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DESIGN AND EVALUATION OF AN ELECTROHYDRAULIC SERVOACTUATOR USING ACTIVE STANDBY REDUNDANCY
FINAL PROGRESS REPORT
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# DESIGN AND EVALUATION OF AN ELECTROHYDRAULIC SERVOACTUATOR USING ACTIVE STANDBY REDUNDANCY

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## TABLE OF CONTENTS

## FORWARD

This report was prepared by the Bertea Corporation, Irvine, California under NASA Contract NAS 8-27821. The report describes the design, fabrication, test and analysis of a three channel electrohydraulic servoactuator with hydromechanical fault detection and correction features.

The "Active Standby Servovalve/Actuator Development" contract was sponsored by the George C. Marshall Splace Flight Center, National Aeronautics and Space Adminstration, Marshall Space Flight Center, Alabama 35812. The contracting officers technical representative was C. S. Cornelius, Astrionics Laboratory.

The work was performed by members of the Engineering Department of Bertea Corporation, Irvine, California 92664. The principal investigators were R. L. Anderson and W. E. Cover with assistance from J. W. Blanton, C. R. Seitz and D. G. Waggoner.

Work on the contract was performed between June 30, 1971 and August 17, 1972.

## 1.0 INTRODUCTION

Current aircraft and space vehicle performance envelopes demand improvements in actuation techniques. State of the art electrohydraulic servo actuation techniques are capable of meeting these expanding performance envelopes but can not always meet specified reliability goals. The reliability of an actuator may be improved by:

a) Ultrareliable components

b) Multiple control paths which function independently (active standby)

c) Multiple control paths which function in unison (parallel active)

The work described in this document was an investigation of the independent multiple control path approach as applied to electrohydraulic servo actuators. The prime objective of this work was to define requirements, identify techniques for monitoring active channel failures, and for switching control to a standby channel. The work included the mechanization and investigation of three hydromechanical fault detection and correction schemes.

## 2.0 SUMMARY

This report describes the application of active standby redundancy techniques to a large electrohydraulic servo actuator. The conceptual section of the report serves to identify the advantages and limitations of active standby redundancy. Special areas of investigation during the development test phase of the program were the evaluation of output transients as a function of channel switching and the nuisance switching characteristics of the system.

The application sections of this report describe the design, fabrication, and evaluation of a laboratory model of a large electrohydraulic servo actuator using the active standby redundancy technique. The design approach described in this report was selected to meet the requirements of:

a) No degradation of performance after two signal failures.

b) Maximum stability of the hydromechanical failure detector.

c) Flexible mechanization to allow the evaluation of a large number of system parameters.

2.0 SUMMARY (Continued)

Evaluation of the laboratory model was directed toward identifying fault detection and switching characteristics. The evaluation and analysis are reported in a manner such as to assist a designer in predicting the performance of alternate design approaches.

The feasibility of constructing large electrohydraulic servo actuators using active standby redundancy was successfully demonstrated in the development program. In particular the stability and predictability of a properly designed hydromechanical failure detector was demonstrated.

## 3.0 ACTIVE STANDBY REDUNDANCY CONCEPT

The application of redundancy in which failed components are replaced by standby components is referred to in this document as active standby redundancy. The major advantages of the active standby redundancy technique for electro-hydraulic servo actuators are:

1) No reduction in performance resulting from the presence of redundant channels.

2) Minimum interaction between redundant channels.

The major disadvantages of the active standby redundancy techniques are:

1) Potential failure of the fault detection and correction mechanisms.

2) Transients in output resulting from active channel failures.

3) Nuisance switching.

## 3.1 PERFORMANCE

Basic to the active standby redundancy technique is the concept that the servo actuator output is controlled by only one channel of components. The standby channels

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

3.1 PERFORMANCE (Continued)

do not (normally) interfere with the actuator output. This is a distinct advantage of active standby redundancy as compared to parallel active redundancy. The application of parallel active redundancy typically results in a compromise in actuator performance due to the voting or averaging required at the parallel channel summation point. The application of active standby redundancy requires no such compromise. The performance of an actuator using active standby redundancy may be predicted by well established servo actuator analysis techniques.

3.2 CROSS CHANNEL COUPLING

Theoretically the reliability of a servo actuator will increase exponentially with the number of redundant channels. In practice the actual reliability is limited by common mode failures (failure which affect more than one channel). Parallel active redundancy techniques require a common output device which averages or votes the individual channels. Active standby redundancy techniques require only cross channel monitoring and therefore are potentially less susceptible to common mode failures.

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

3.3 MONITOR REDUNDANCY

The reliability of a multichannel servo actuator which uses the active standby redundancy techniques is limited by the reliability of the fault detection and fault correcting devices. The failure rate of the servo actuator can never exceed the failure rate of a single channel times the failure rate of the monitor. An infinite number of redundant channels are of no use if the monitor is incapable of switching from a failed active channel to a standby channel. Therefore, the monitor reliability is as critical as the control channel reliability.

3.4 SWITCHING TRANSIENTS

The application of active standby redundancy is limited to control functions which will accept small output transients. In all active standby applications a discrepancy must be allowed to exist in a failed channel. This discrepancy is required to activate the failure detection and correction mechanism. Therefore, this discrepancy is one source of actuator output transients.

A second source of actuator output transients must be considered if there is any disagreement between the

3.0 ACTIVE STANDBY REDUDNANCY CONCEPT (Continued)

3.4 SWITCHING TRANSIENTS (Continued)

position commands of the redundant channels. This second source of transients is not unique to the active standby technique. All multiple channel actuators experience output transients associated with redundant component failures. However, for actuators which use active standby redundancy, the interchannel mismatch transients are additive to the transients associated with failure detection threshold and failure correction time lag.

3.5 NUISANCE SWITCHING

From the above discussion it would appear desirable to define a very sensitive failure detection threshold. The limitation on failure detection threshold is that the threshold must be larger than the steady state offset between the active channel and its reference plus differences in gain, dynamic performance, failure detector threshold tolerance, the effects of working environment, actuator life requirements, power supply fluctuation, and signal noise.

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

3.5 NUISANCE SWITCHING (Continued)

The control system must be designed to produce acceptable transients after accounting for the above defined failure detection threshold, the switching time delay, and the interchannel offsets. In general a finite probability of nuisance switching must be accepted in order to comply with output transient requirements. The major objective of the work defined in this document has been to investigate techniques for reducing both output transients and nuisance switching.

3.6 FAILURE DETECTOR DESIGN

The failure detector design must take into consideration the effects of both switching transients and nuisance switching. The failure detection threshold should be set high to avoid nuisance switching but not so high as to induce large transients when switching from a failed channel to a standby channel. In general some compromise must be accomplished between desirable output transients and nuisance switching.

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

3.6 FAILURE DETECTOR DESIGN (Continued)

Fortunately, it is possible to establish a frequency dependent failure detection threshold which will reduce the amplitude of the failure induced transients and decrease the incidence of nuisance switching. The frequency dependent threshold takes advantage of the fact that control signals are typically an order of magnitude lower in frequency than signal noise. This concept is represented graphically in Figures 3-1 and 3-2.

Figure 3-1 illustrates a failure detection threshold defined by allowable output transients. As suggested on this figure, output transients may increase in amplitude if their duration is short. The steady state offset shown on this curve represents the interchannel null differences. Figure 3-1 considers only actuator performance. In an airframe application the vehicle dynamics would handle this steady state offset as an out-of-trim condition.

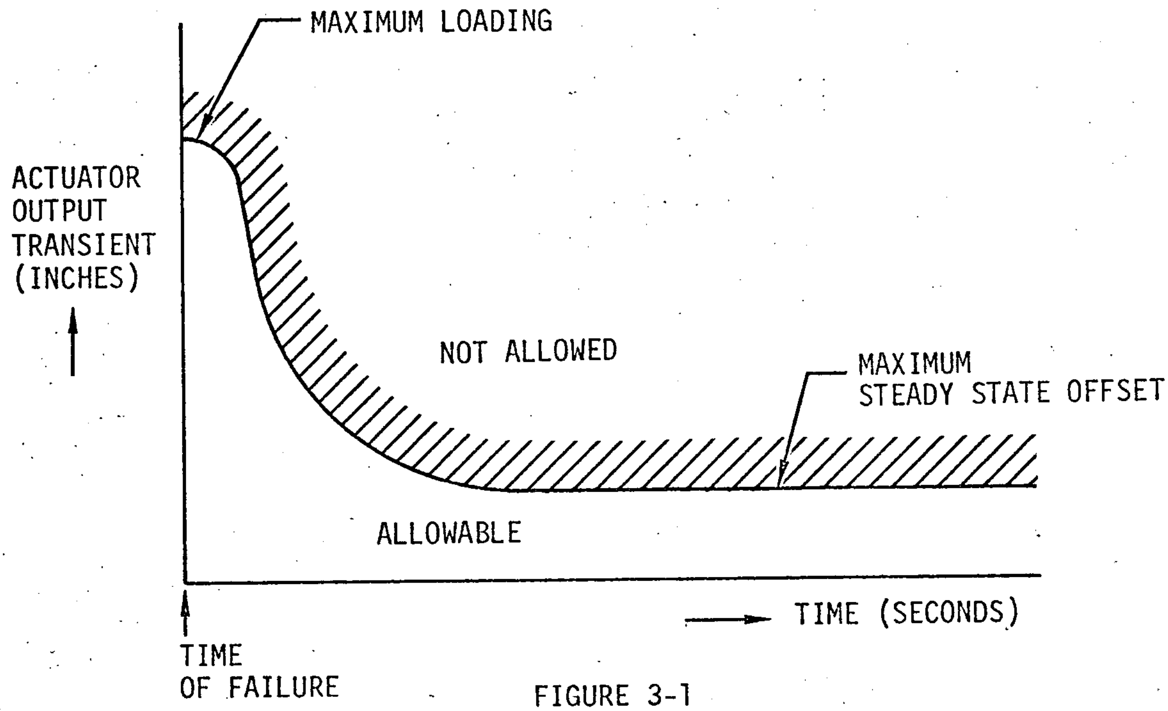


FIGURE 3-1
ALLOWABLE OUTPUT TRANSIENT

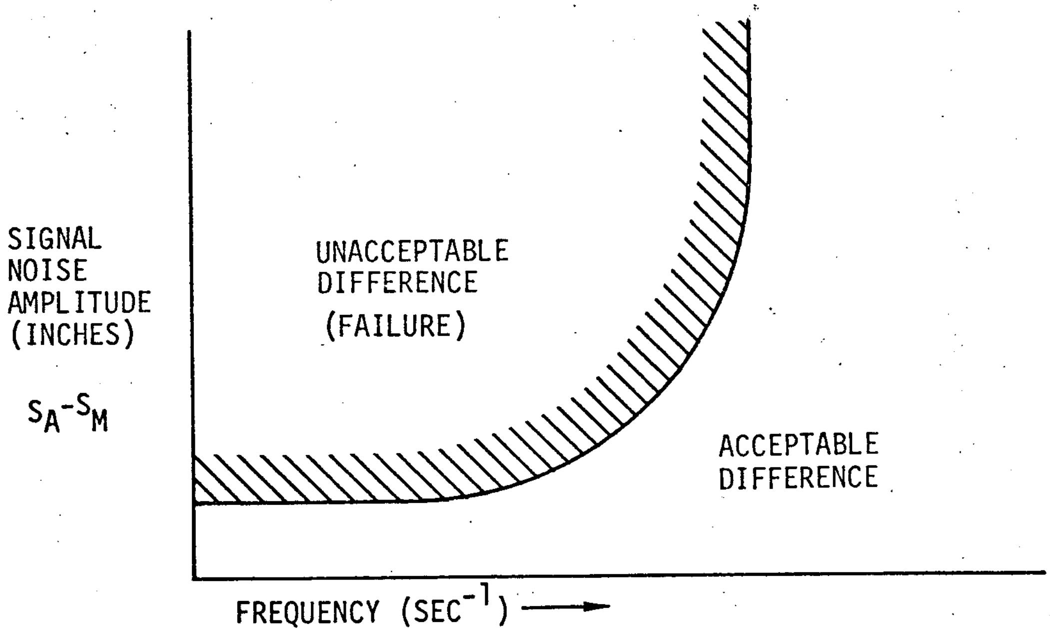


FIGURE 3-2
NOISE REJECTION

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

3.6 FAILURE DETECTOR DESIGN (Continued)

Nuisance switching results whenever the active channel and its model disagree by a value larger than the failure detection threshold. At low frequencies this disagreement must be less than the steady state offset shown in Figure 3-1. At higher frequencies it may be desired that the disagreement be allowed to increase. Figure 3-2 shows a typical monitor rejection curve which allows larger differences between the active channel ($S_A$) and its model ($S_M$) at higher frequencies. This characteristic of the failure detector is desirable to compensate for differences in dynamic performance and to reject line noise which may be introduced by switching in other circuits, EMI, etc.

If the failure detector is to perform in an acceptable manner its threshold must be programmed to fall between the transient requirements (Figure 3-1) and the noise requirements (Figure 3-2). This technique of programming the failure detection threshold allows the active standby technique to be applied to a great number of servo actuators which could not perform satisfactorily using a fixed threshold detection level.

3

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

3.6 FAILURE DETECTOR DESIGN (Continued)

If the output transient requirements and the monitor rejection requirements are not compatible the active standby redundancy technique can not be applied to the servo actuator. In this case one of the parallel active redundancy techniques will be required.

3.7 FAILURE CORRECTION

As noted in the preceding paragraphs the monitor function is two fold: failure detection and failure correction. The failure detector performance must be carefully programmed to achieve the desired performance. The failure correction function is much simpler. The failure correction function is to switch the channels as rapidly as possible after the failure detection threshold has been exceeded.

This fast response requirement for the failure correction device has resulted in a great deal of interest in hydromechanical mechanization of the failure detector. The use of a hydromechanical failure detector eliminates the time delay associated with an electrohydraulic interface.

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

3.8 MONITOR LOCATION

The failure detection and correcting mechanism may operate on either an actuator position or a servo valve position. Figures 3-3 and 3-4 show block diagrams for the failure detector in each functional location. In either case the logic switches control channels when its inputs exceed a predefined error value.

The actuator monitoring location (Figure 3-3) has the advantage of utilizing redundant actuators. However, in actual practice simplex (single channel) cylinder assemblies have been found far more reliable than electrohydraulic servo valves with their associated wires and connectors. Therefore, the weight penalty of a second actuator may be more significant than the gain in reliability offered by the redundant actuator.

The valve monitoring location (Figure 3-4) offers the advantage of early failure detection and potentially smaller failure induced transients. A hard over failure may be corrected at the valve output before the actuator integrates to the full failure detection level. Therefore, for some types of failures the resulting actuator

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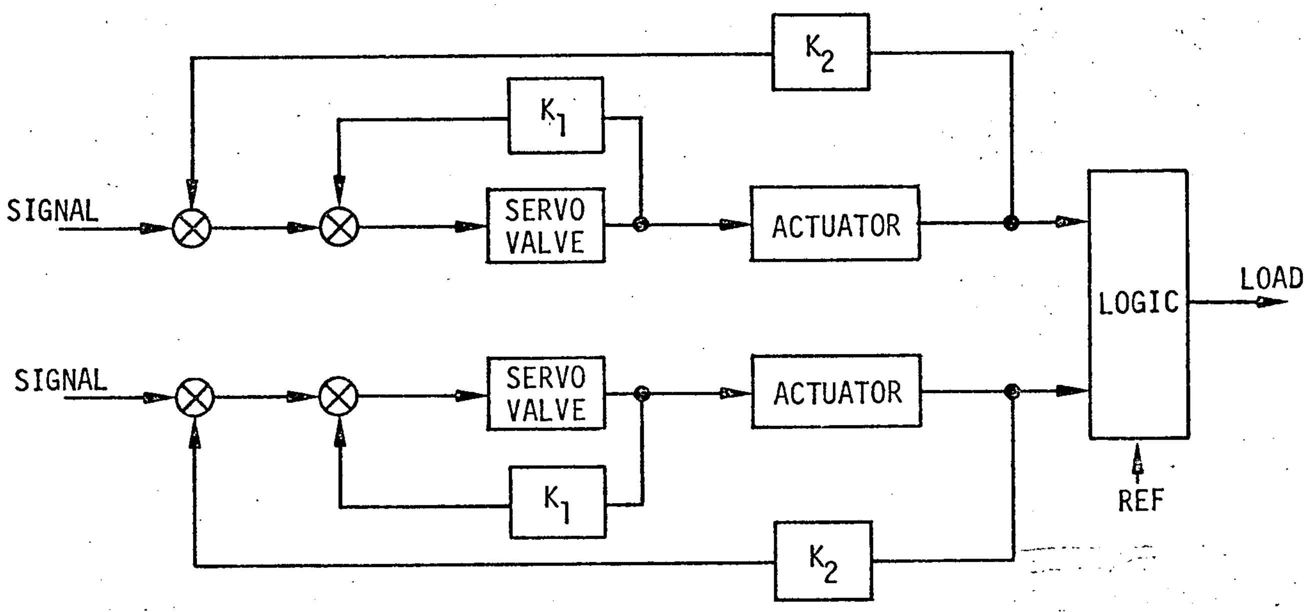
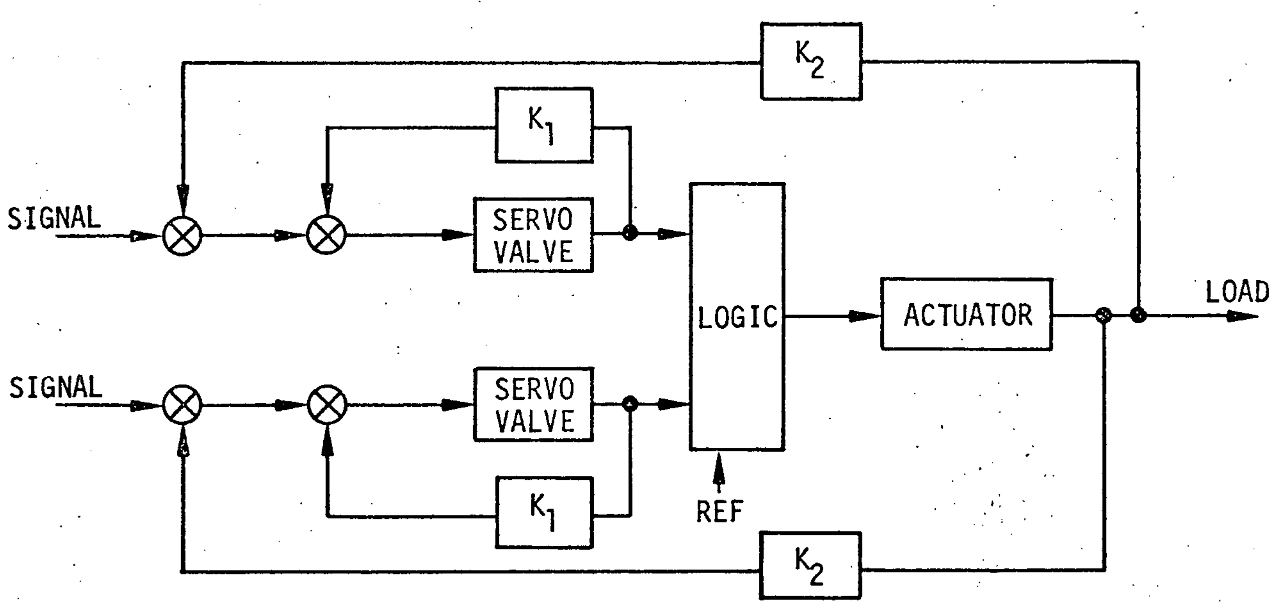



ACTUATOR MONITOR
FIGURE 3.3




VALVE MONITOR
FIGURE 3.4

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

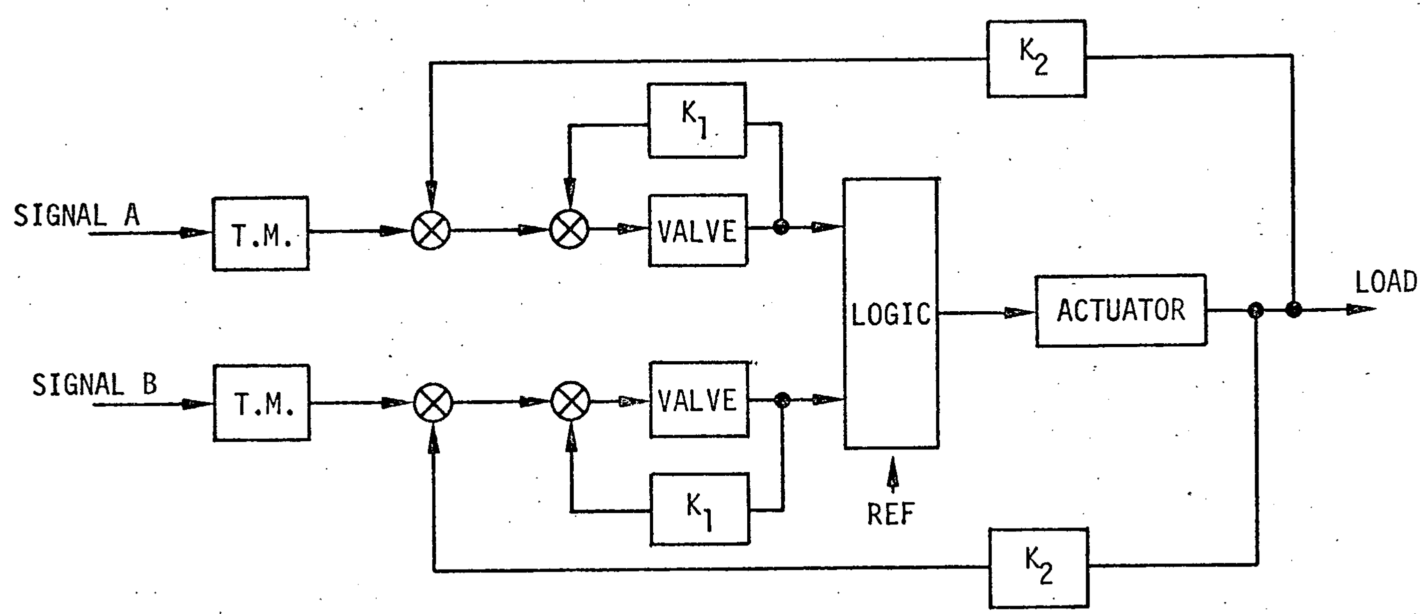
3.8 MONITOR LOCATION (Continued)

transient may be smaller for the valve monitor than for the actuator monitor. The valve monitoring location offers the added advantage that the failure detection signal can be large compared to the valve stroke thereby greatly simplifying the mechanization task. The valve monitor, however, may be more sensitive to nuisance switching as there is less filtering of signal noise due to the relatively high response of the servo valve.

