little saturation (reference Table C-1, Appendix C).

SECTION V

PILOT PRODUCTION LINE DESIGN

BACKGROUND

The ECW process has previously been used successfully in a highly controlled laboratory environment for the fabrication of fluidic components for various developmental fluidic programs. One goal of the ECW producibility program is to determine if this process can be used in a production environment operated by production personnel. This objective also includes the requirement that the hardware be tested against written performance requirements on certified test equipment, and that the hardware meet these requirements.

To meet this goal, a pilot production line was designed. This line includes the following major items:

- Equipment needed to inject and plate the required piece parts
- Equipment needed to test the required piece parts

EQUIPMENT NEEDED FOR INJECTION AND PLATING

The process used to produce acceptable fluidic hardware by the ECW process can be broken down into three major areas:

- Wax formulation
- Wax injection
- Nickel plating, cleaning and machining

Wax Formulation -- The formulation of this wax requires the use of standard equipment only; no special-purpose tooling has been ordered.

Wax Injection -- Wax injection is a delicate process. Care must be taken such that when the baseplate and mold are separated, the wax will adhere to the baseplate and not to the mold. This problem, called lifted-wax mandrels, is a function of mold design, baseplate cleanliness, and injection pressure settings. If the wax mandrel lifts slightly, the plating solution will wick under, causing the part to raise up. Because the bottom of the manifold is ground flush for mounting purposes, this raising of the mandrel results in a thin-plated area. The other problem created by the wax mandrel adhering to the mold is wax cracking. Any crack in the wax form will cause the

plating solution to form a curtain across the affected passage area. Such a failure is very hard to discover and impossible to repair. It must be prevented or discovered before plating has started. At the present time, every wax form (mandrel) will be visually inspected for these two failures by using a microscope. It is anticipated that this inspection can be discontinued after additional experience is gained in wax injection.

The injection of the wax onto a suitable baseplate requires an ultrasonic cleaner, a vacuum pump, an abrasive blast facility, an injection molder of suitable capacity, and a source of heating water. The pieces of special-purpose tooling that have been ordered are listed in Table 4.

TABLE 4. SPECIAL-PURPOSE TOOLING REQUIRED FOR WAX INJECTION		
Tool Part Number	Name	Quantity
YG1158T15	Ultrasonic Cleaner	1
YG1158T19	Injection Molder	1

Using this equipment in conjunction with existing facilities will allow us to inject wax on the three types of baseplates used for the producibility programs.

Nickel Plating -- Once the wax mandrel has been injected onto the baseplate, the whole assembly must be plated with a Barret Sulfamate Nickel plating. The plating process itself consists of H_2SO_4 cleaning, a Wood's Nickel Strike, a deionized water wash, and the actual plating for a long period of time. It takes only a few minutes to complete the first three steps of the plating process, but the final step is done very slowly to minimize the amount of nickel buildup on the edge of the part. The total process takes approximately two days. After the plating is finished, the part must be inspected under magnification to ensure proper plating. Some of the parts, such as the rate sensor and integrated circuit, will require a small amount of machining to clean up the mounting areas. Once this step is complete, the part is mounted on the flushing pump. This removes any trace of the wax mandrel. The part is then ready to test.

Each part requires a special fixture to hold it once it has been injected with the wax. These fixtures are listed in Table 5, and drawings of them are shown in Appendix D. These fixtures are based on previous designs with the improvements required to make them suitable for a production environment.

TABLE 5. REQUIRED PLATING RACKS		
Tool Part Number	Tool Name	Used Piece Parts
YG1158-T16	VRS Plating Fixture	10047498 Assembly, Pickoff
YG1158-T17	Resistor Plating Fixture	10050020 Manifold, Resistor
YG1158-T18	I/C Plating Fixture	10050022 Amplifier, Manifold

Figure 21 shows the layout of the production plating line, and Table 6 contains a listing of the purchase tooling required to set up the line.

EQUIPMENT NEEDED FOR TESTING

Test equipment consisted of the three major assemblies listed below, which are shown in Figure 22.

- Rate table
- Test equipment console
- Fluidic test fixtures and hydraulic power supply

Table 7 lists these assemblies by part number, and the equipment drawings are shown in Appendix D.

Rate Table -- This piece of test equipment supplies the rate input that results in a pressure output from the fluidic rate sensor. This is a special rate table in that it requires a hydraulic connection to provide for both the input and return flows of the hydraulic fluid. The rate sensor test fixture mounts on top of the rate table and provides both a holder for the rate sensor and a fixture for the plumbing required to perform the specified tests.

Test Equipment Console -- The test equipment console contains all of the equipment shown in Figure 23. It provides a tamper-proof container for all of the test equipment, which means that the equipment purchased for this program will remain in one place at all times. This type of setup has two advantages: (1) data gathered on this test setup will be consistent within the accuracy of the test equipment, as the same certified equipment will be used at all times, and (2) no time will be wasted in the gathering of test equipment and its interconnection. Setup time can become significant, especially in a testing laboratory environment.

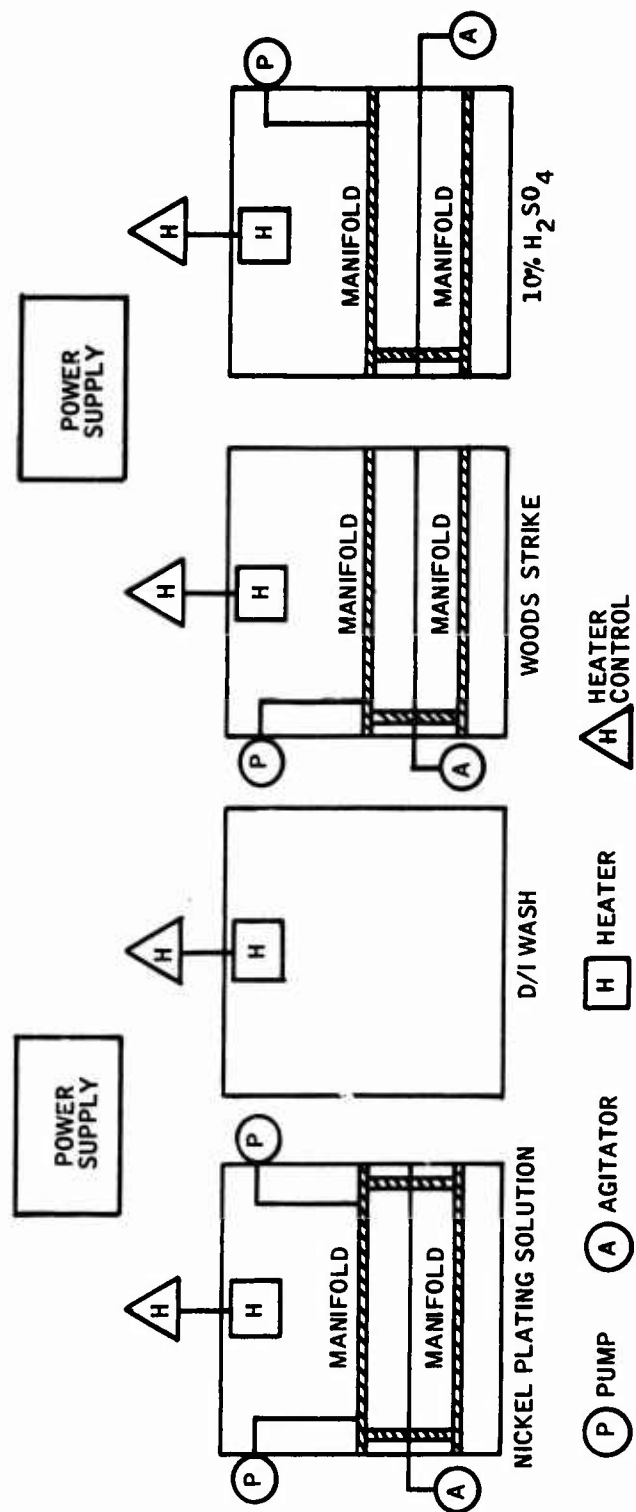


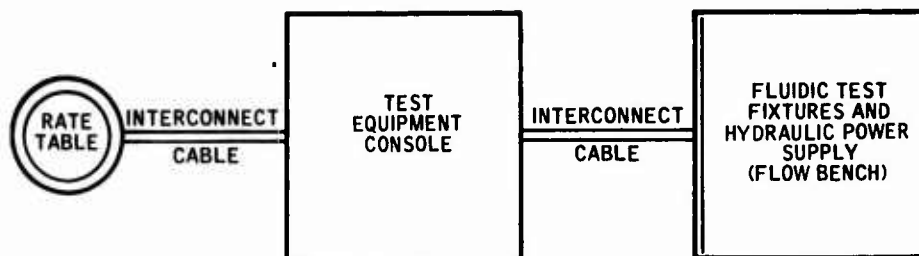
Figure 21. ECW Plating Line.

TABLE 6. PURCHASE TOOLING REQUIRED FOR PLATING LINE

Tool Part Number	Name	Quantity
YG1158-T2	Quartz Heater	1
YG1158-T3	Cancelled; see T21	-
YG1158-T4	Plating Power Supply	1
YG1158-T5	NI Anodes, Bags and Hooks	6
YG1158-T7	Plating Tank	3
YG1158-T8	Plating Tank	1
YG1158-T9	Circulation Pump	4
YG1158-T10	Filter Pump	1
YG1158-T11	Plating Materials (SNAP)*	5 lb
YG1158-T12	Plating Materials (SNAC)*	20 lb
YG1158-T13	Plating Solution (SN)*	50 gal
YG1158-T14	Plating Solution (SNS)*	10 gal
YG1158-T16	VRS Plating Fixture**	1
YG1158-T17	Resistor Plating Fixture**	1
YG1158-T18	I/C Plating Fixture**	3
YG1158-T20	Cathode Rod Agitator	3
YG1158-T21	Flushing Pump	1
YG1158-T22	1 kw Tank Heater	3

*Consumed during plating

**Assembly tooling included for reference only.



DEFINITION	FUNCTION
RATE TABLE	PROVIDE RATE INPUTS TO FLUIDIC RATE SENSOR
TEST FIXTURES AND HYDRAULIC POWER SUPPLY	PROVIDE HOLDING PLATFORM FOR THE AMPLIFIER TEST FIXTURE (YG1158T102) AND FOR THE PILOT INPUT DEVICE (YG1158T105). ALSO PROVIDE THE FRAMEWORK FOR THE HYDRAULIC POWER SUPPLY (FLOW BENCH).
TEST EQUIPMENT CONSOLE	PROVIDE A SEALED ENVIRONMENT FOR ALL OF THE VARIOUS PIECES OF TEST INSTRUMENTATION.

Figure 22. Test Equipment.

TABLE 7. MAJOR TEST EQUIPMENT ASSEMBLIES		
Tool Part Number	Name	Quantity
YG1158E100	Fluidic Test Station	1
YG1158E101	Test Station Control Panel	1
YG1158E102	Hydraulic Test Bench	1
YG1158E103	Amplifier Test Fixture	1
YG1158E104	Connector Interface Panel	1
YG1158E105	PID Test Fixture	1
YG1158E106	Rate Sensor Test Fixture	1
YG1158E107	Indicator Panel	1

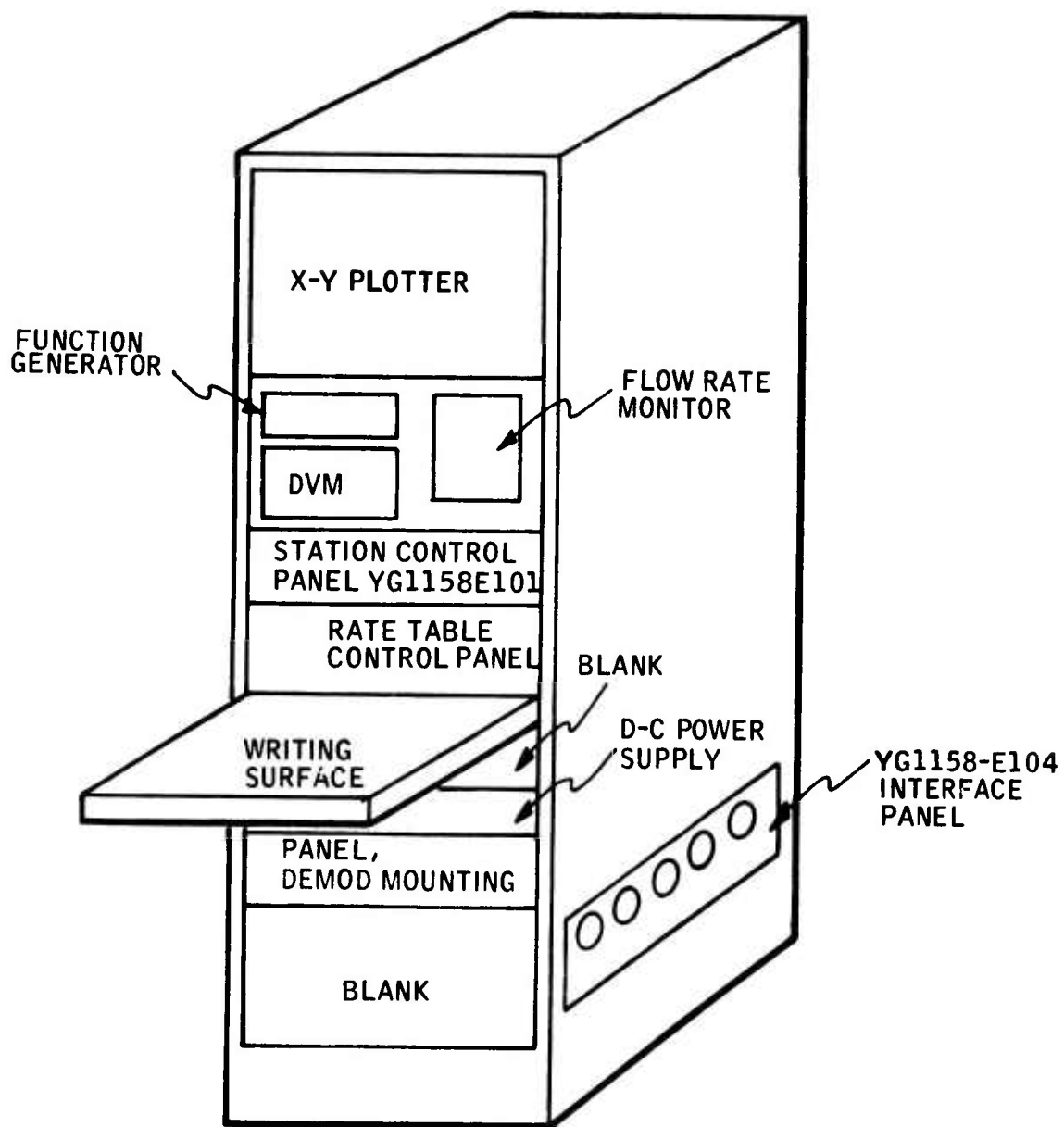


Figure 23. Test Equipment Console (YG1158E100).

Fluidic Test Fixture and Hydraulic Power Supply -- The hydraulic fluid used to power both the integrated circuit (I/C) and the rate sensor is contained in the hydraulic test bench shown in Figure 24. The test bench provides the hydraulic fluid at the correct temperature and pressure for testing these fluidic components, and it is flexible such that the test equipment can be located in any area. The test bench also provides a mounting surface for the I/C test fixture and the pilot input device test fixture, which are hard-plumbed into the hydraulic test bench with the pressure outputs being monitored by electronic pressure transducers. These transducers are connected by cables to the test equipment console, which is then used to record the test data gained during a specific test.

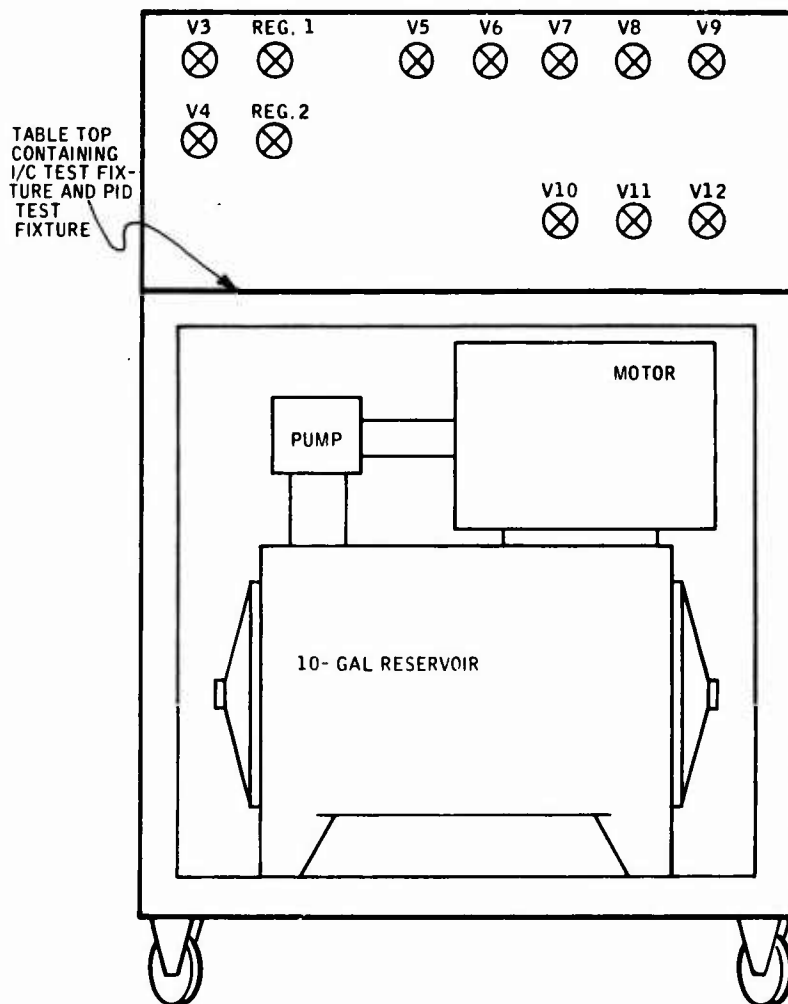


Figure 24. Hydraulic Test Bench.

SECTION VI

CONCLUSIONS

- The developmental work has shown the feasibility of incorporating the amplifiers, resistors, and interconnecting channels on an integrated circuit manifold. Using the integrated circuit and incorporating the design changes explained in this report, this configuration will be used to begin Phase II.
- The pilot production line, as defined in this report, will be implemented.

APPENDIX A

ENVIRONMENTAL TEST PLAN

1.0 SCOPE

This test plan defines the procedures followed for qualification testing of the yaw SAS controller and servoactuator (Yaw Axis Hydrofluidic Stability Augmentation System). The environmental tests consisted of temperature tests, vibration tests, and open-loop response tests. The unit operated with working fluid temperatures from 40° to 180°F.

2.0 APPLICABLE DOCUMENTS

- a. DS 24470-01
- b. MIL-STD-810B Environmental Test
- c. MIL-H-5606 Hydraulic Fluid

3.0 TEST REPORTS

- a. Test reports shall be standard Honeywell format.
- b. DCAS witnessing is required for this testing.

4.0 TEST ITEM

- a. The system shall consist of a hydrofluidic controller and a hydraulic servoactuator. The hydrofluidic controller may be tested separately or with the servoactuator.
- b. The system design goals shall be as listed in Paragraph 3.4 of DS 24470-01.

5.0 STANDARD TEST CONDITIONS

- a. Unless otherwise specified, all tests will be run at standard room-temperature conditions ($70 \pm 5^{\circ}\text{F}$) and at room barometric pressure.

- b. Mounting: All tests, unless otherwise specified, shall be conducted with the controller mounted as it would be on the servo-actuator. The servoactuator will be mounted with the output axis horizontal. All of the components comprising the system will be rigidly mounted to the test fixture. All connections with the exception of the power supply and the return lines shall be with rigid tubing.
- c. Standard Power Flow: Standard hydraulic power for the unit shall be MIL-H-5606 hydraulic fluid. The power supply shall be capable of supplying 8 in.³/sec at an input pressure of 600 psig. Standard fluid operating temperature will be $120^{\circ} \pm 5^{\circ}\text{F}$. All fluid flow supplied to the system will be filtered to 10 microns absolute.

6.0 TEST SCHEDULE

Temperature, vibration, and open-loop response tests will be conducted in that order.

7.0 TEMPERATURE TESTS

- a. Mount the system on the rate table in the standard configuration. Stabilize the oil temperature at -25°F or as cold as practical with existing equipment. Apply a sinusoidal input rate of ± 2 deg/sec at 0.4 cps to the system. Energize the system and record the servoactuator or controller output. Increase the oil temperature to 40°F and allow it to stabilize. Cover the system with a box or blanket to reduce the temperature gradient between ambient and oil temperature. Apply sinusoidal input rates of ± 2 deg/sec at frequencies of 0.01, 0.02, 0.04, 0.1, 0.2, 0.4, 1.0, 2.0, 4.0 and 10 cps. Record the output of the servo-actuator or controller. Repeat the test at the same frequencies with the input amplitude increased to ± 5 , ± 10 , and ± 15 deg/sec.

Record the output from the test unit with no input rate applied to the system. The total peak-to-peak noise and null of the system will meet the equivalent requirements of Paragraphs 3.4.4 and 3.4.7, respectively, of DS 24470-01.

- b. Repeat the tests of paragraph 7a at oil temperatures of 60° , 90° , 120° , 180°F .
- c. The output of the test unit will meet the equivalent requirements of Figure 2 of DS 24470-01, or Figure B-2 of this report.

- d. Apply a mechanical input to the rudder input device under the same conditions as in paragraph 7a and 7b. Total peak-to-peak motion of the input measured at the end of the control cable shall be 0.02 ± 0.005 inch. Apply frequencies of 0.01, 0.04, 0.1, 0.4 and 1.0 cps, and record the output of the test unit. Repeat the test at amplitudes of 0.04 and 0.08 inch of control cable motion. The output of the test unit will meet the equivalent requirements of Figure 3 of DS 24470-01, or Figure B-3 this report.
- e. Rotate the Built in Test (BIT) actuator on the controller clockwise (CW). Allow sufficient time for the test unit output to decay and release the BIT actuator. Record the test unit output during this complete test. Repeat this procedure at each temperature.
- f. Apply a steady rate of 10 deg/sec CW to the system while recording the output. Allow sufficient time for the test unit to stabilize. Remove the rate and again allow the test unit to stabilize. The gain shall meet the equivalent requirements of paragraph 3.4.5 of DS 24470-01. Repeat the test in the counter-clockwise (CCW) direction and at rates of 30° and 50°/sec. This test shall be run at each temperature.

8.0 VIBRATION TESTS

- a. Mount the complete system in the standard configuration on a vibration driver. The axis of the input vibration will be vertical and parallel with the rate sensor input axis. Supply the system with standard flow and pressure. The temperature of the fluid will be $120^\circ \pm 5^\circ\text{F}$.
- b. Vibrate the complete system while it is energized and operating. The vibration amplitude and frequency shall be according to Curve M of Figure 514-1 of MIL-STD-810B. Record the test unit output during the complete test, and note the frequency where the test unit oscillates or null shift occurs. Vibrate the system at those frequencies where the null shift was greater than 0.05 inch or equivalent controller output for 10 minutes.
- c. Remount the system such that the axis of vibration is parallel to the servoactuator ram axis. The rate sensor input axis should still be vertical. Vibrate as in paragraph 8b.
- d. Rotate the system 90° about the rate sensor input axis and repeat paragraph 8b.

- e. During all of the vibration tests, there shall be no increase in leakage from the system, and there shall be no line breakage or failure of fittings in the system. The maximum null shift shall be 0.05 inch of equivalent servoactuator output.

9.0 OPEN-LOOP TESTS

- a. Remount the system on the rate table. Energize the system and supply it with standard flow and pressure. Allow the system to stabilize at $120^{\circ} \pm 5^{\circ}\text{F}$. Apply input rates of ± 2 deg/sec at 0.01, 0.02, 0.04, 0.1, 0.2, 0.4, 1.0, 2.0, 4.0 and 10 cps. Record the outputs of the test unit.
- b. Repeat the above tests with an input of ± 10 deg/sec. Record the output of the test unit.
- c. The results will meet the equivalent requirements of Figure 2 of DS 24470-01, or Figure B-2 this report.
- d. Apply rudder inputs as described in paragraph 7d. Record the test unit output.
- e. The results will meet the equivalent requirements of Figure 3 of DS 24470-01, or Figure B-3 this report.
- f. The noise and null recorded with no rate input will not exceed the equivalent requirements of paragraphs 3.4.4 and 3.4.7 of DS 24470-01.
- g. Perform the tests of paragraph 7e of this document.
- h. Perform the tests of paragraph 7f of this document.

APPENDIX B
DETAIL SPECIFICATION,
YAW-AXIS HYDROFLUIDIC
STABILITY AUGMENTATION SYSTEM
DS24470-01

1.0 SCOPE

This specification defines the performance requirements for the YG1116A01 Stability Augmentation System. The system is a hydrofluidic control package which mounts on top of the boost and SAS actuator of the OH-58A helicopter. This system is added to the aircraft to improve the handling qualities in the yaw axis.

The requirements of this specification are design goals.

2.0 APPLICABLE DOCUMENTS

The following documents and drawings and the applicable specifications referenced therein shall apply to the extent specified herein.

- 2.1 MIL-H-5606, Hydraulic Fluid, Petroleum Base, Aircraft, Missile and Ordnance.

3.0 REQUIREMENTS

3.1 General

The system shall consist of the following functional units:

- 3.1.1 Vortex Rate Sensor - Provides a differential pressure signal that is proportional to the aircraft angular rate in the yaw axis.
- 3.1.2 Amplifiers - Accept and amplify differential pressure signals.
- 3.1.3 Shaping Networks - Usually a combination of resistors and capacitors (bellows) designed to provide the following functions:
- a) Lag - With a characteristic of $\frac{1}{TS + 1}$

- b) High-pass - With a characteristic of $\frac{TS}{1 + TS}$

Note: T is a time constant.

- 3.1.4 Pilot Input Device - Provides an output which is a function of pedal displacement. This will reduce the tendency of the control system to "fight" the pilot in the yaw axis.
- 3.1.5 Servoactuator - If mounted effectively in series with the aircraft power boost servo, accepts differential pressure signals and converts them to displacements of the power boost servo pilot valve. Weight, bulk, and power consumption shall be optimized to the extent possible without compromising reliable and demonstrable functioning. Interunit connections shall be accomplished in a manner that will permit replacement of individual functional components.
- 3.1.6 Flow Control Valve - Maintains a constant flow to the system when provided a differential pressure of over 100 psid.
- 3.1.7 Engage Valve - Solenoid operated, hydraulic and remotely controlled from the cockpit to engage all or part of the control system.
- 3.1.8 Back Pressure Regulator - Maintains a constant return pressure level on the controller regardless of downstream pressure surges.

3.2 ENVIRONMENT

- 3.2.1 Vibration - A 15-minute vibration scan, with the system operating and output null monitored, will be conducted in each of the three axes at 5 g's from 20 to 500 Hz. The testing shall be conducted with the hydraulic supply and connections simulating the actual aircraft installation as nearly as practicable.
- 3.2.2 Temperature - The system shall operate over the ambient temperature range from 0° to 180°F when the operating fluid is in the range of +40°F to +180°F.

3.3 Power Supplies

- 3.3.1 Input power to the system shall be hydraulic fluid per MIL-H-5606 at a pressure of 600 psig (Nom), which is obtained from the aircraft hydraulic power system. The system (except augmentation servoactuators) shall not require more than $2.7 \frac{\text{in.}^3}{\text{sec}}$.

3.3.2 Electrical power for the solenoid will be 28 vdc.

3.4 System Performance

All performance requirements in this section pertain to normal operating conditions. Normal operating conditions are defined as:

- Ambient temperature - $70^{\circ} \pm 5^{\circ}\text{F}$
- Hydraulic fluid temperature - $120^{\circ} \pm 5^{\circ}\text{F}$
- Hydraulic fluid pressure - 500 to 600 psig ahead of the flow regulator; a minimum of 40 psig return pressure.

3.4.1 System requirements are summarized in Figure B-1.

3.4.2 Range - The system shall have a range of at least ± 30 deg/sec ahead of the high pass and ± 100 percent actuator stroke downstream of the high pass.

3.4.3 Linearity - The system linearity including the servoactuator shall be within ± 10 percent of full scale. Linearity is defined as the width of the band enclosing all the test points.

3.4.4 Noise - Peak-to-peak noise at output of the actuator shall not exceed ± 0.015 inches of actuator motion.

3.4.5 Accuracy - The system shall maintain gain and time constants within tolerances shown in Figures B-2 and B-3 for the high-pass and pilot input loops.

3.4.6 Phasing - CCW rotation of the system shall cause the series servoactuator to retract. CW rotation of the PID cam shall cause the series servoactuator to retract (right pedal).