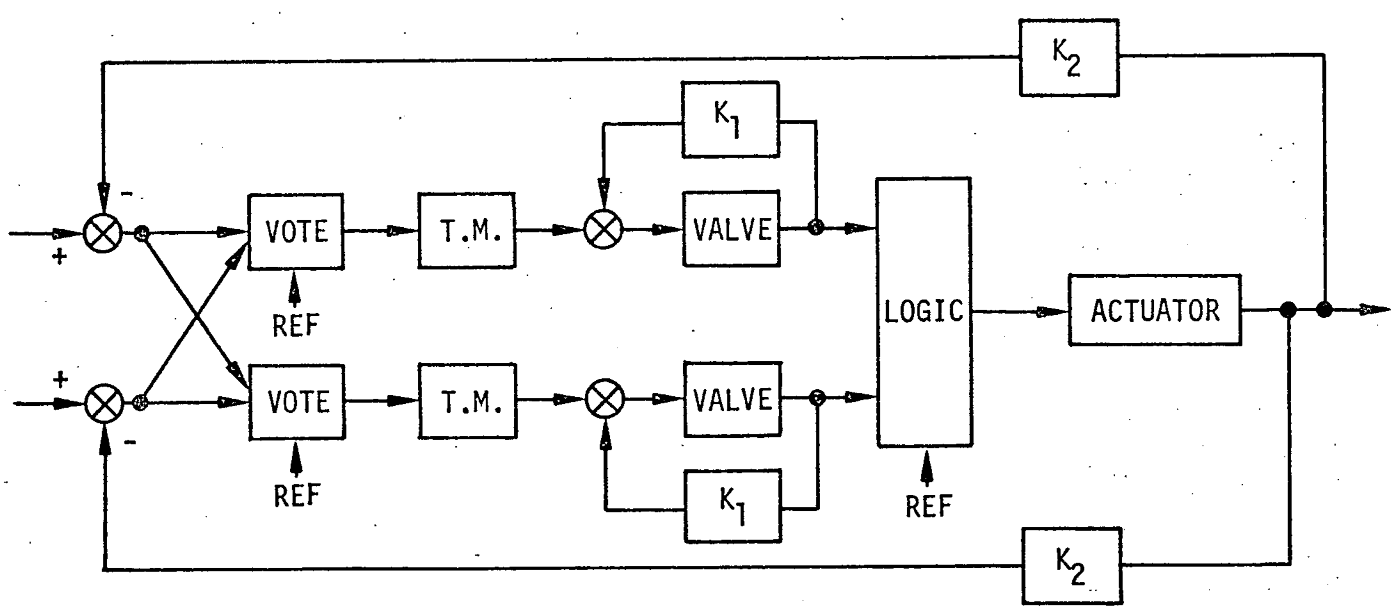
3.9 FEEDBACK

Either electrical or mechanical feedback may be used to close the servo loop. Mechanical feedback offers greater reliability than electrical feedback. However, the mechanical feedback requires summation downstream of a torque motor as shown in Figure 3-5. This requires that the failure detector threshold be set at a level which will reject torque motor drift as well as differences in response, gain, and saturation levels.

The use of electrical feedback allows the torque motor to be moved inside the first summing junction as shown in Figure 3-6. The torque motor's static error contribution is then reduced by a factor proportional to the loop




VALVE MONITOR - MECHANICAL FEEDBACK
FIGURE 3.5




VALVE MONITOR - VOTED ERROR SIGNAL
FIGURE 3.6

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

3.9 FEEDBACK (Continued)

gain. In addition, the difference in feedback signals may be eliminated by voting the error signal resulting from the first summing junction. This will eliminate static bias and gain differences between feedback signals.

3.10 VOTING REFERENCE

Figures 3-3 through 3-6 indicate that the voting logic receives two control signals and a reference signal. The reference signal is required in order to determine if one of the two control signals has failed.

Two voting techniques are available. One technique is to compare the active channel to the reference input and switch control from the active channel to a standby channel whenever the active channel and reference input disagree. The second technique is to compare the active channel to both the reference input and to the standby channel and to switch control when the active channel disagrees with both. This second technique prevents nuisance switching due to failures in the reference input. In either case three voting inputs are required to achieve fail operational performance.

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

3.10 VOTING REFERENCE (Continued)

To achieve fail operational performance twice (FO/FO) the voting logic is somewhat more complex. Theoretically the FO/FO performance may be achieved using a four input voter. Following the first failure the voter examines the remaining three channels to detect a second failure. This approach requires that the first failed channel be excluded from the voting logic. If the first failed channel was not excluded the voting logic would not be capable of producing FO/FO performance. After two failures the voting logic inputs would be two failed channels and two good channels. Under these conditions the voter would be incapable of transferring control to a good channel. To prevent this condition the failed input must be permanently excluded from the voter after it has failed.

The permanent exclusion of the first failed channel may be undesirable. Should the control system experience a condition which introduced significant line noise an otherwise good channel may be permanently switched off, thereby, reducing the reliability of the remaining system.

## 3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

### 3.10 VOTING REFERENCE (Continued)

A second approach to providing FO/FO performance is to use a five input voting logic. With five inputs the voting logic is capable of selecting one good channel even after two failures. The five input voting logic may examine "failed" channel and thereby avoid the loss in reliability experienced with the four input voter. The disadvantage of the five input voter is its complexity, particularly in hydromechanical mechanizations.

A simplified voting technique which reduces mechanical complexity and has inherent redundancy is also available. This technique utilizes a dedicated model and comparator for each active channel. The comparator is a two input device which generates a failure signal whenever the two inputs disagree. This signal may then be used to switch from the active to a standby channel. The comparators are inherently redundant, one per channel. The comparators are also simple to mechanize as each comparator has only two inputs.

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

3.10 VOTING REFERENCE (Continued)

The two channel comparator is simpler in that it is not required to select its inputs. This leads to a second advantage. A "failed" channel may be "reset." That is, after the first failure the "failed" channel may again be energized and if the failure no longer exists the control system will revert to its original degree of redundancy.

Two of the two channel comparators may be used in series to obtain FO/FO performance. The first comparator switches control from the active channel to a standby channel whenever the active channel and its model disagree. The second comparator performs an identical function using the new active channel. This technique may be used for any level of redundancy with no additional comparator complexity. To achieve FO/FO performance using a hydromechanical comparator a total of five electrohydraulic channels are required: a control valve and model for the first comparator, a control valve and model for the second comparator, and a third control valve.

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

## 3.11 HYDROMECHANICAL COMPARATOR MECHANIZATION

Three factors are required for acceptable performance of a comparator: 1) reliability, 2) repeatability, and 3) stability. A hydromechanical comparator has the potential of excelling in all three of these areas.

Assuming that the required comparator was to monitor the servo valve output there are several mechanizations available. The flow output of the active and model servo valves could be compared. This would result in a large power loss in that the standby channel would be dissipating as much power as the active channel. A more efficient approach would be to compare power valve slide position to model slide position. This in fact may be superior to flow monitoring in that it is less sensitive to actuator loading.

There are three methods available for mechanizing the hydromechanical comparator. A pressure signal may be generated which is proportional to valve slide position and these pressure signals may then be compared. In practice this method has been found susceptible to a host of secondary influences and therefore neither stable or repeatable.

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

3.11 HYDROMECHANICAL COMPARATOR MECHANIZATION (Continued)

In a similar manner a flow may be generated which is proportioned to power valve position. This is an improvement over the pressure sensor method but is still sensitive to such effects as contamination.

A third method of comparison would be to monitor the valve position directly. This method utilizes techniques which are well proven in practice and are the least sensitive to secondary influences. This method of comparison requires that mechanical linkage be attached to both the power valve slide and to a model slide. This linkage is used to generate a differential signal proportional to the disagreement between the power slide and model slide. There are a number of drawbacks however. The required linkage will reduce valve response as well as complicating valve design.

A fourth technique of comparison would be to monitor the driving device for the valve slide. This technique would be of special interest if a three stage valve configuration were being considered.

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

3.11 HYDROMECHANICAL COMPARATOR MECHANIZATION (Continued)

The mechanization using position comparison via mechanical linkage may also incorporate artifical synchronization. That is, the linkage which is connected to the two power valve slides may also be used to mechanically limit disagreement between the active channel and its model. This will cause both the model and power valve to stall and thereby reduce the actuator transient resulting from a hard over failure.

Another technique which may be used to limit the effects of a hard over failure is to allow the model to control 50% of the total flow output. For example, the power slide may control flow for signals from 0 to 50% of command and the monitor control flow from 50% to 100% of command. If a hard over failure were to occur in the active channel the power actuator would start to integrate the failure at a rate of 50% of full velocity. The monitor would sense this error and command its valve in a direction which will correct the error. This action will neutralize the failed channel and reduce the resulting transient. However, the effect of connecting

3.0 ACTIVE STANDBY REDUNDANCY CONCEPT (Continued)

3.11 HYDROMECHANICAL COMPARATOR MECHANIZATION (Continued)

system pressure to both sides of the actuator would completely eliminate load resistance in one direction.

A final monitoring technique which deserves comment is phase sensitive monitoring. This monitoring technique is useful if "failure" is defined by a velocity command $180^{\circ}$ out of phase with the actuator error signal. This failure definition is particularly useful in reducing nuisance switching. This technqiue allows the montior to ignore gain variations in the summing amplifier, torque motor, and mechanical feedback.

## 4.0 DESCRIPTION OF THE TEST ACTUATOR

An actuator and associated control electronics were designed and fabricated to demonstrate the feasibility of controlling a large electrohydraulic servo actuator using active standby redundancy techniques. The design goal was to produce a workable design which would provide fail operate/fail operate/fail safe (FO/FO/FS) performance.

The servo actuator design which was selected for the active standby redundancy demonstration is a three channel configuration. Each channel has a flow control servo valve, a model servo valve, and a hydromechanical failure detector (comparator). Any of the three electro-hydraulic valving channels may be connected to a common power actuator by opening a selector valve. Position feedback from the power actuator is electrical. A common signal is supplied to all three channels with offset capabilities within each channel. A simplified schematic of the test actuator is shown in Figure 4-1.

Components used in the construction of the test actuator were not required to be flight quality hardware but were of sufficient quality to evaluate the active standby redundancy technique. The actuator was sized to

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| PAGE | 27 | DOCUMENT NO. 221400-17 | REV. |
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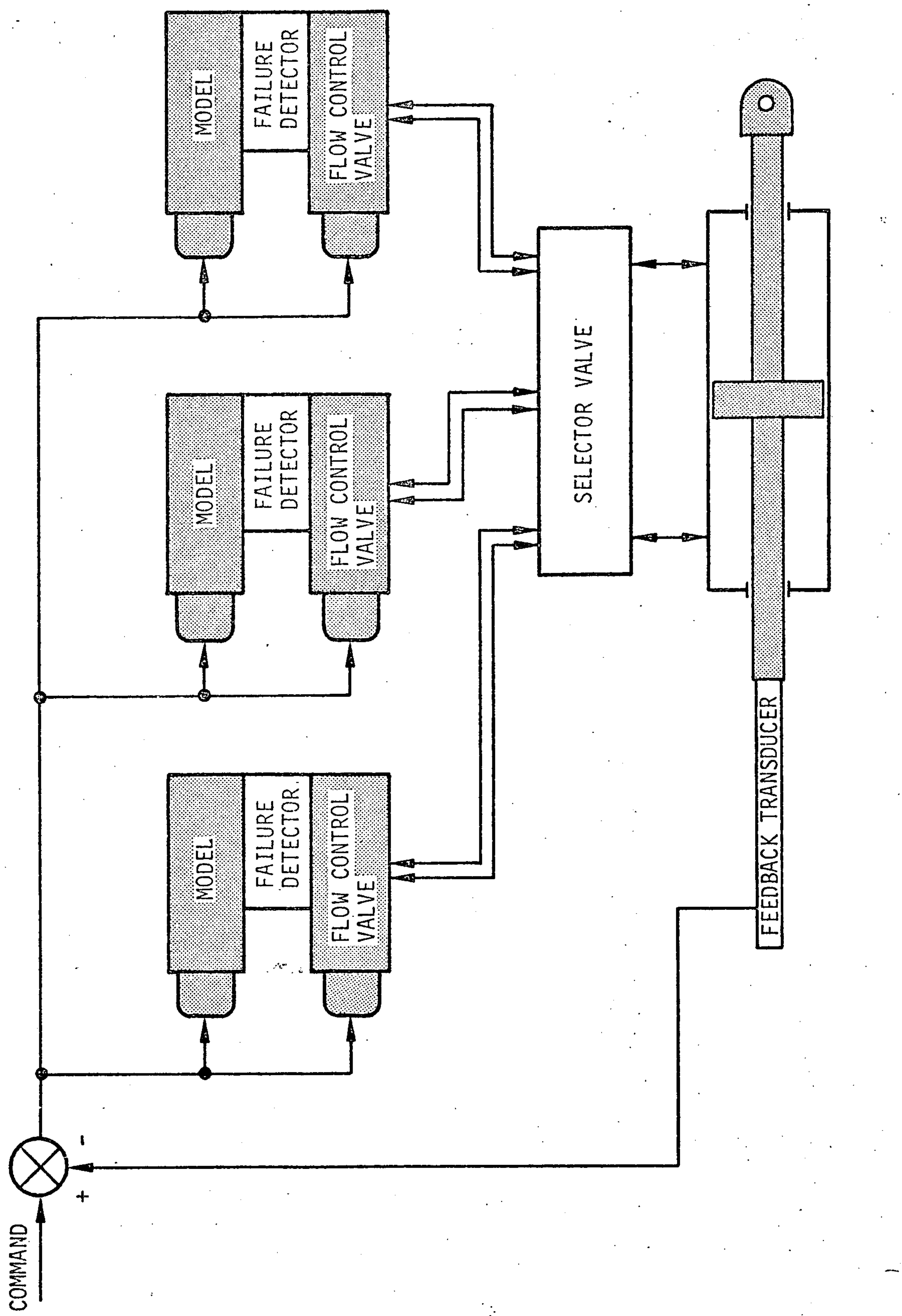


TEST ACTUATOR SCHEMATIC
FIGURE 4-1

4.0 DESCRIPTION OF THE TEST ACTUATOR (Continued)

produce a 216,000 newton (48,600 lb) force when operated at 4350 newtons/$cm^2$ (3000 psi). Each of the three manifold assemblies were designed to control 150 liters/minute (40 gpm). An over-all view of the actuator assembly is shown in Figure 4-2.

4.1 CONTROL MANIFOLD ASSEMBLY

Three control manifold assemblies are attached to a common actuator. Each of the manifold contain all valving associated with one control channel: flow control, model, comparator, interlock, and blocking (selector) valves. Figure 4-3 shows a schematic of the flow control manifolds and their connections to the servo actuator.

The flow control valve is a two stage electrohydraulic servo valve. The first stage of the valve receives electrical inputs and control flow to position the second stage. Mechanical feedback from the second stage to the torque motor provides closed loop servo control of second stage valve position. The mechanical relationship between the first and second stages is shown in Figures 4-4 and 4-5.

TITLE ACTIVE STANDBY REDUNDANCY

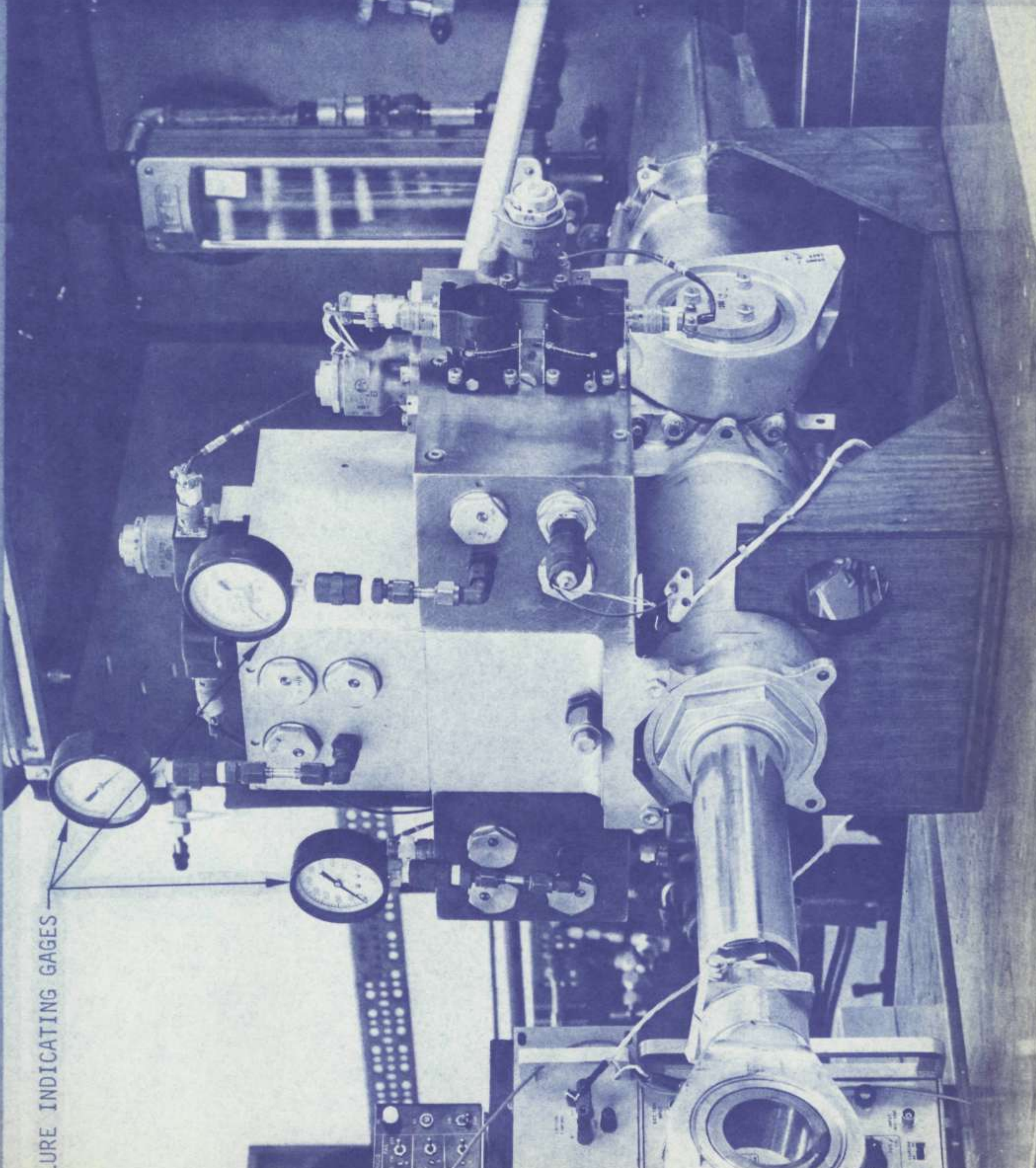


FIGURE 4-2

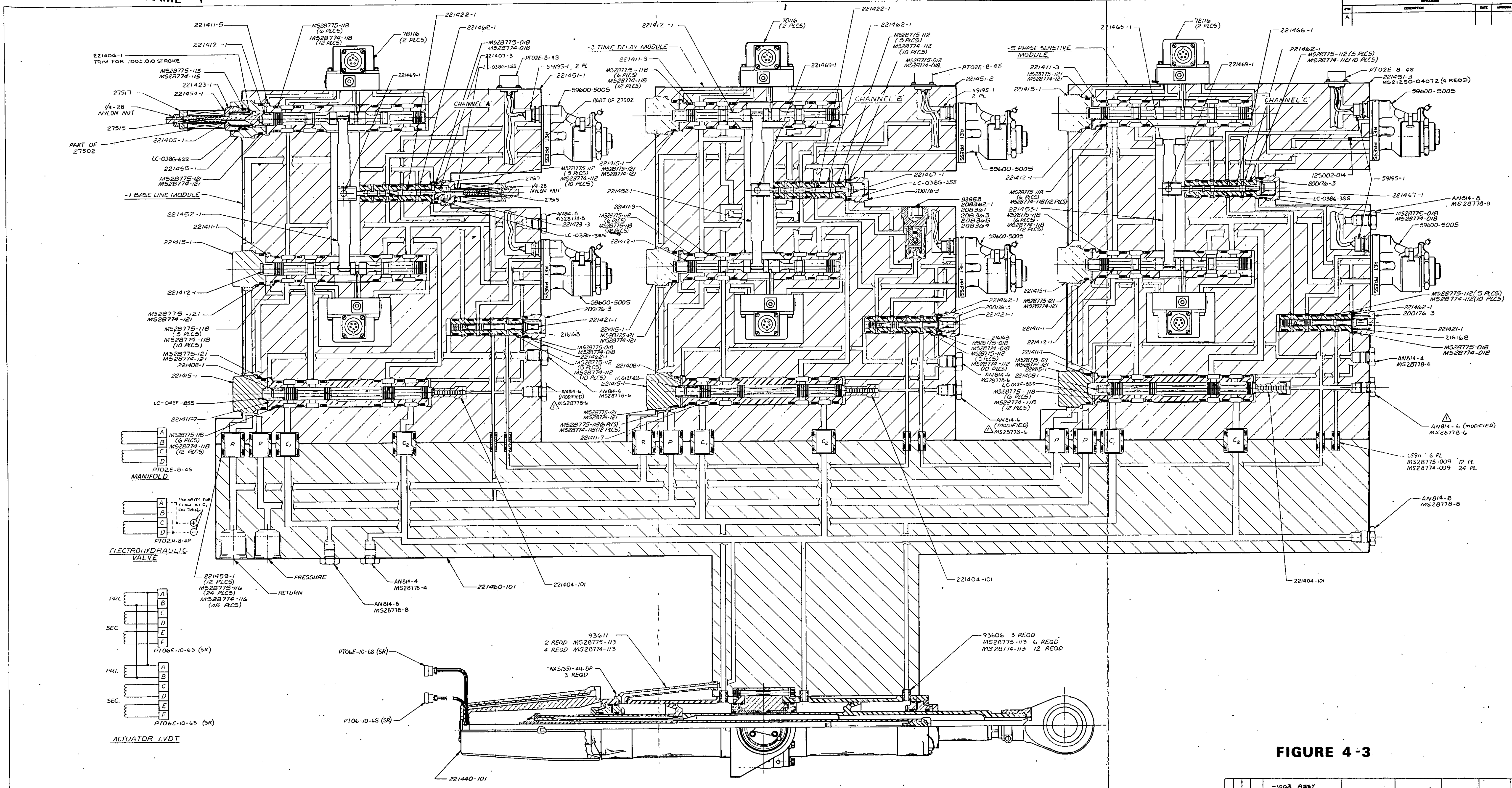


**FIGURE 4-3**

⚠ MODIFY AN814-6 FITTING (3 PLACES) BY TRIMMING FOR SLIGHT PRELOAD OF 221404-1 SLEEVE. MACHINE 4 SLOTS APPROX .06 WIDE x .06 DEEP ON THD END OF CAP.

NOTES:

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4.0 DESCRIPTION OF THE TEST ACTUATOR (Continued)

4.1 CONTROL MANIFOLD ASSEMBLY (Continued)

The first stage is an Abex Model 405 servo valve. This valve contains the torque motor, hydraulic preamplifier, and mechanical feedback. The torque motor receives both electrical and mechanical input. A ±10 ma electrical command to the torque motor may be balanced by a mechanical feedback of ±.100 inch from the second stage. The torque motor is balanced in all three axes against the effects of lateral acceleration and vibration. The torque motor has an atmospheric seal and is isolated from the hydraulic fluid. The hydraulic preamplifier utilizes the jet pipe principle. The jet pipe hydraulic preamplifier may be represented by a four arm hydraulic bridge with all arms active. This preamplifier yields high hydraulic efficiencies and high contamination tolerance. The first stage oil passes through a 90 micron screen which may easily be removed for inspection.

Performance of the flow control valve is monitored by a model and a comparator valve. The model valve is mechanically a duplicate of the flow control valve. The model valve and the flow control valve slide positions

TITLE ACTIVE STANDBY REDUNDANCY

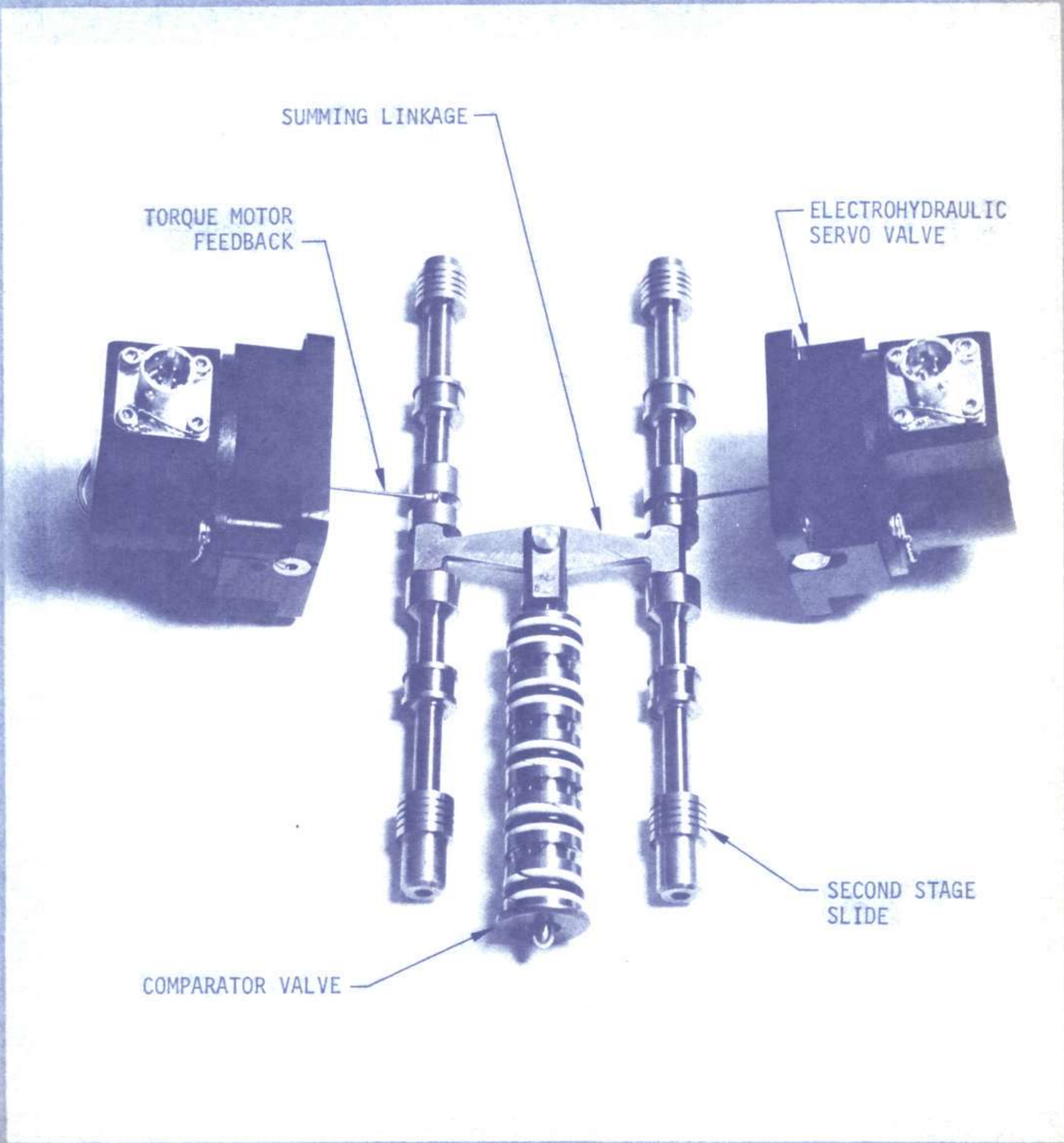


FIGURE 4-4

4.0 DESCRIPTION OF THE TEST ACTUATOR (Continued)

4.1 CONTROL MANIFOLD ASSEMBLY (Continued)

are compared by a summing linkage as shown in Figure 4-4. Under normal operating conditions the model and flow control valves are $180^{\circ}$ out of phase. Therefore the mid-point of the summing lever does not move.

Under failure conditions the summing lever mid-point moves off center and displaces the comparator valve. Whenever the comparator valve displacement exceeds a preset threshold a "failure" signal is generated. The "failure" signal is ported through an interlock valve to the blocking (selector) valve.

The function of the blocking valve is to isolate the flow control valve from the servo actuator, this is defined as blocking valve closed. The blocking valve has three modes of operation. First, with no pressure supplied to the control manifold assembly the blocking valve is held closed by a spring. Second, when pressure is supplied to the "engage" port the blocking valve is opened. Third, whenever the internal "failure" signal exceeds 290 psi the blocking valve will again close.

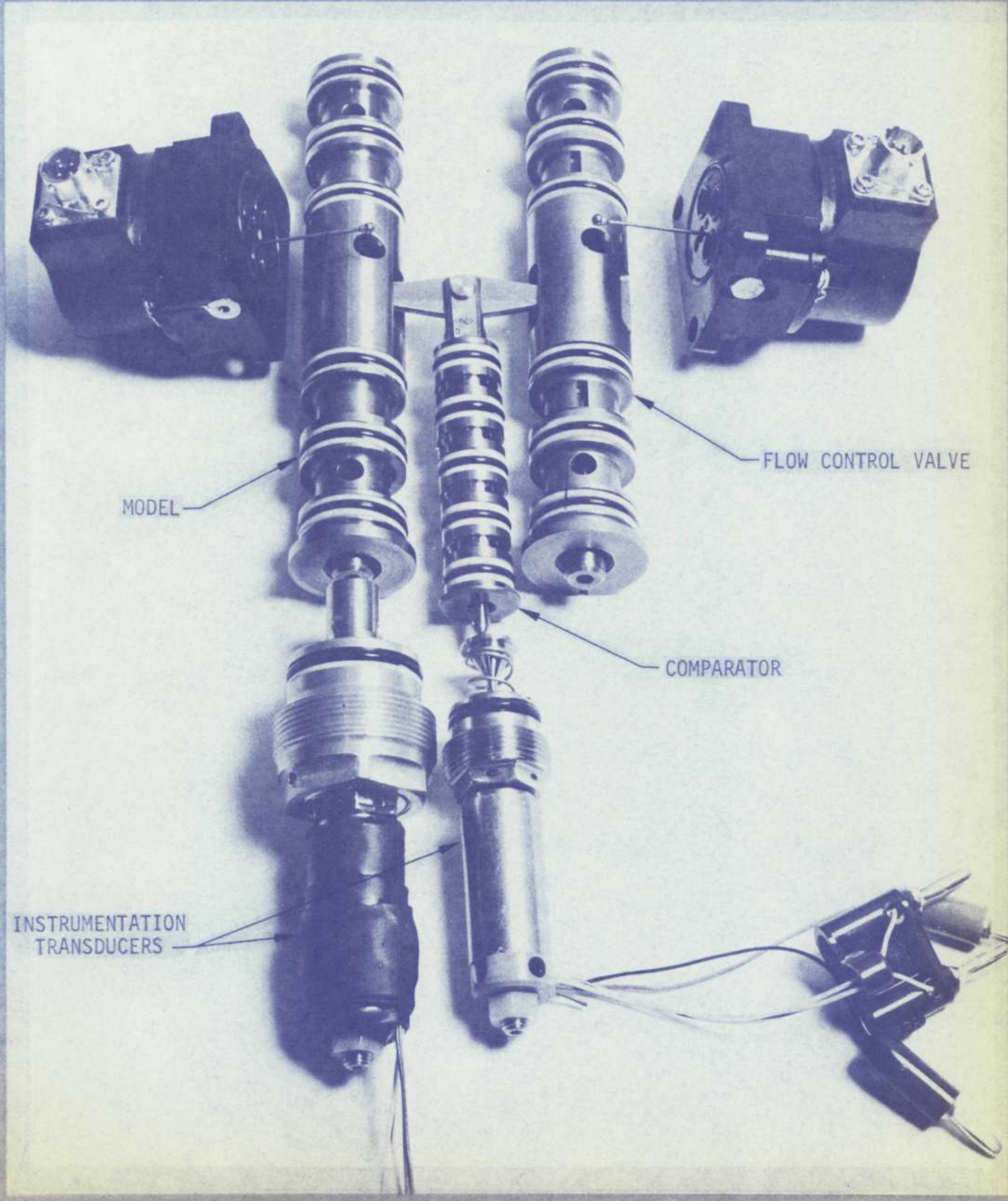
FLOW CONTROL VALVE
MODEL
COMPARATOR
INSTRUMENTATION
TRANSDUCERS

FIGURE 4-5

4.0 DESCRIPTION OF THE TEST ACTUATOR (Continued)

4.1 CONTROL MANIFOLD ASSEMBLY (Continued)

The "failure" signal also operates a interlock valve. Whenever the "failure" signal exceeds 615 psi the interlock valve moves to the full retract position. In this position the interlock valve ports system pressure into the "failure" signal line and thereby lock both itself and the blocking valve into the "failure" position. In this position the interlock valve also ports system pressure to the "engage" port on the next control manifold assembly.

Each control manifold assembly contains two solenoid valves. One solenoid valve will "reset" the interlock valve after it has locked onto a failure signal. The "reset" solenoid is normally energized and system pressure is ported to the interlock valve inlet port. The "reset" function may be initiated by de-energizing the solenoid valve, this ports the interlock valve inlet port to return.

The second solenoid valve may be used to switch off or fail an active channel. When the "failure" solenoid valve is energized it ports system pressure into the "failure" signal line.

4.0 DESCRIPTION OF THE TEST ACTUATOR (Continued)

4.2 CHANNEL "A"

The failure detection technique demonstrated in Channel "A" can be considered a basic approach of which the other two channels are variations. Channel "A" is shown in block diagram form in Figure 4-6. It uses one electrohydraulic valve and second stage combination as a power control valve, and another electrohydraulic valve and second stage slide as a model. The position of each slide is summed at the comparator using a summing lever. The comparator has symmetrical overlaps on the pressure-to-fail lands and equivalent underlaps on the fail-to-return lands. The amount of over and underlap determines the threshold level. Two comparator slide sleeve combinations were tested: one with .040" overlap and one with .008" overlap. This is equivalent to 80% and 16% valve stroke respectively.

4.3 CHANNEL "B"

A block diagram of Channel "B" is shown in Figure 4-7. This channel is equivalent to Channel "A" except both slides are flow control slides. The first slide provides flow over the first 40% of the stroke. The second slide provides flow over the last 40% of its stroke. The