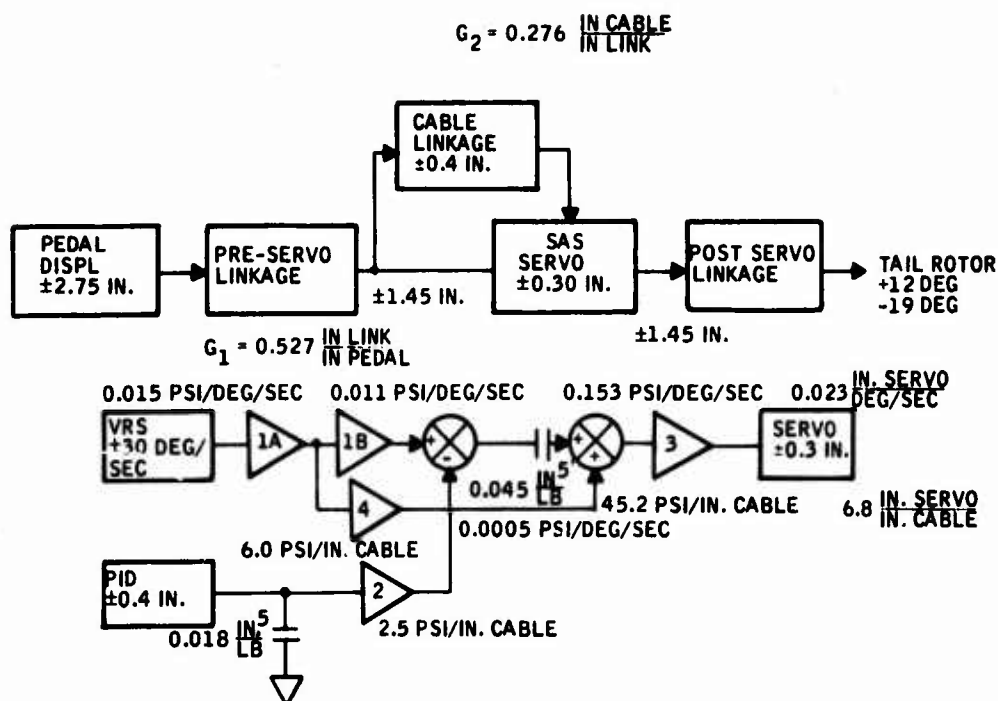
3.4.7 Null - the servoactuator null offset at zero input turning rate shall be no greater than ± 0.07 in.

3.5 Component Performance

Performance shall be determined at room temperature ambient with fluid at $120^{\circ} \pm 5^{\circ}\text{F}$, unless otherwise specified.

3.5.1 The vortex rate sensor shall meet the following performance requirements when the system is supplied with $2.7 \frac{\text{in.}^3}{\text{sec}}$:

- Scale factor 0.014 psid/deg/sec, dead ended
- Range ± 30 deg/sec, minimum



COMPONENTS

$$G_{VRS} = 0.015e^{-0.06S} \text{ DEAD END PSI/DEG/SEC}$$

$$G_{PID} = 6.0 \text{ PSI/IN. OF CABLE}$$

$$G_{AMP1} = 0.731 \text{ PSI/PSI}$$

$$G_{AMP2} = 0.42 \text{ PSI/PSI}$$

$$G_{AMP3} = 14.0 \text{ PSI/PSI}$$

$$G_{AMP4} = 0.025$$

$$G_{SERVO} = 0.15 \left[\frac{\text{PSI/PSI}}{(62.8)^2} \right] \text{ IN./PSI}$$

$$G_{CABLE} = 0.276 \text{ IN. CABLE/IN. LINKAGE}$$

$$G_{LINKAGE} = 0.527 \text{ IN. LINKAGE/IN. PEDAL}$$

SYSTEM

RATE LOOP

$$G_R = 0.023 \left[\left(\frac{2.5S}{2.5S + 1} \right) \left(\frac{3950}{S^2 + 88S + 3950} \right) \right] e^{-0.06S} \text{ IN. SERVO/DEG/SEC}$$

PID LOOP

$$G_{PID} = 6.8 \left[\left(\frac{1}{S + 1} \right) \left(\frac{2.5S}{2.5S + 1} \right) \left(\frac{3950}{S^2 + 88S + 3950} \right) \right] \text{ IN. SERVO/IN. CABLE}$$

Figure B-1. System Performance (Yaw).

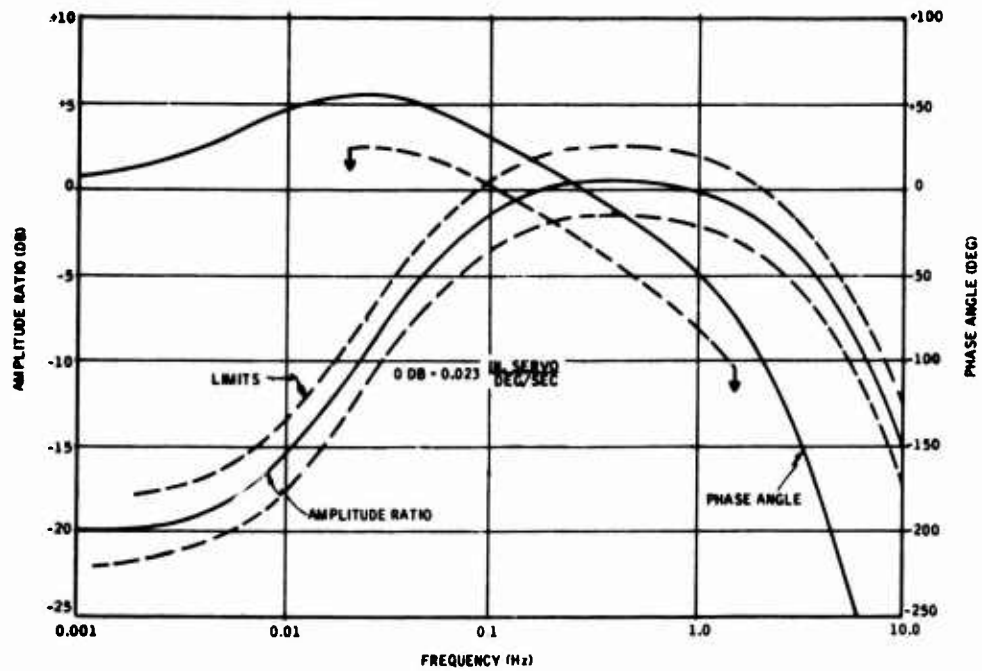


Figure B-2. Rate Transfer Function Requirements.

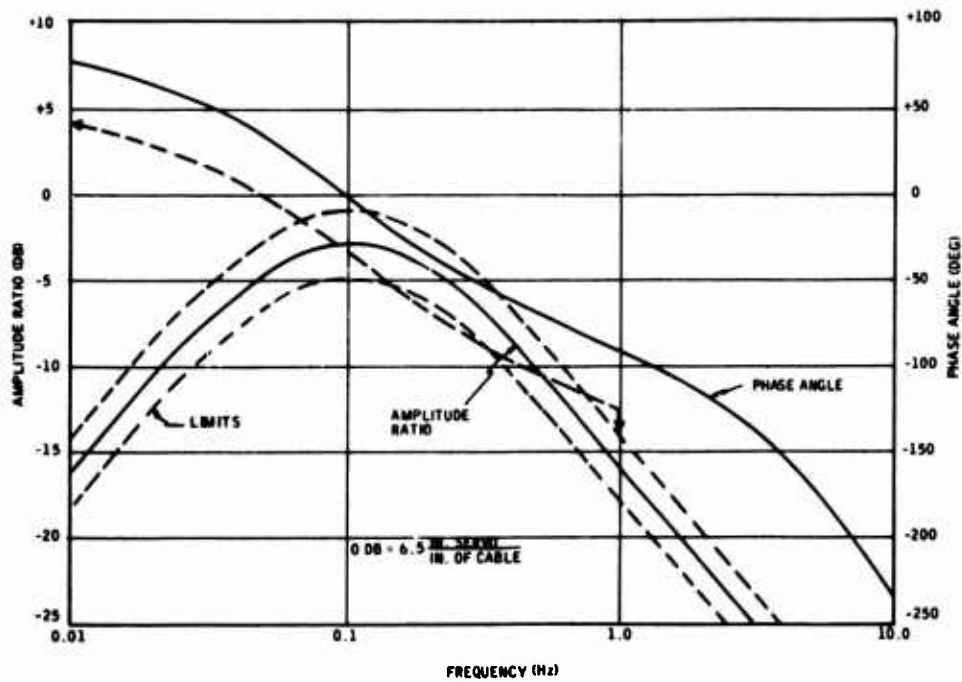


Figure B-3. Pilot Input Transducer Transfer Function Requirements.

- Linearity - ± 5 pct of full scale
- Time Delay - 0.060 sec or less
- Noise - ± 0.65 deg/sec max
- Calibrate Button - A sensor calibrate button shall be utilized with the capability of inserting a signal equivalent to a step rate of about 5 degrees per second.

3.5.2 Amplifiers - Amplifiers shall meet the following performance requirements when supplied with a pressure of >6.5 psid.

- Input impedance for VRS load amplifier--180 ohms minimum
- Output impedance for output amplifier--100 ohms maximum
- Gain and load - Requirements for each application are described in Figure B-1.

3.5.3 Servo - The servoactuator shall meet the following performance requirements:

Quiescent level (above R_c)	5 psig $\pm$ 1 psig
Full control signal range	± 2 psig
Max (above R_c)	15 psig
R_c Max	100 psig
Effective capacitance	<0.0005 in. ⁵ /lb
System pressure	600 psi
Stroke	± 0.300 in.
Threshold	1.0 pct max
Dynamic response	90° phase lag at 10 Hz (min) at 10 pct rated input
Linearity and hysteresis	± 5 pct of rated stroke
Inlet proof pressure	900 psi
Return proof pressure	600 psi
Burst pressure	1500 psi
Neutral leakage	0.10 gpm

3.6 Product Configuration

3.6.1 Drawing Number YG1116A defines the overall installation of the system.

4.0 QUALITY ASSURANCE

Conformance of the hardware to program objectives shall be evaluated with the following tests. Performance tests will be conducted before and after vibration tests.

4.1 Vibration

- 4.1.1 A 15-minute vibration scan, with the system operating and output null monitored, will be conducted in each of the three axes at 5 g's from 50 to 500 Hz. The testing shall be conducted with the hydraulic supply and connections simulating the actual aircraft installation as nearly as practicable.

4.2 Performance Tests

- 4.2.1 Conformance to dynamic range requirements of Paragraph 3.4.2 shall be determined by imposing rates of ± 30 deg/sec and measuring output of the appropriate stage amplifier.
- 4.2.2 Gain and response requirements shall be determined by measuring system output at 0.01, 0.02, 0.04, 0.1, 0.2, 0.4, 1.0, 2.0, 4.0, and 10 Hz. Amplitudes of ± 2 , ± 5 , ± 10 and ± 15 deg/sec shall be used. Response shall be measured with fluid temperatures of 40°, 70°, 90°, 120° and 180°F. Results shall meet the requirements of Paragraph 3.4.
- 4.2.3 Gain and response of the pilot input device shall be determined by measuring system output at 0.01, 0.04, 0.1, 0.4 and 1 Hz. Amplitudes of ± 0.01 and ± 0.04 in. of cable shall be used. Response shall be measured at the same temperatures as in Paragraph 4.2.2. Results shall meet the requirements of Paragraph 3.4.

4.3 Verification

- 4.3.1 Inspect the systems for quality of workmanship and conformance to installation drawing.
- 4.3.2 Determine that the system contains the features described in Paragraph 3.6.1.
- 4.3.3 Establish that the power required does not exceed the amount specified in Paragraph 3.3.1.

APPENDIX C
DEVELOPMENT AND EVALUATION LAB
ENGINEERING TEST REPORT

1.0 ABSTRACT

Object: To conduct qualification testing of the YG1158A01 Yaw HYSAS for Phase I of the Producibility Study Program according to Attachment 1 of the contract document DAAJ02-74-C-0012/USAAMRDL.

Summary: Because no actuator was available for this test, output differential pressures were recorded and a conversion factor of 0.15 inch/psid was used. Results are presented in graphical and tabular form for the temperature and open-loop tests. Vibration test results were satisfactory. Except for very small regions on the frequency response graphs, phase goals were met. Nominal operating temperature goals were attainable; however, refinement of the amplitude characteristics, noise, and null shifts at low temperature was abandoned as a new integrated configuration was being developed.

The tests were monitored by DCAS and Honeywell Quality Control personnel.

It is noted that the MIL-H-5606 oil in the flow bench has a viscosity at 120°F equivalent to new oil at 143°, and at 180° equivalent to new oil at 210°. The temperatures required by the specification were used. The lower viscosity bench oil could influence the characteristics of the system.

2.0 UNIT TESTED

One YG1158A01 Yaw Axis Hydrofluidic Stability Augmentation System (HYSAS) was tested without a servomotor. The outstanding feature of this system is that the amplifiers were electroformed into an integrated manifold circuit. The schematic diagram of the circuit is shown on drawing number C13789AA01. The configuration used for this test is shown as Figure C-1.

3.0 REFERENCE DOCUMENTS

- Attachment 1 of Contract DAAJ02-74-C-0012 specifies the environmental test plan.
- DS 24470-01 lists the system performance goals for this test.

- DS 24860-01 lists the goals for the YG1143 HYSAS, a similar circuit without the servoactuator, which was used as a guide.
- MIL-STD-810B Environmental Test

4.0 PROCEDURE AND RESULTS

The tests were conducted in the following sequence:

1. Temperature
2. Vibration
3. Open-loop response

4.1 Temperature Tests

The system, mounted on a rate table, was instrumented to measure, record, or provide:

- Output differential pressure
- Rate table sinusoidal inputs at various frequencies, steady-state inputs, and outputs
- Pedal input cable drive (hydraulic rotary actuator) and input linear pot, at the device, with power supply
- Oil temperature at the outlet of the system
- Oil flow through the system.

Hydraulic power was sent to the system through a heat exchanger with the temperature regulated by a Hi-Lo Temperature Control Unit. The input pressure at the system was maintained between 550 and 600 psig and at the outlet at 55 psig. A 2-micron filter and hard tubing were connected directly to the inlet. The system was covered by towels to minimize heat loss.

At exit oil temperatures of 46° (lowest obtainable with the setup), 60°, 90°, 120°, 150° (extra test), and 180°F, the following tests were made:

1. Sinusoidal input rates of ± 2 , ± 5 , ± 10 , and ± 15 deg/sec were applied at frequencies of 0.01, 0.02, 0.04, 0.1, 0.2, 0.4, 1.0, 2.0, 4.0, and 10 Hz. A Bafco Frequency Response Analyzer was used to apply the input signal and to display the frequency response data. The system frequency response data was recorded and plotted. The pedal input level was centered for these tests.

X-Y gain plots were made at the same four amplitudes for pressure output versus rate input at about 0.1 Hz. X-Y time-travel plots were made of the output while the BIT was rotated to the end of its travel, held until stabilized, and released. BIT sensitivity, noise, and off-null information is indicated by the plot.

2. X-Y time-travel plots were made of the output at steady-state rates of 10, 30, and 50 deg/sec. First, a CW rotation was imposed and held until stable; then the motion was stopped until the output was leveled, and the process was repeated in the CCW direction.
3. Sinusoidal inputs were applied to the pedal input cable actuator to produce peak-to-peak motions at the lever of 0.08 (± 0.04), 0.04, and 0.02 inch at frequencies of 0.01, 0.04, 0.1, 0.4, and 1.0 Hz by using the Bafco Analyzer. The frequency response data was obtained as was done for the rate.

X-Y gain plots were made at the three amplitudes for pressure output versus cable movement at 0.1 Hz.

The frequency responses of the rate and pilot input device (PID) loops are shown in Figures C-2 through C-5. Response data for 120°F fluid temperature, before and after vibration, is shown in Figures C-2 and C-4. Response data taken at various temperatures is shown in Figures C-3 and C-5. Other response data taken at various input levels is not shown due to the similarity of results with the presented data.

Tables C-1 and C-2 summarize the rate loop and PID performance at various fluid temperatures. This data was obtained from many recordings, some of which are shown in Figures C-6 through C-8. These figures show the rate loop and PID performance at 120°F fluid temperature and are representative of the recordings taken at the other fluid temperatures.

4.2 Vibration

Vibration machine mountings were made such that the system could be vibrated in each of the three mutually perpendicular axes while maintaining the rate sensor input axis vertical.

For the hydraulic supply, a 2-micron filter was connected directly to the system, flexible hoses were used, and pressure gages and the back-pressure regulator were connected away from the vibration machine. The supply pressure was set to 640 psig and the back pressure at 50 psig. Exit oil temperature was maintained at $120^{\circ} \pm 5^{\circ}\text{F}$.

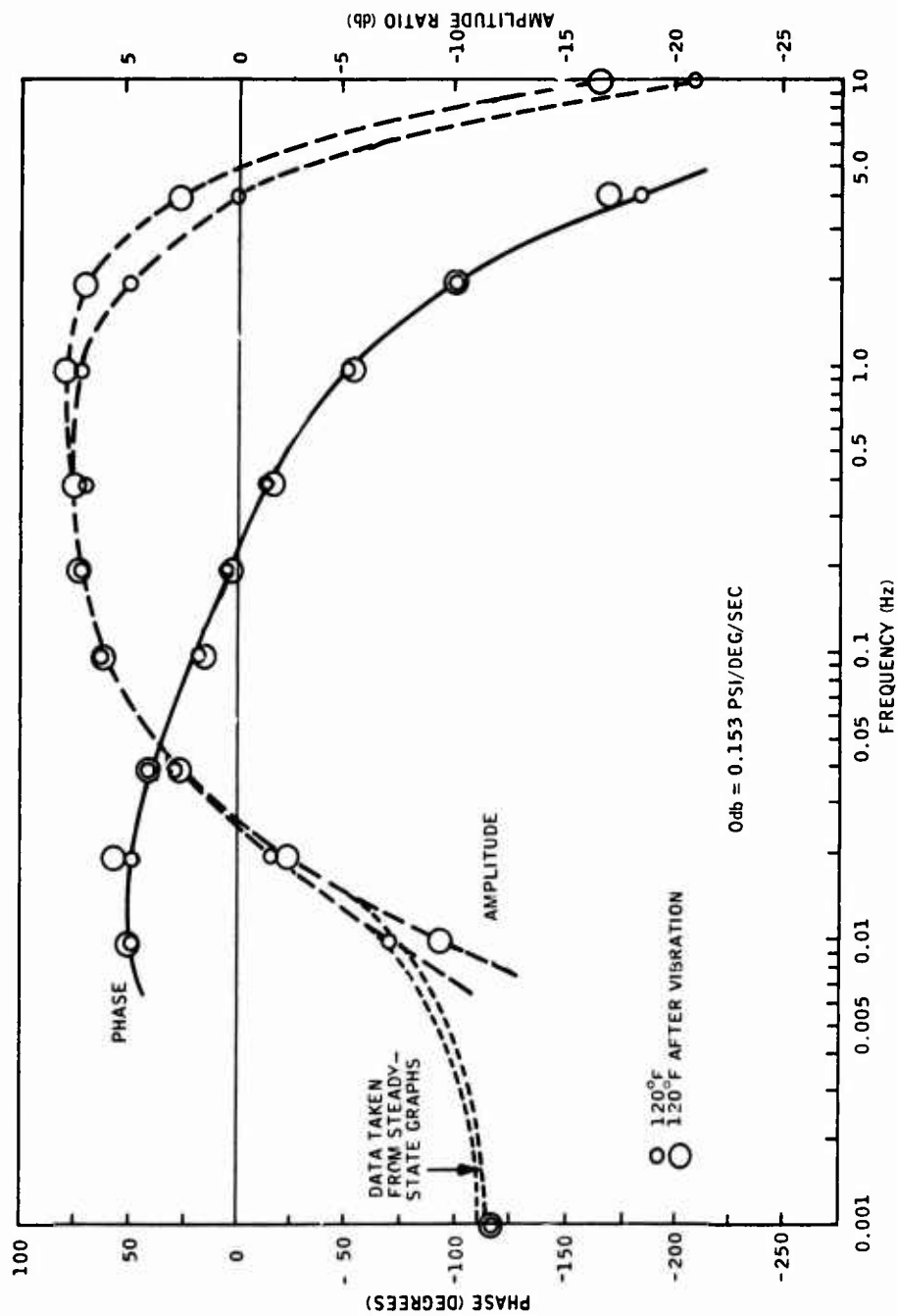


Figure C-2. Yaw SAS Frequency Response.

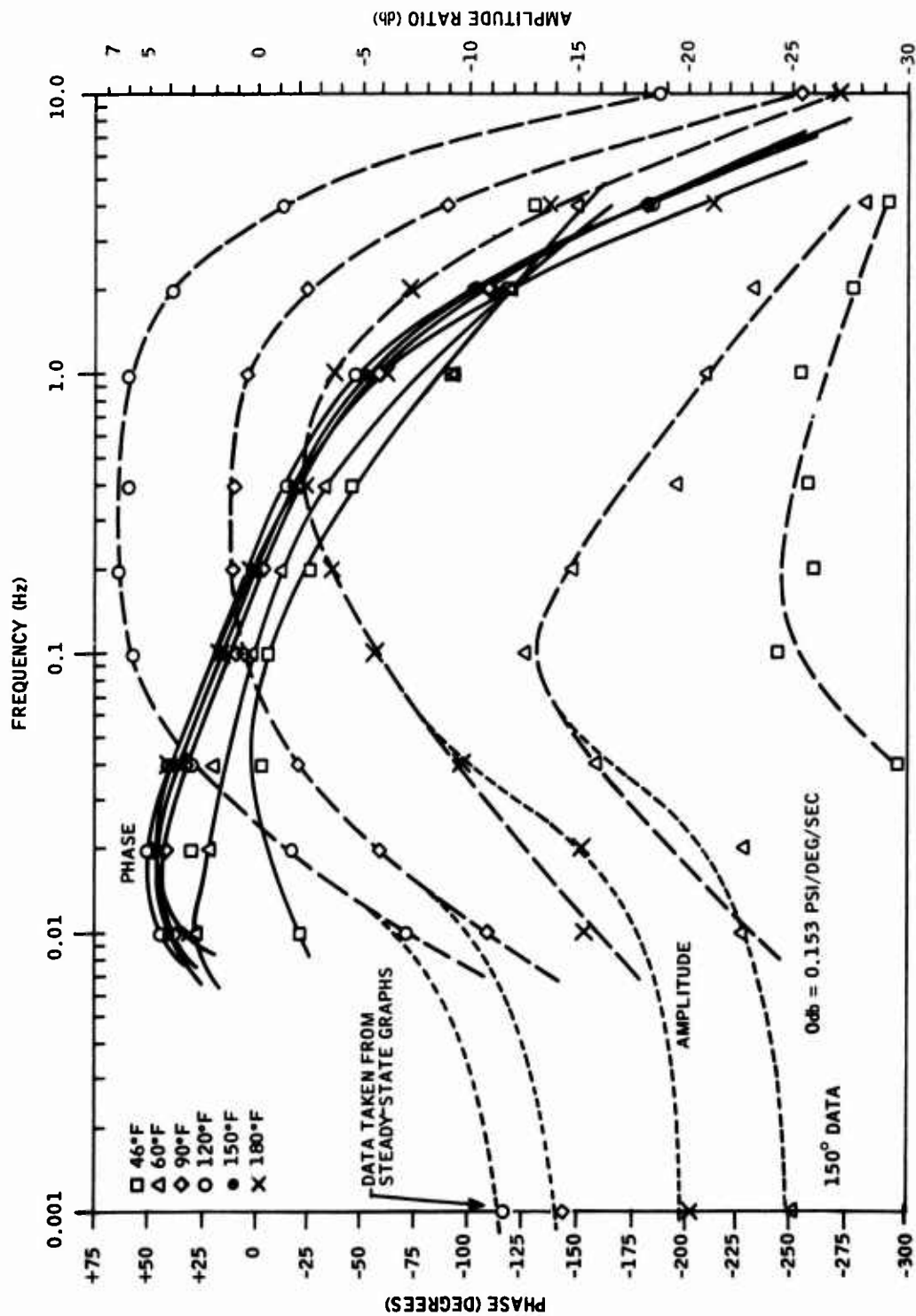


Figure C-3. Yaw SAS Frequency Response.

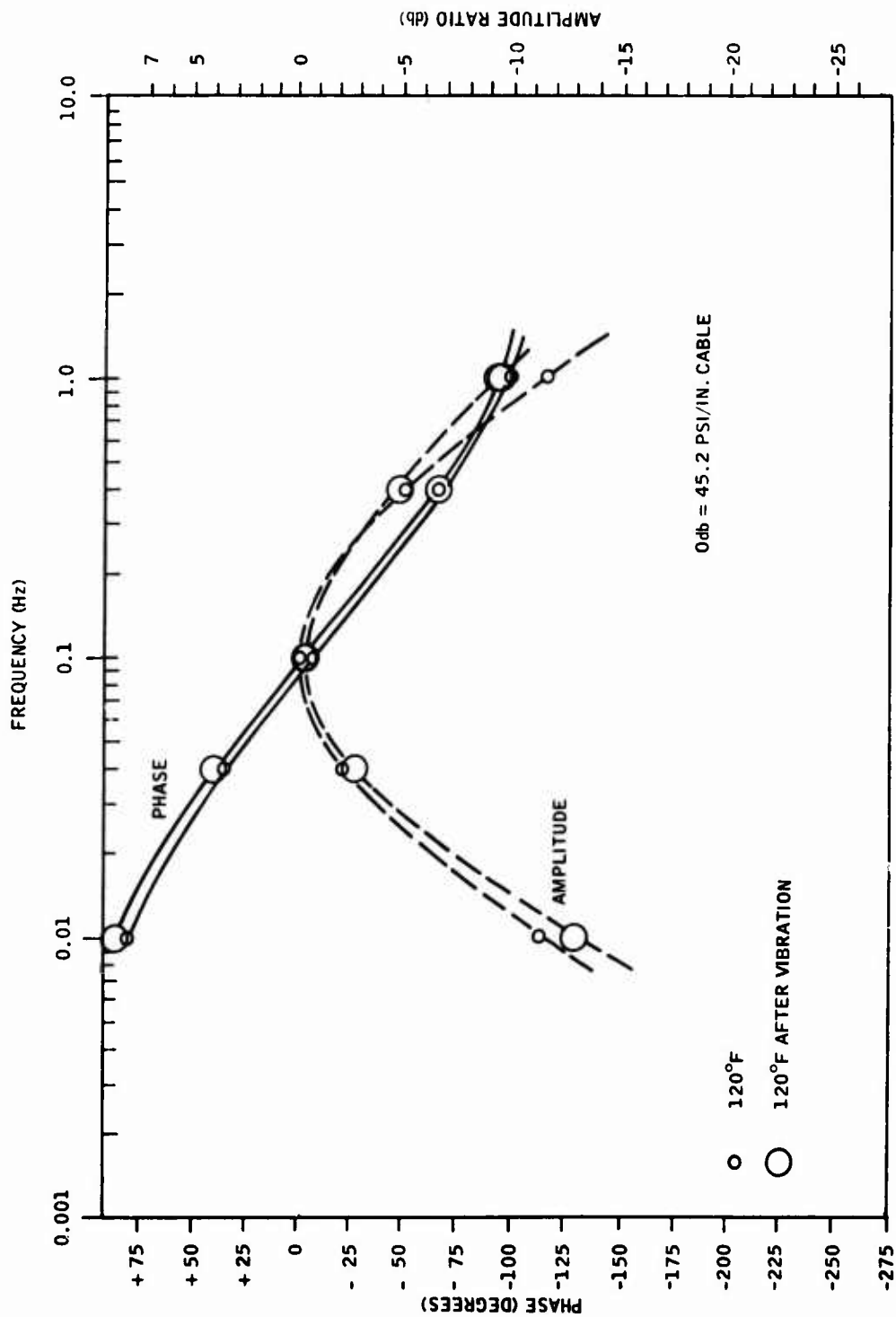


Figure C-4. PID Loop Frequency Response.

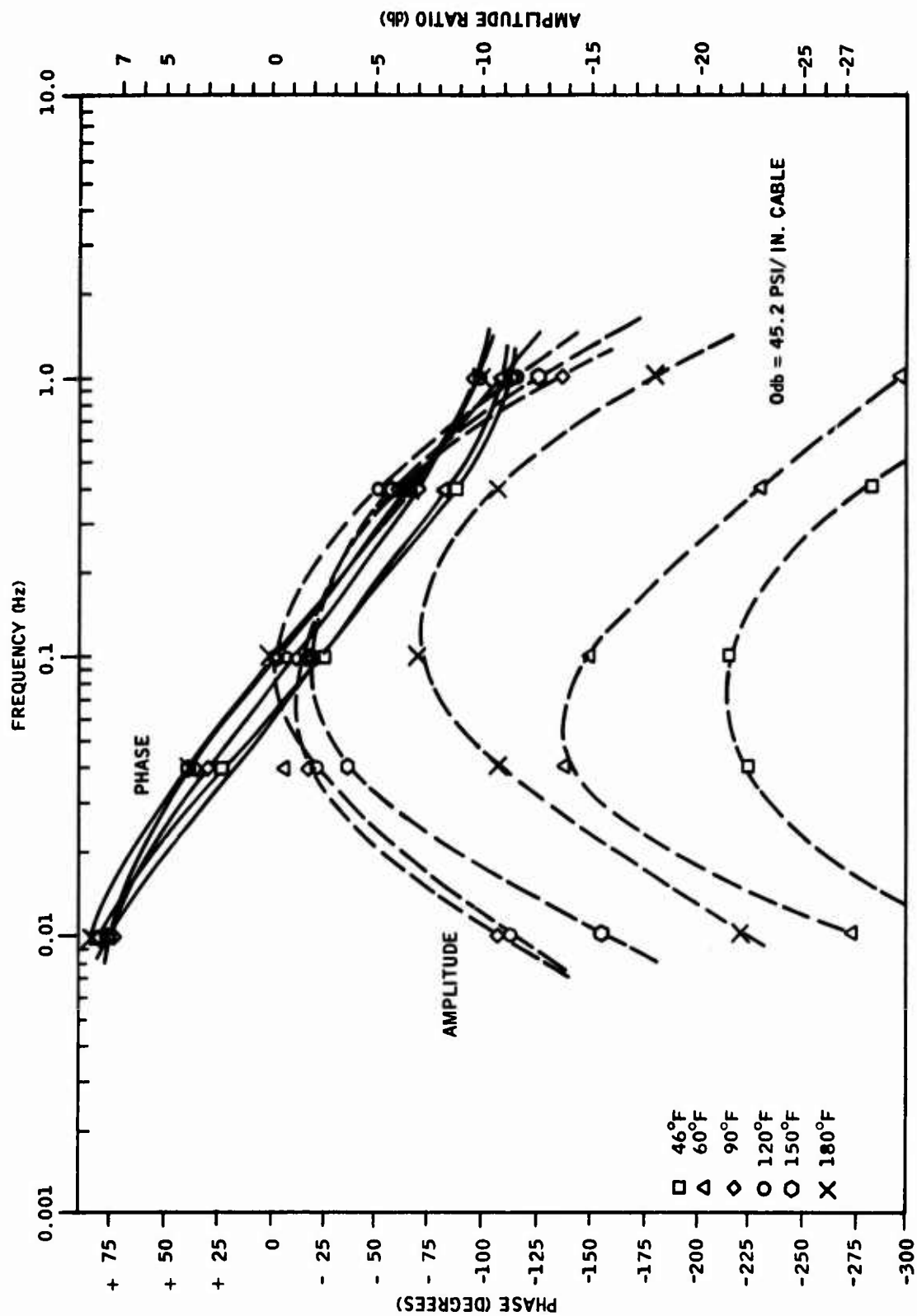


Figure C-5. PID Loop Frequency Response.