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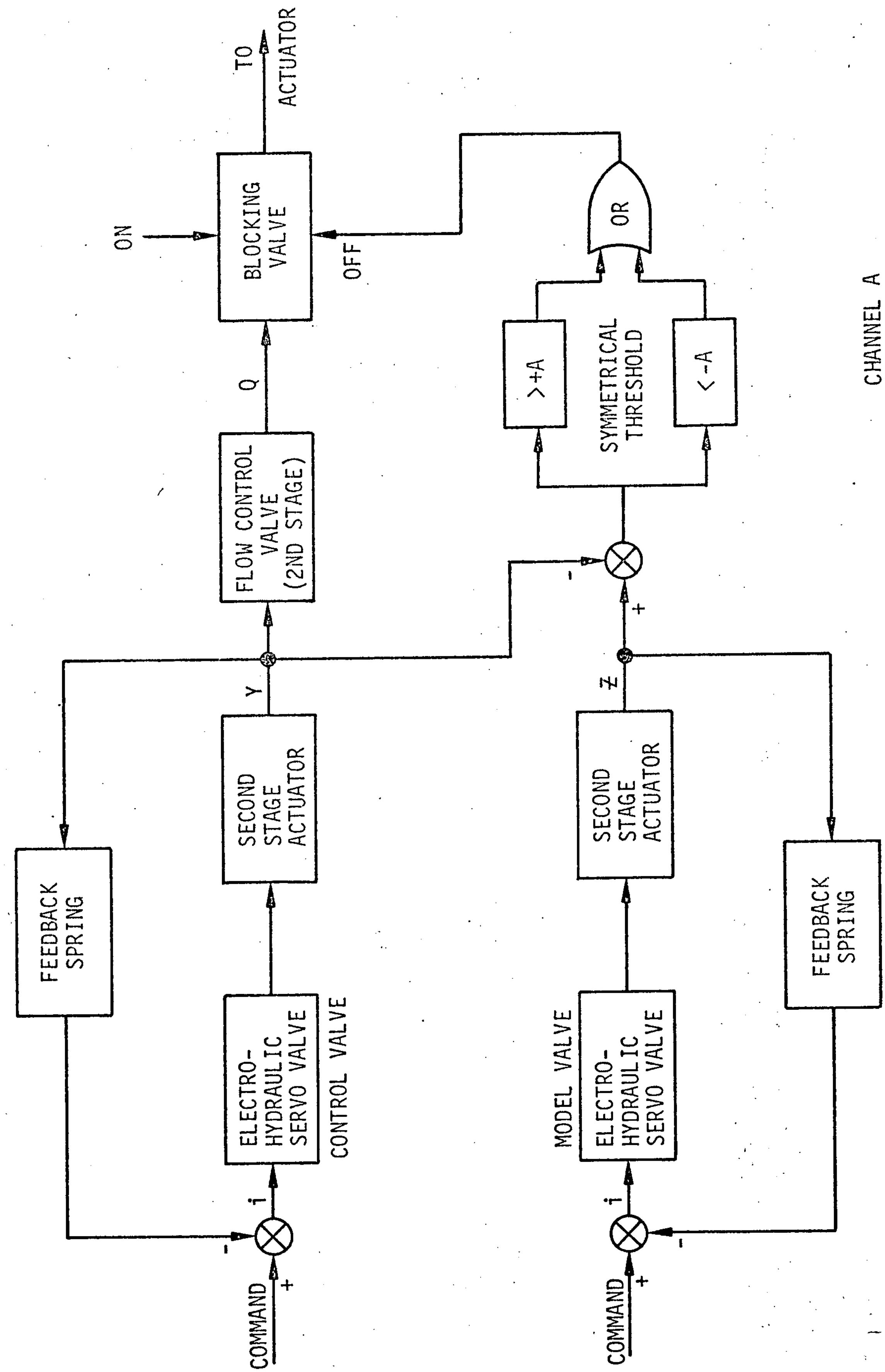
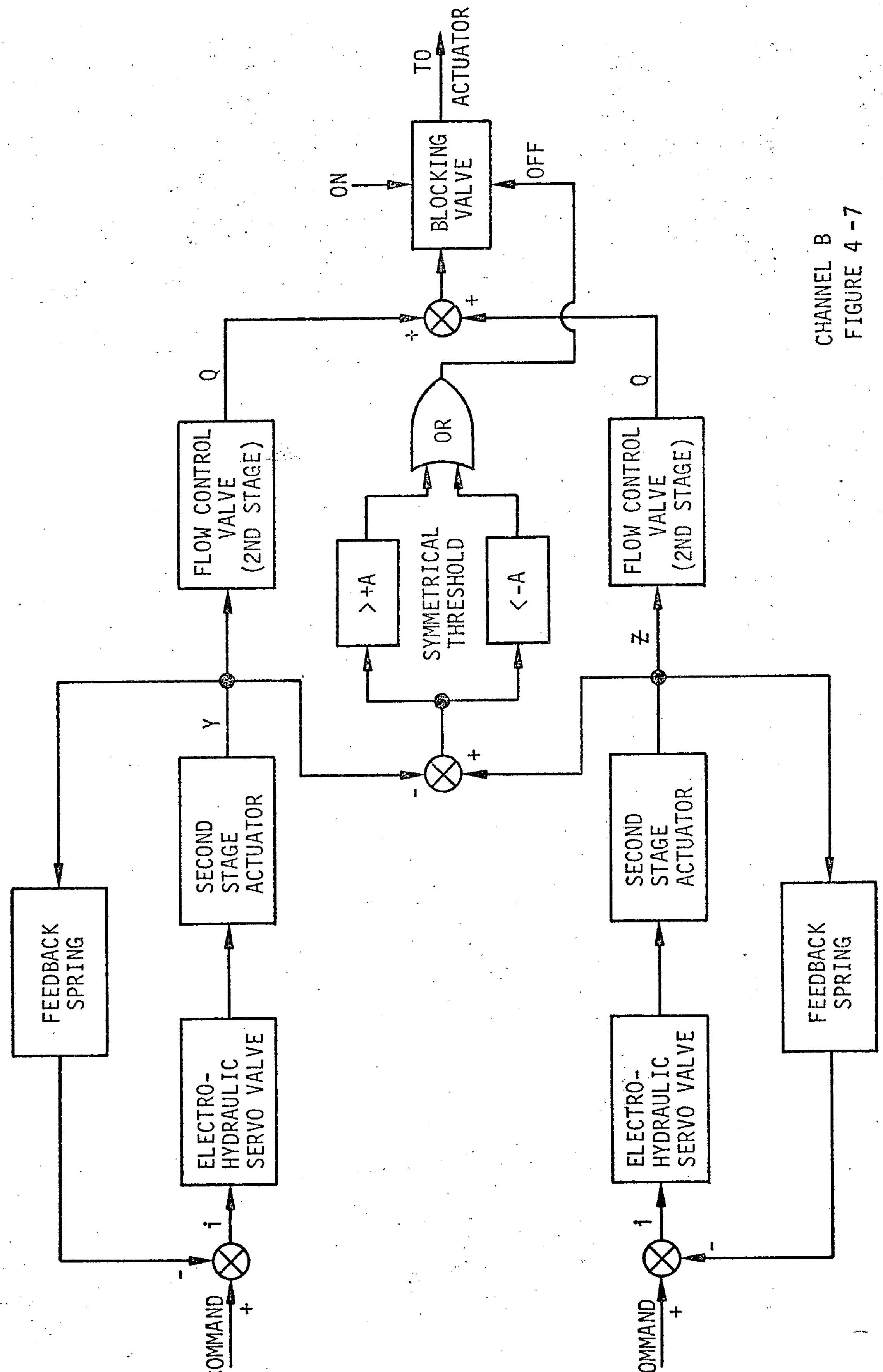



CHANNEL A
FIGURE 4-6




CHANNEL B
FIGURE 4-7

4.0 DESCRIPTION OF THE TEST ACTUATOR (Continued)

4.3 CHANNEL "B" (Continued)

flow gain is 125% of the Channel "A" flow gain over the flow control portion of the stroke. This is an average flow gain equivalent to Channel "A" over the full stroke. The purpose of the 20% no-gain band is to preclude a potential 200% gain region which could result due to tolerances if the slides provided flow over a nominal 50% of the stroke.

A "hard over" failure in one of the control valves can be nullified by compensating flow from the other valve. However, a load at the actuator can only be sustained in a direction opposite to that of the failure.

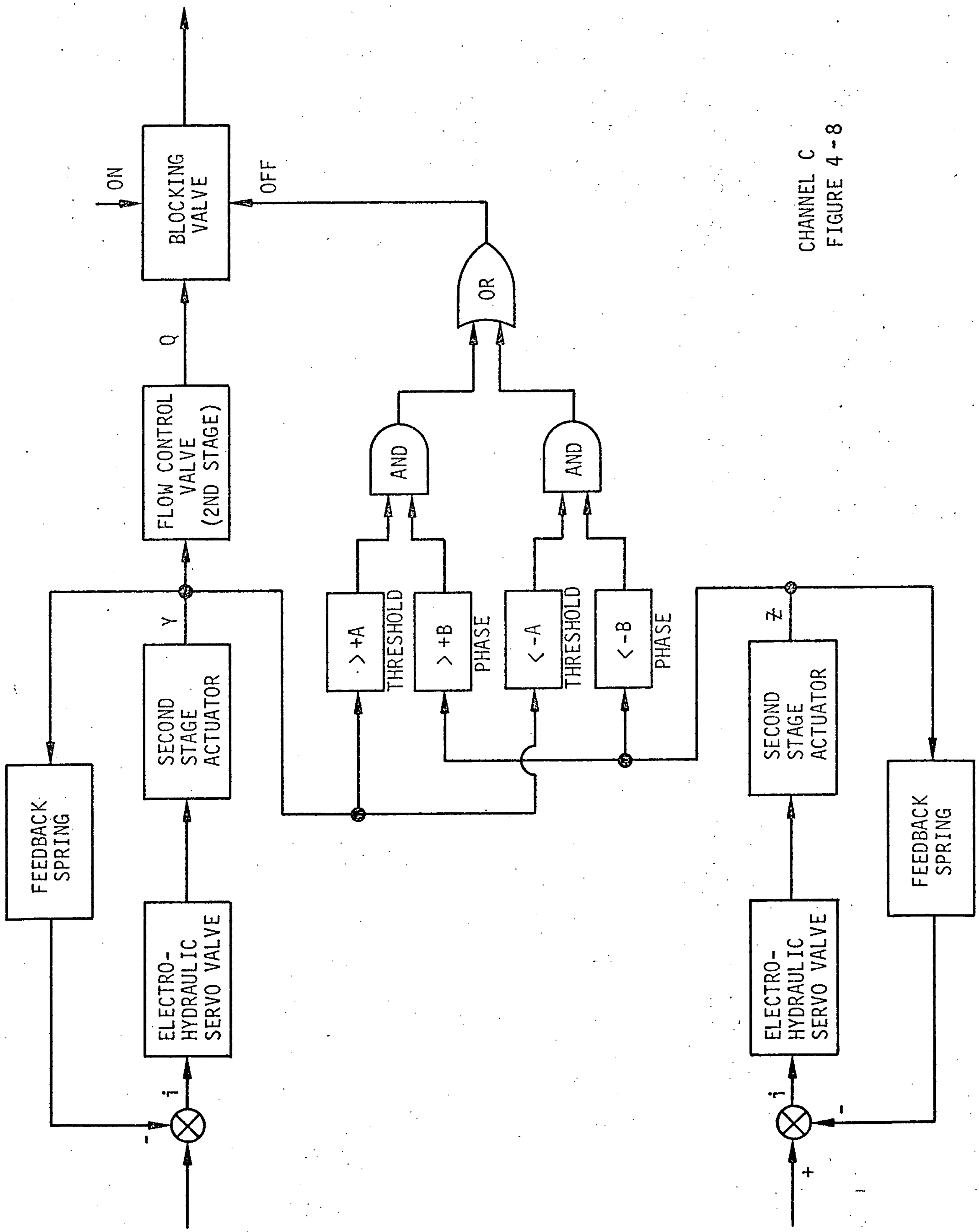
The "B" Channel also includes a time delay orifice which can add up to .6 seconds to the switching time. Two different time delay assemblies were tested.

4.4. CHANNEL "C"

Channel "C" has power and model valves similar to Channel "A" except the model valve is used to indicate phase rather than position. Phase is reported to the

D

TITLE ACTIVE STANDBY REDUNDANCY




CHANNEL C
FIGURE 4-8

4.0 DESCRIPTION OF THE TEST ACTUATOR (Continued)

4.4 CHANNEL "C" (Continued)

comparator valve as a pressure signal. Linkage transmits the power valve phase and position to the comparator valve. The comparator is configured to interpret this information as shown in Figure 4-8. One shortcoming of this method of failure analysis is that passive failures occurring in the power valve will not automatically be detected.

4.5 ELECTRONIC CONTROLLER

The electronic controller required for the active standby electrohydraulic actuator contains four types of circuits.

1. Servo Control Circuits
2. Monitor Readout Circuits
3. Selectors to Simulate and Reset Failures
4. Power Supply

Figure 4-9 shows the general arrangement of components used to close the actuator servo control loop. These components sum command with feedback and provide buffered signals to the individual transfer valves.

The demodulator converts actuator position transducer signals from 400 Hz to direct current. Gain of the demodulator is 1 VDC/1 VAC (rms). Input impedance

TITLE ACTIVE STANDBY REDUNDANCY

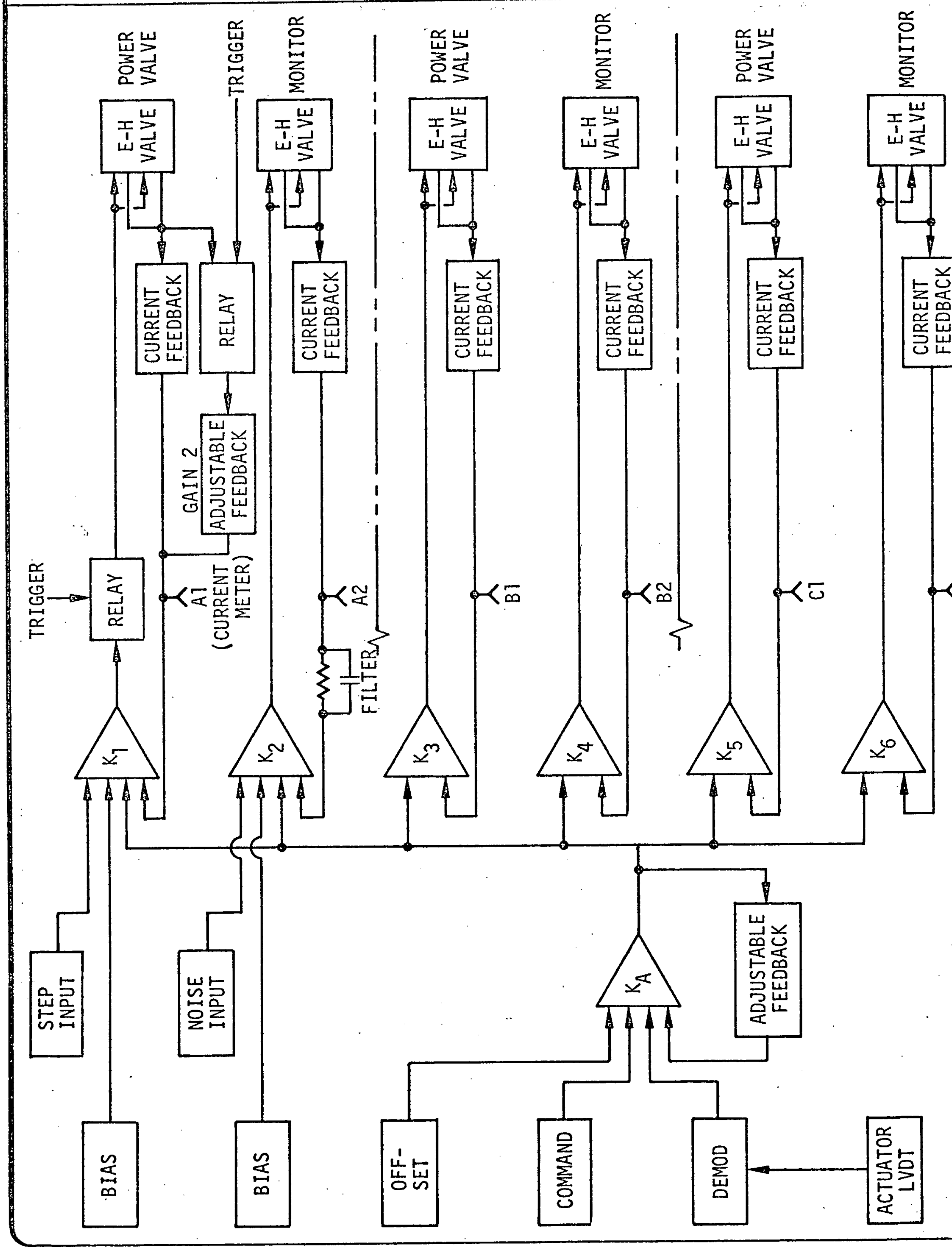



FIGURE 4-9

4.0 DESCRIPTION OF THE TEST ACTUATOR (Continued)

4.5 ELECTRONIC CONTROLLER (Continued)

is approximately 10,000 ohms. Sensitivity of the actuator position transducer is 5.9 volts/inch (± 26 V maximum). Excitation of the transducer is 26 VAC at 400 Hz with power drain of less than 1.5 volt-amp.

A dual banana jack is provided on the controller to accept external commands. Full stroke of the power actuator will require ± 12 VDC. Input impedance is approximately 4,000 ohms.

An external adjustment is provided to allow adjustment of command null over ±50% of actuator stroke. Internal bias control is also provided to allow adjustment of the buffer amplifier output.

The servo amplifier receives command, bias, and demodulator inputs and provides an adjustable voltage gain from demodulator input to amplifier output of 6.85 volts/volt. Output of the amplifier is ±12 VDC with an impedance of less than 50 ohms.

4.0 DESCRIPTION OF THE TEST ACTUATOR (Continued)

4.5 ELECTRONIC CONTROLLER (Continued)

A buffer amplifier is supplied for each electrohydraulic valve to prevent dynamic interaction between valves. The amplifier has a 1 MA/V gain with a 121,000 ohms input impedance. Current feedback is utilized to obtain an output impedance which is greater than 10,000 ohms.

The electrohydraulic valves required ±10 ma for full signal and have a coil resistance of 500 ohms when connected in parallel. A meter and selector switch is provided for checking electrohydraulic valve current. The meter also has a 20X momentary switch for greater resolution around null.

The output of the number one buffer amplifier contains a switch to allow simulation of an open circuit failure. The switch is activated by applying a voltage +5 to +50 volts DC to the jacks identified as "open T.V."
The gain of the number one buffer amplifier may be changed from 1 MA/VDC to any gain between approximately 0.45 to 1.25 MA/VDC by adjusting the "gain 2" pot. Applying voltage of +5 to +50 VDC triggers the gain

4.0 DESCRIPTION OF THE TEST ACTUATOR (Continued)

4.5 ELECTRONIC CONTROLLER (Continued)

change. A reset button is supplied to clear both triggers. External signals may be introduced to the #1 buffer amplifier through the "step input" dual banana jacks.

The #2 buffer amplifier contains provisions for introducing a time lag in the feedback loop. A capacitor is packaged external to the controller and is connected by a dual banana jack to allow for the selection of time constants.

The external capacitor adds a simple time lag: $\frac{1}{1 + \tau s}$.

The time constant $\tau$ in milliseconds is 12.1 times the external capacitor in microfarads (e.g. A 1$\mu$F capacitor results in a 12.1 ms lag).

The actuator feedback transducer is supplied with two PTO6E(SR)-10-6S plug connectors. One connector is attached to each section of the redundant feedback transducer. One section is used for feedback and one section is available for monitoring. Each of the six electrohydraulic servo valves have a PTO2H-8-4P receptacle connector.

4.0 DESCRIPTION OF THE TEST ACTUATOR (Continued)

4.5 ELECTRONIC CONTROLLER (Continued)

The 221450-101 Manifold Assembly contains two 27502 transducers, one to monitor the power servo valve slide and one to monitor the comparator slide. The transducers are driven by 26 volts at 400 Hz and have gains of 26 volts (RMS) per inch of stroke. Both applications of the transducer have ±.100 inch strokes. The electronic controller contains demodulators and dual banana jacks to allow monitoring of the power servo and comparator. It whould be noted that only the 221450-101 manifold assembly contains the above described monitor transducers.

## 5.0 PERFORMANCE ANALYSIS

The analysis, testing, and evaluation sections of this report deal with the problems of switching transients and nuisance failures. The objective of these sections is to develop design criteria for applying active standby redundancy to large electrohydraulic actuators. The analytical techniques developed in this section of the report are somewhat cumbersome for design purposes but were required to prove correlation between theory and practice using a model which has significant non-linearities. For design purpose the techniques may be linearized and simplified within the constraints of the required accuracy.

## 5.1 EVALUATION CRITERIA

The first step in analyzing a multi-channel redundancy technique is to select a yardstick for measuring the actuator's performance. Conventional servo actuator analysis techniques are well developed and provide adequate tools for measuring frequency response, stability, hysteresis, threshold, authority, etc. The tools for analyzing the failure detection and failure correction mechanisms are more vague and are the subject of this section of the report.

5.0 PERFORMANCE ANALYSIS (Continued)

5.1 EVALUATION CRITERIA (Continued)

The analytical tools presented in this report have been developed to handle the three most significant types of signal anomalies experiences in practice. The end use of these tools is to promote a maximum knowledge of that fine line which exists between signal noise and signal failures.

The performance analysis of the failure detection and correction mechanism has been performed in three stages:

1) The output transient resulting from a hard over signal failure.
2) The ability of the failure detector to reject line noise.
3) The ability of the failure detector to reject component null and gain aberrations.

The first two conditions predict performance of the failure detector under steady state conditions in which the amplitude of the signal anomaly is large as compared to control signal amplitude at any given frequency. The third condition predicts performance of the failure

5.0 PERFORMANCE ANALYSIS (Continued)

5.1 EVALUATION CRITERIA (Continued)

detector under dynamic conditions in which the amplitude of the signal anomaly is small as compared to control signal amplitude at any given frequency.

5.2 HARD OVER FAILURE

A hard over failure may be considered the worst case signal failure in that it is a large amplitude signal representing all frequency components. The hard over failure may not represent the worse case output transient but it does represent the largest transient which has a failure rate of concern to the designer.

Actuator response to a hard over command may be predicted from the servo actuator and failure detector transfer functions. The servo actuator transfer function may be developed from the block diagrams shown in Figures 5-1 and 5-2. The actuator output (X) will follow a step input until the flow is interrupted by the blocking valve. The time lag ($T_1$) from introduction of the step input to the closing of the blocking valve is the sum of the time required for the flow control slide (Y) to exceed the error threshold plus the time required for the comparator "failure" signal to drive the blocking

TITLE ACTIVE STANDBY REDUNDANCY

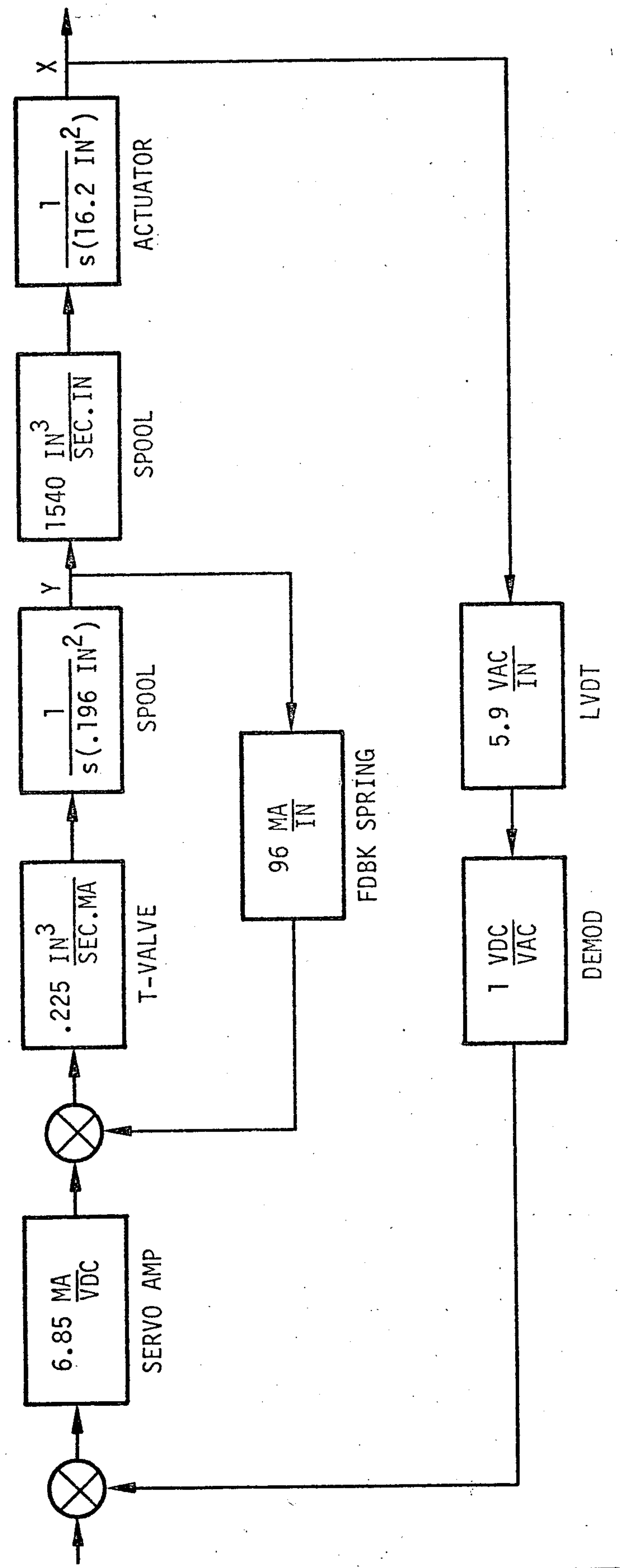
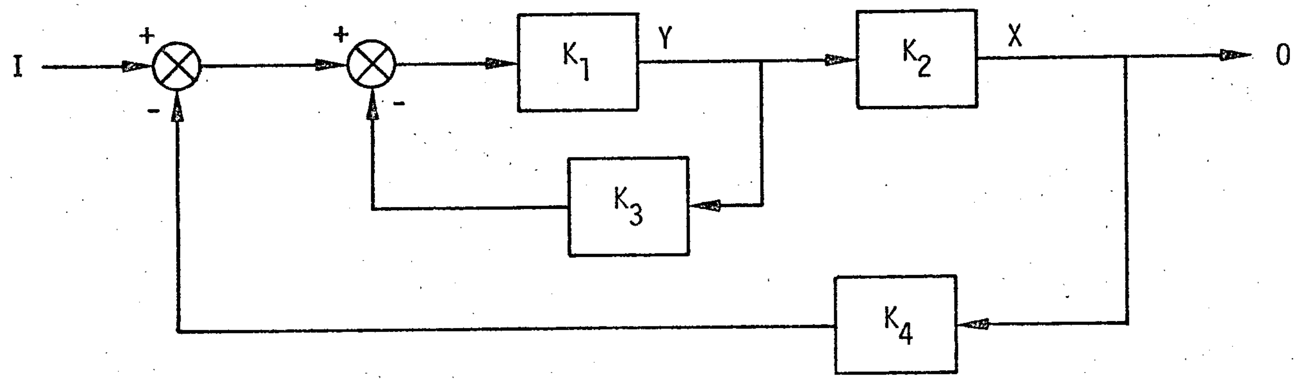



FIGURE 5-1




$$\frac{0}{I} = \frac{1/K_4}{\dfrac{1}{K_1\ K_2\ K_4} + \dfrac{K_3}{K_2\ K_4} + 1}$$

WHERE $K_1 = \frac{1}{s}(1.15)$ IN/SEC/MA

$K_2 = \frac{1}{s}(95)$ IN/SEC/IN

$K_3 = 96$ MA/IN

$K_4 = 40.5$ MA/IN

$$\frac{0}{(6.85)I} = \frac{.0247}{.000226s^2 + .0249s + 1}$$

FIGURE 5-2

5.0 PERFORMANCE ANALYSIS (Continued)

5.2 HARD OVER FAILURE (Continued)

valve closed. Once the blocking valve has closed the actuator position (X) will be constant. The actuator ports are blocked while control is being transferred from the "failed" control channel to a standby channel. This second lag ($T_2$) may be calculated from the time required for the interlock valve in the "failed" channel to "engage" or open the blocking valve in a standby channel. Actuator response following this transfer of control may be predicted from the transfer function associated with the standby channel. Figure 5-3 shows a typical test result for a .250 inch step input.

5.2.1 CLOSED LOOP CONTROL

During the test phase of the development program it was found that step inputs of intermediate size would produce larger actuator transients than hard over step inputs. Upon further investigation it was found that this phenomenon could be attributed to the fact that the failure detector is located inside of the control loop as illustrated in Figure 5-4.

"A" CHANNEL
BASIC CONFIGURATION
.250 INCH STEP INPUT

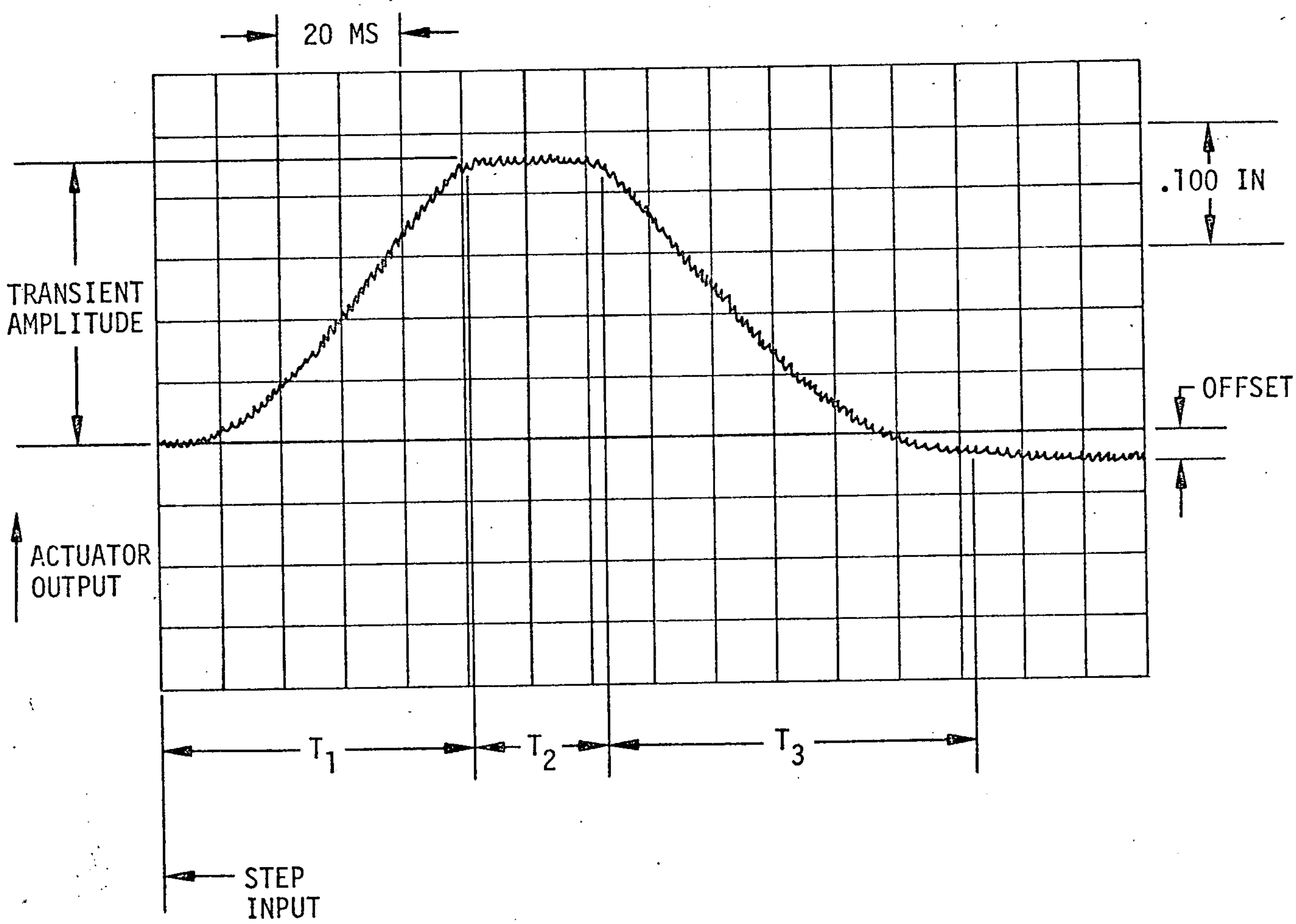



FIGURE 5-3

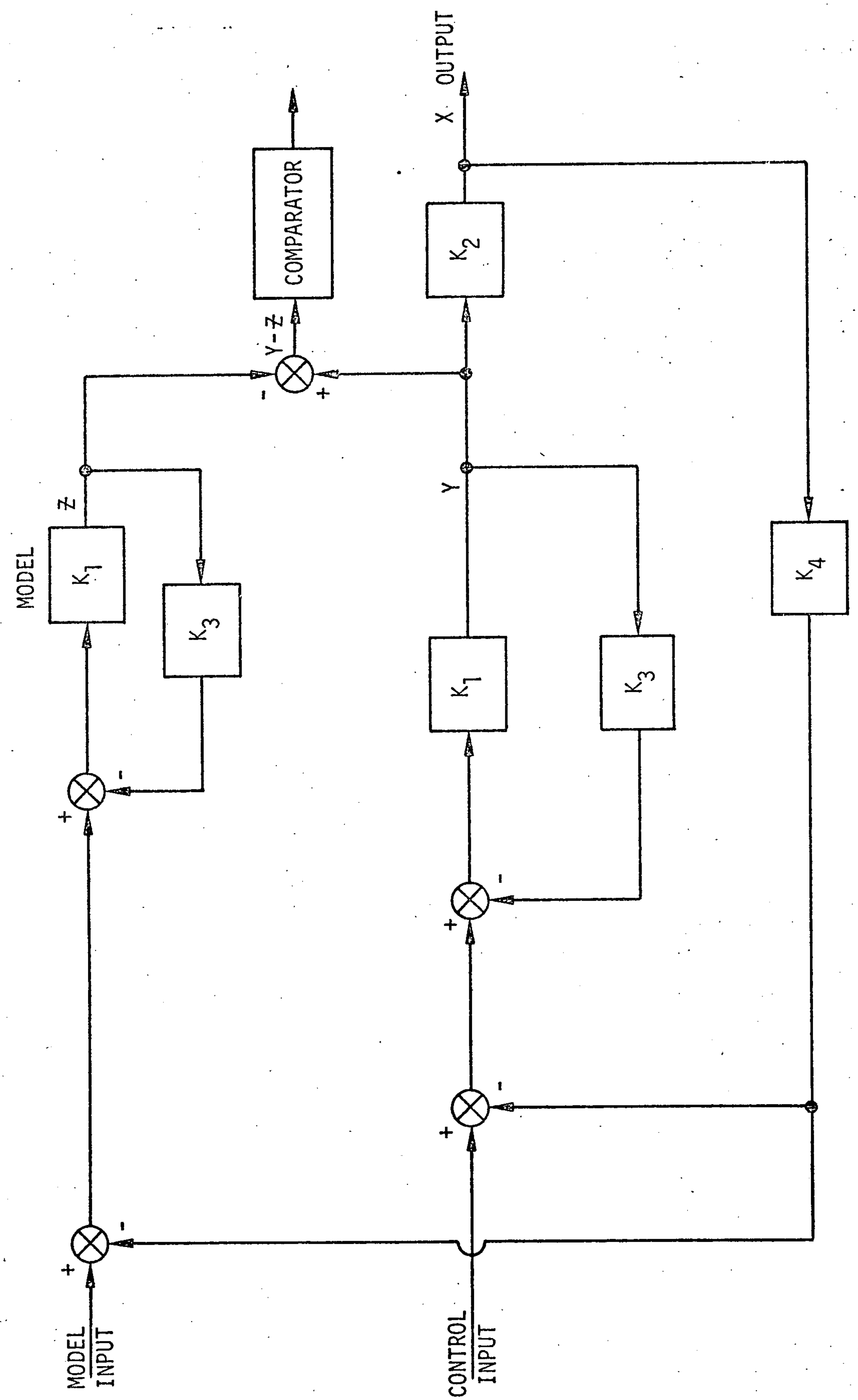

COMPARATOR
X OUTPUT
$K_2$
Y-Z
Y
Z
MODEL
$K_1$
$K_3$
$K_1$
$K_3$
$K_4$
MODEL INPUT
CONTROL INPUT

FIGURE 5-4

5.0 PERFORMANCE ANALYSIS (Continued)

5.2 HARD OVER FAILURE (Continued)

5.2.1 CLOSED LOOP CONTROL (Continued)

The actuator responds to a step input into the control channel by starting to follow the command. This actuator motion is fed back to the flow control valve reducing its stroke and thereby inhibiting operation of the failure detector.

Initial attempts at predicting the actuator response to step inputs did not correlate well with test results. A rigorous analysis indicated that a number of flow control valve secondary effects were significant for the failure detector analysis: mass of the flow control valve slide, response of the hydraulic power supply, and flow saturation.

Figure 5-5 shows the difference between flow control valve response as predicted by Figure 5-1 and actual test results. At 40 Hz there are considerable errors resulting from the use of the first order transfer function.

Test results agree quite well with the third order transfer function which includes the effects of control

TITLE ACTIVE STANDBY REDUNDANCY

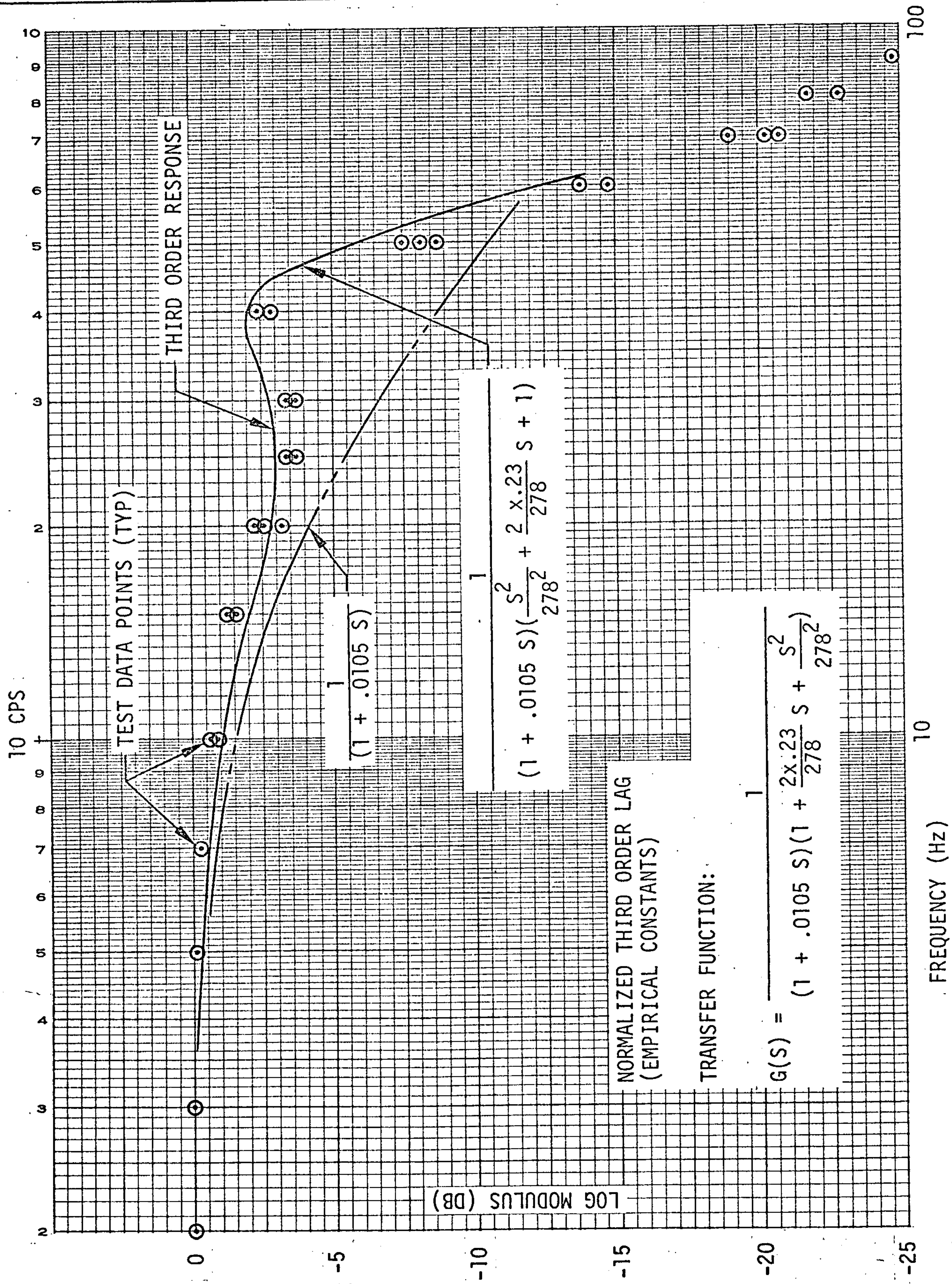



FIGURE 5-5

5.0 PERFORMANCE ANALYSIS (Continued)

5.2 HARD OVER FAILURE (Continued)

5.2.1 CLOSED LOOP CONTROL (Continued)

valve mass and hydraulic spring. Figure 5-6 shows the response of the flow control valve (Y) to a step input using the third order transfer function. Also, shown on Figure 5-6 are the model response (Z) and comparator response (Y-Z) as predicted from the block diagram in Figure 5-4.

Two response curves are shown for the flow control valve (Y). One curve represents a linear system and the other curve shows the effect of control valve flow saturation. The hydraulic power supply used for the developmental testing had a capacity of 31 GPM, the flow control valve had a capacity of 40 GPM. The model and comparator curves reflect this flow saturated test condition.