TABLE C-1. RATE LOOP PERFORMANCE VERSUS FLUID TEMPERATURE							
Fluid Temp (°F)	Rate Gain (psi./deg./sec)			Null Offset (psi)	Noise (psi)	Steady-State Gain	
	±2 deg./sec	±5 deg./sec	±10 deg./sec			±15 deg./sec	psi/deg./sec
46	0.0077	0.0074	0.0077	0.0087	0.010	0.0045	61
60	0.0260	0.0200	0.0250	0.0190	0.025	0.0125	62
90	0.1340	0.1480	0.1660	0.2000	0.050	0.0300	20
120	0.2700	0.2800	0.2700	0.2800	0.250	0.0360	13
150	0.2100	0.1440	0.1350	0.1750	-	0.0250	17
180	0.0920	0.1080	0.0890	0.0740	0.25	0.0170	16
120 (Post-vibration)	0.3360	-	0.3360	-	0.20	0.0360	11

TABLE C-2. PILOT INPUT DEVICE (PID) PERFORMANCE VERSUS FLUID TEMPERATURE				
Fluid Temp (°F)	PID Gain (psi/in.)			
	±0.01 inch cable input	±0.02 in.	±0.04 in.	
46	2.3	2.6	3.1	
60	6.1	5.7	8.8	
90	26.8	28.6	42.4	
120	38.1	42.2	44.9	
150	36.1	39.5	37.0	
180	18.0	17.9	18.9	
120 (Post-vibration)	39.3	37.4	43.2	

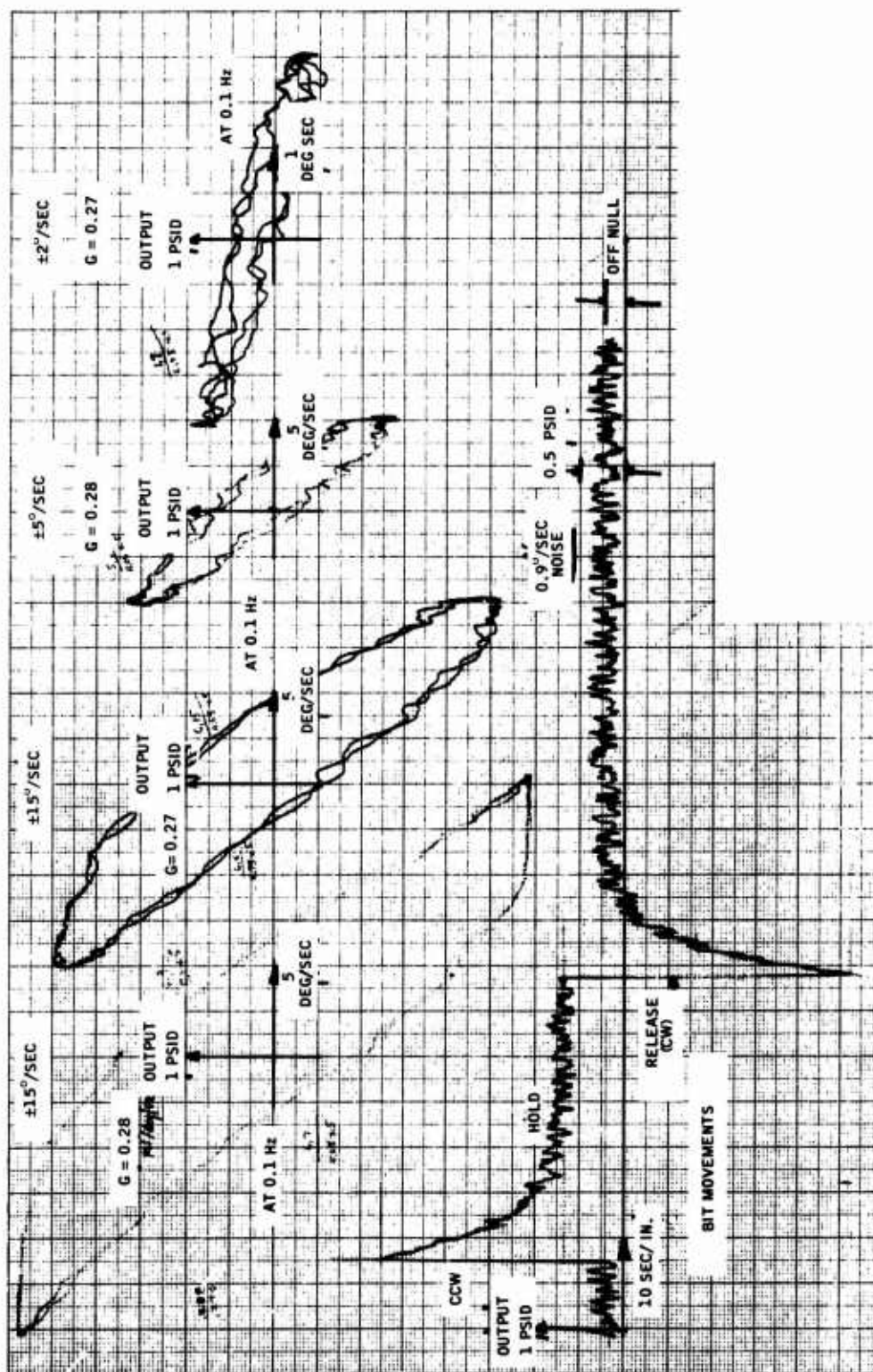


Figure C-6. Yaw SAS Gains, BIT, Noise, and Null at 120°F.

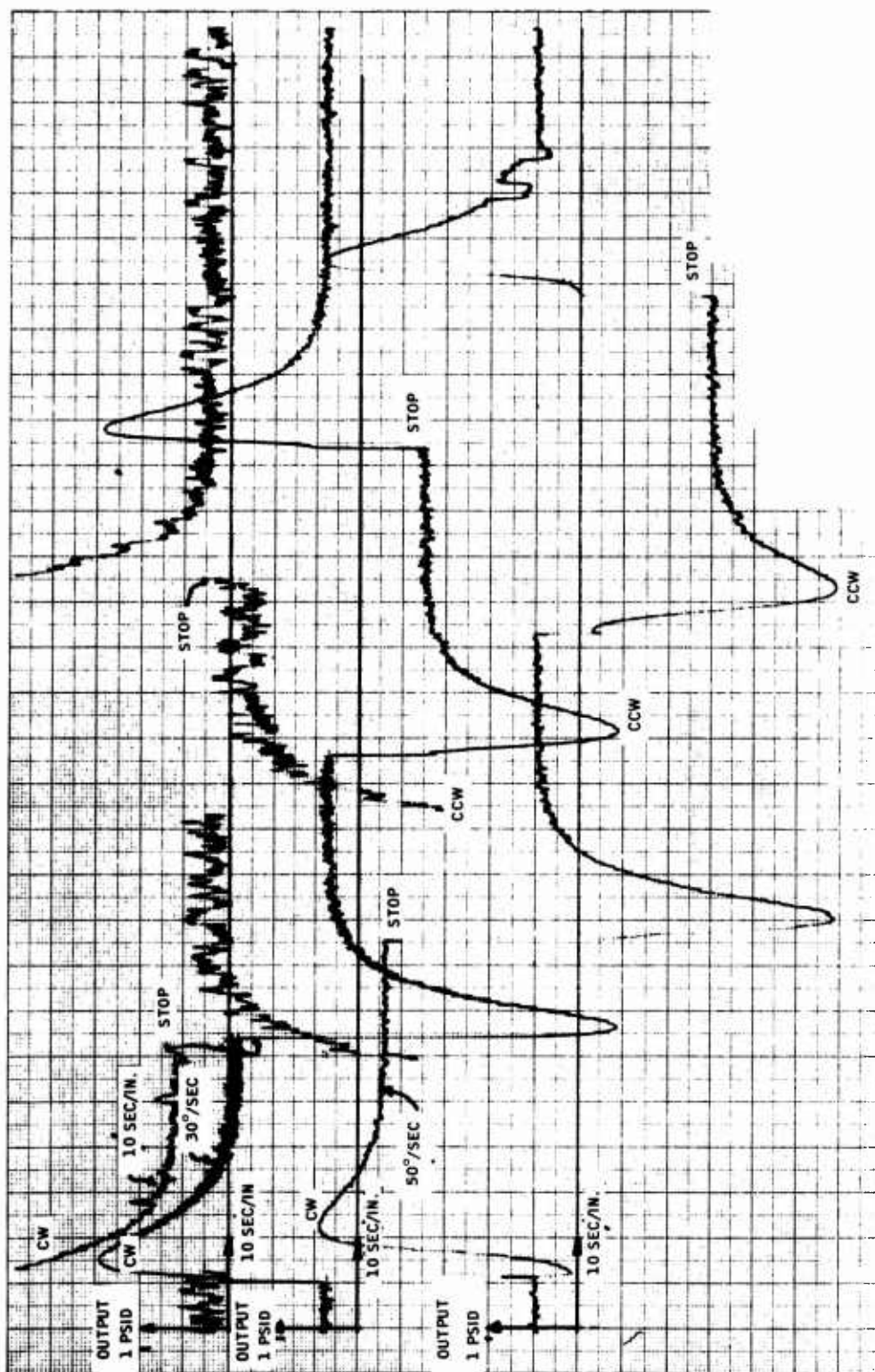


Figure C-7. Yaw SAS Steady - State Rates at 120°F.

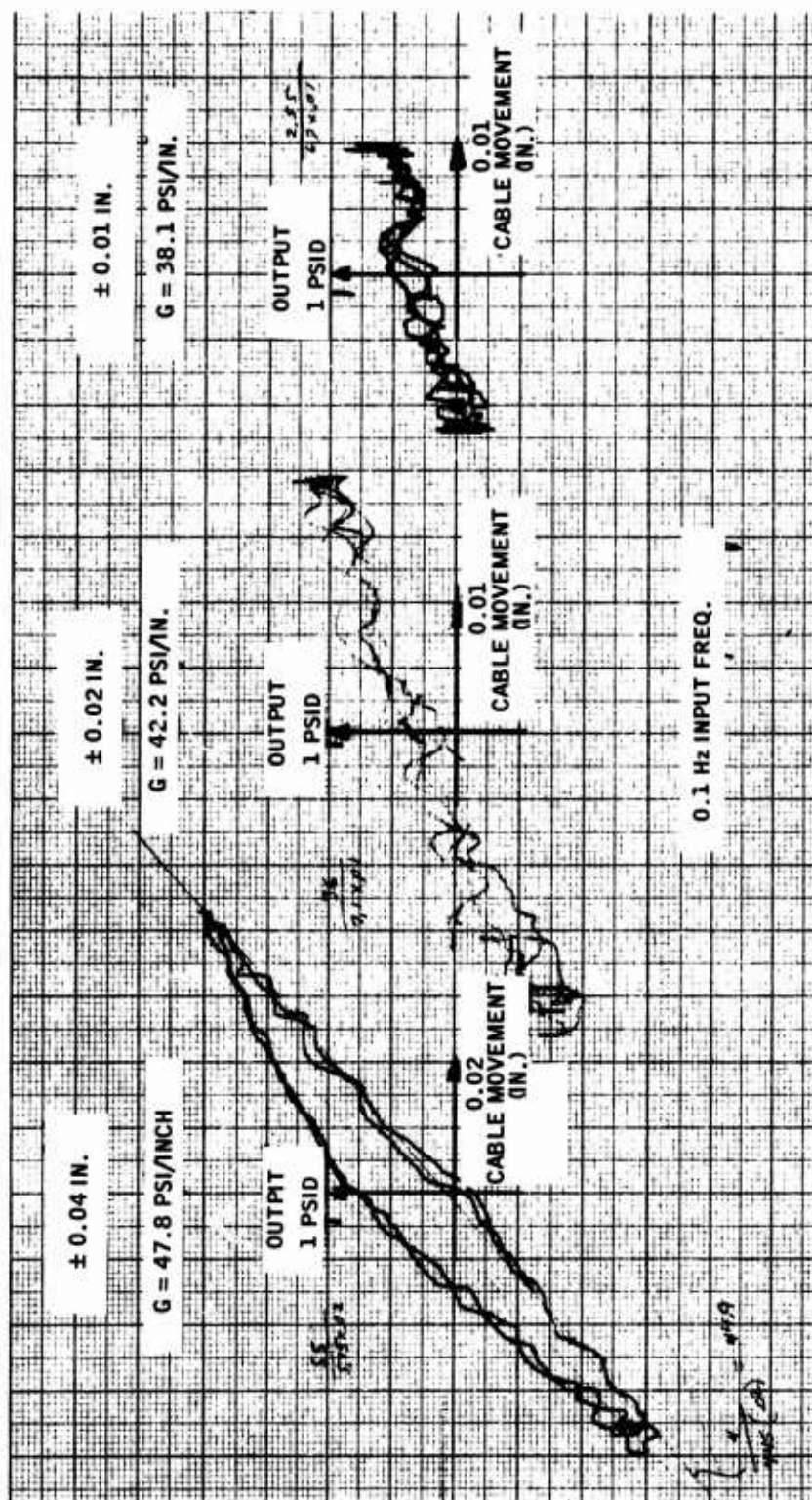


Figure C-8. Yaw SAS Pedal Input Gains at 120°F.

Fifteen-minute vibration scans were run from 5 to 500 Hz and back, following the amplitudes and frequencies shown on curve M of Figure 514-1 of MIL-STD-810B for each of the three axes. The system output was recorded on one channel of a four-channel Sanborn recorder to observe null shifts.

Two of the vibration axes indicated no excessive null shifts. For the vertical vibration axis parallel to the rate sensor axis, a momentary excessive null shift was indicated at 125, 305, and 315 Hz. Ten-minute vibration was sustained at 125 and at 310 Hz; the null remained constant and no adverse effects were noted. The vibration tests produced no leakage.

4.3 Open-Loop Response

The tests of paragraph 4.1 were repeated at 120°F except that the rate inputs at ± 5 and ± 15 deg/sec were not run. During these tests, there were indications that the fork in the pedal input mechanism had shifted during vibration with respect to the input lever. The fork and the operating shaft were pinned together as had been done for the suitability program on YG1143. The pedal input device was adjusted back to null with the lever centered, and the response tests were repeated. The system responses are shown in Figures C-1 and C-3 and the system performance after vibration is tabulated in Tables C-1 and C-2.

5.0 INSTRUMENTATION

The following instruments were used for the temperature and response tests:

- Bafco Frequency Response Analyzers 198-3801-002 and 198-3801-004
- Hewlett-Packard X-Y Plotter 827-0603-001
- Pressure Transducer, ± 15 psi, 370-128 with Transducer Demodulator 760-093
- Flowmeter 420-079 and Electronic Counter 175-0527-001
- D.C. Power Supply 510-1933-001
- Test Gage, 100 psi, 360-007
- Pressure Gage, 600 psi, 360-0811-002
- Temperature Potentiometer 320-019
- Temperature Control Unit 589-548
- QE2 Flowbench
- Rotary Hydraulic Actuator

Additions for the vibration test include:

- Sanborn 4-channel Recorder 812-044 with dc Preamp 816-146
- Pressure Transducer, ± 50 psi, 370-1601-004 with Transducer Demodulator 760-103
- Portable Flowbench SP-1
- Vibration Machine and Instrumentation

6.0 RECOMMENDATIONS

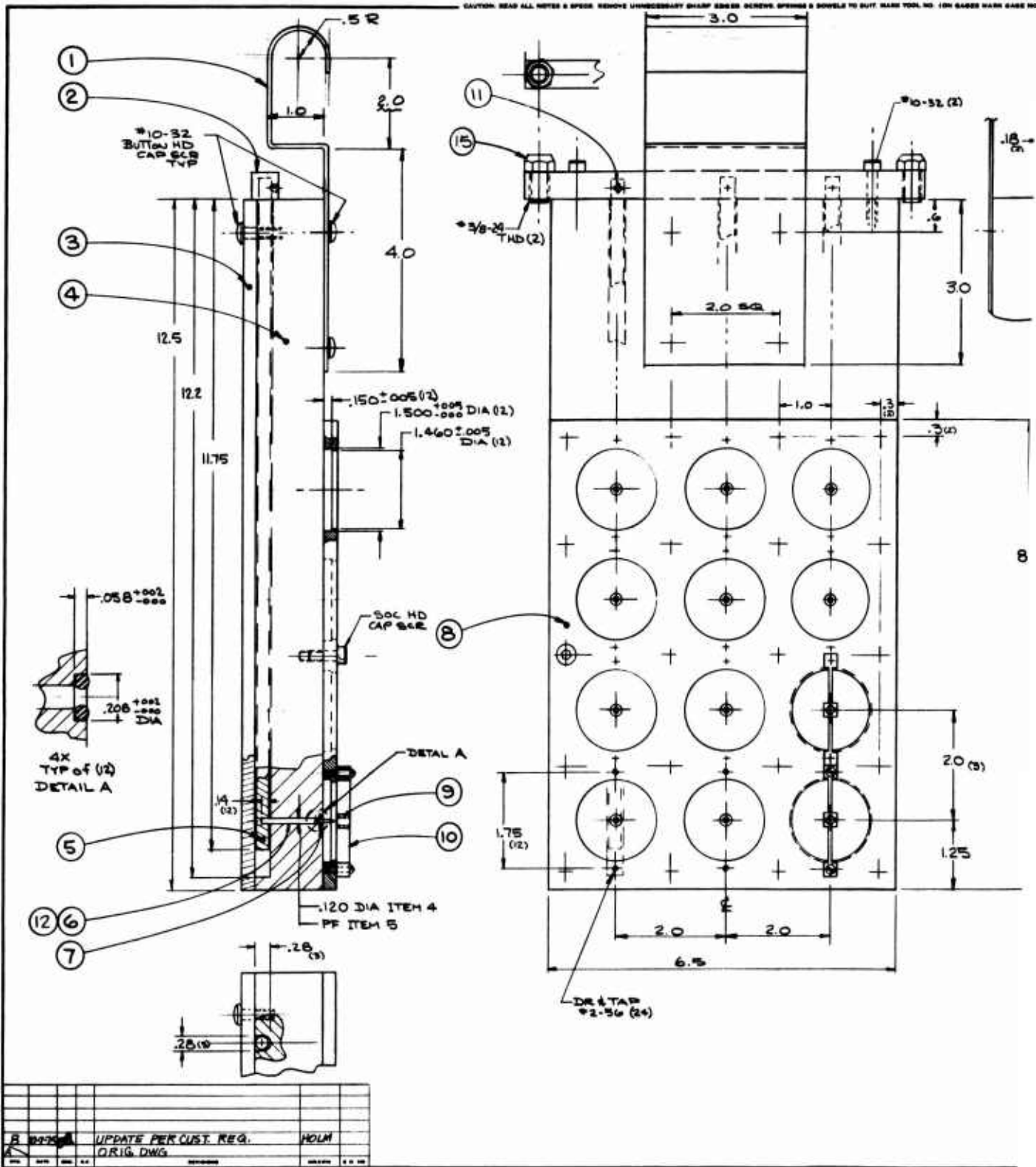
During the prequalification testing, the following changes were proposed:

- Add fixed standoffs to the manifold
- Change some passageways to equalize return pressure drops
- Improve "O"-ring seal configuration in feedback resistors.

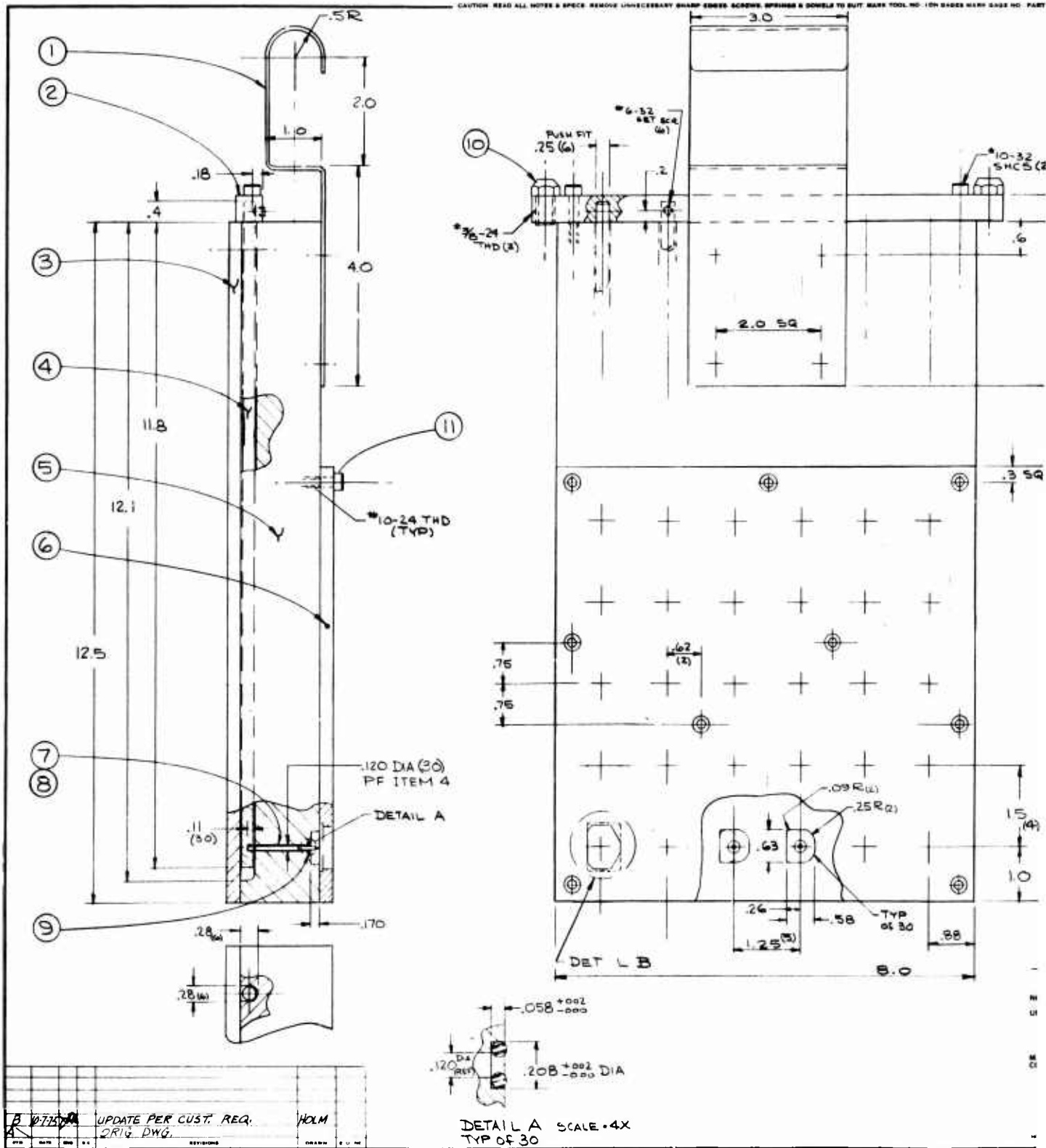
A recommendation is made that additional development work be performed on a system with the proposed changes to reduce noise and temperature sensitivity. Areas to explore include flow and back pressures, feedback resistor configurations, and orifice sizes.

APPENDIX IV
PLATING FIXTURE AND TEST EQUIPMENT DRAWINGS

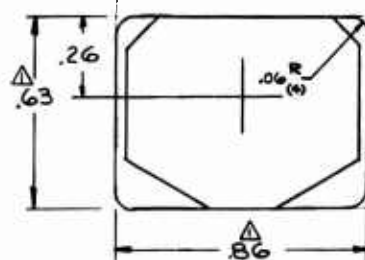
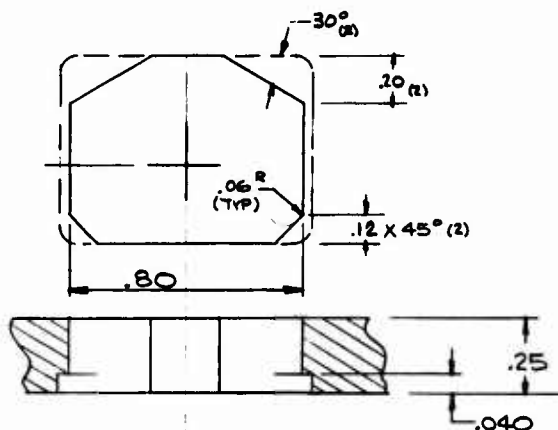
Title	Drawing Number	Page No.
VRS Plating Fixture	YG1158-T16	73
Resistor Plating Fixture	YG1158-T17	75
IC Plating Fixture	YG1158-T18, Sheet 1	77
IC Plating Fixture	YG1158-T18, Sheet 2	79
Fluidics Test Station	YG1158-E100, Sheet 1	81
Fluidics Test Station	YG1158-E100, Sheet 2	83
Fluidics Test Station	YG1158-E100, Sheet 3	85
Fluidics Test Station	YG1158-E100, Sheet 4	87
Fluidics Test Station	YG1158-E100, Sheet 5	89
Fluidics Test Station	YG1158-E100, Sheet 6	91
Test Control Panel	YG1158-E101, Sheet 1	93
Test Control Panel	YG1158-E101, Sheet 2	95
Test Control Panel	YG1158-E101, Sheet 3	97
Hydraulic Test Bench	YG1158-E102, Sheet 1	99
Hydraulic Test Bench	YG1158-E102, Sheet 2	101
Hydraulic Test Bench	YG1158-E102, Sheet 3	103
Amplifier Test Fixture	YG1158-E103, Sheet 1	105
Amplifier Test Fixture	YG1158-E103, Sheet 2	107
Amplifier Test Fixture	YG1158-E103, Sheet 3	109
Amplifier Test Fixture	YG1158-E103, Sheet 4	111
Interface Panel	YG1158-E104	113
Pilot Inp. Transducer	YG1158-E105, Sheet 1	115
Pilot Inp. Transducer	YG1158-E105, Sheet 2	117
Rate Sensor Test Fixture	YG1158-E106, Sheet 1	119
Rate Sensor Test Fixture	YG1158-E106, Sheet 2	121
Rate Sensor Test Fixture	YG1158-E106, Sheet 3	123
Rate Sensor Test Fixture	YG1158-E106, Sheet 4	125
Instrument Panel	YG1158-E107	127







STRIVE TOWARD ERROR-FREE PERFORMANCE



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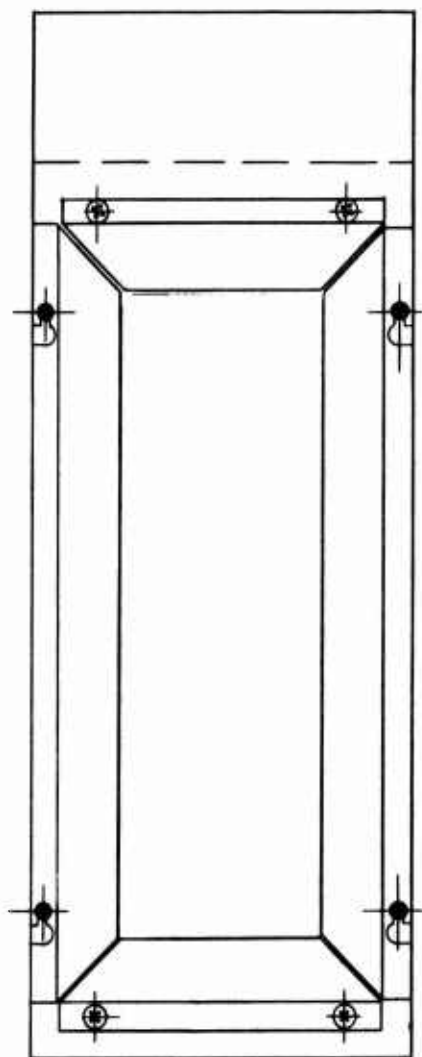


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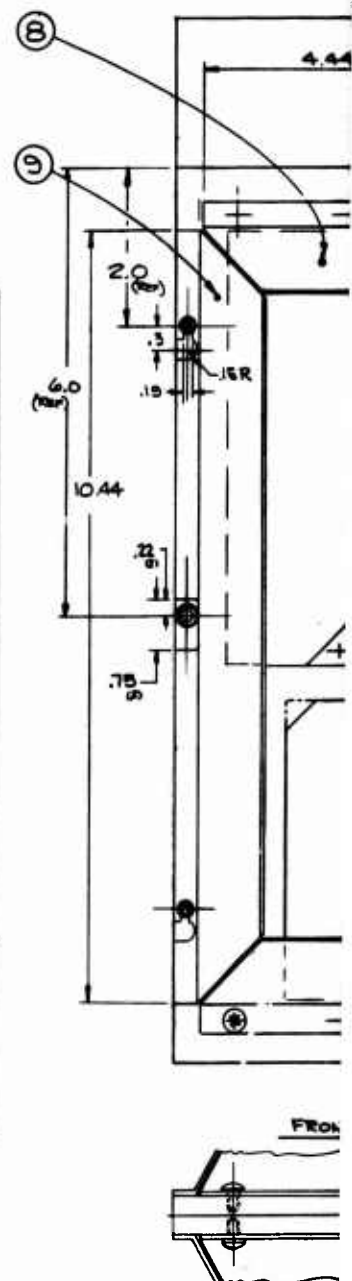
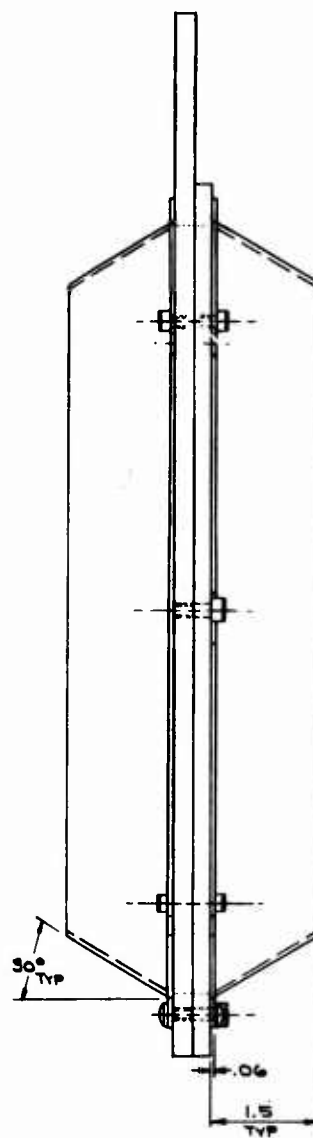
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CAUTION: READ ALL NOTES & OTHER CRITICAL INFORMATION ABOUT THIS PRODUCT BEFORE USING IT. PLEASE SEE THE USER MANUAL FOR MORE DETAILS.