5.2.2 CHANNEL SWITCHING

Using the comparator response curve shown in Figure 5-6 the step input actuator transient may be predicted. The first step is to predict $T_1$, the time required to close the blocking valve. The shaded area on the comparator position curve, Figure 5-6, indicates the amount of comparator valve opening as a function of time. The

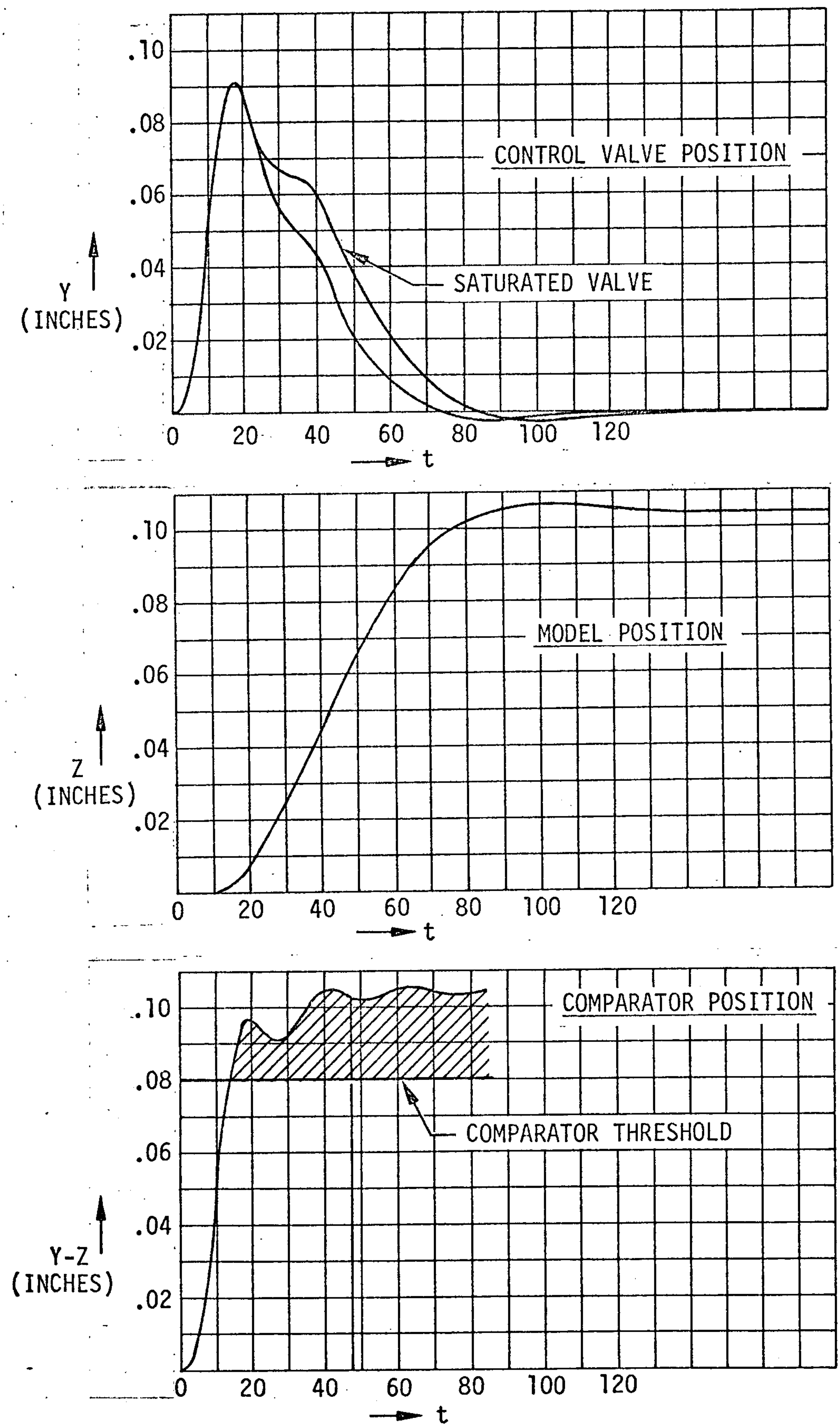

.10
.08
.06
.04
.02
Y (INCHES)
CONTROL VALVE POSITION
SATURATED VALVE
0
20
40
60
80
100
120
t
.10
.08
.06
.04
.02
Z (INCHES)
MODEL POSITION
0
20
40
60
80
100
120
t
.10
.08
.06
.04
.02
Y-Z (INCHES)
COMPARATOR POSITION
COMPARATOR THRESHOLD
0
20
40
60
80
100
120
t

FIGURE 5-6

5.0 PERFORMANCE ANALYSIS (Continued)

5.2 HARD OVER FAILURE (Continued)

5.2.2 CHANNEL SWITCHING (Continued)

flow of fluid through the comparator valve may be calculated from the comparator valve opening, the geometry of the comparator metering orifice, and the pressure drop. Figure 5-7 indicates the comparator flow as a function of comparator stroke.

The four curves shown represent comparator flow for extend commands and for retract commands as well as for the reduction in supply pressure resulting from the 31 GPM flow saturation. The difference in extend flow and retract flow is due to differences in the two flow paths. The retract flow path contains a .030 diameter orifice to restrict the maximum flow.

The comparator flow is plotted in terms of blocking valve velocity. The blocking valve must travel .250 inch to close off control valve flow and has a .125 inch overlap.

A numerical integration of the shaded area shown in Figure 5-6 using the 1800 psi retract curve on Figure 5-7 indicates that .049 seconds are required from the time of

TITLE ACTIVE STANDBY REDUNDANCY

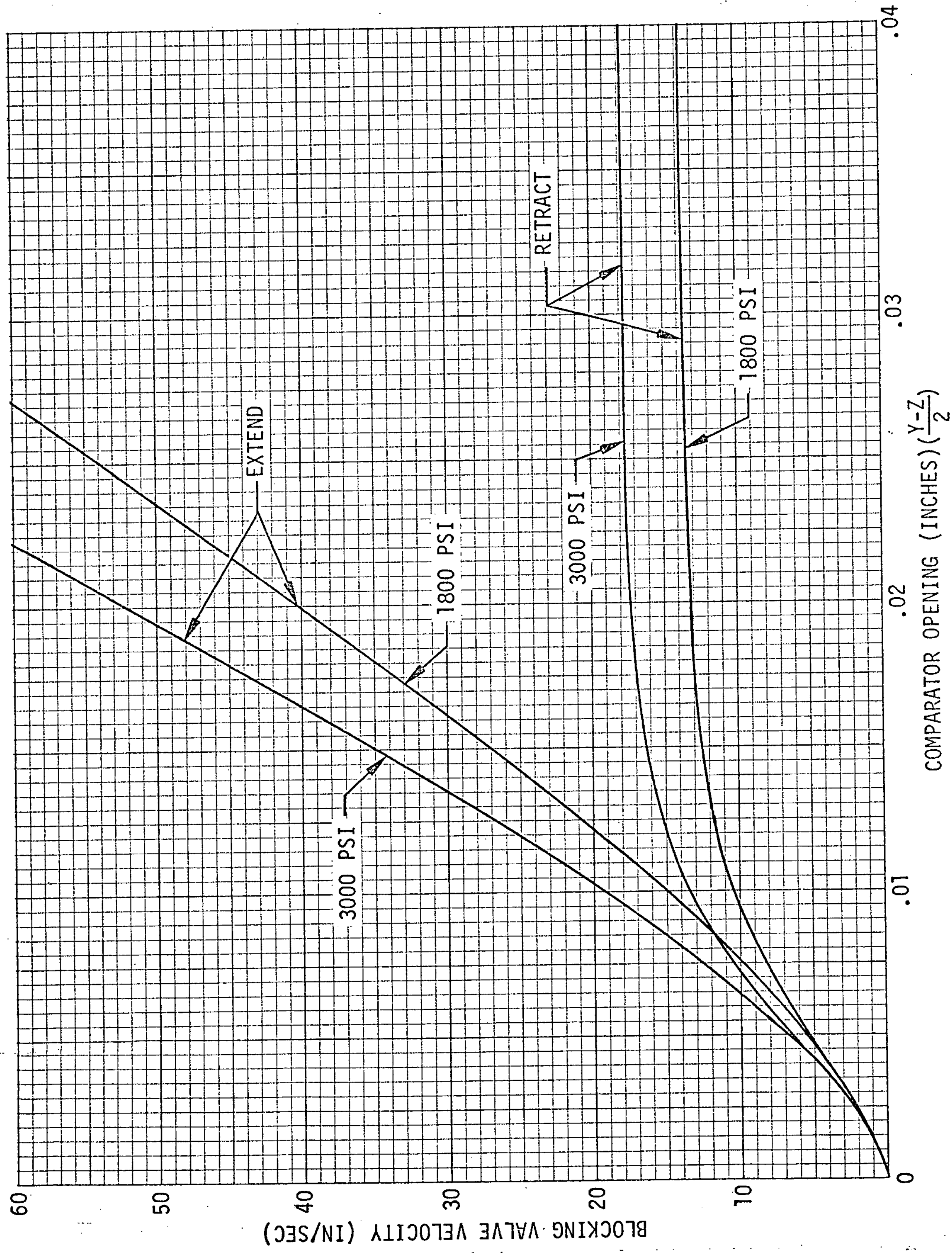



FIGURE 5-7

5.0 PERFORMANCE ANALYSIS (Continued)

5.2 HARD OVER FAILURE (Continued)

5.2.2 CHANNEL SWITCHING (Continued)

the step input until the blocking valve has traveled .250 inches. This is in agreement with the experimental results shown in Figure 5-3 (approximately .050 seconds).

The resulting actuator displacement during $T_1$ (.049 seconds) may be predicted from the actuator transfer function. Figure 5-8 shows both the linear response and the flow limited response. In predicting actuator displacement the hydraulic power supply time constant must be considered. The power supply used in the test setup had a pressure regulator with a .004 second lag. A first order approximation of actuator displacement may be obtained by subtracting the .004 second lag from $T_1$ (.049 - .004 = .045). From Figure 5-8 the actuator displacement at .045 seconds is 85% of the input or .213 inches. This is in agreement with the experimental results shown in Figure 5-3 (.225 inch transient).

The time ($T_2$) required to open the blocking valve in the standby channel may be predicted from an analysis of the flow paths shown in Figure 4-3. The actuator output (X)

TITLE ACTIVE STANDBY REDUNDANCY

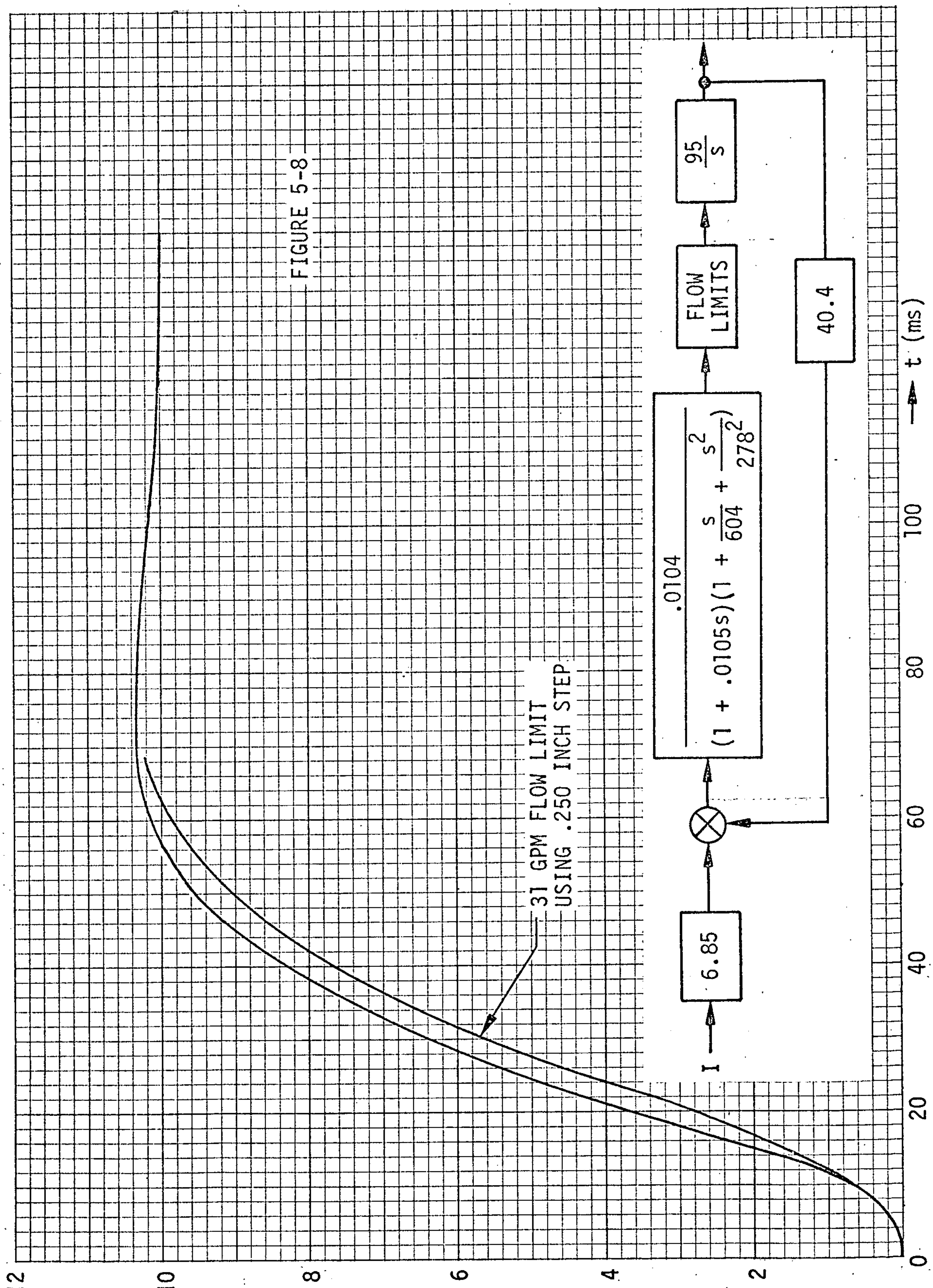



FIGURE 5-8

5.0 PERFORMANCE ANALYSIS (Continued)

5.2 HARD OVER FAILURE (Continued)

5.2.2 CHANNEL SWITCHING (Continued)

stops after the active channel blocking valve has closed its flow passages. The blocking valve has a .125 inch overlap which will require .009 seconds to close (from Figure 5-7). After the blocking valve stops moving the "failure" signal increases in pressure until the interlock valve starts to open. The interlock valve travel is .100 inch and requires .002 seconds.

When the interlock valve stops, system pressure is ported to the small piston of the blocking valve to be opened. This pressure must displace the fluid volume at the large end of the piston and also work against the mechanical spring.

The small drive piston has a .156 inch diameter and the blocking valve has a diameter of .500 inch. The small piston must also work against a spring with an average force output of 9 pounds. The pressure ($P_C$) available to expel fluid from large end of the blocking valve is:

$$\frac{\pi}{4}(.500^2) \quad P_C = \frac{\pi}{4}(.156^2) \quad 3000 \text{ psi} - 9 \text{ lbs}$$

$$P_C = 290 \text{ psi}$$

5.0 PERFORMANCE ANALYSIS (Continued)

5.2 HARD OVER FAILURE (Continued)

5.2.2 CHANNEL SWITCHING (Continued)

The fluid from the blocking valve must be expelled through the comparator valve underlap. At mid-stroke this underlap area is .0056 $in^2$ (assuming .040 inch underlap). There are two such resistances in series. Using the 290 psi available, the resulting flow is 6.7 $in^3$/sec. The .500 inch diameter blocking valve will travel through the .125 inch overlap plus open .030 inch in .004 seconds.

The actuator time at stall ($T_2$) may be found by adding the time required to fully close the "failed" channel blocking valve, activate the interlock valve, crack open the standby channel blocking valve and the hydraulic power supply time lag.

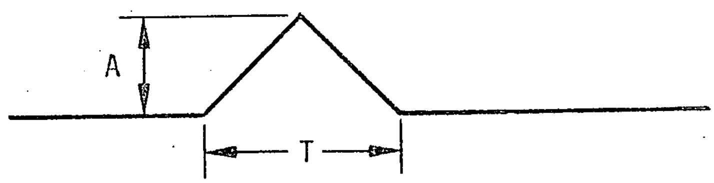
$$T_2 = .009 + .002 + .004 + .004 = .019 \text{ seconds}$$

This agrees with the experimental results shown on Figure 5-3 (approximately .020 seconds).

5.0 PERFORMANCE ANALYSIS (Continued)

5.3 NOISE REJECTION

The ability of the failure detector to reject line noise may be examined by analyzing the comparator response to the triangular shaped signal pulse as shown below.




This signal represents the type of electromagnetic interference which results from switching inductive loads: solenoid valves, relays, motor, etc. The failure detector is analyzed to determine what amplitudes and frequency of the triangular pulse signal will "trip" the failure detector.

Figure 5-9 shows the response of the failure detector to signal noise of various pulse widths. The noise rejection curve defines the noise amplitude which will cause the active channel to switch itself off. The ordinate axis is the ratio of signal noise amplitudes: the amplitude required to activate the failure detector divided by the failure detector threshold value. The abscissa axis is the inverse of pulse width (equivalent

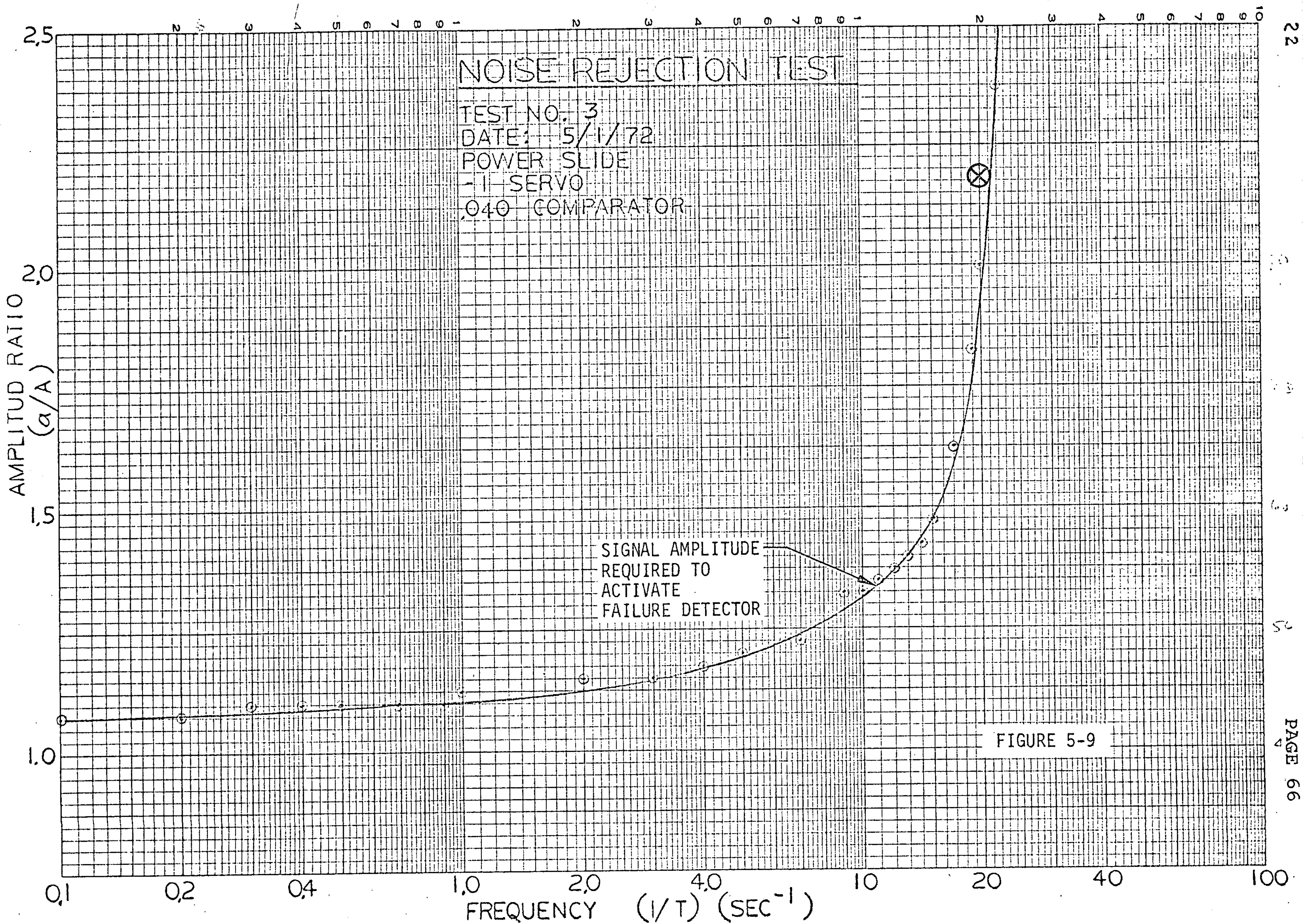

NOISE REJECTION TEST
TEST NO. 3
DATE: 5/1/72
POWER SLIDE
-1 SERVO
.040 COMPARATOR
SIGNAL AMPLITUDE
REQUIRED TO
ACTIVATE
FAILURE DETECTOR
AMPLITUD RATIO
(a/A)
2,5
2,0
1,5
1.0
0,1
0,2
0,4
1,0
2,0
4,0
10
20
40
100
FREQUENCY (1/T) (SEC$^{-1}$)

FIGURE 5-9

5.0 PERFORMANCE ANALYSIS (Continued)

5.3 NOISE REJECTION (Continued)

to frequency). As shown in Figure 5-9 the failure detector will accept larger signal noise amplitudes at higher frequencies than it will at low frequencies.

The actual shape of the failure rejection curve is a function of servo gains and comparator metering geometry.

The comparator metering orifice may be configured to fit most any dynamic requirement which is capable of being described by a well behaved equation.

The response of the flow control valve slide to the triangular pulse is shown in Figure 5-10. The family of curves shown have been plotted in a nondimensional form. To determine the signal noise amplitude required to exceed the failure detector threshold, it is necessary to integrate the comparator's "failure" signal flow. The active channel will be switched off when this integrator is sufficient to bottom the blocking valve and energize the interlock valve.

The following example will illustrate the procedure for predicting failure detector response. Suppose

TITLE ACTIVE STANDBY REDUNDANCY

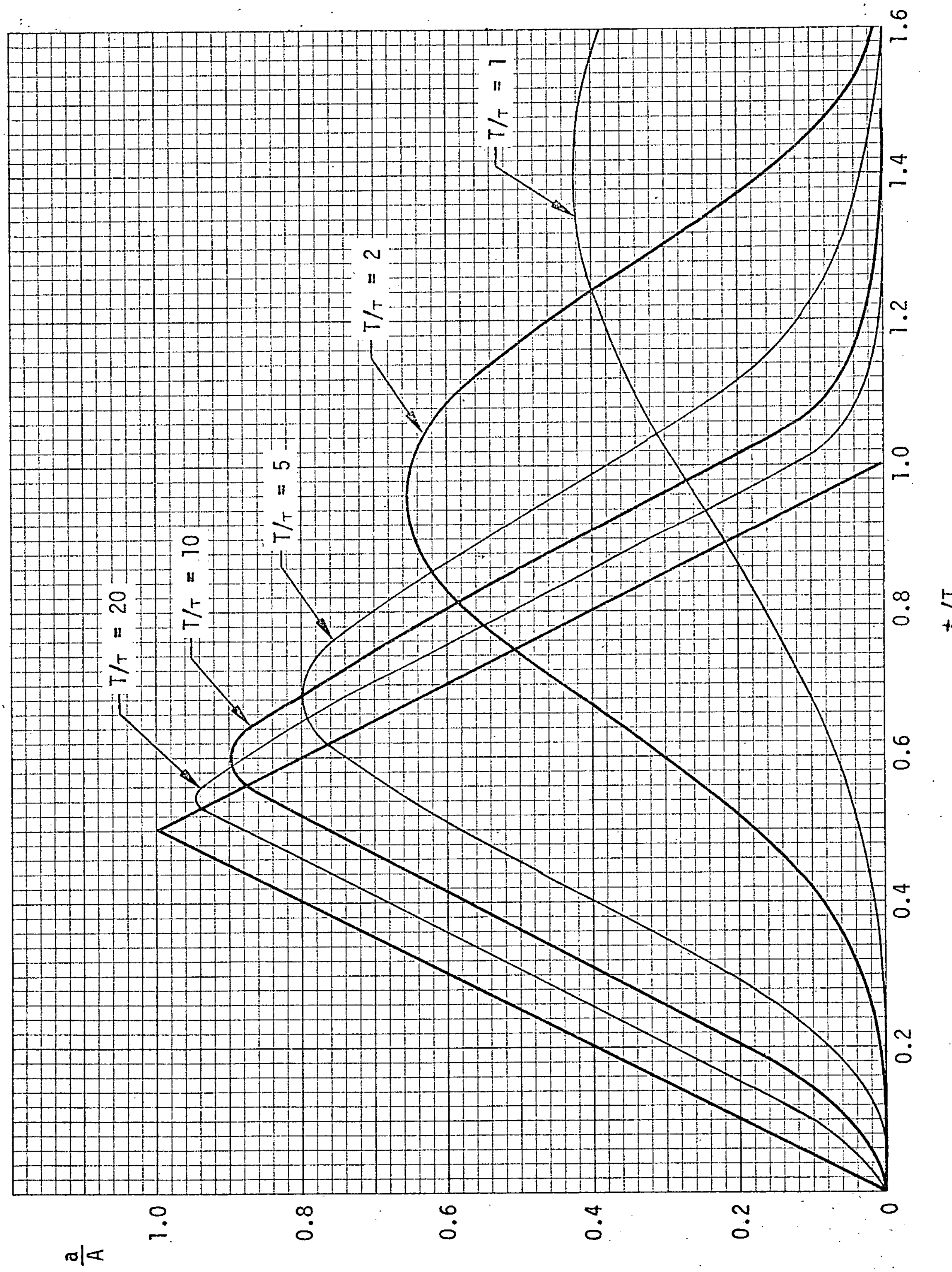



FIGURE 5-10

5.0 PERFORMANCE ANALYSIS (Continued)

5.3 NOISE REJECTION (Continued)

that it is desired to predict the "A" channel "basic" configuration noise rejection at 20 cps (pulse width of .05 seconds). The inner loop time constant ($\tau$) is .0105. The desired response curve is defined by:

$$T/\tau = .05 \text{ sec}/.0105 \text{ sec}$$

$$T/\tau \approx 5$$

The "A" channel "basic" configuration has a comparator overlap of .040 inches and a total comparator stroke of .050 inches. The maximum comparator flow at .010 opening is equivalent to a blocking valve velocity of 19 in/sec (extend, 3000 psi, curve from Figure 5-7). The total blocking valve stroke is .375 inches. Therefore, the failure detector will lock on the failure if the comparator valve is full open for .020 seconds plus .002 seconds for the interlock valve.

A first approximation of the noise rejection amplitude at this frequency may be determined as shown on Figure 5-11. Two points are selected which are .022 seconds apart, these points represent the average time that the comparator

TITLE ACTIVE STANDBY REDUNDANCY

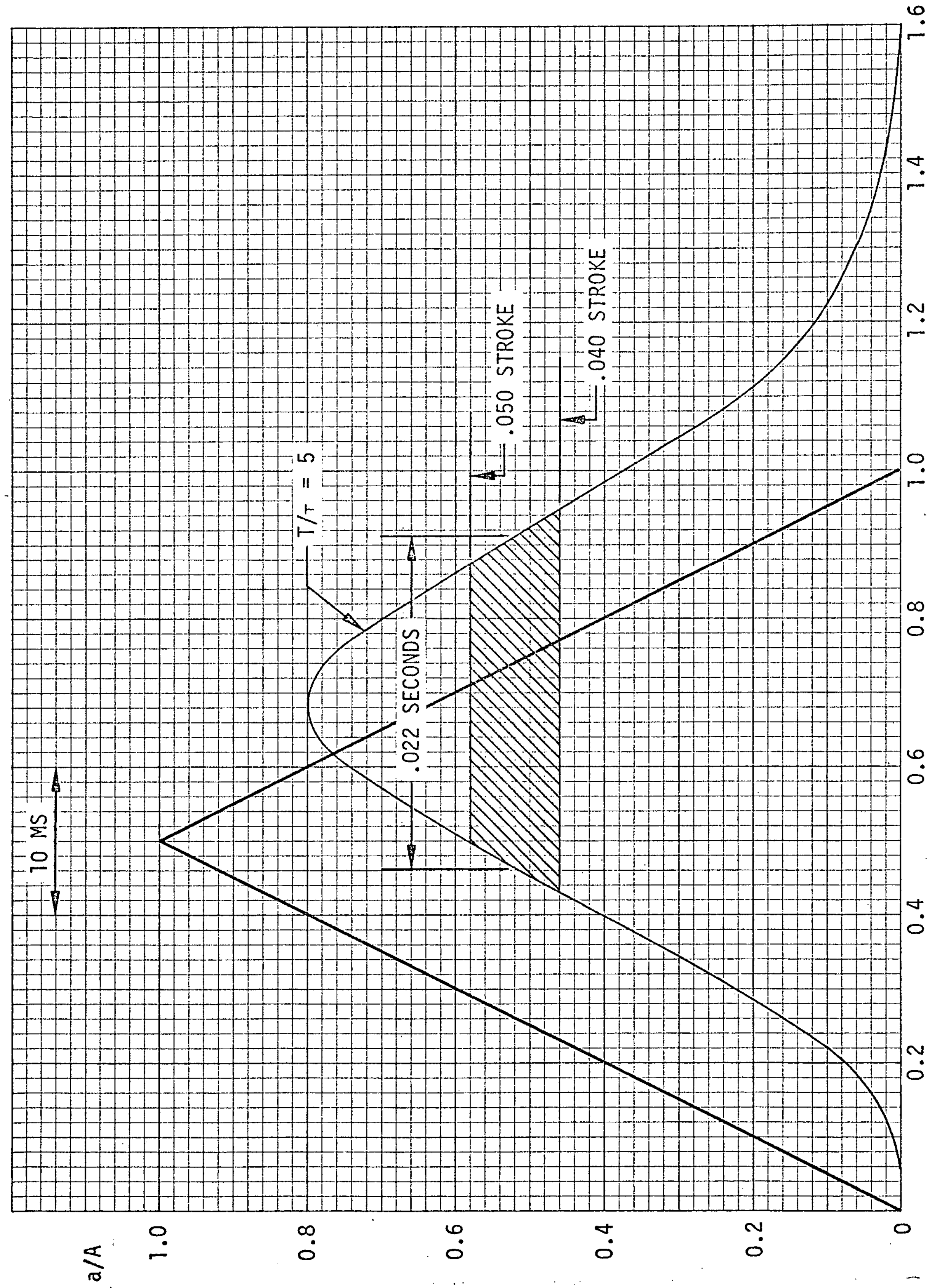



FIGURE 5-11

5.0 PERFORMANCE ANALYSIS (Continued)

5.3 NOISE REJECTION (Continued)

valve is full open. The comparator threshold (.040) and maximum stroke (.050) may be established ten percent above and below a line established by the .022 second requirement. As shown on Figure 5-11 the comparator threshold for 20 cps is 46% of command signal or a 2.17 times increase in signal is required to fail the unit. The 2.17 amplitude ratio at 20 cps is shown on Figure 5-9.

The amplitude ratio calculated above is approximately 10% greater than the ratio determined by test. This is due to an approximation used in calculating the length of time the comparator valve is open. Figure 5-11 indicates that the comparator valve clips the control signal at a stroke of .050 inches. Therefore, when the control signal reverses the comparator slide inertia will keep the valve open longer than predicted by the above analysis.

## 6.0 TESTS

In order to provide data for establishing a correlation between signal noise (level and frequency), nuisance failures, and switching transients, tests were performed as outlined in Table 5.1.

Eleven tests were performed on the basic active standby actuator configuration. These tests provided data for determining the basic characteristics of the servo valves and fault detecting mechanisms.

Subsequent to the preliminary testing, nine modifications were made and tested. The parameters changed, included:

1. Comparator Threshold
2. Open Loop Gain
3. Time Lag between Failure Detection and Channel Lockout

## 6.1 FREQUENCY RESPONSE TEST - INNER LOOP

The frequency response of the electrohydraulic valve and servo valve combination was experimentally determined. The test was conducted using a sinusoidal command while measuring valve position with a linear position transducer. The test was performed as described in Appendix B, Test No. 1. The results of this test are presented in

TITLE ACTIVE STANDBY REDUNDANCY

TABLE 5.1

| TEST NO | COMPARATOR TRIP LEVEL (% OF ACTUATOR STROKE | TEST DESCRIPTION | TIME DELAY ORIFICE | AVERAGE OPEN LOOP GAIN (RAD/SEC) @ 3000 PSI | CHANNEL |
|---|---|---|---|---|---|
| 1 | | Frequency Response Inner Loop | | 110 | A |
| 2 | | Frequency Response Outer Loop | | 40 | A |
| 3 | 2.5% | Noise Rejection Failure Map | | 40 | A |
| 4 | 2.5% | Noise Rejection Failure Map | | 40 | B |
| 5 | .35% | Noise Rejection Failure Map | | 40 | C |
| 6 | 2.5% | Supply Pressure Transients | | 40 | A |
| 7 | 2.5% | Return Pressure Transients | | 40 | A |
| 8 | 2.5% | Standard Test Series (STS) Basic | | 40 | A |
| 9 | 2.5% | STS - Basic | | 40 | B |
| 10 | .35% | STS - Basic | | 40 | C |
| 11 | 2.5% | Reduced Pressure Performance (STS) | | 40 | A |
| 12 | 2.5% | Simulate EH Valve Contamination (STS) | | 40 | A |
| 13 | .5% | STS - Mod 1 | | 40 | A |
| 14 | .5% | STS - Mod 2 | | 20 | A |
| 15 | 1.0% | STS - Mod 3 | | 20 | A |
| 16 | 2.5% | STS - Mod 4 | .0125 DIA Lee Jet | 40 | B |
| 17 | 2.5% | STS - Mod 5 | .0075 DIA Lee Jet | 40 | B |
| 18 | .5% | STS - Mod 6 | .0075 DIA Lee Jet | 40 | B |
| 19 | 1.75% | STS - Mod 7 | | 40 | C |
| 20 | 3.50% | STS - Mod 8 | | 20 | C |
| 21 | .70% | STS - Mod 9 | | 20 | C |

6.0 TESTS (Continued)

6.1 FREQUENCY RESPONSE TEST - INNER LOOP (Continued)

Appendix B. The second part of the test determined the response to step inputs. The results of this test are also shown in Appendix B, Test 1.

6.2 FREQUENCY RESPONSE TEST - OUTER LOOP

A frequency response test was conducted which correlated dynamic response to sinusoidal input. The first test was conducted with no load connected to the main actuator ram. The test was performed as described in Appendix B, Test No. 2. Results of this test are presented in Appendix B, Test No. 2.

The frequency response test described was repeated with the addition of an 11 lb - sec$^2$/ in inertial mass attached to the main actuator ram. The test setup is shown in Figure 6-1. Results of this test are presented in Appendix B, Test No. 2.

6.3 NOISE REJECTION TESTS

Tests were conducted on the three basic configurations to evaluate the ability of each comparator to reject signal noise. A triangle pulse was introduced into one of the electrohydraulic valves on the channel with

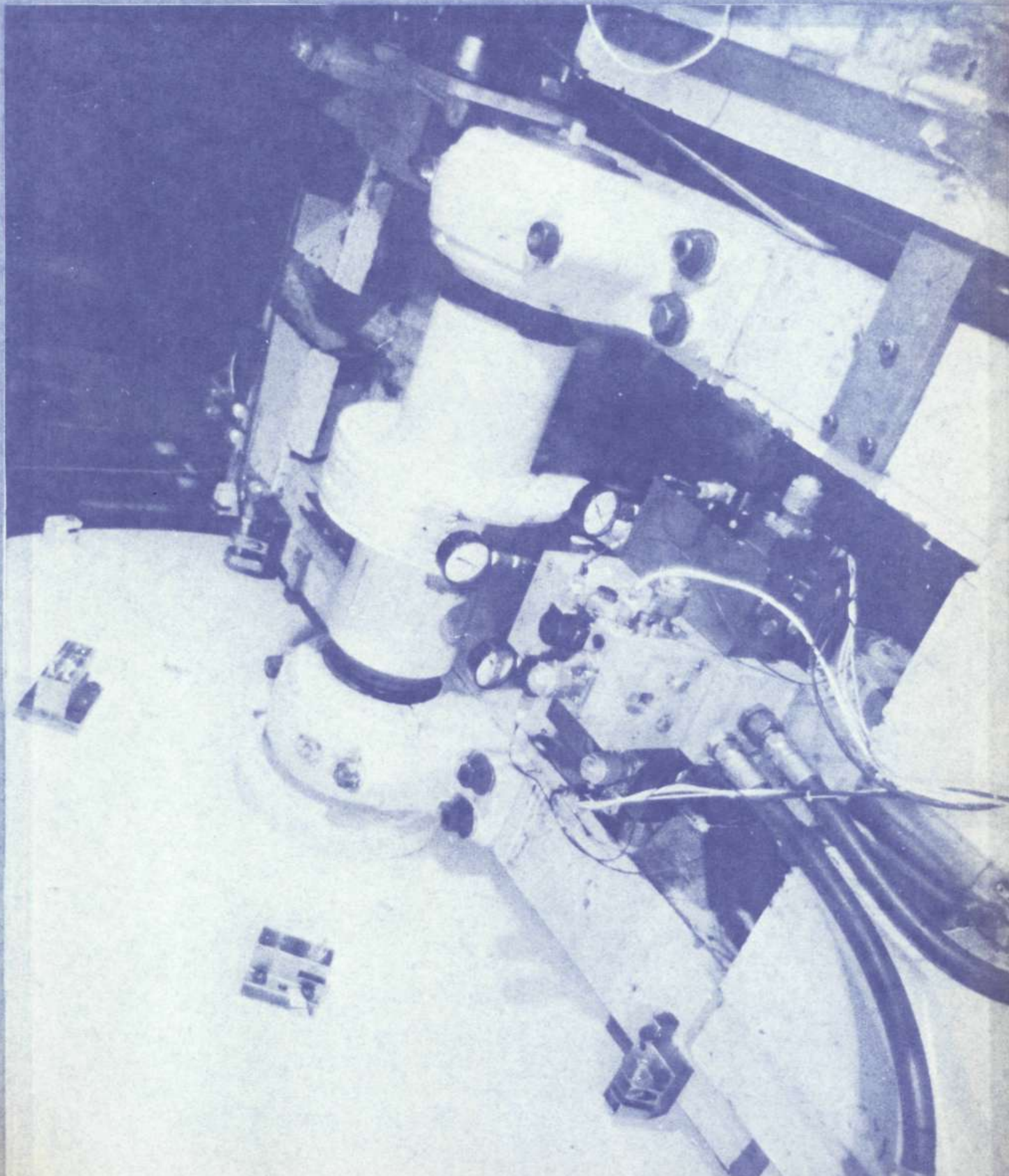


FIGURE 6-1

6.0 TESTS (Continued)

6.3 NOISE REJECTION TESTS (Continued)

authority. Holding the pulse duration constant, the amplitude of the "noise" was increased until lockout occurred. A detailed description of the test procedure as well as test data are shown in Appendix B, Test No's 3, 4, and 5. The "amplitude" shown on the test results has been nondimensionalized by the use of an amplitude ratio; the reference being the minimum steady state command for which switching occurs.

6.4 SUPPLY AND RETURN TRANSIENTS TEST

The effect of pressure transients on the fault detecting mechanisms was explored using 1000 psi transients. These transients were induced separately into the supply and return lines. The comparator slide position was monitored during both no-command and cyclic conditions. The actuator was commanded $\pm.100"$ and $\pm.025"$ during cycling at .1, 1, and 10 Hz. The complete test procedure is included in Appendix B, Test No. 6. The results of this test are shown in Table 5.2.

TITLE ACTIVE STANDBY REDUNDANCY

| | | MAXIMUM COMPARATOR MOTION | |
|---|---|---|---|
| FREQUENCY | AMPLITUDE | 1000 PSI PRESSURE TRANSIENT | 1000 PSI RETURN TRANSIENT |
| 0.1 | ±.025 | .0001" | .0003" |
| 1.0 | ±.025 | .0002" | .0005" |
| 10.0 | ±.025 | .0030" | .0023" |
| 0 | ±.100 | .0001" | .0005" |
| 0.1 | ±.100 | .0001" | .0003" |
| 1.0 | ±.100 | .0001" | .0003" |
| 10.0 | ±.100 | .0035" | .0008" |

TABLE 5.2

6.0 TESTS (Continued)

6.5 STANDARD TEST SERIES (Continued)

A standard series of tests were performed on each of the fourteen failure detector configurations. The standard test series provided information for evaluating the fault correcting mechanism response to three types of failures: hard over, passive, and soft failures.

The hard over failure tests were conducted by introducing a large step command into the #1 buffer amplifier. The servo valve was initially in a steady state null condition. The actuator transients were monitored and recorded. A detailed description is included in Appendix B, Test No's 8 through 21. Reduced pressure performance data (Test No. 11) was taken on most of the basic and modified test configurations.

# APPENDIX A

OPERATION INSTRUCTIONS FOR TEST ACTUATOR
(BERTEA P/N 221400-1003)

I AUXILIARY MATERIAL AND EQUIPMENT

A. MIL-H-5606 hydraulic fluid at 3000 psi supply pressure and 40 gpm capacity (inlet filter 25$\mu$ absolute).

B. 115 VAC, 400 Hz to electronic controller (P/N TF1-221400)
28 VDC to electronic controller

C. Pressure gages, pressure transducers, function generators, etc. as required by specific test requirements.

II ASSEMBLY

A. Connect pressure and return lines to appropriate ports on base manifold (color: gold). A 25$\mu$ absolute filter should be used in the pressure line as the test unit does not contain a filter.