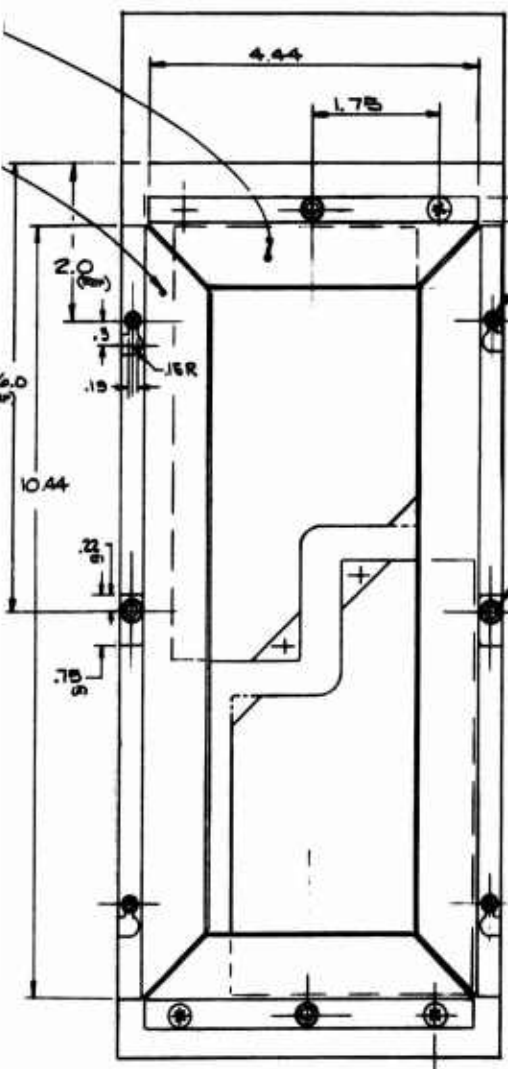


REAR VIEW

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STRIVE TOWARD ERROR-FREE PERFORMANCE

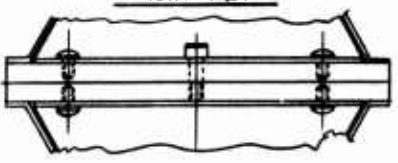
AS TO UNIT, MARK TOOL, NO. (ON GAGE MARK GAGE NO., PART NO., PURCH. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY.



* 8-32
(8) 4 EA SIDE
LONG SHIELDS (4) REMOVABLE

* 10-24 X 1/2 SOCKET HEAD CAP SCREW
(4) THIS SIDE ONLY
HOLD (2) 1/4 PLATES
TOGETHER

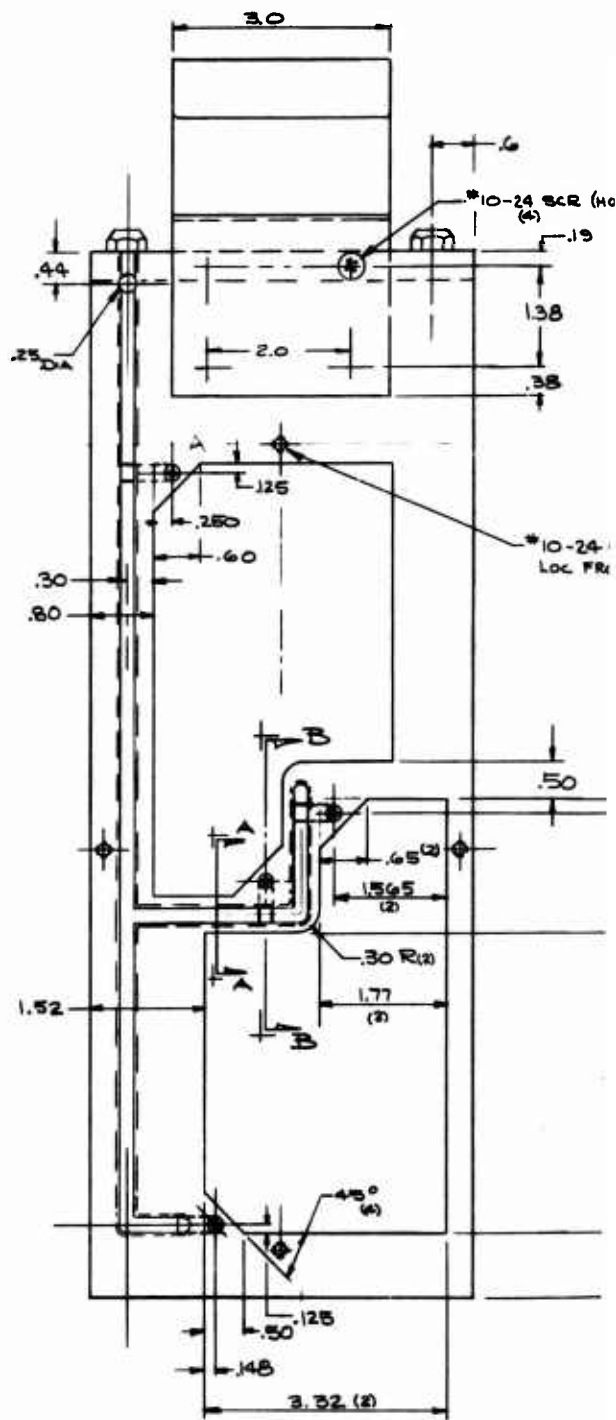
FRONT VIEW



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8	4	SHIELD	1/4 X 2 1/4 X 4 1/2	LUKTB				
7	7	NUT	1/4 X 1/4 X 5/8	BRASS				
6	4	O-RING	M328778-006	STK	SIZE C			
5	1	COVER	1/4 X 5 1/4 X 12		POLYPROPYLENE			
4	1	PLATE	1/4 X 5 1/4 X 14		POLYPROPYLENE			
3	1	BAR	1/8 X 1/2 X 5 1/4	LUKTB				
2	2	RAWT BRASS JACK	* 187	PUR	HH SMITH			
1	1	HOOK	1/4 X 3 X 5 1/4	68				

TOLERANCES UNLESS NOTED		DESIGNED FOR		DATE		Honeywell	
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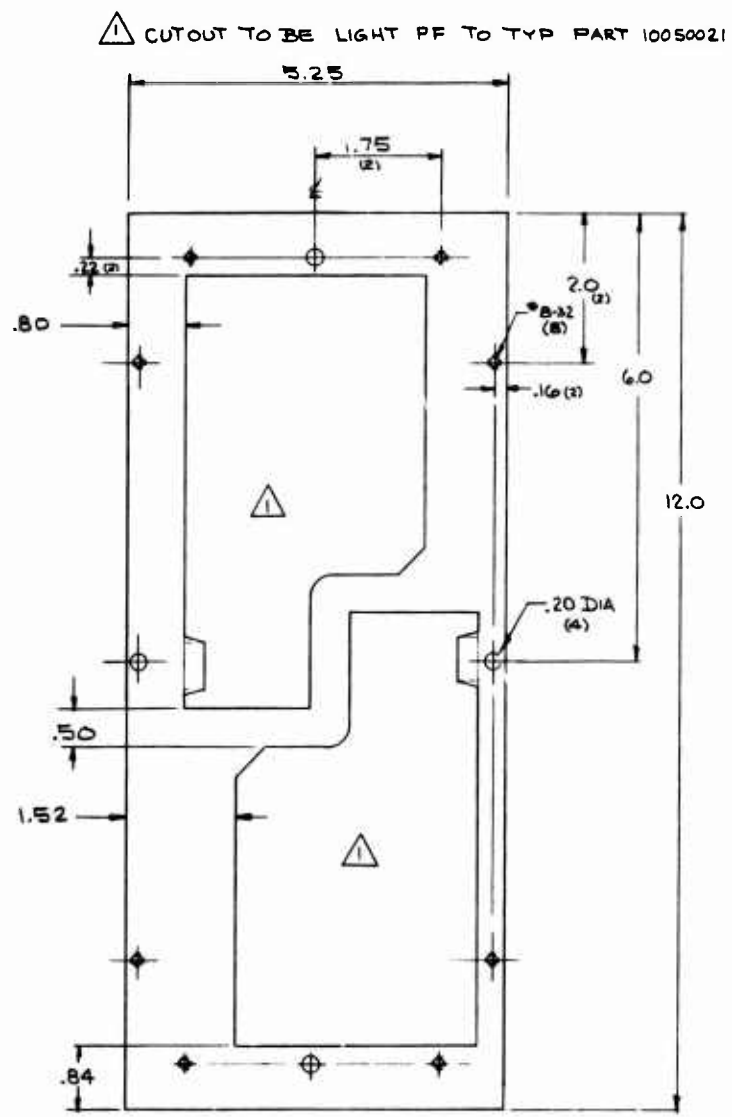
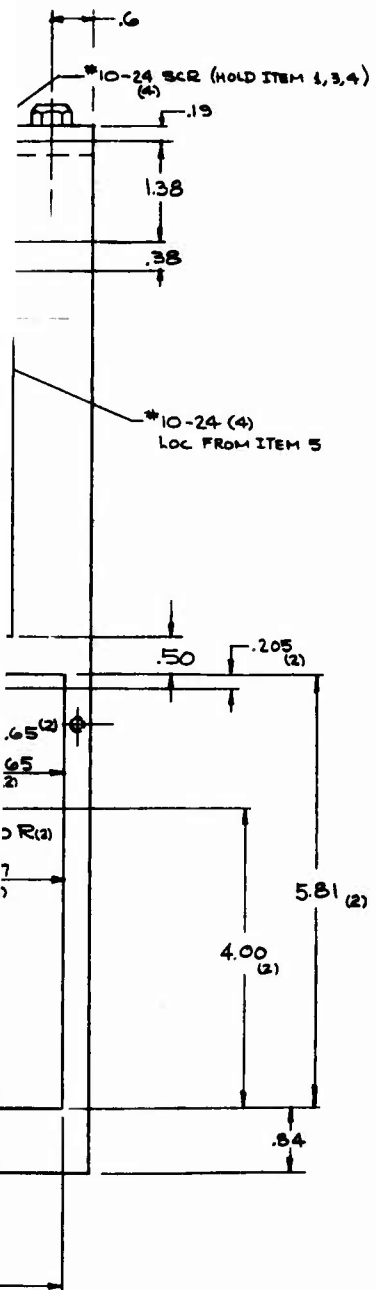
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STRIVE TOWARD ERROR-FREE PERFORMANCE

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MAIN TOOL NO. 100 BARS MARK GAGE NO., PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY

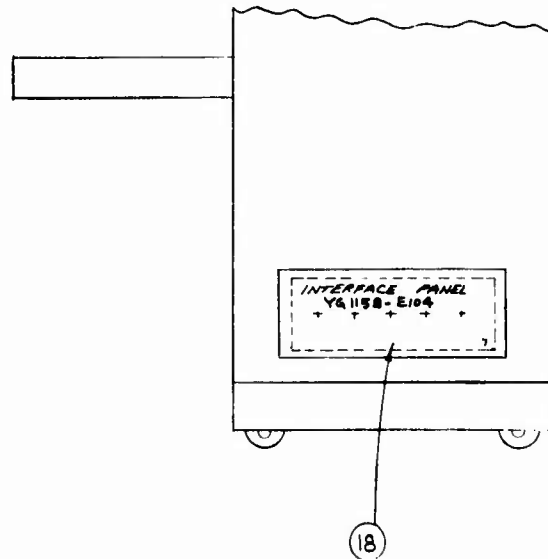
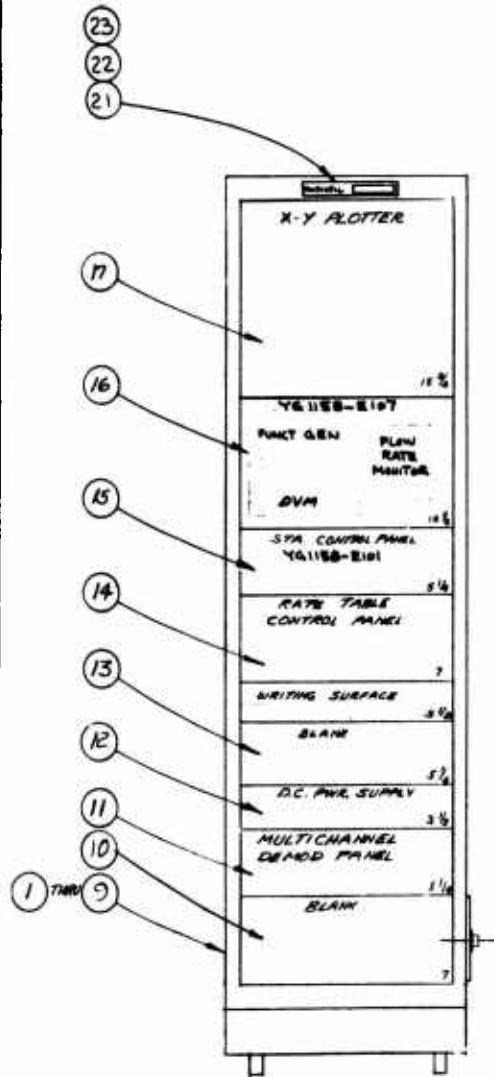


⑤ 1/4 x 5/4 x 12
POLY PROPYLENE

REV	NO	NAME	FINISHED SIZE	MAT'L	HEAT TR	MAT'L USED	QTY	UNIT	TOTAL
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DESIGNED FOR DATE 1/7/8 PIECES 300 NAME IC PLATING FIXTURE PART 10050021 QTY 2 NO SHEETS 2 SHEET NO 1 BY YG1158-T18									
DRAWN RAYA CHECKED APP'V ENG. G.C.									

CHK NO TOOL NO BIN CHK TO

CAUTION: READ ALL NOTES & SPECS. REMOVE UNNECESSARY SHARP EDGED SCREWS, SPRINGS & BOWELS TO SUIT MARK TOOL NO. 1 ON SAGEE MARK 64



△ SUPPLIER W/RA

REV	DATE	BY	CHK	APP	DESCRIPTION	DATE
1	7/72				UPDATE PER CUST. REQ.	HOLM
					ORIGINAL	

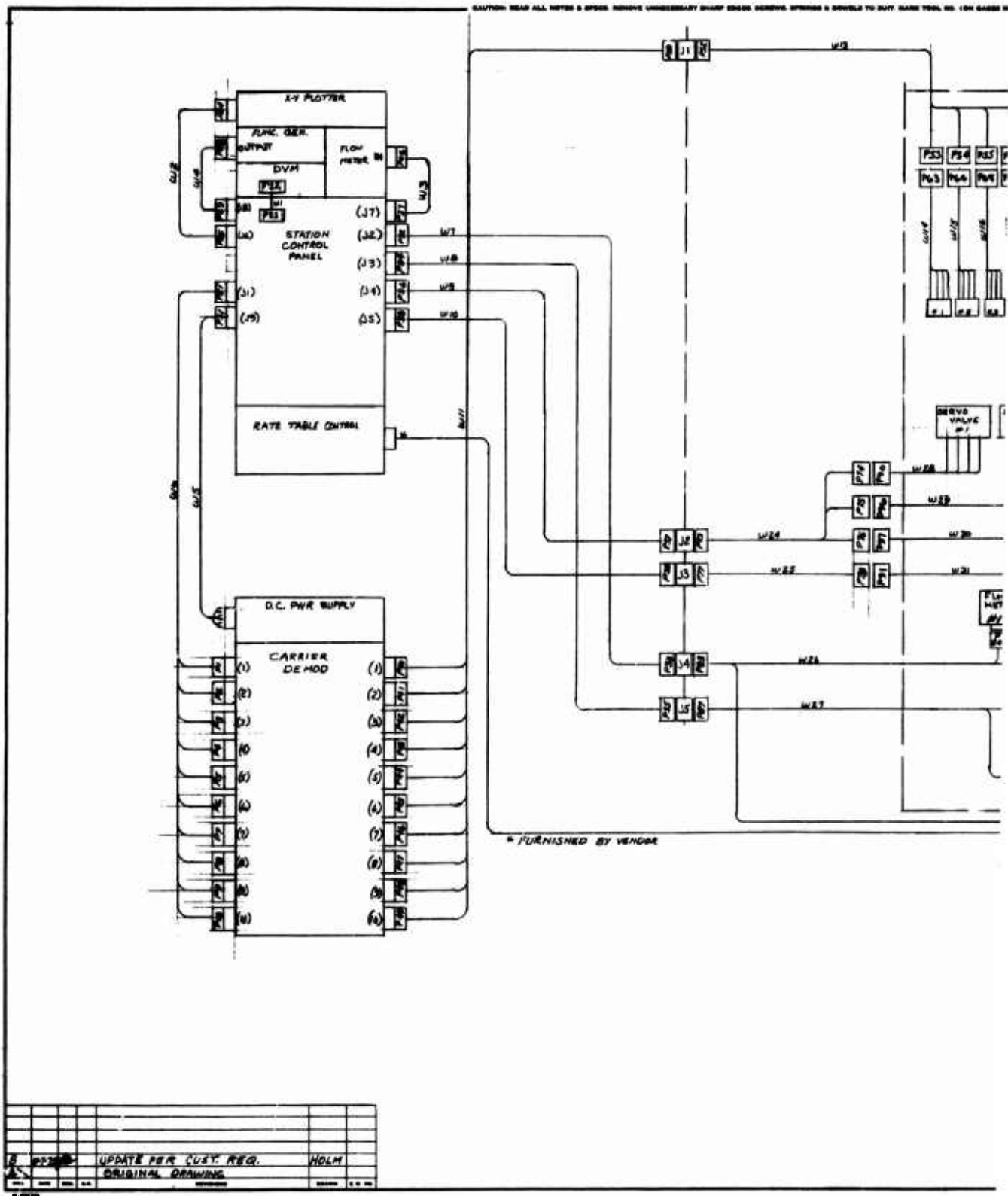
STRIVE TOWARD ERROR-FREE PERFORMANCE

SUIT MARK TOOL NO. (ON BASES MARK BASE NO. PART NO. FUNCT. OF BASE & LAST REV. LETTER). DON'T FORGET SAFETY.

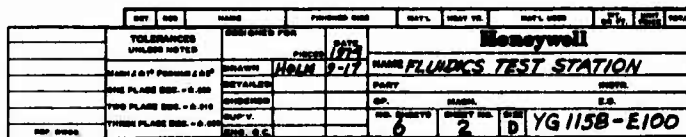
P95	58	1	CONNECTOR	BENDIX * PTO1A-8-4S (SR)	PUR
P93	57	1		MS3106A-28-21P (SR)	Δ
P92	56	1		BENDIX * PTO6-8-4P (SR)	PUR
P91	55	1		BENDIX * PTO1-1-M-SP (SR)	PUR
P86	54	1		MS3106A-28-21P (SR)	Δ
P84, 85	53	3		MS3106A-10SL-4S	Δ
	52				
P28, 29	51	2		AMPH * 31-002	PUR
P27	50	1		BENDIX * PTO6A-8-4S (SR)	PUR
P26	49	1		MS3106A-10SL-3S	Δ
P25	48	1		BENDIX * PTO6A-12-10P (SR)	PUR
P23, 24	47	2	CONNECTOR	POMONA * 2970	PUR
P51	46		NOT USED		
P24	45	1	CONNECTOR	CIMEX * DEM-31P	Δ
P78	44	1	CONNECTOR	BENDIX * PTO6A-14-5S (SR)	PUR
P63, P72	43	13	CONNECTOR	BENDIX * PTO6A-8-4H (SR)	PUR
P58, P64, P76	42	13	CONNECTOR	BENDIX * PTO1A-8-4S (SR)	PUR
P52	41	1	CONNECTOR	BENDIX * PTO6A-20-41P (SR)	PUR
P50	40	1	CONNECTOR	BENDIX * PTO6A-20-41S (SR)	PUR
P40-P43	39	10	CONNECTOR	CANNON * WK4-21C	PUR
P31, 39	38	2	CONNECTOR	BENDIX * PTO6A-14-5S (SR)	PUR
P38, P77	37	2	CONNECTOR	BENDIX * PTO6A-14-5P (SR)	PUR
P35	36	1	CONNECTOR	BENDIX * PTO6A-16-8S (SR)	PUR
P34, 87	35	2	CONNECTOR	BENDIX * PTO6A-16-8P (SR)	PUR
P33, P37	34	2	CONNECTOR	BENDIX * PTO6A-14-5S (SR)	PUR
P32, P36, P73, P83	33	4	CONNECTOR	BENDIX * PTO6A-14-15P (SR)	PUR
P21	32	1	CONNECTOR	BENDIX * PTO6A-20-39P (SR)	PUR
P11, P20	31		(NOT USED)		
P1-P10	30	10	CONNECTOR	CANNON * ALR-3-11C	PUR
	29	3	CLAMP	MS3057-12B	PUR
	28	15	CLAMP	MS3057-8B	AIA
	27	2	CLAMP	MS3057-10B	PUR
	26	26	CLAMP	MS3057-3B	PUR
	25				
	24				
	23	1	METAL LABEL	PER SHT 6	
	22	2	CLIP	HON 10023544-101	
	21	1	IDENT PLATE	HON 10023543	
	20				
	19				
	18	1	INTERFACE PANEL	YG 115B-E104	
	17	1	X-Y PLOTTER	HEWLETT-PACKARD MODEL # 7044A, OPTION 001, 002, 003A, 004A, 1201, 605E, 100A	
	16	1	INSTRUMENT PANEL	YG 115B-E107	
	15	1	STA. CONTROL PANEL	YG 115B-E101	
	14	1	RATE TABLE	PEROTECH # ART100-1	
	13	1	CONTROL PANEL		
	12	1	BLANK PANEL		5 1/4"
	11	1	D.C. POWER SUPPLY	HEWLETT PACKARD #6289A	
	10	1	MULTICHANNEL DEMOD. PANEL	VALIDDYNE #MC-110	
	9	1	BLANK PANEL		7"
	8	1	POWER STRIP	WABER # 70SCB-15	
	7	1	CABINET FRAME	MONEYWELL # 41H19	
	6	1	BOT. PANEL	# 15PG	
	5	1	L. SIDE PANEL	# H0LK	
	4	1	R. SIDE PANEL	# F9RK	
	3	1	ANTI-TILT BASE	# ATB15-25-4	
	2	1	REAR DOOR	# H1AW	
	1	1	CABINET WRITING SURF.	MONEYWELL # W331B-25-1	

Δ SUPPLIED BY VENDOR
W/ RATE TABLE

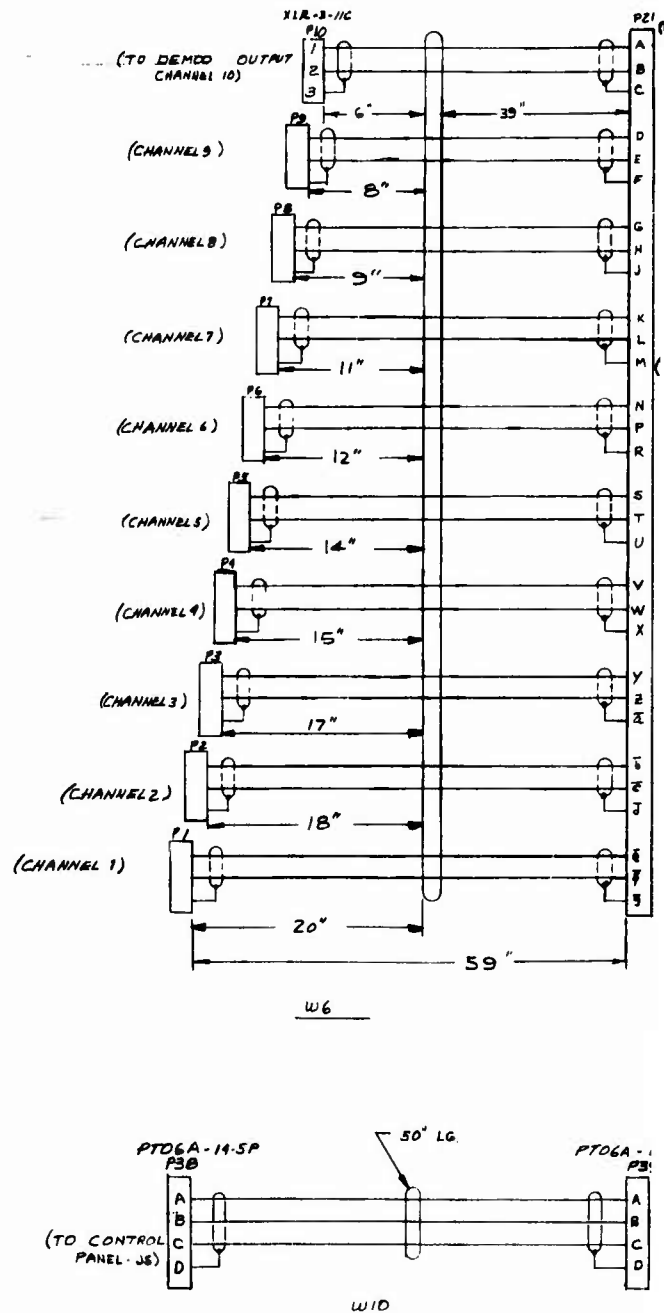
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STRIVE TOWARD ERROR-FREE PERFORMANCE



CAUTION: WEAR ALL PROTECTIVE GEAR. REMOVE UNNECESSARY SHARP EDGES, SCREWS, SPRINGS & BOWELS TO SUIT MARK TOOL NO. (ON CASES MARK CASE NO. PART NO.

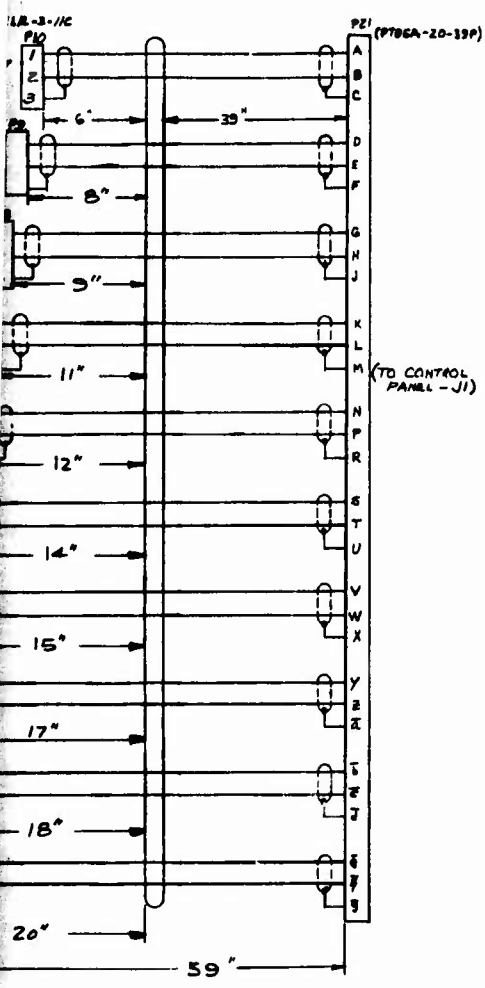


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| 1/1/78 | 10:00 | W. J. H. M. | UPDATE PER CUST. REQ.
ORIENTAL DRAWING | 1/1/78 | 10:00 | W. J. H. M. | UPDATE PER CUST. REQ.
ORIENTAL DRAWING |

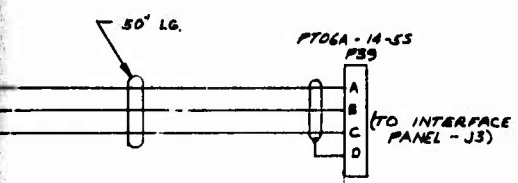
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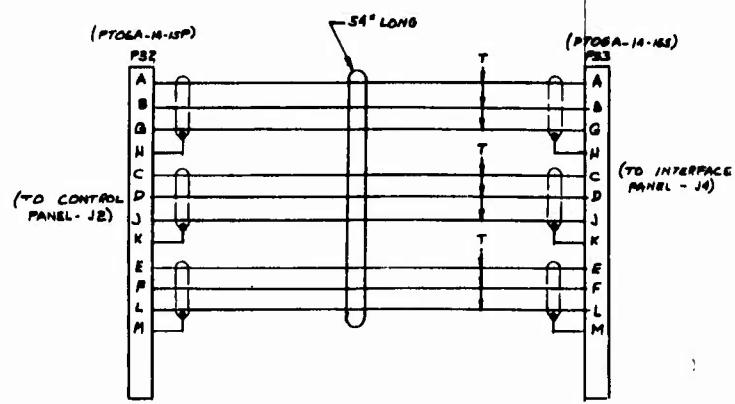
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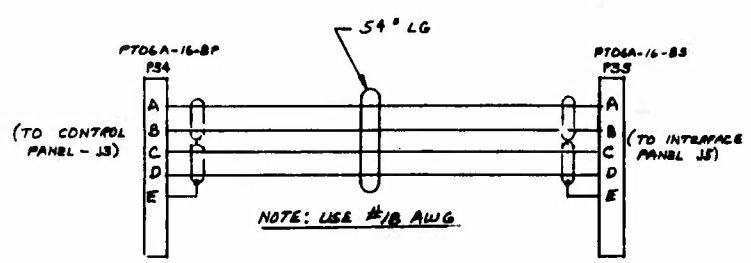
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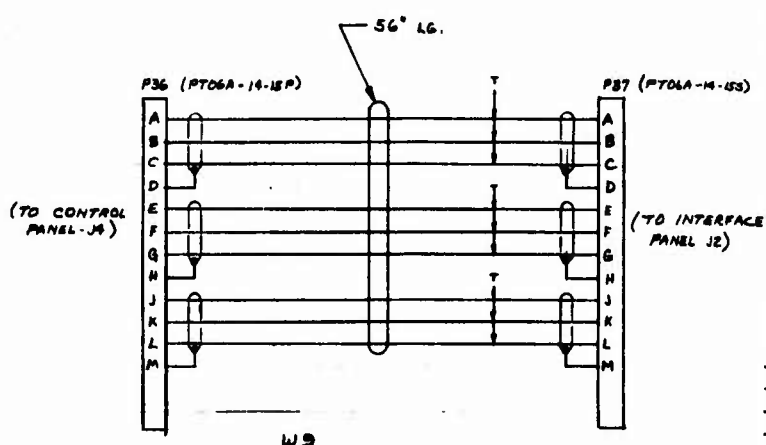
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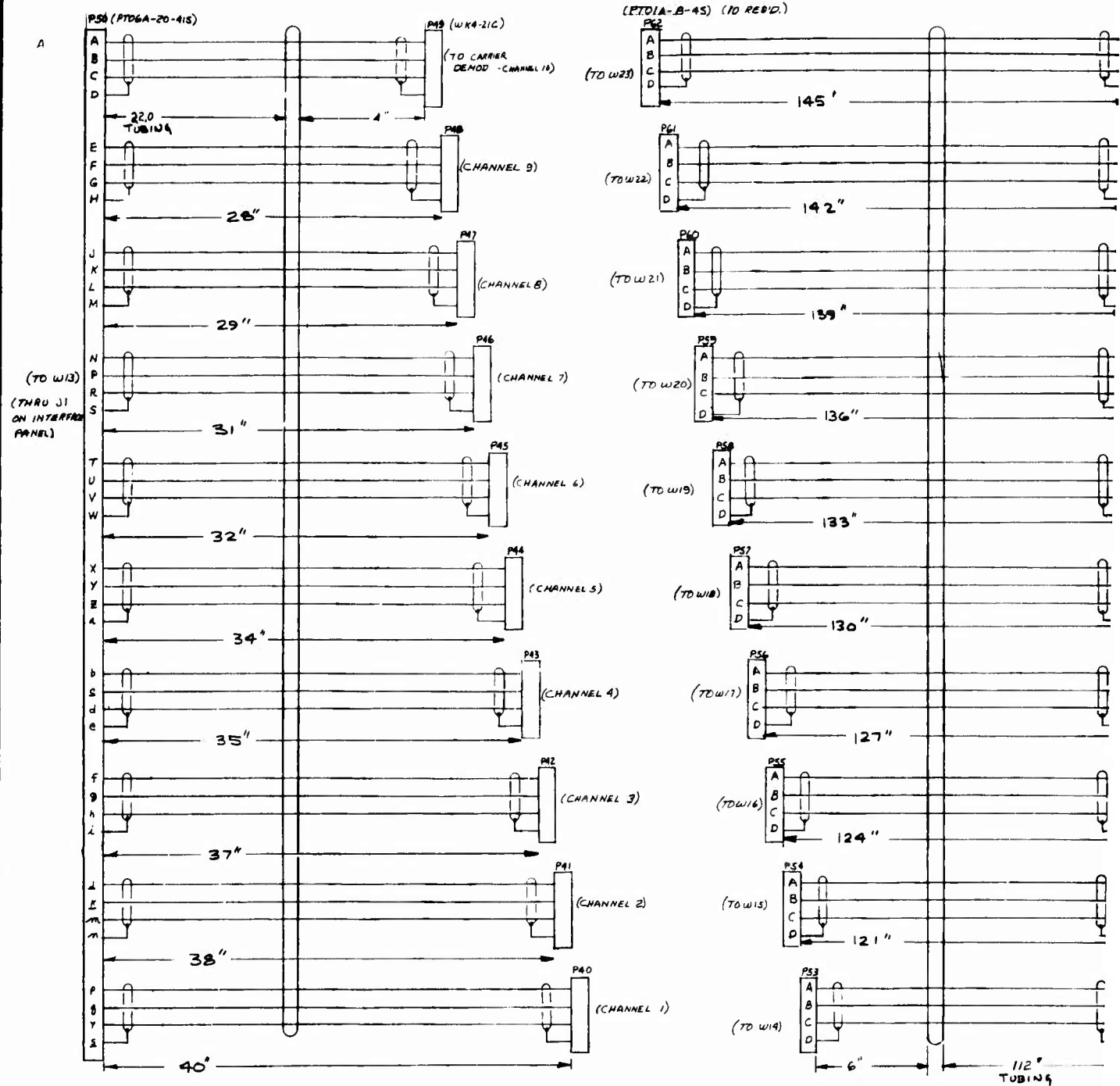
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CAUTION READ ALL NOTES & SPECS REMOVE UNNECESSARY SHARP EDGES SCREWS SPRINGS & DOWELS TO SUIT MARK TOOL NO 10N BASES MARK BASE NO PART

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W13

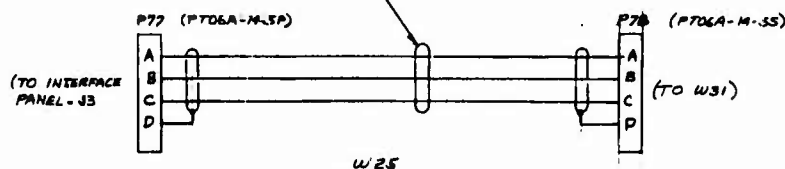
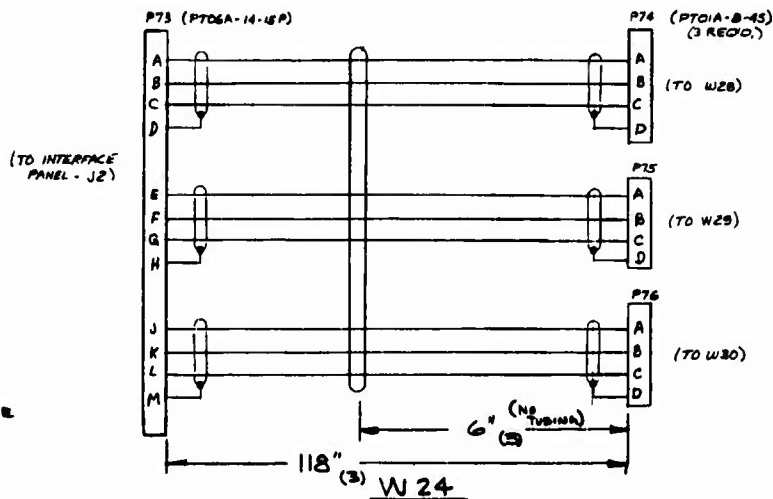
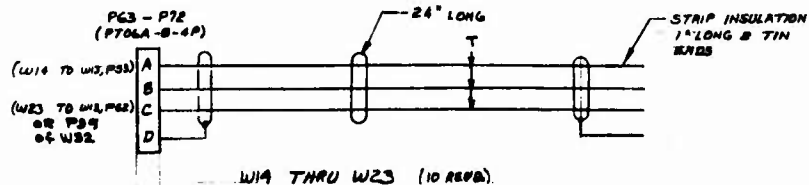
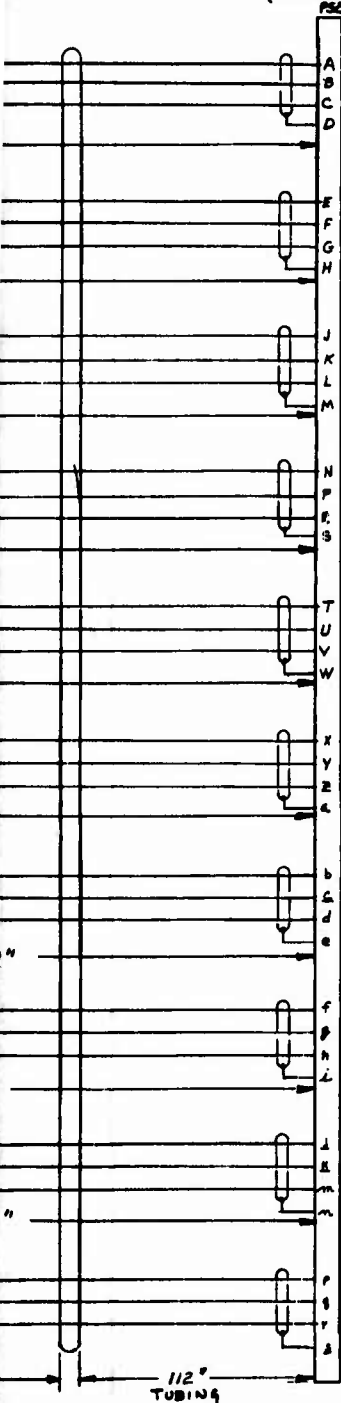
[illegible]

STRIVE TOWARD ERROR-FREE PERFORMANCE

1 TO GUY. MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., POINT, OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY

2

(PTDGA-B-41P)



W13

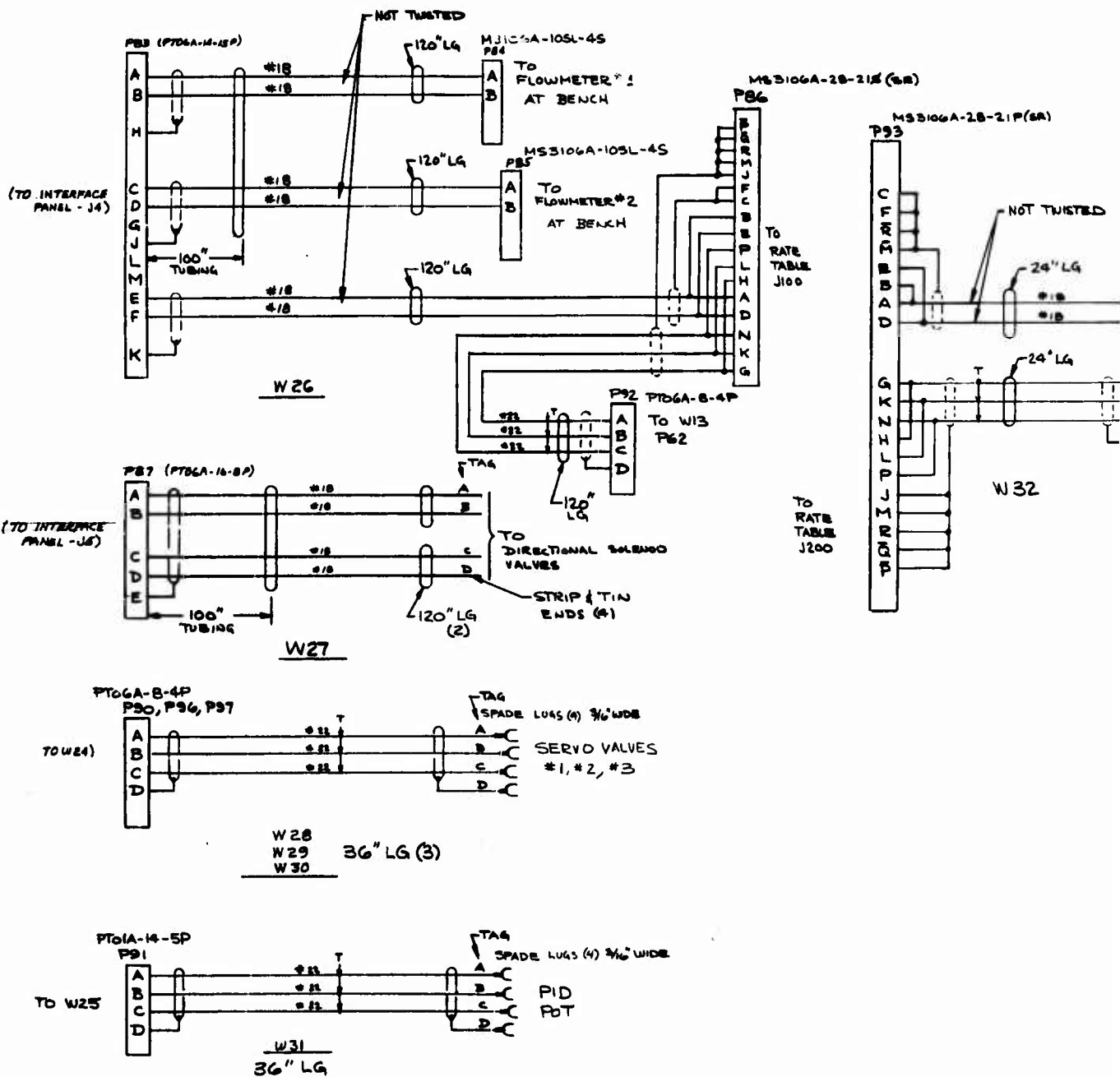
REV	REV	NAME	FORWARDED ONE	DATE	REV TO	DATE USED	REV TO	DATE USED	TOTAL
TOLERANCES UNLESS NOTED					Honeywell FLUIDICS TEST STATION				
DRAWN					PART				
CHECKED					DATE				
THICK PLATE DIM. ± 0.010					NO. OF SHEETS				
THIN PLATE DIM. ± 0.010					SHEET NO.				
CNC. NO.					CNC. TO				

CAUTION: READ ALL NOTES & SPCS REMOVE UNNECESSARY SHARP EDGES SCREWS SPRINGS & DOWELS TO SUIT MARK TOOL NO (ON GAGES MARK GAGE NO. PART

STRIVE TOWARD ERROR-FREE PERFORMANCE



CAUTION: READ ALL NOTES & SPECS. REMOVE UNNECESSARY SHARP EDGES, SCREWS, SPRINGS & BOWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO.)



REV.	DATE	BY	CHK.	APP.	DATE	BY	CHK.	APP.	DATE	BY	CHK.	APP.
1	10/1/78											
UPDATE PER CUST. REQ.										HOLM		
ORIGINAL DRAWING												

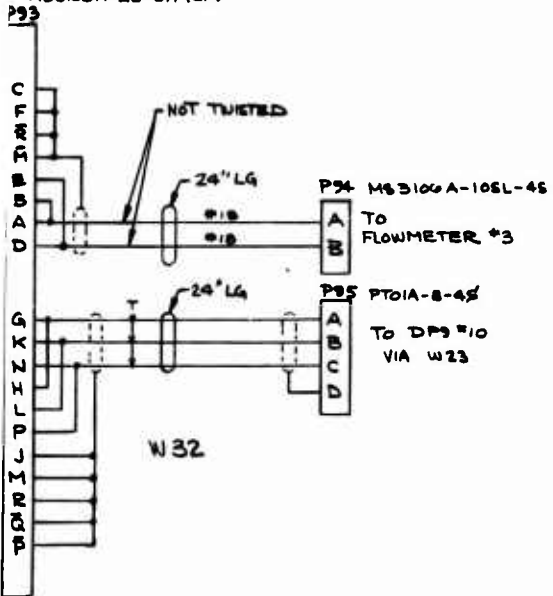
STRIVE TOWARD ZERO-DEFECT PERFORMANCE

2

REFERS TO BUT: MARK TOOL NO. (ON GAGE MARK GAGE NO. PART NO. FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY

1(68)

M53106A-2B-21P(6A)



REV	REV	NAME	PREPARED BY	DATE	REV	REV	REV	REV	REV	REV	REV
TOLERANCES UNLESS NOTED			DESIGNED FOR		Honeywell						
MACH & DTP FORMER & DTP			DRAWN		DATE		NAME FLUIDICS TEST STATION				
ONE PLACE DEC. - A 0.00			DETAILS		PART		REV.				
TWO PLACE DEC. - A 0.01			CHECKED		OP.		E.D.				
THREE PLACE DEC. - A 0.001			IN P.Y.		NO. SHEETS		6				
REF. CODE			529.35		REV. NO.		5				
					REV. NO.		D				
					REV. NO.		YG 115B-E100				

CHG. NO. TOOLIN DW CHG. YG

MARK TOOL NO. YG 1158-E100

DON'T FORGET SAFETY

L

YG1158 E100

FLUIDICS TEST STATION

L

MAKE METAL LABEL
BLACK LETTERS

BYM	DATE	ORIG	REVISIONS	DESIGNED FOR	PIECES	DATE
B 10-15-74			UPDATE PER CUST. REQ.		RAY A	1974
A			ORIG. DWG			21 SEPT
TOLERANCES UNLESS NOTED			MACH $\pm .01$ FORMED $\pm .02$			
ONE PLACE DEC. $\pm .009$			ONE PLACE DEC. $\pm .010$			
TWO PLACE DEC. $\pm .010$			THREE PLACE DEC. $\pm .009$			
MACH. DWGS.			ENG. Q.C.			

Honeywell

NAME FLUIDICS TEST STATION

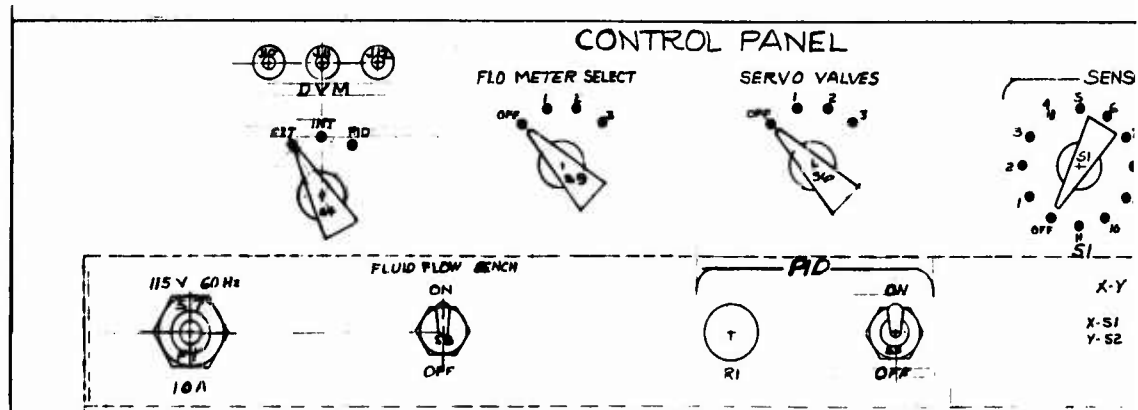
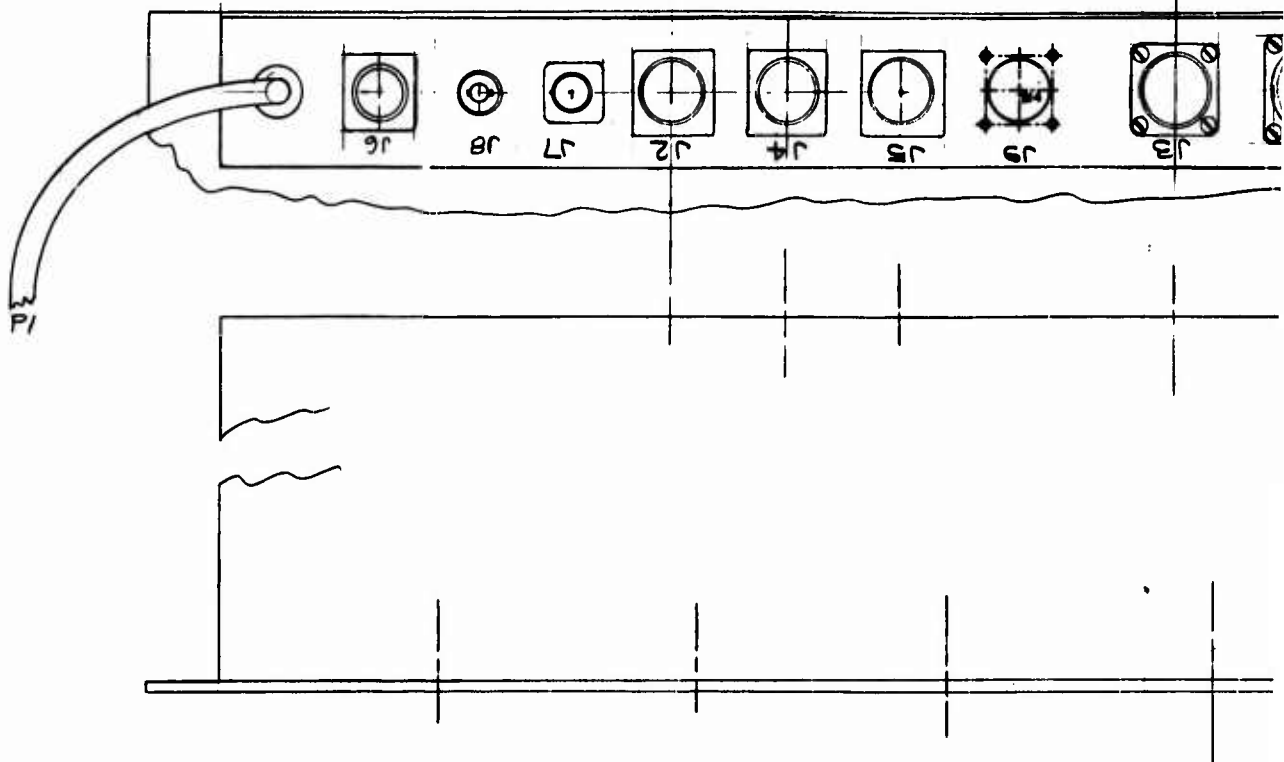
PART INSTR. E.O.

OP. MACH. E.O.

NO. SHEETS 6 SHEET NO. 6 SIZE A YG 1158-E100

STRIVE TOWARD ERROR-FREE PERFORMANCE

CAUTION: READ ALL NOTES & SPECS. REMOVE UNNECESSARY SHARP EDGES, CORNERS, SPINDLES & BOWELS TO SUIT. MARK TOOL NO. FOR GAGE MARK CASE H

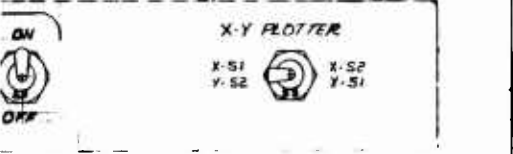
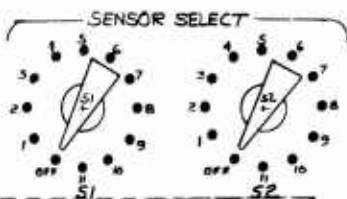
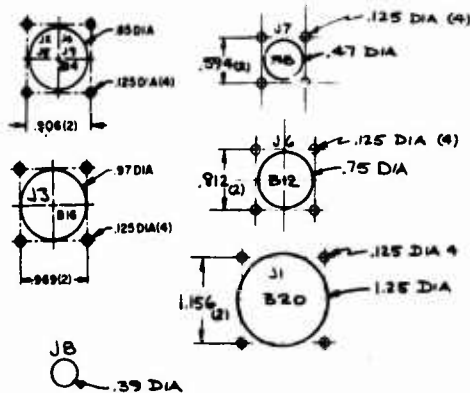
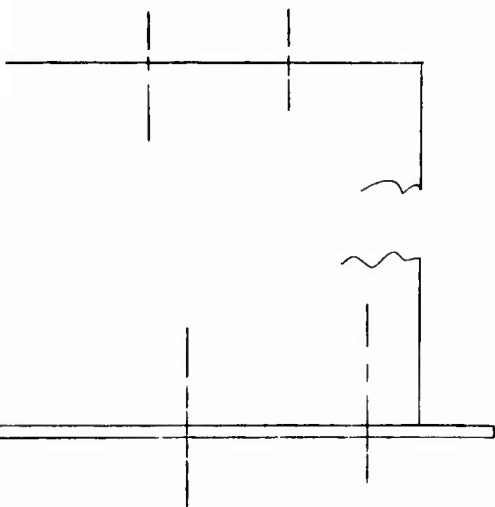
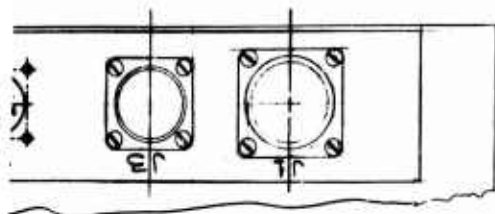


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1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100

STRIVE TOWARD ZERO-DEFECT PERFORMANCE

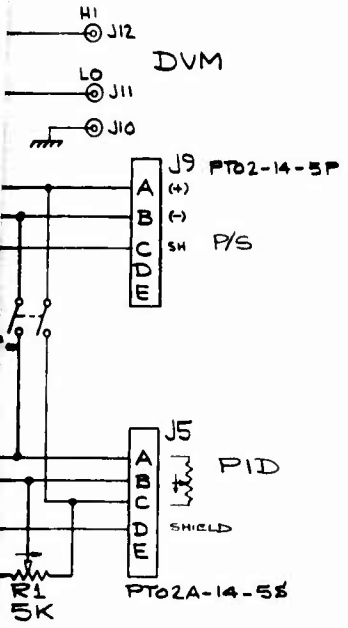
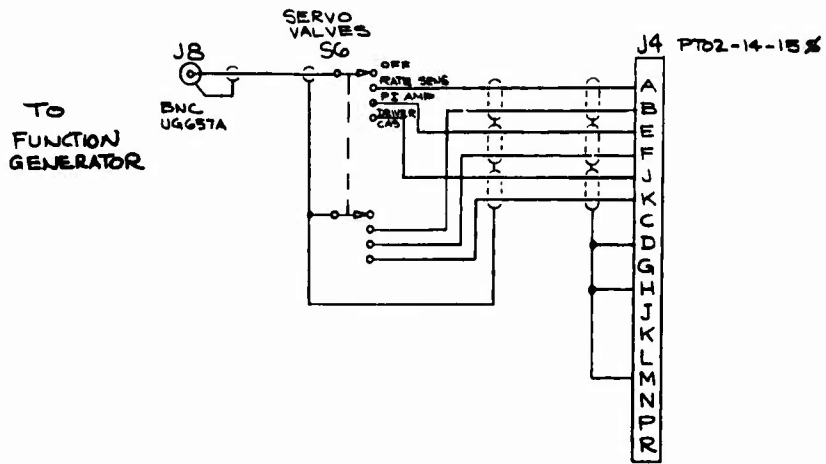
2

© BUY MARK TOOL NO. (ON GAGE MARK GAGE NO. PART NO. FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY.



R1	24	1	POTENTIOMETER	AMPHENOL 4201B	10 TURN	5K																																																																																																			
J12	23	1	BANANA JACK	EF JOHNSON *108-0902-001		RED																																																																																																			
J11	22	1	BANANA JACK	EF JOHNSON *108-0903-001		BLK																																																																																																			
J10	21	1	BANANA JACK	EF JOHNSON *108-0901-001		WHT																																																																																																			
XS1,2,4,6,9	20	5	KNOB	WALDOM *WA2300	67-166	OR 67-163																																																																																																			
S7	19	1	SWITCH	ROWAN FCA-W-R																																																																																																					
	18																																																																																																								
S5,8	17	2		MICRO BA2011																																																																																																					
S4,6,9	16	3		OAK 399-477-JC																																																																																																					
S3	15	1		MICRO BA4011																																																																																																					
S1,2	14	2	SWITCH	OAK 399-471-JC																																																																																																					
XP1	13	1	STRAIN RELIEF	HEVCO SR-GPA-4																																																																																																					
P1	12	1	POWER CORD	BELDEN *1740B-B																																																																																																					
J9	11	1	CONNECTOR	PT02A-14-5P																																																																																																					
J8	10	1		AMPH*31-102		BNC																																																																																																			
J6	9	1		PT02A-12-10S																																																																																																					
J5	8	1		PT02A-14-5S																																																																																																					
J7	7	1		PT02A-8-4P																																																																																																					
J3	6	1		PT02A-16-BB																																																																																																					
J2,4	5	2		PT02A-14-15S																																																																																																					
J1	4	1	CONNECTOR	PT02A-20-39B																																																																																																					
F1	3	1	FUSE	10AMP 1/4" X 1/4"																																																																																																					
	2	1	CHASSIS	BUD *AC-1416		2X7X17																																																																																																			
	1	1	PANEL	BUD *PA-1103		5 1/4"																																																																																																			
<table><tr><td>DES</td><td>QTY</td><td>NAME</td><td>DESCRIPTION</td><td>DATE</td><td>BY</td><td>UNIT</td><td>PRICE</td><td>TOTAL</td></tr><tr><td colspan="9">Honeywell</td></tr><tr><td colspan="3">TOLERANCES UNLESS NOTED</td><td>DESIGNED FOR</td><td>DATE</td><td colspan="4"></td></tr><tr><td colspan="3"></td><td>*RECD</td><td>1974</td><td colspan="4"></td></tr><tr><td colspan="3">MACH & 1/2 FORMULA & 0.01</td><td>DRAWN</td><td>RAYA</td><td>12/24</td><td colspan="3">NAME TEST CONTROL PANEL</td></tr><tr><td colspan="3"></td><td>DETAILED</td><td colspan="4">PART</td><td>INSTR</td></tr><tr><td colspan="3">ONE PLACE DEC = 0.000</td><td>CHECKED</td><td colspan="4">QTY</td><td>EO</td></tr><tr><td colspan="3"></td><td>EXP V</td><td colspan="4">NO SHEETS</td><td>MACH</td></tr><tr><td colspan="3">TWO PLACE DEC = 0.010</td><td>ENG JC</td><td colspan="4">SHEET NO</td><td>EO</td></tr><tr><td colspan="3"></td><td></td><td colspan="4">3</td><td>D YG 1158-E101</td></tr><tr><td colspan="3">REF DIMS</td><td></td><td colspan="4"></td><td></td></tr></table>							DES	QTY	NAME	DESCRIPTION	DATE	BY	UNIT	PRICE	TOTAL	Honeywell									TOLERANCES UNLESS NOTED			DESIGNED FOR	DATE								*RECD	1974					MACH & 1/2 FORMULA & 0.01			DRAWN	RAYA	12/24	NAME TEST CONTROL PANEL						DETAILED	PART				INSTR	ONE PLACE DEC = 0.000			CHECKED	QTY				EO				EXP V	NO SHEETS				MACH	TWO PLACE DEC = 0.010			ENG JC	SHEET NO				EO					3				D YG 1158-E101	REF DIMS								
DES	QTY	NAME	DESCRIPTION	DATE	BY	UNIT	PRICE	TOTAL																																																																																																	
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			DETAILED	PART				INSTR																																																																																																	
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TWO PLACE DEC = 0.010			ENG JC	SHEET NO				EO																																																																																																	
				3				D YG 1158-E101																																																																																																	
REF DIMS																																																																																																									

RENDER & BOWELS TO SUIT MARK TOOL NO. (ON SAGES MARK SAGE NO., PART NO., FUNCY OF SAGE & LAST REV LETTER) DON'T FORGET SAFETY

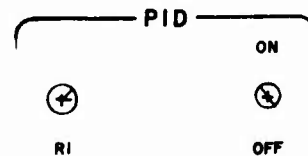
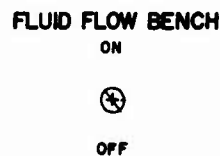
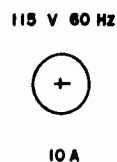
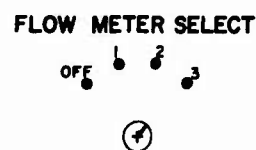
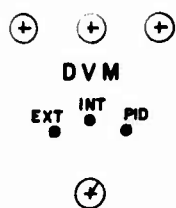


DET	DES	NAME	FINISHED SIZE	MAT'L	HEAT TR	MAT'L VOLT	WT	UNIT PRICE	TOTAL
Honeywell									
DESIGNED FOR									
DRAWN RAY A									
NAME TEST CONTROL PANEL									
PART									
CHECKED									
MACH									
NO SHEETS									
SHEET NO									
DIN									
Y61158-E101									

PRECEDING PAGE BLANK NOT FILMED

CAUTION: READ ALL NOTES & SPECS. REMOVE UNNECESSARY SHARP EDGES, SCREWS, SPRINGS & DOWELS TO SUIT. MARK TOOL NO. 1 ON GAGES MARK GAGE NO., PART NO., FUNCT. OF GAGE & LA

CONTROL PANEL



$\oplus$.265 DIA (3)

$\oplus$.313 DIA (3)

$\oplus$.390 DIA (6)

$\oplus$.750 DIA.

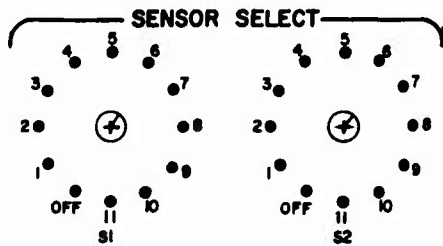
REV.	DATE	ENG.	Q.C.	REVISIONS	DRAWN	Q.C. NO.
B	10-1-75			UPDATE PER CUST. REQ.	HOLM	
A				ORIGINAL DRAWING		

DET.	DES.	NAME

CHG. NO.

INK GAGE NO., PART NO., FUNC. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY

3



X-Y PLOTTER

ON



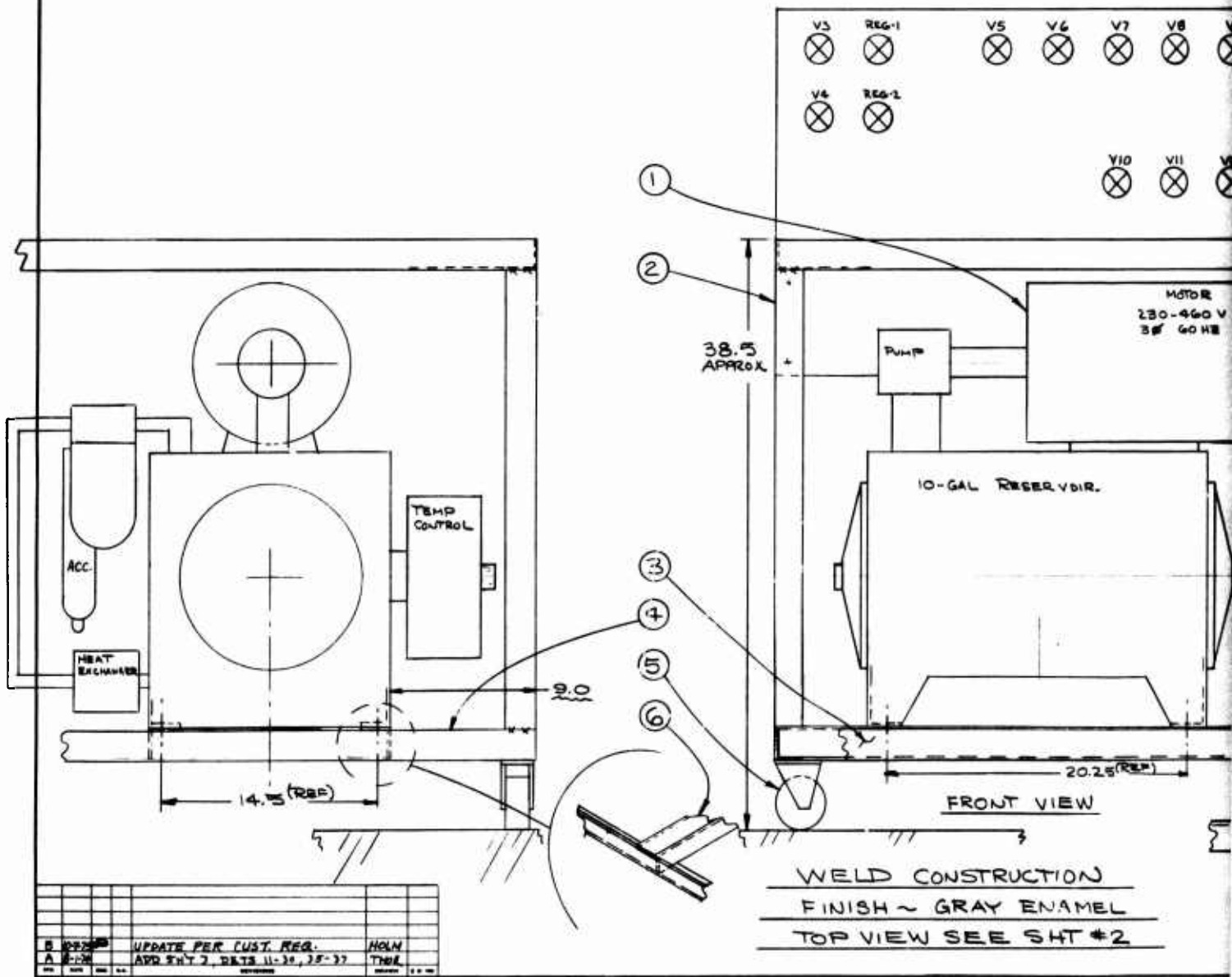
OFF

X-81 X-82
Y-82 Y-81

DET.	ORG.	NAME	PRINTED NAME	BAT'L	HEAT NO.	BAT'L USED	NO. OF LETT.	UNIT NO.	TOTAL
TOLERANCES UNLESS NOTED			DESIGNED FOR	DATE	Honeywell				
DRAWN			PIECES	1974	NAME TEST CONTROL PANEL				
MAG. & 1" FORMS & 2"			JHA	6-19	PART		INTR.		
ONE PLACE DEC. - & 0.000			DETAILED		OP.		MAGH. E.G.		
TWO PLACE DEC. - & 0.01			CHECKED		NO. SHEETS		SHEET NO.		
THREE PLACE DEC. - & 0.001			SUP'Y.		3		3		
ENG. G.C.					YG 1158-E101				
CNS. NO.			TOOLING		SIN.		CNS. TO		

CAUTION: READ ALL NOTES & SPECS. REMOVE UNNECESSARY SHARP EDGES, SCREWS, SPRINGS & BOWELS TO SUIT. MARK TOOL NO. (ON CASE) MARK CASE NO. PART NO. PO

SCALE = 1/4



STRIVE TOWARD ERROR-FREE PERFORMANCE

2 RATING 6000PSIG, STAINLESS STEEL BODY,
T-BAR ADJ. HANDLE, 1/4" AN PORTS

V10 V11 V12

MOTOR
230-460 V
3Ø 60 HZ

●-GAL RESERVOIR

30.0

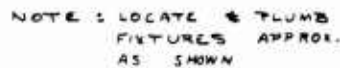
20.25 (R)

FRONT VIEW

CONSTRUCTION
GRAY ENAMEL
SEE SHT #2

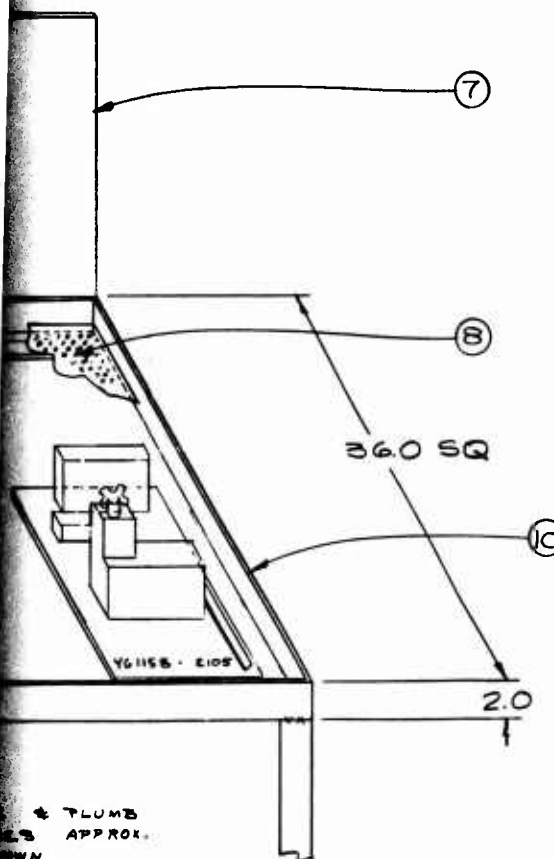
[illegible]

CAUTION: READ ALL NOTES & SPEC. REMOVE UNNECESSARY SHARP EDGES, SCREWS, SPRINGS & BOWTIE TO SUIT MARK TOOL NO. 10M PAGE WITH CASE NO. 2

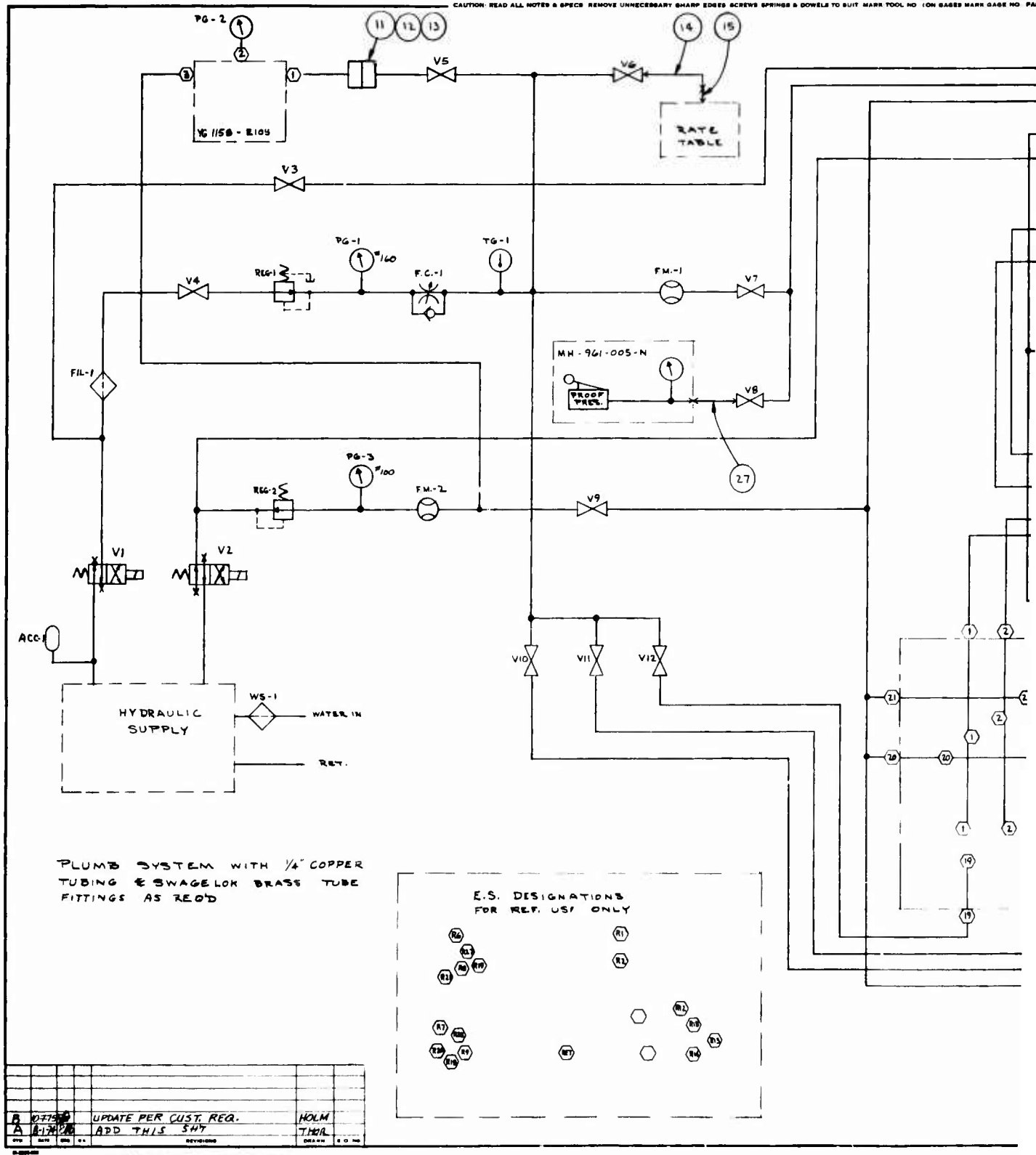


B	075	15	UPDATE PER CUST. REQ.	HOLM
A	11-14	570	ADD DE73 11-13	THWR
776	0415	000	REVISING	8 0 00

STRIVE TOWARD ERROR-FREE PERFORMANCE

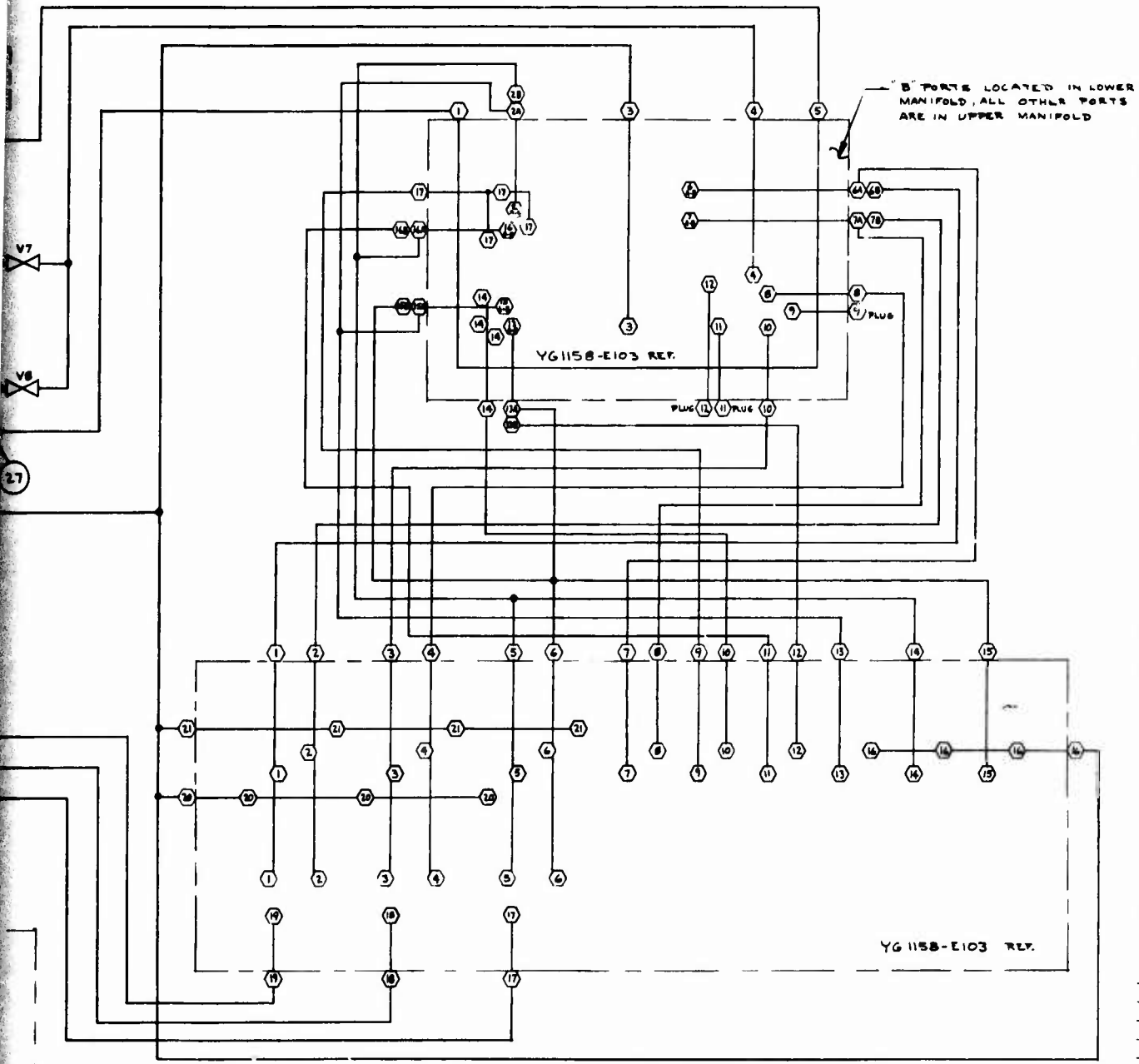
[illegible]

CNS NO. _____ YOSLM _____ SN _____ CNS. 7



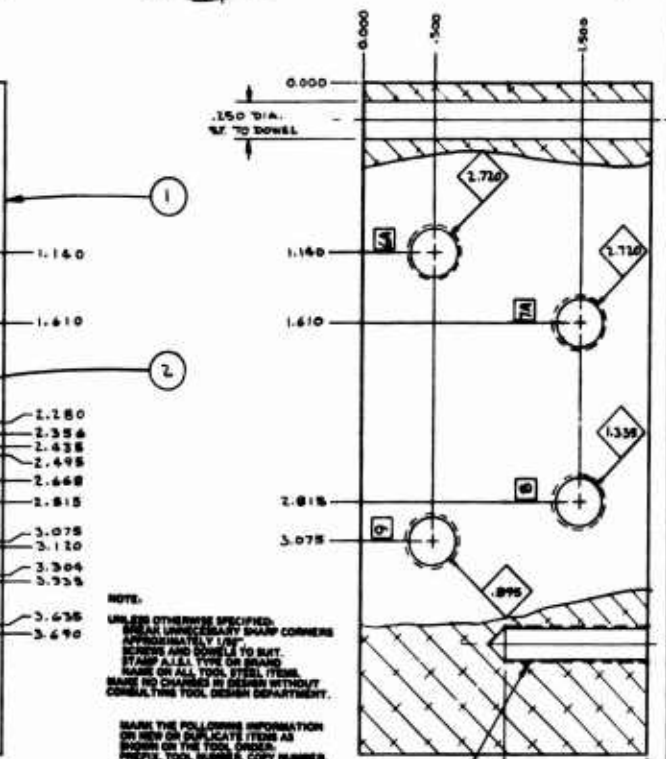
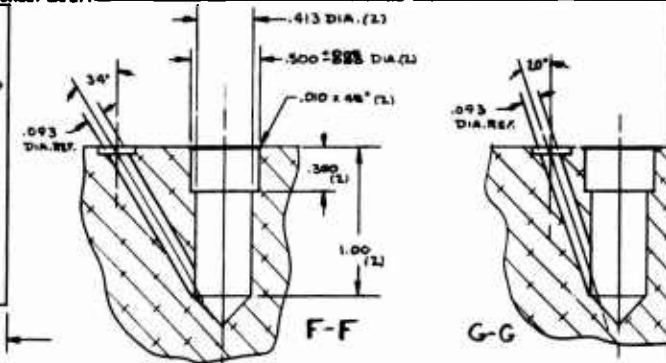
2

PLEASE SPECIFY & DOUBLE TO BUY. MARK TOOL NO. (ON GAGE MARK GAGE NO. PART NO. FUNCY OF GAGE & LAST REV LETTER). DON'T FORGET SAFETY



REV	NO	DATE	FINISHED SIZE	MAT'L	HEAT TR	MAT'L VOLS	WT LBS	UNIT PRICE	TOTAL
TOLERANCES UNLESS NOTED		DESIGNED FOR	DATE	Honeywell					
MACH & 0.1" FORMUL & 0.01"		DRAWN	THOR 8-1-74	NAME HYDRAULIC TEST BENCH					
ONE PLACE DEC - & 0.05		DETAILED		PART					
TWO PLACE DEC - & 0.10		CHECKED		OP. MACH. E.O.					
THREE PLACE DEC - & 0.01		REP V		NO SHEETS 3 SHEET NO 3 D YG1158-E102					
REV 0000		ENG D.C.							

CHG NO. TOOLM. SIN. CHG TO.



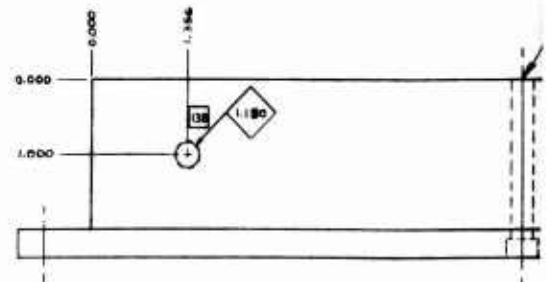
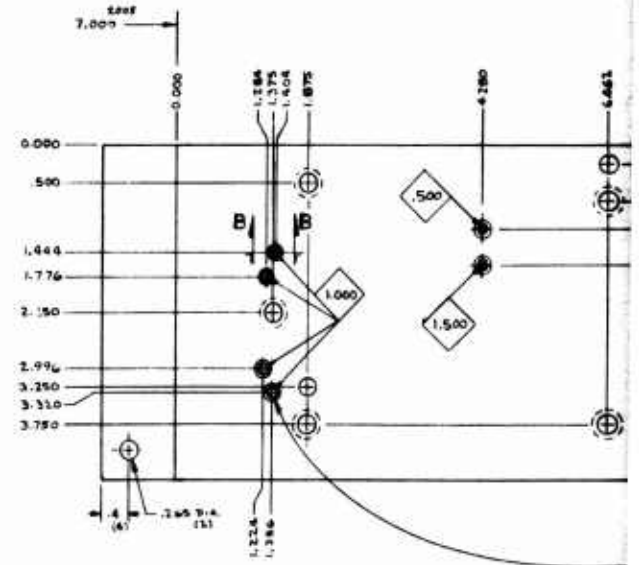
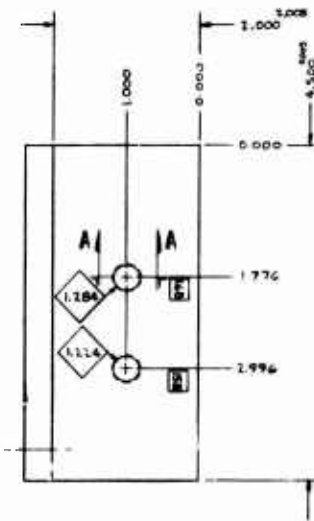
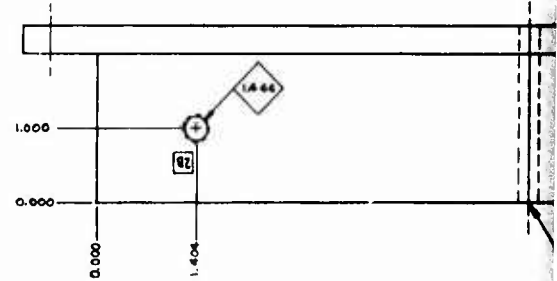
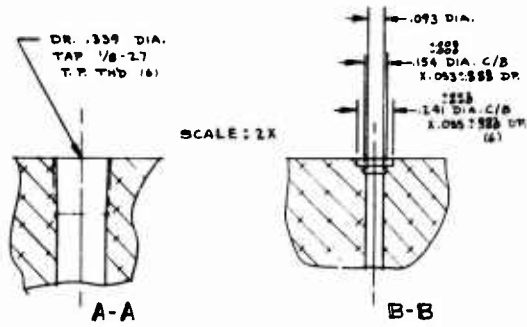
SCALE : 2X

JIG BORE TOL. $\pm .001$ ON ALL HOLES (EXCEPT (2) PLUGS)
 FLAG  DENOTES DEPTH OF HOLES TOL. $\pm .010$
 DR. & PLUG (2) HOLES BEFORE FINISH GRINDING
 METAL STAMP $\frac{1}{8}$ " HIGH LETTERS
 DET'S CONT. SH 3 & 4

TOLERANCES UNLESS NOTED		NEED FOR FINISH		DATE		Honeywell NAME AMPLIFIER TEST FIXTURE	
TOLERANCE NOT FINISHED		THICK		6-4-74		PART	
ONE PLACE DEC - 0.00		DETAILS				QTY	
TWO PLACE DEC - 0.01		CHANGES				MACH. E.O.	
THREE PLACE DEC - 0.001		MKT.				NO. SHEETS 4	
FOUR PLACE DEC - 0.0001		MATERIAL				SHEET NO. 1 D YG1158-E103	

PRECEDING PAGE BLANK-NOT FILMED

CAUTION: READ ALL NOTES & SPECS. REMOVE UNNECESSARY SHARP EDGES, SCREWS, SPRINGS & BOWELS TO GUY MARK TOOL NO. (ON GAGES MARK GAGE NO.)

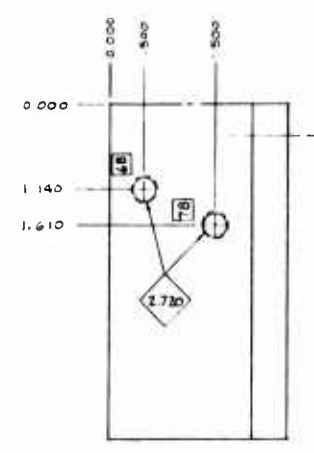
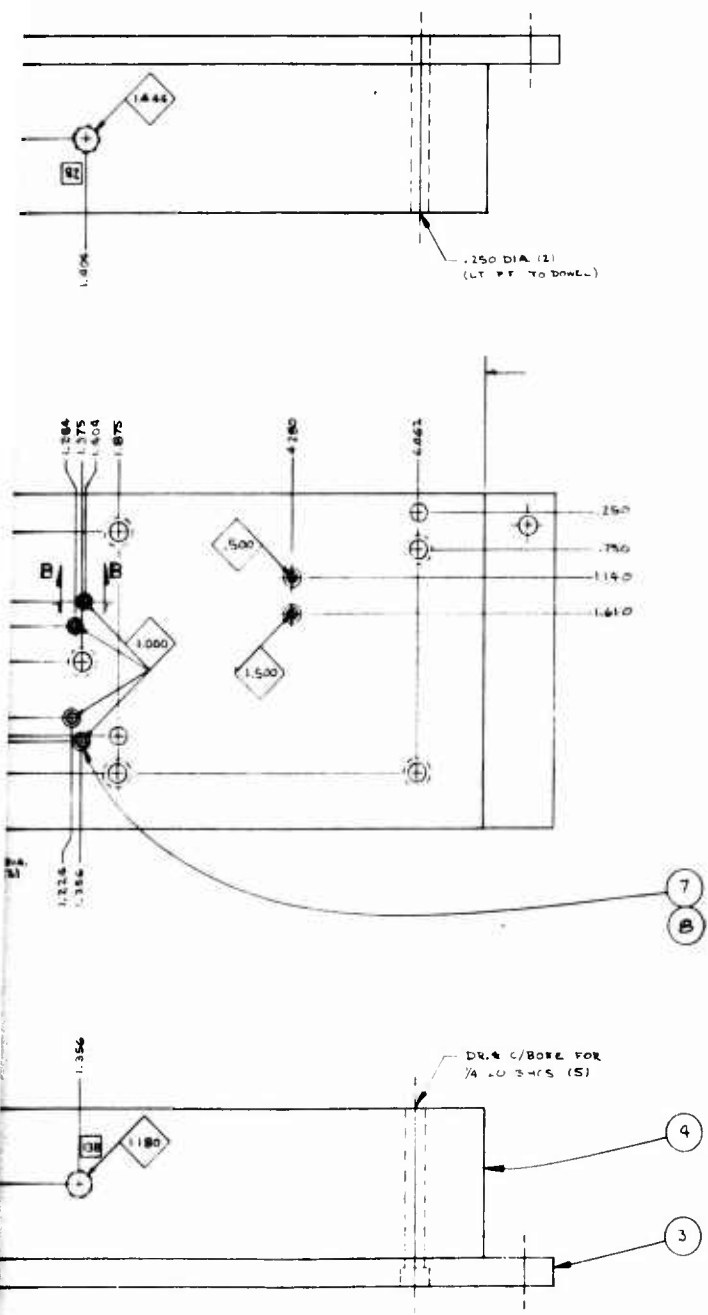


REV	DATE	BY	CHK	APP	DESCRIPTION	DRW	DATE
1	11/11/77				UPDATE PER CUST. REQ.	HOLM	
2					ORIG. DWG.		

STRIVE TOWARD ERROR-FREE PERFORMANCE

2

BE SCREWS SPRINGS & DOWELS TO SUIT MARK TOOL NO. (ON BASE) MARK GAGE NO. PART NO. FUNC. OF GAGE & LAST REV. LETTER. DON'T FORGET SAFETY.

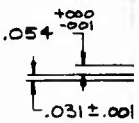


8	6	RESTRICTOR	TO BE DETERMINED AT CALIB.
7	6	O-RING	MS 28775-005
DET	REV	NAME	FINISHED SIZE
		MAT'L	HEAT TR
		MAT'L USED	WT. OF PT
		UNIT	TOTAL

TOLERANCES UNLESS NOTED		DESIGNED FOR	DATE	NAME	
MACH 1 ST FORMULA 4 ST		THOR	6-9-76	AMPLIFIER TEST FIXTURE	
ONE PLACE DEC - 0.000		DRAWN		PART	INSTR
TWO PLACE DEC - 0.010		DETAILED		OP	FO
THREE PLACE DEC - 0.001		CHECKED		NO SHEETS	SHEET NO
REV. TIMES		SUP V		4	2
		ENG. Q.C.		D	YG1158-E103

CHG NO TOOLM BIN CHG TO

CAUTION: READ ALL NOTES & SPECS REMOVE UNNECESSARY SHARP EDGES SCREWS, SPRINGS & BOWELS TO SUIT MARK TOOL NO. (ON BAGS MARK BAG NO. PART NO.)

[illegible]

109

2

1998

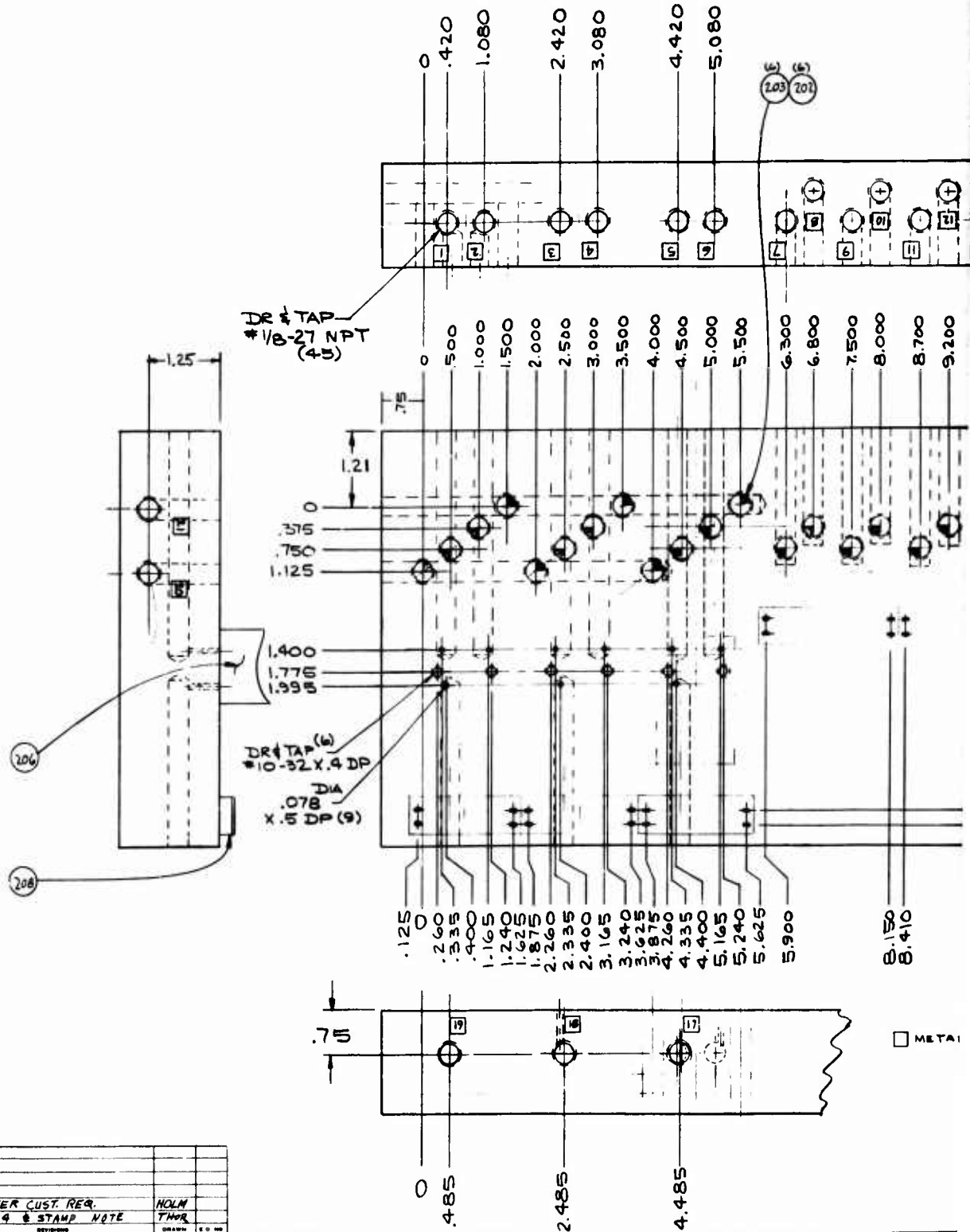
STOCKS

10

NAME _____

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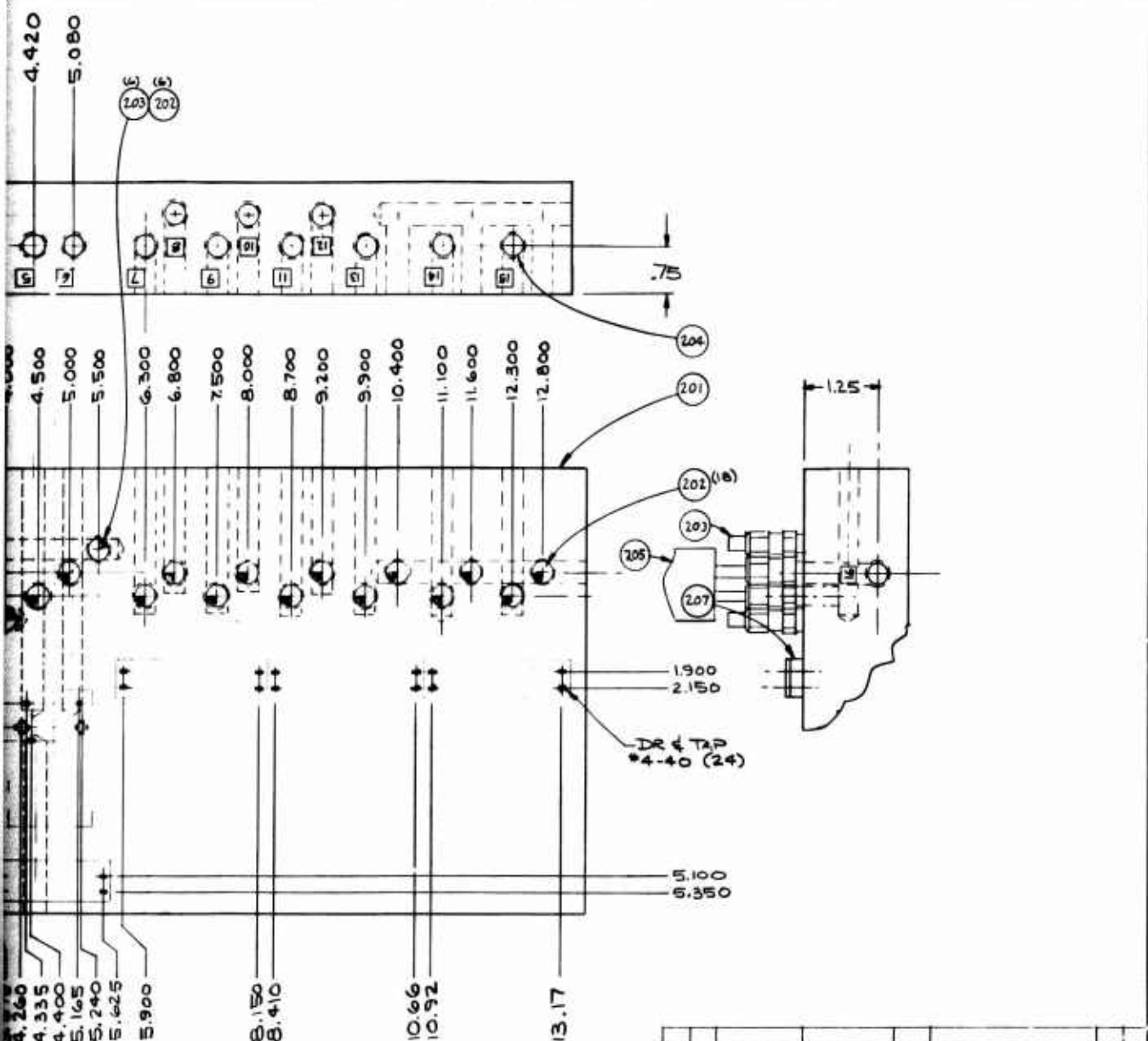
CAUTION: READ ALL NOTES & SPECS REMOVE UNNECESSARY SHARP EDGES SCREWS, SPRINGS & DOWELS TO SUIT MARK TOOL NO. 10N BASES MARK BASE NO. 1000



A	01-10	UPDATE PER CUST. REQ.	NOLM
A	01-10	ADD SMT 4 & STAMP NOTE	THOR
REV	DATE	DESCRIPTION	BY

STRIVE TOWARD ERROR-FREE PERFORMANCE

SPRINGS & BOWELS TO SUIT MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY.



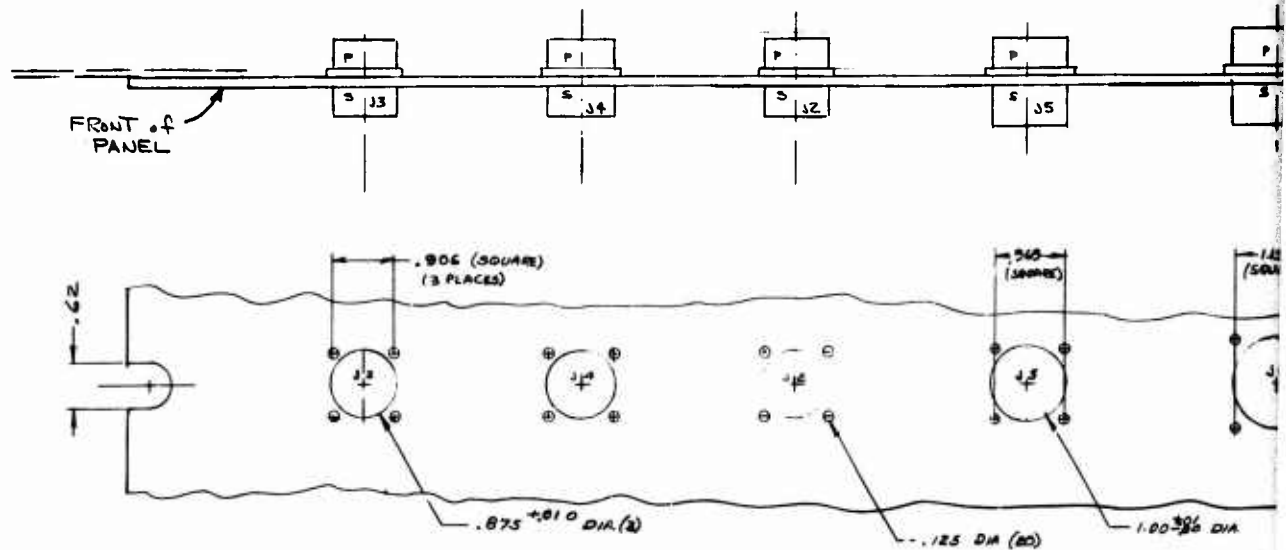
□ METAL STAMP 1/8" HIGH LETTERS

208	3	TERM BLOCK	CINCH	*G-172
207	3	TERM BLOCK	CINCH	*B-172
206	3	SERVO	HYDRAULIC RESEARCH A THERMOMETER CO.	MODEL #20 1st STAGE ONLY 7/4 300860-1
205	9	DIFFERENTIAL PRESSURE TRANSDUCER	VALIDYNE	*DP9
204	21	FITTING	SWAGELOK	*400-1-2
203	6	CAP	SWAGELOK	*200-C
202	24	FITTING	SWAGELOK	*200-1-2
201	1	MANIFOLD	1 1/2 X 7 X 1 1/4 ALUM	

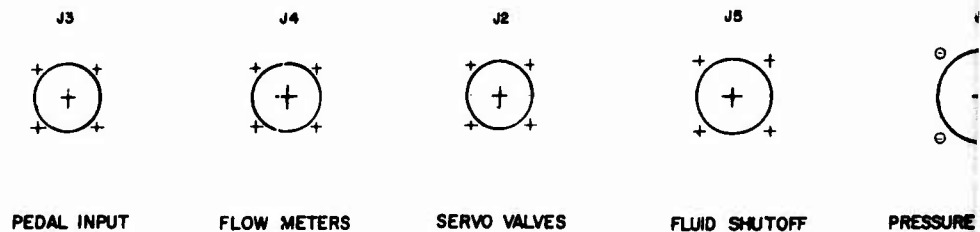
DESIGNED FOR	DATE	NAME
RAY A	1974	AMPLIFIER TEST FIXTURE
DRAWN	DATE	PART
RAY A	1974	
CHECKED	DATE	BY
NO. SHEETS	SHEET NO.	DWG NO.
4	4	D YG1158-E103

4.485

CAUTION: READ ALL NOTES & SPECS. REMOVE UNNECESSARY SHARP EDGES. SCREWS, SPRINGS & BOLTS TO SUIT. MARK TOOL NO. (ON LAGS) MARK GAGE NO. (ON



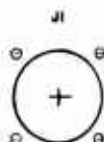
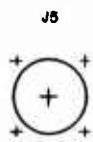
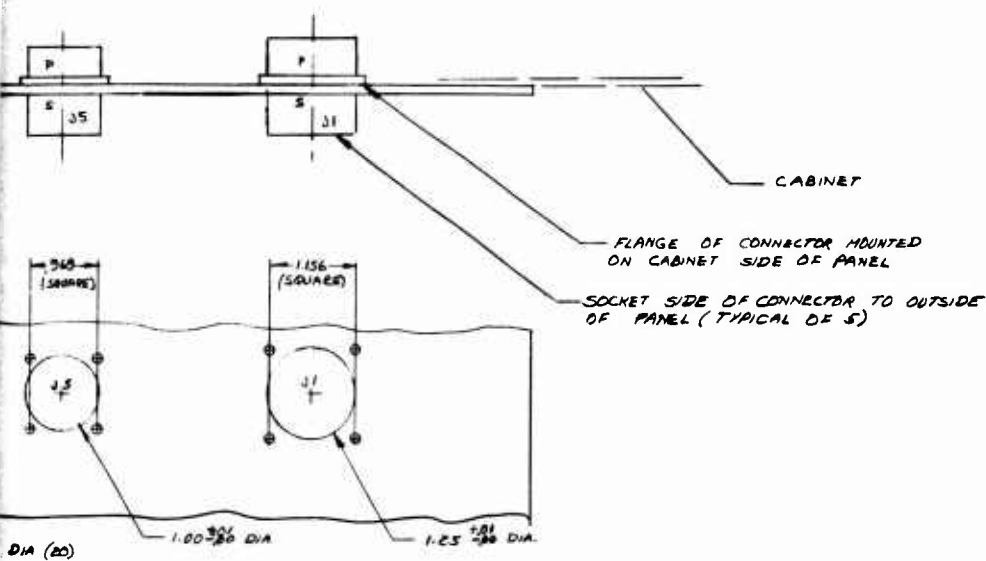
INTERFACE PANEL



REV	DATE	BY	CHK	APP	DESCRIPTION	DRAWN	CHECKED
1					UPDATE PER CUST. REQ. ORIGINAL DRAWING	HOLM	

STRIVE TOWARD ERROR-FREE PERFORMANCE

2



FLUID SHUTOFF

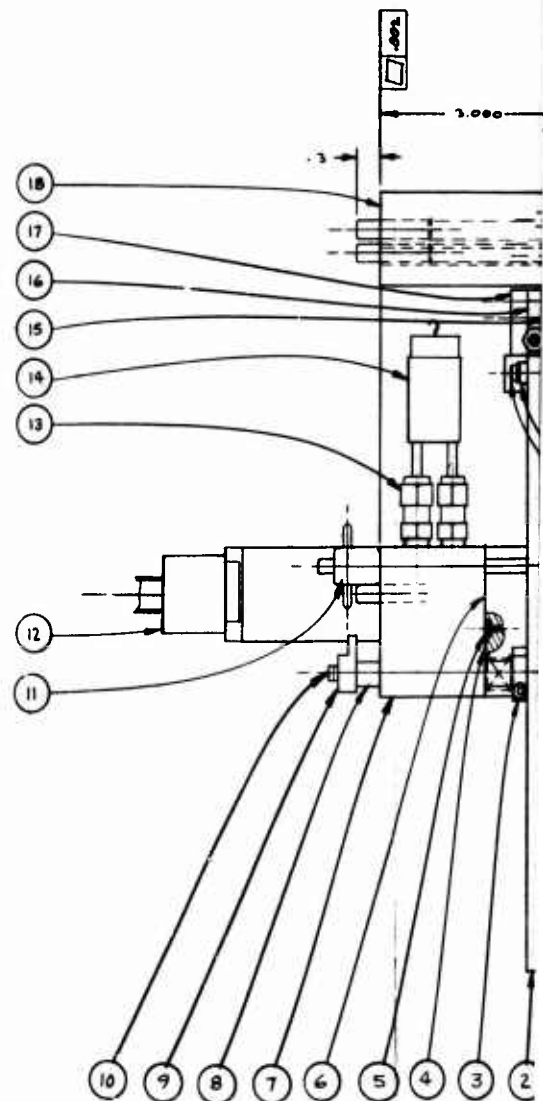
PRESSURE PICKOFFS

QTY	QTY	NAME	FINISHED SIZE	MAT'L	MAT'L TP	MAT'L USR	WT. LB PT	UNIT PRICE	TOTAL
5	1	PANEL		BUD	#PA1104	PUR.			
J3	4	CONNECTOR		BENDIX	#PTB-A-5PS	PUR.			
J5	3	CONNECTOR		BENDIX	#PTB-16BPS	PUR.			
J2, J4	2	CONNECTOR		BENDIX	#PTB-14-15PS	PUR.			
J1	1	CONNECTOR		BENDIX	#PTB-20-41PS	PUR.			

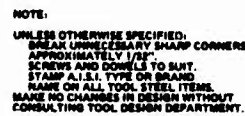
TOLERANCES UNLESS NOTED		DESIGNED FOR		DATE 1/74		NAME	
MACH & IT FORMED & P		DRAWN		SWA 9-25		PART	
ONE PLACE DEC - & 010		DETAILED				INSTR	
TWO PLACE DEC - & 010		CHECKED				E O	
THREE PLACE DEC - & 010		SUP V				NO SHEETS	
REF DIMS		ENG SC				SHEET NO 1	
						D YG 1158-E104	

CHG NO TOOLM BIN CHG TO

CAUTION: READ ALL NOTES & SPECS. REMOVE UNNECESSARY SHARP EDGES, SCREWS, SPRINGS & BOWELS TO SLIT MARK TOOL NO. (ON GAGE) MARK GAGE NO.

[illegible]

STRIVE TOWARD ERROR-FREE PERFORMANCE

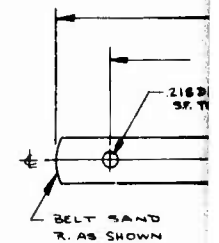


MARK THE FOLLOWING INFORMATION
ON NEW OR DUPLICATE ITEMS AS
SHOWN ON THE TOOL ORDER:
PREFIX, TOOL NUMBER, COPY NUMBER,
OWNER SERVICE,
CUSTOMER TOOL NUMBER

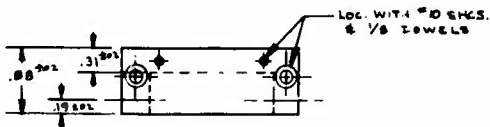
29	1	PIN	3/32 DIA. x 3/4	BRASS	
23	1	YOKER			HON. "MS 35012-1
22	1	POTENTIOMETER			BOURNS "B0194-200178 1010
21	1	ADAPTOR	3/16 x 1/2 x 2 1/2	ALUM	2024-T3
20	1	BASE	3/8 x 1 1/2 x 2 1/2	ALUM	2024-T3
19	1	SHOU. SCREW			PIC "4416 OR EQUIV
18	1	LOC. BLOCK	1 1/4 x 3 x 4 1/8	ALUM	7075-T651
17	1	COVER	1/4 x 3/8 x 2 1/2	ALUM	2024-T3
16	1	RETAINER	7/16 x 3/8 x 2 1/2	ALUM	2024-T3
15	1	BLOCK	3/32 x 3/8 x 2 1/2	ALUM	2024-T3
14	1	TRANSDUCER			VALIDDYNE "DP9
13	2	FITTING			SWAGelok "200-1-2
12	1	SWING CLAMP			CARR-LANE "CL-4-SWA-1-N
11	1	LOCK-T-PIN			CARR-LANE "CL-3-BLP-R-2.5-S
10	1	SHAFT	3/16 DIA x 3 1/8	ST. STL	
9	1	ADAPTOR	1/4 x 3/16 x 3/4	ST. STL	
8	2	BUSHING	107-127-02824		AMERICAN "PT
7	1	UPR MANIFOLD	2 x 3 3/8 x 4 1/4	ALUM	7075-T651
6	1	LOW MANIFOLD	1 1/2 x 2 x 3 1/4	ALUM	7075-T651
5	3	RESTRICTOR	5/16 DIA x 9/16	ALUM	2024-T3
4	6	O-RING			MS 88775-005
3	1	CLAMP			PIC "LI-4
2	1	HANDLE	3/16 x 5/8 x 1 1/2	STSL	
1	1	BASE	1/2 x 7 x 11	ALUM	2024-T3

[illegible]

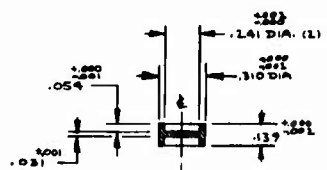
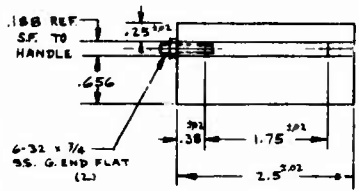
CAUTION: READ ALL NOTES & SPECS. REMOVE UNNECESSARY SHARP EDGES, SCREWS, SPRINGS & DOWELS TO SUIT. MARK TOOL NO. (ON GAGES) MARK GAGE NO. PART NO.



DRILL & BOWLS TO SUIT MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY

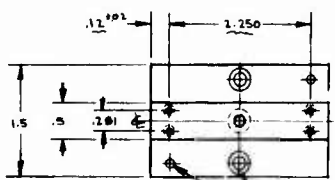


15
16
17

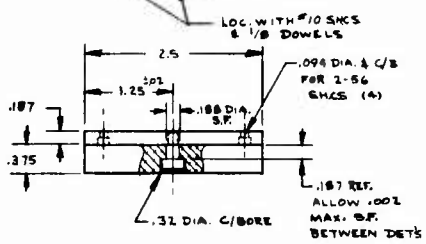


5

SCALE: 2X

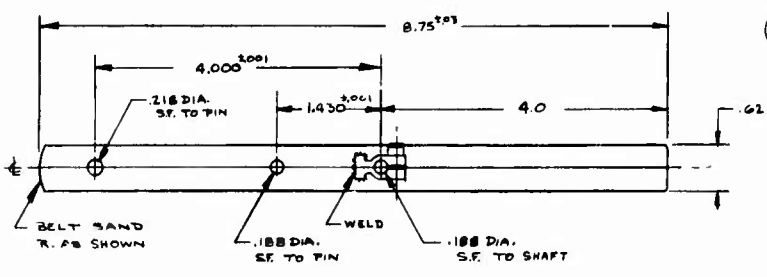
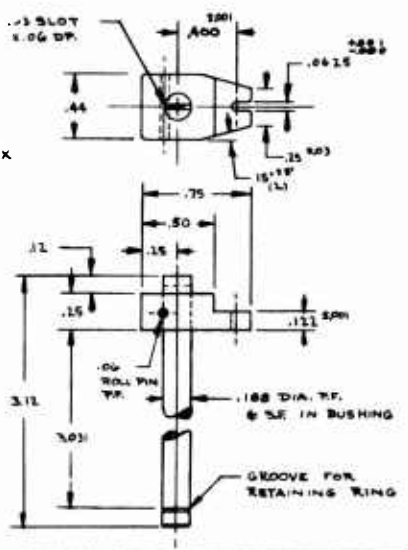


19
20
21

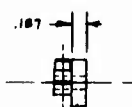


SCALE: 2X

9
10



2 3

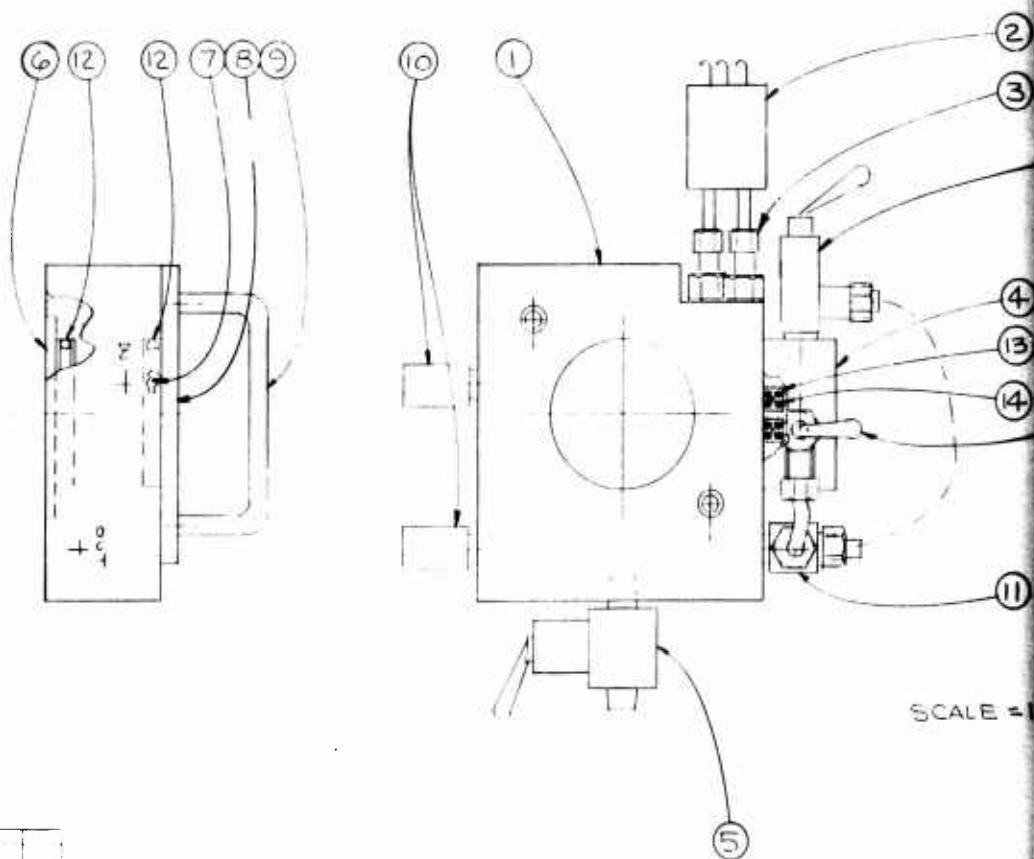


DET	QTY	NAME	PROPOSED DES.	DATE	REV. TO	DATE	BY	CHKD.	TOTAL
TOLERANCES UNLESS NOTED									
DESIGNED FOR									
DRAWN									
ONE PLACE DEC. - A OR									
TWO PLACE DEC. - A OR									
THREE PLACE DEC. - A OR									
HONEYWELL									
NAME PILOT INR TRANSDUCER									
PART									
MATERIAL									
NO. SHEETS									
2									
SHEET NO.									
2									
D YG1158-E105									

CHKD. NO. TOOL NO. IN CHG. TO

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CAUTION READ ALL NOTES & SPECS REMOVE UNNECESSARY SHARP EDGES SCREWS SPRINGS & DOWELS TO BUY MARK TOOL NO. 10N 8485 MARK GAGE NO. PART NO.

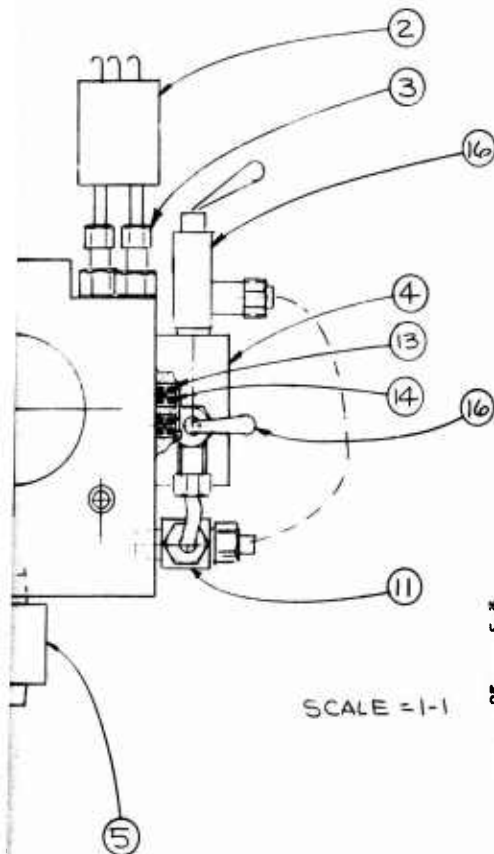


C. H. H. H. D. H. H. H. A. H. H. H.	UPDATE PER CUST. REQ. SEE SHT 3 RUMAS 2 PWD, (2) CHG (5) ADD SHT 1 & 3	HOLM RAY A RAY A
REV. 1 REV. 2 REV. 3 REV. 4	REV. 1 REV. 2 REV. 3 REV. 4	REV. 1 REV. 2 REV. 3 REV. 4

STRIVE TOWARD ERROR-FREE PERFORMANCE

10 & DOWELS TO SUIT. MARK TOOL NO. 10W SAGES MARK SAGE NO. PART NO. PUNCT. OF SAGE & LAST REV. LETTER. DON'T FORGET SAFETY.

- △ USE ON MIL-H-5606 HYDRAULIC FLUID @ 120°F
ALSO WITH MATING CONNECTORS TO 1/4" OD TUBE
- △ RATING 6000 PSIG, STAINLESS STEEL BODY,
T-BAR ADJ. HANDLE, 1/4" AN PORTS



SCALE = 1-1

NOTE:
UNLESS OTHERWISE SPECIFIED,
BREAK UNNECESSARY SHARP CORNERS
APPROXIMATELY 1/32".
SCREWS AND DOWELS TO SUIT.
STAMP A.I.S.I. TYPE OR BRAND
NAME ON ALL TOOL STEEL ITEMS.
MAKE NO CHANGES IN DESIGN WITHOUT
CONSULTING TOOL DESIGN DEPARTMENT.

MARK THE FOLLOWING INFORMATION
ON NEW OR DUPLICATE ITEMS AS
SHOWN ON THE TOOL ORDER.
PREFIX, TOOL NUMBER, COPY NUMBER,
OWNER SERVICE,
CUSTOMER TOOL NUMBER

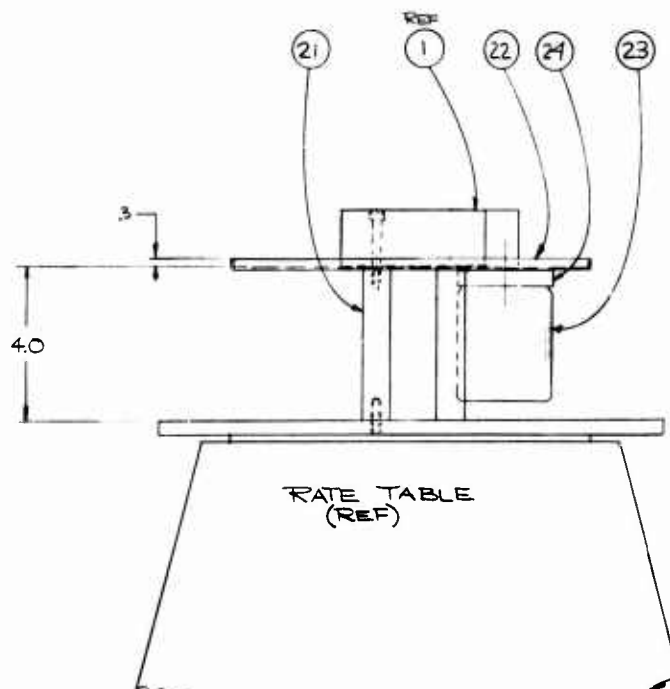
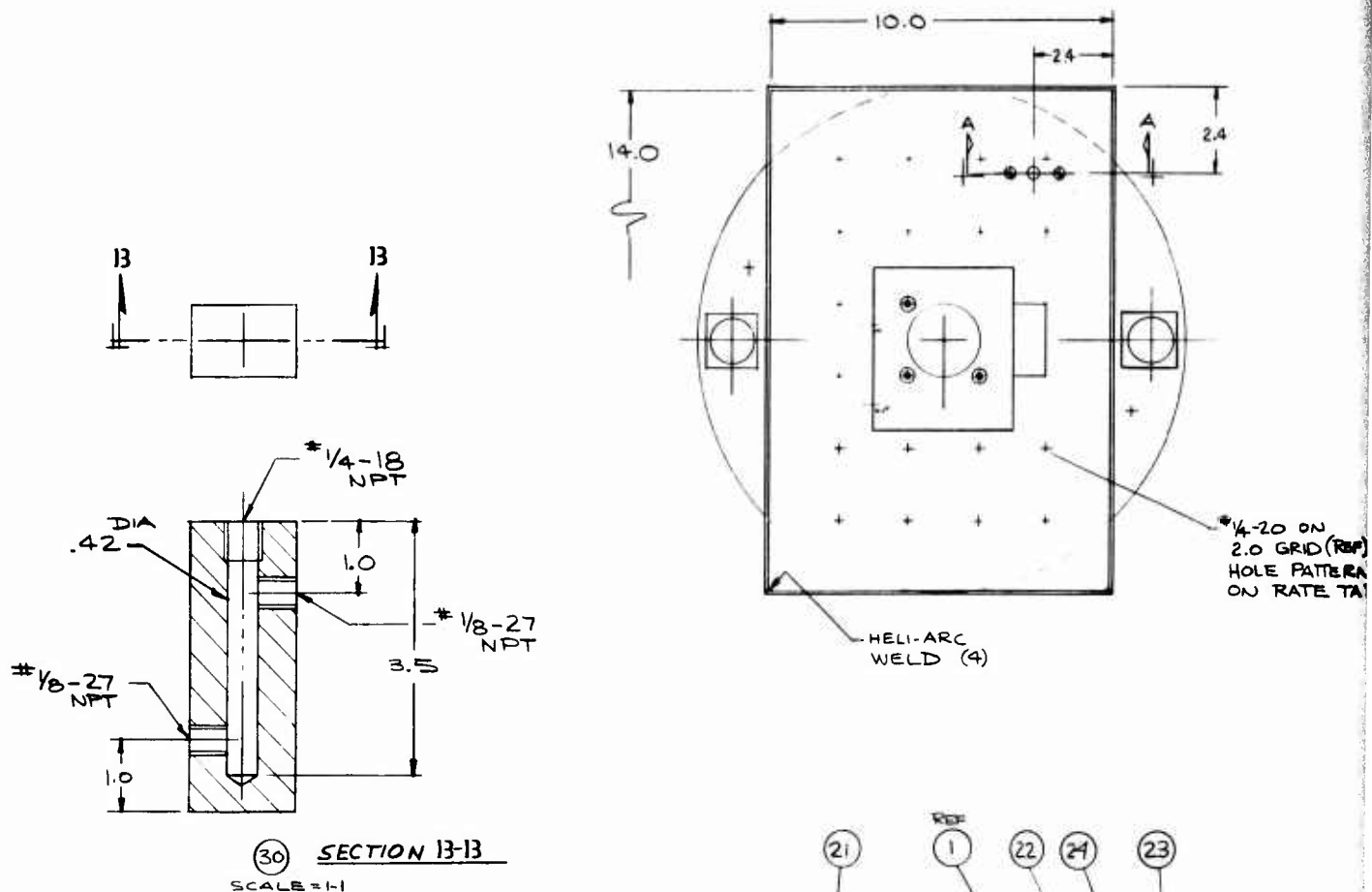
38	1	FILTER ELEMENT	PURULATOR			7509200	
37	1	FILTER	PURULATOR			7509600	
36	2	FITTING	SWAGELOK			*400-6-4AN	
35	2	FITTING	ORDERED AS PART of			DET *29	
34	2	FITTING	SWAGELOK			*400-3-4TTF	
33	2	FITTING	SWAGELOK			*600-1-DR	
32	1	REGULATOR	TESCOM			26-2322-34-064	0-250 PSIG
31	1	THERMOMETER	MARSHALLTOWN			*99	20-140° 1" DIA. 1/8" TUB
30	1	BLOCK	1X1 1/2 X 4	ALUM			
29	1	FLOW METER	FLOW TECHNOLOGY INC.			FT-5M1-LB	0.07 TO 1.14 GPM
28	1	PRESSURE GAUGE	MARSHALLTOWN			*23	DIAL 2 1/2" 0-100 PSI
27	2	VALVE	WHITEY			*1R54	
26	1	VALVE	MARSHALLTOWN			*23	DIAL 2 1/2" 0-100 PSI
25	1	VALVE	WHITEY			*1V54	
24	1	METAL COVER	METAL HANDLING	STK			
23	1	JAR	METAL HANDLING	STK			
22	1	TRAY	1/16 X 10 3/8 X 14 1/2	ALUM		6061-T4	
21	3	POST	3/4 HEX X 4	ALUM			
20							
19							
18							
17							
16	2	VALVE	WHITEY			B-04M2-92-A	1/2 NPT X 1/2 TUB
15	2	THUMB SCR	PIC *4042				
14	4	O'RING	M528775-005				
13	2	RESTRICTOR	3/16 DIA X 7/32	ALUM			
12	2	O'RING	M528775-133				
11	1	FITTING	SWAGELOK			B-200-3TMT	1/2 NPT X 1/2 TUB
10	3	FITTING	SWAGELOK			*400-1-2	1/2 NPT X 1/2 TUB
9	1	HANDLE	BUD 4-9168-B				
8	1	PLATE	1/4 X 2 X 4	ALUM			
7	1	TOP COVER	2 DIA X 1/2	ALUM		2024-T3	
6	1	BOTTOM COVER	2 3/4 DIA X 3/8	ALUM		2024-T3	
5	1	VALVE	HOKE			*1511 M2B	
4	1	MANIFOLD	1 X 1 X 2	ALUM		2024-T3	
3	2	FITTING	SWAGELOK			*200-1-2	1/2 NPT X 1/2 TUB
2	1	TEMPERATURE TRANSDUCER	VALLEYVIEW MODEL 75-9				
1	1	HOUSING	1 3/8 X 4 X 4 1/2	ALUM		2024-T3	

TOLERANCES UNLESS NOTED		DESIGNED FOR		DATE		Honeywell	
FINISH	NOTES	DATE	BY	DATE	BY	NAME	RATE SENSOR TEST FIXTURE
10042046	ONE PLACE DEC - 0.05	3 JUN					
	TWO PLACE DEC - 0.01						
	THREE PLACE DEC - 0.001						
		PART		MACH		WTHR	
		NO SHEETS		SHEET NO		SHEET	
		4		1		D YG 1158-E106	

CHG NO TOOLM BIN CHG TO

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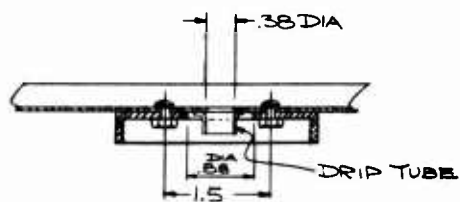
CAUTION READ ALL NOTES & SPECS REMOVE UNNECESSARY SHARP EDGES SCREWS SPRINGS & DOWELS TO PREVENT MARK TOOL NO 1 ON CASES MARK CASE NO PART NO



SCALE :

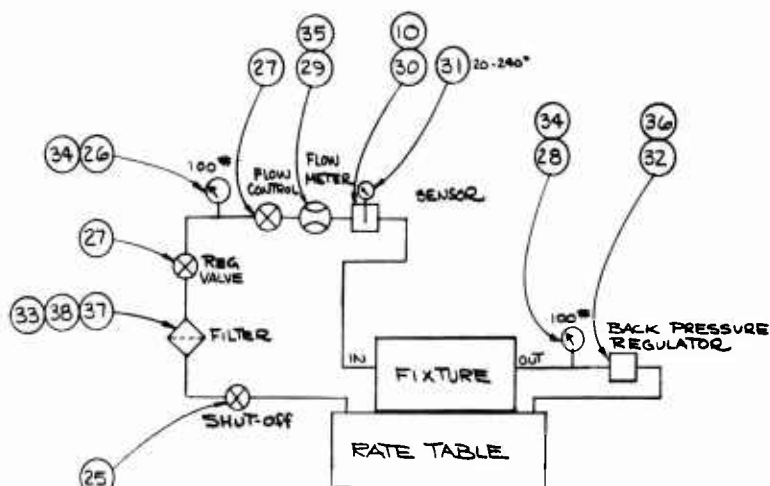
B	DTF		UPDATE PER CUST. REQ.	HOLM
AIR	NAVY	SEA	ORIG DWG.	
			REV 1-6-70	CHE & W T
				G & P

STRIVE TOWARD ERROR-FREE PERFORMANCE



SECTION A-A

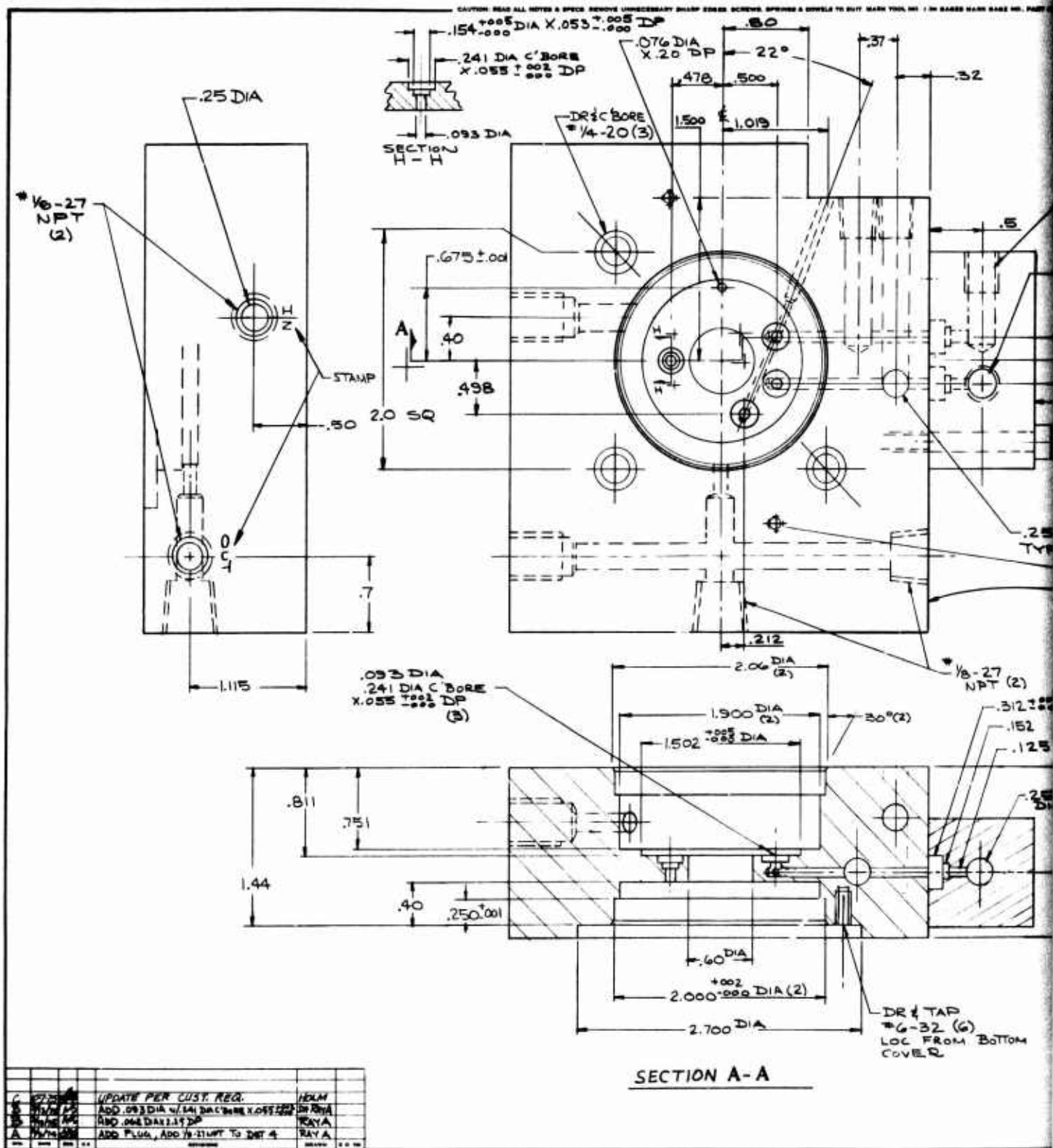
* 1/4-20 ON
2.0 GRID (REF)
HOLE PATTERN
ON RATE TABLE



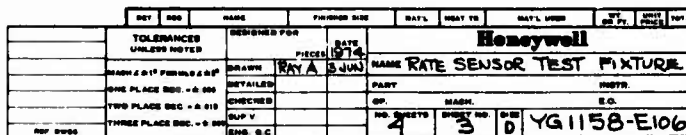
SCALE = $\frac{1}{2}$

[illegible]

CMR NO	TOOL NO	BIN	CMR NO
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STRIVE TOWARD ERROR-FREE PERFORMANCE



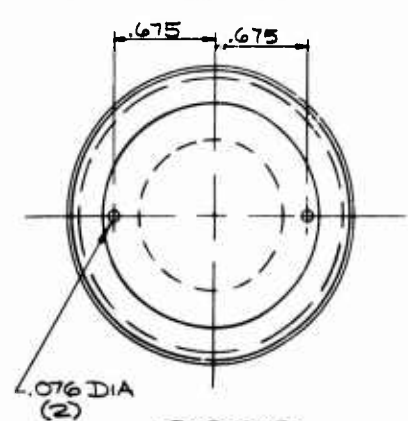
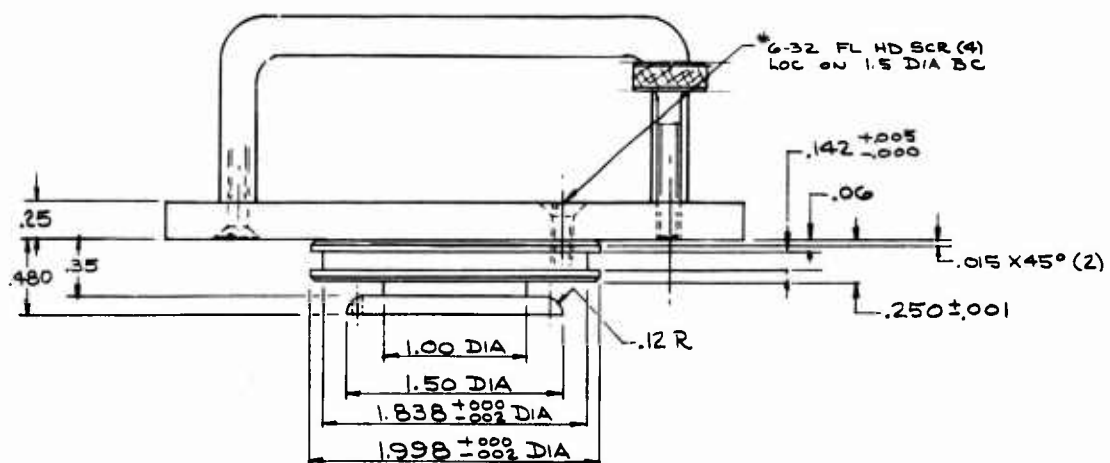
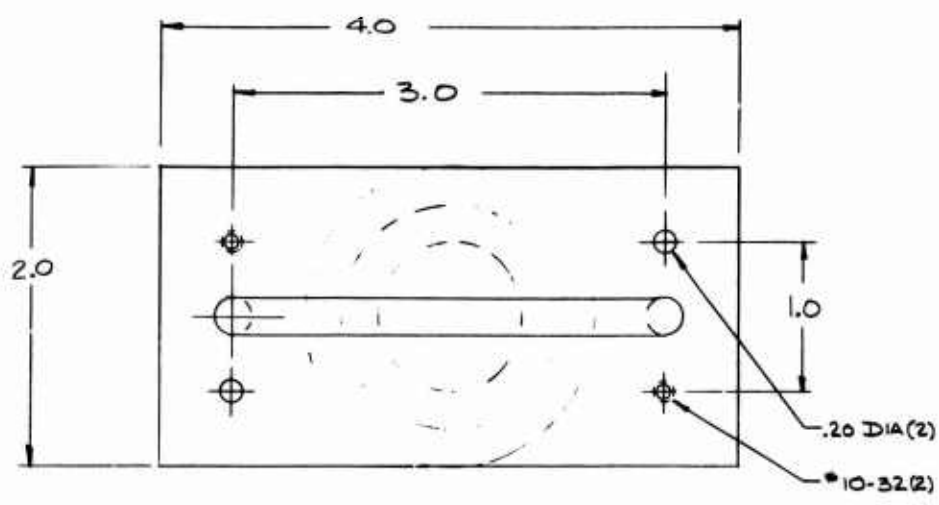
CMR 80

FROM 11

2000

2004

1. 8 BOWELS TO SUIT. MARK TOOL NO. (ON GAGE) MARK GAGE NO. PART NO. FUNCT. OF GAGE & LAST REV LETTER. DON'T FORGET SAFETY.

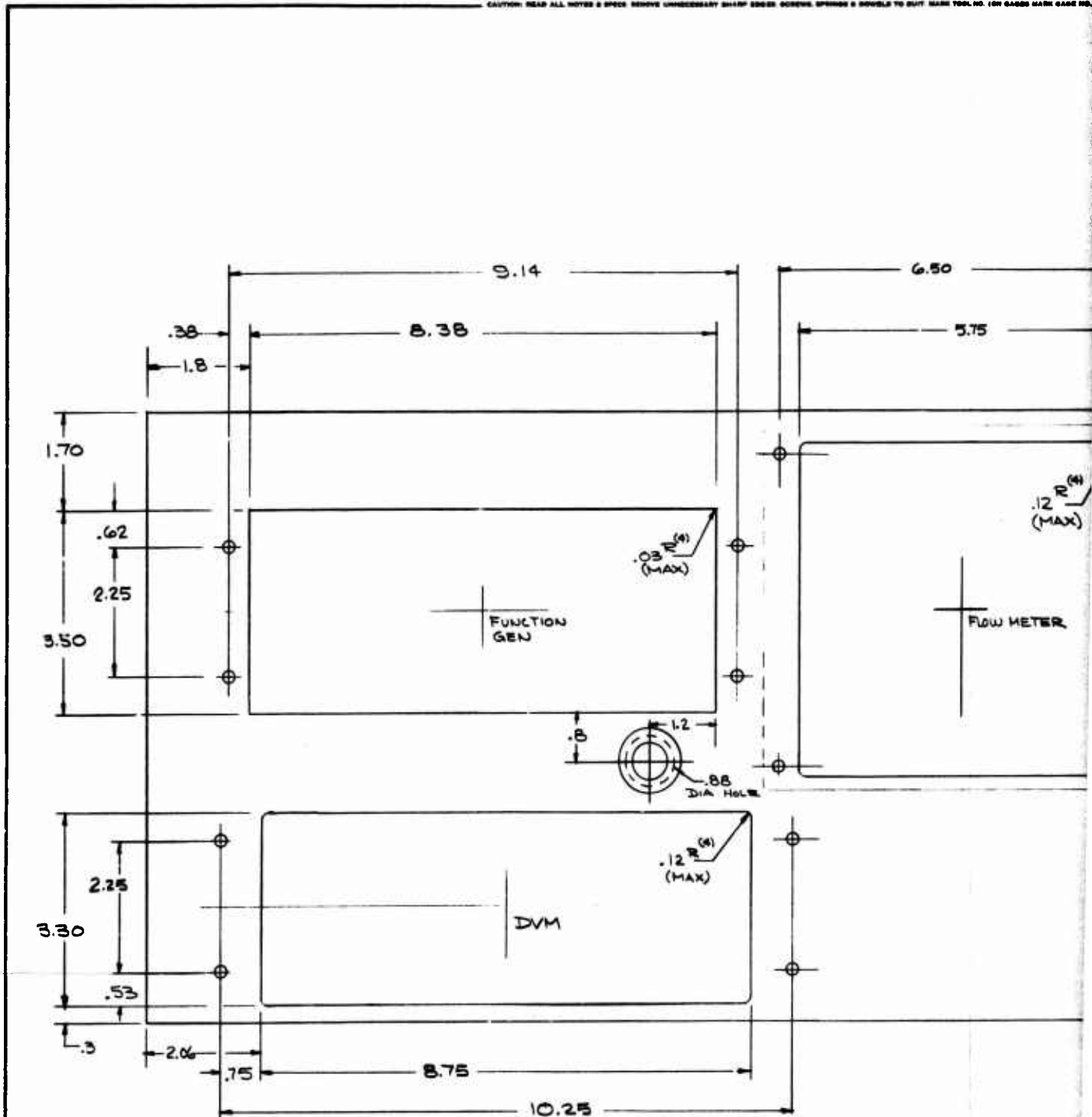


78915

REV	REV	NAME	DESIGNED FOR	DATE	REV	REV TO	REV	REV	REV	REV	REV	REV	REV
TOLERANCES UNLESS NOTED				DESIGNED BY RAY A. JUN		Honeywell RATE SENSOR TEST FIX							
DRAWN BY RAY A. JUN				CHECKED BY RAY A. JUN		PART		NOTE					
ONE PLACE DEC - 0.001				TWO PLACE DEC - 0.01		THREE PLACE DEC - 0.001		REV					
100-7444				100-7903		NO SHEETS		SHEET NO		REV		DATE	
100-7903				100-7903		4		4		D		YG1158-E106	
REV				TOOL		DIN		CHG. TO					

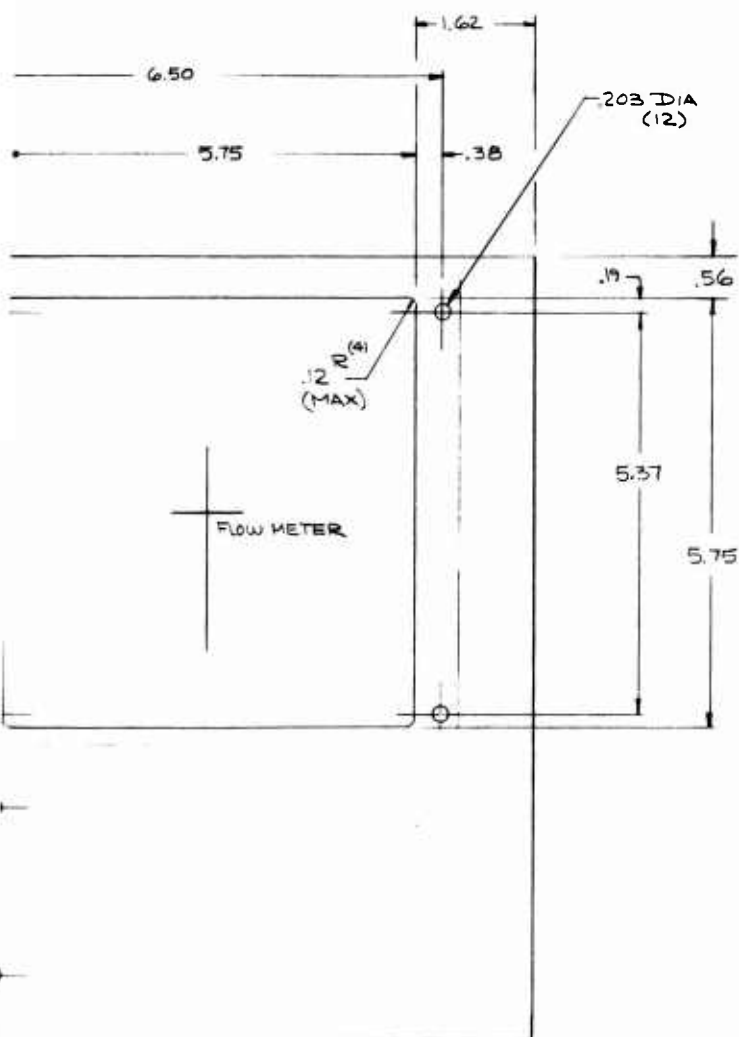
PRECEDING PAGE BLANK NOT FILMED

CAUTION: READ ALL NOTES & SPEC. REMOVE UNNECESSARY SHARP EDGES. SCREWS, SPRINGS & BOWELS TO SUIT. MARK TOOL NO. (ON CASES MARK CASE NO.)



REV	DATE	BY	CHK	DESCRIPTION	REVISION	DATE	BY	CHK	DESCRIPTION
1	11/15/66			UPDATE PER CUST. REQ.					HOLM
2				ORIG. DWG.					

STRIVE TOWARD ERROR-FREE PERFORMANCE



△ FINISH ~ CLEAR ANODIZE

[illegible]