B. Connect 115 VAC, 400 Hz and 28 VDC to appropriate jacks on back panel of electronic controller. See Figure 1.

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| PAGE 2 | DOCUMENT NO. 221400-18 | REV. |
|---|---|---|
| ORIG. DATE 8-25-72 | REV. DATE | |

TITLE

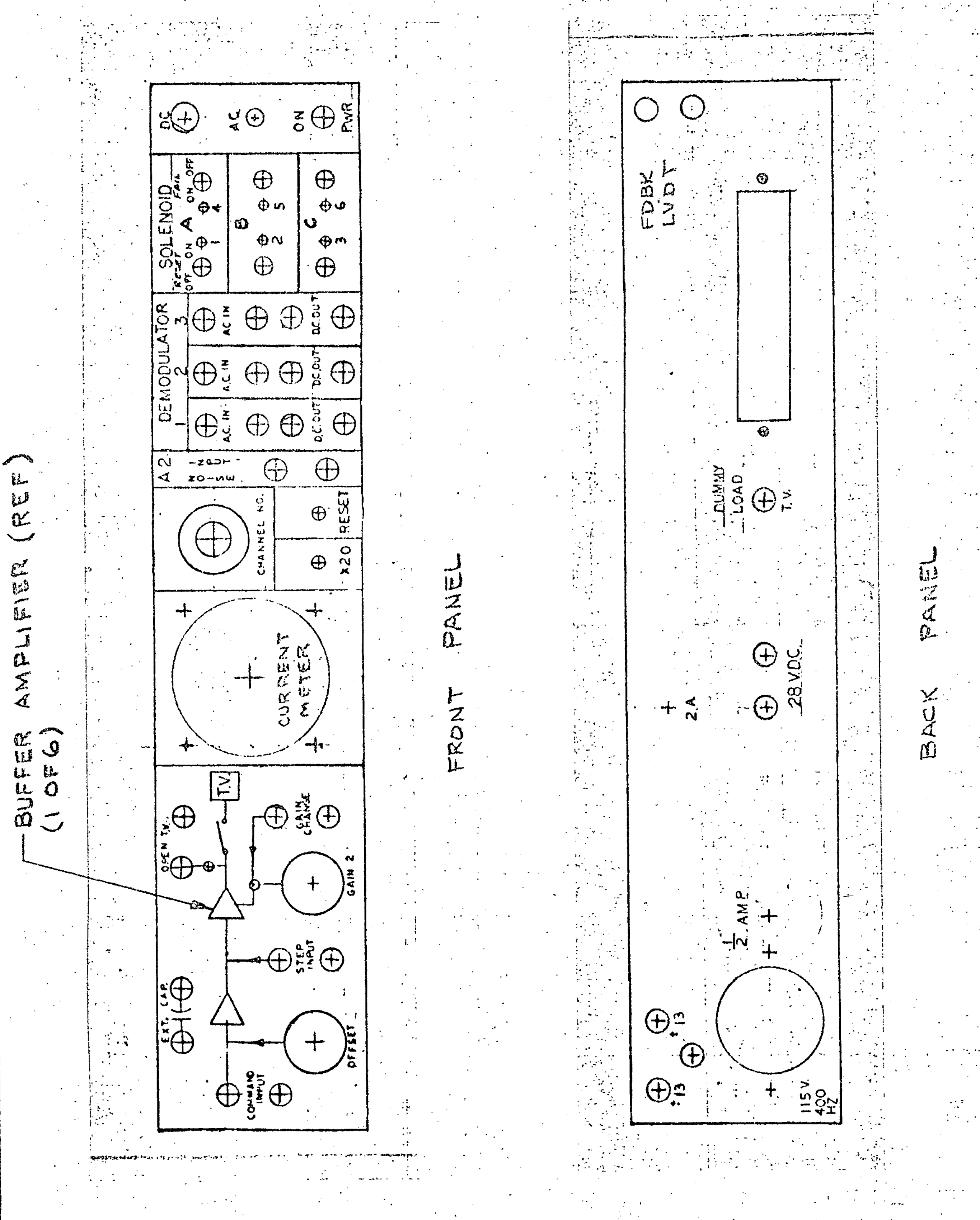



FIG. 1

G

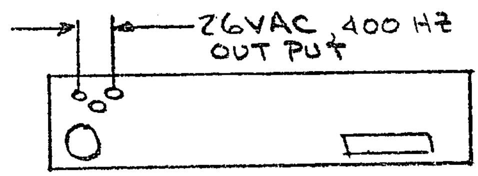
16-01

TITLE

OPERATION INSTRUCTIONS FOR TEST ACTUATOR
(BERTEA P/N 221400-1003)

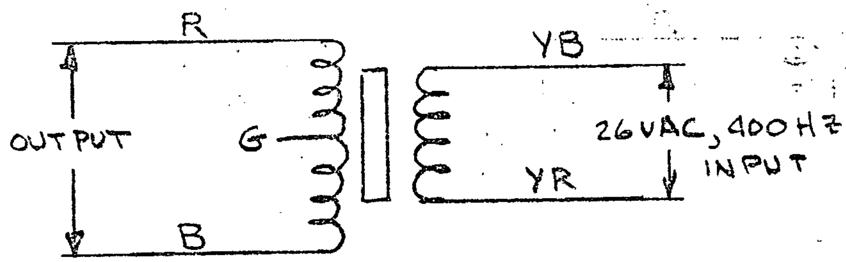
II ASSEMBLY (Continued)

C. Connect 26 VAC excitation voltage (from jacks shown) to primary coils of monitor LVDT's on Channel 'A' (color: red).




BACK PANEL OF ELECTRONIC CONTROLLER

APPROX GAIN:
26.5 VAC/IN




LVDT SCHEMATIC

D. Connect wiring harness to rectangular connector on back of controller. Join connectors to positions labeled (T.V. = transfer valve or electrohydraulic valve, reference).

E. In order to determine which channels have failed, it is convenient to connect gages to the failure indicating ports as shown in Figure 2.

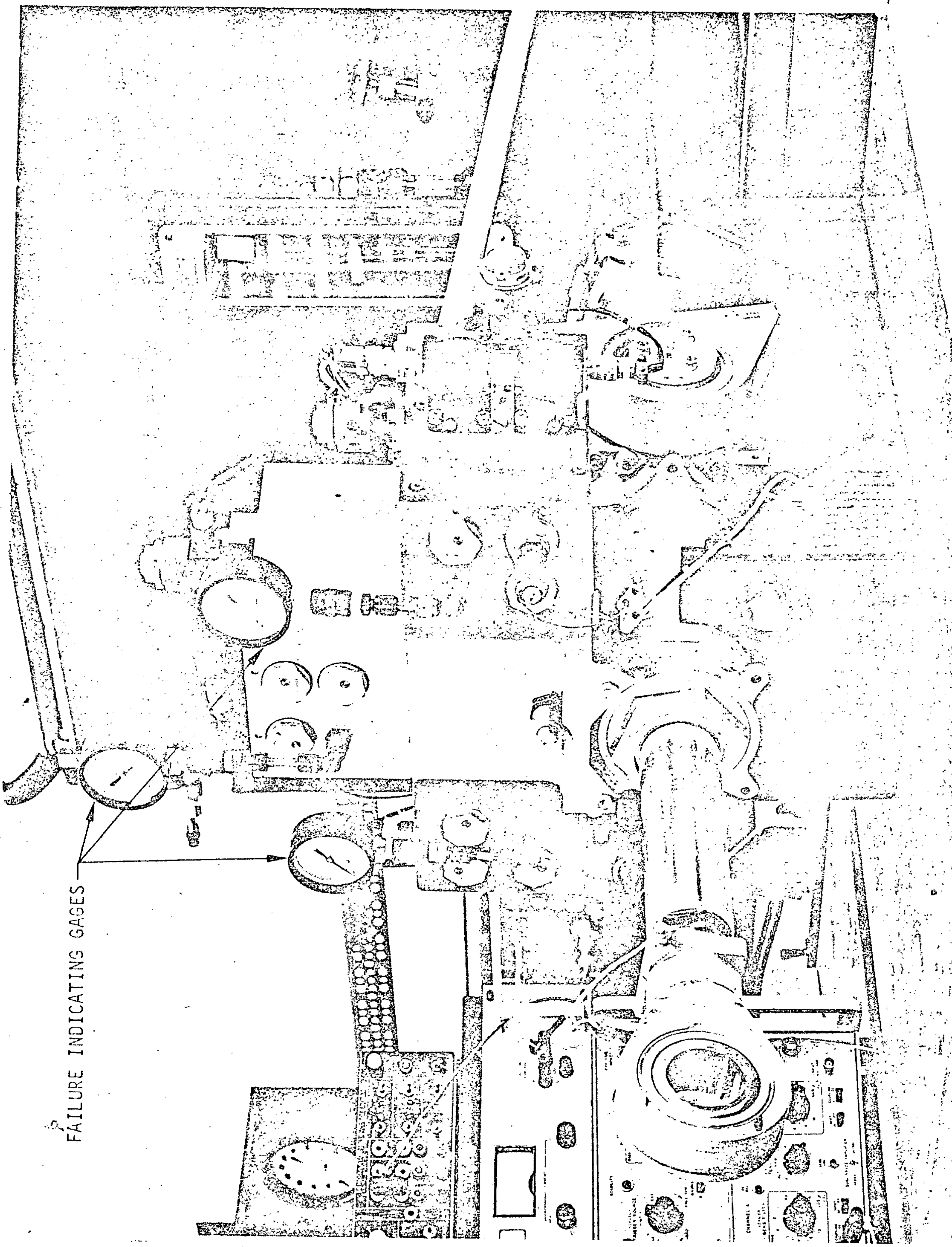



FIGURE 2

OPERATION INSTRUCTIONS FOR TEST ACTUATOR
(BERTEA P/N 221400-1003)

III OPERATION

A. Cautions:

1. Feedback wand protruding through base of electro-hydraulic valve is extremely delicate. Never lay the valve on the wand. Be particularly careful during assembly and disassembly from the main manifolds. Never stroke wand more than .110" from neutral.

2. Do not apply more than 3 VAC to "AC IN" jacks of Demodulators #2 and #3.

3. Contaminated oil can cause clogging of electro-hydraulic valves. Do not omit filter in pressure supply line.

B. Electronic Controller (Reference Figure 1 and TF1-221400)

1. Front Panel

a. The schematic shown on the front right side of the controller is for the "A1" circuit only. However, the "command" jacks and "off-set" pot are inputs to all six buffer amplifiers. See Drawing 221400L.

OPERATION INSTRUCTIONS FOR TEST ACTUATOR
(BERTEA P/N 221400-1003)

III OPERATION (Continued)

B. Electronic Controller (Reference Figure 1 and TF1-221400) (Cont

1) The "step input" jacks are connected to buffer amp "A1" only and can be used to command a single electrohydraulic valve.

2) The "open T.V." jack is for input from an external trigger (+5 to +50 VDC) which simulates an open circuit or passive failure at the transfer valve (T.V.). Light on signals open circuit.

3) Ten-turn "gain 2" pot allows gain adjustment of A1 buffer amp. Applying +5 to +50 VDC to "gain change" jacks triggers the gain change. Light on signals change to second gain.

b. Reset button used to reset triggers (pushing button should result in trigger lights off).

OPERATION INSTRUCTIONS FOR TEST ACTUATOR
(BERTEA P/N 221400-1003)

III <u>OPERATION</u> (Continued)

B. Electronic Controller (Reference Figure 1 and TF1-221400) (Cont

c. Selector switch is used in conjunction with current meter. "X20" button multiplies original reading twenty times at the meter.

d. "A2 noise input" jacks are connected to "A2" buffer amp only and can be used to command a single electrohydraulic valve.

e. Demodulators

1) #1 is connected to ram monitor LVDT output. Jacks labeled "AC IN" may be used to tap AC output of LVDT. "DC OUT" is demodulated LVDT output. Both signals are attenuated by approximately a factor of ten.

2) #2 and #3 may be used to demodulate outputs from monitor LVDT's on comparator and servo valve spools.

OPERATION INSTRUCTIONS FOR TEST ACTUATOR
(BERTEA P/N 221400-1003)

III OPERATION (Continued)

B. Electronic Controller (Reference Figure 1 and TF1-221400) (Cont

f. Solenoids

1) "Reset" solenoid switches should be normally on unless a particular channel has failed and it is desired to reinstate it in the sequence of authority.

2) "Fail" switches should normally be off. Turning switch on will cause the particular channel to be locked out and transmitt an "on" signal to the next channel.

g. Power switch is used to turn controller off and on.

2. Back Panel

a. "Dummy Load, T.V." switch disconnects output of "Al" buffer amplifier from electrohydraulic valve connector and applies a load simulating resistor to the circuit.

OPERATION INSTRUCTIONS FOR TEST ACTUATOR
(BERTEA P/N 221400-1003)

III OPERATION (Continued)

B. Electronic Controller (Reference Figure 1 and TF1-221400) (Cont

b. Feedback transducer jacks are used to tap AC output of main actuator LVDT.

c. Jacks in upper right hand corner are for 26 VAC, 400 Hz used to excite the two monitor LVDT's.

C. Example Test: Fail Channel 'A'

1. Inspect equipment for completeness and correctness.

2. Turn on electronic controller.

3. Apply 3000 psi, MIL-H-5606 to pressure port.

4. Adjust "offset" pot on front panel of controller to position main ram at approximately mid-stroke.

5. Verify authority of Channel 'A' by checking failure indicating pressure gage. Reading should be 0 psi. Turn reset solenoid "off" then "on" if required.

OPERATION INSTRUCTIONS FOR TEST ACTUATOR
(BERTEA P/N 221400-1003)

III OPERATION (Continued)

C. Example Test: Fail Channel 'A' (Continued)

6. Disconnect electrical connector from Channel 'A' power valve, thus opening the loop. Observe monitor T-valve current on meter. Current meter should read approximately 8 ma at switching.

7. Actuator should drift from original position approximately .2" (for .040 overlap comparator valve). At this point switching should occur (3000 psi at failure indicating gage and main ram returns to initial position).

# APPENDIX B

## INNER LOOP FREQUENCY RESPONSE TEST

DESCRIPTION:

THIS TEST PROVIDES A DYNAMIC CORRELATION BETWEEN ELECTRICAL COMMAND TO THE ELECTROHYDRAULIC VALVE AND MOTION OF THE MONITOR SPOOL.

EQUIPMENT REQUIRED:

1. 221450-101, "A" CHANNEL MANIFOLD ASSEMBLY
2. SERVO AMP
3. 26 VAC, 400 CPS POWER SUPPLY
4. AC-DC DEMODULATOR
5. STRIP CHART RECORDER
6. FUNCTION GENERATOR (SINE WAVE)
7. 221466-1 TEST MANIFOLD
8. OSCILLOSCOPE

TEST PROCEDURE:

A. SINUSOIDAL RESPONSE

USING SETUP SHOWN IN FIGURE 1, PERFORM THE FOLLOWING TESTS IN SEQUENCE:

1. CALIBRATE STRIP CHART
2. RECORD INPUT CURRENT VS POWER SPOOL POSITION FOR THE FOLLOWING FREQUENCIES: 1, 2, 3, 5, 7, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100

   NOTE: CURRENT TO ELECTROHYDRAULIC VALVE SHOULD BE ADJUSTED (IF REQUIRED) TO MATCH THE ORIGINAL AMPLITUDE (i.e. AMP OF THE 1/3 CPS TEST) FOR ALL OTHER TESTS.

   CURRENT AMPLITUDE TO BE ±.5 MA

B. STEP INPUT RESPONSE:

USING SETUP SHOWN IN FIGURE 2, PERFORM THE FOLLOWING TEST:

1. CALIBRATE SCOPE - NOTE: USE 400 HZ LVDT OUTPUT; DO NOT DEMODULATE.
2. COMMAND ELECTROHYDRAULIC VALVE WITH STEP INPUT EQUIVALENT TO .075" STEADY STATE OFF-SET. (.0375 AT COMPARATOR)
3. STORE ON SCOPE AND PHOTOGRAPH.

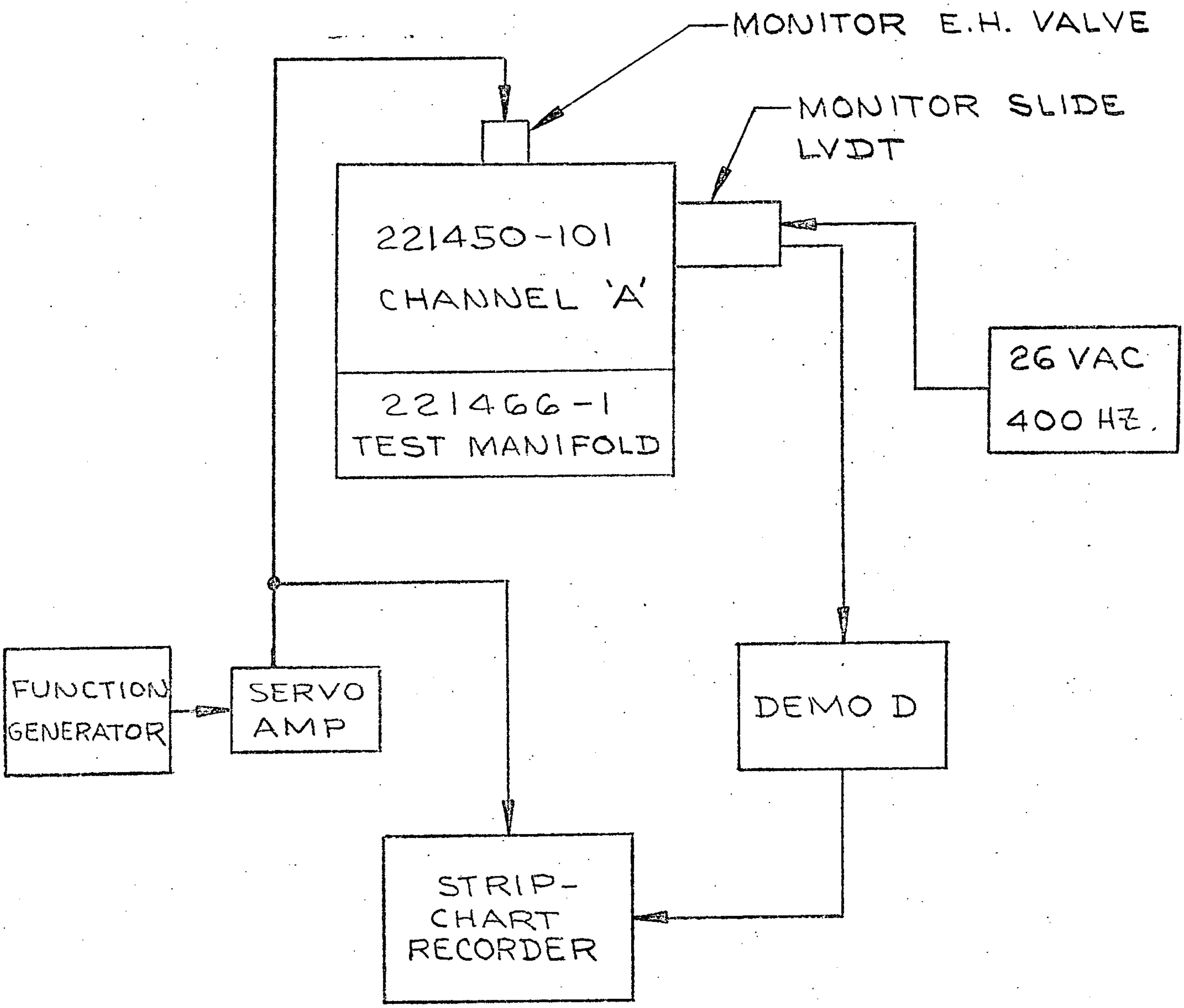

MONITOR E.H. VALVE
MONITOR SLIDE LVDT
221450-101
CHANNEL 'A'
221466-1
TEST MANIFOLD
26 VAC
400 HZ.
FUNCTION GENERATOR
SERVO AMP
DEMOD
STRIP-CHART RECORDER

FIG. 1

3.1

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**PRODUCTION TEST PROCEDURE**

DRAWN BY __________ DATE __________

CHECK BY DATE



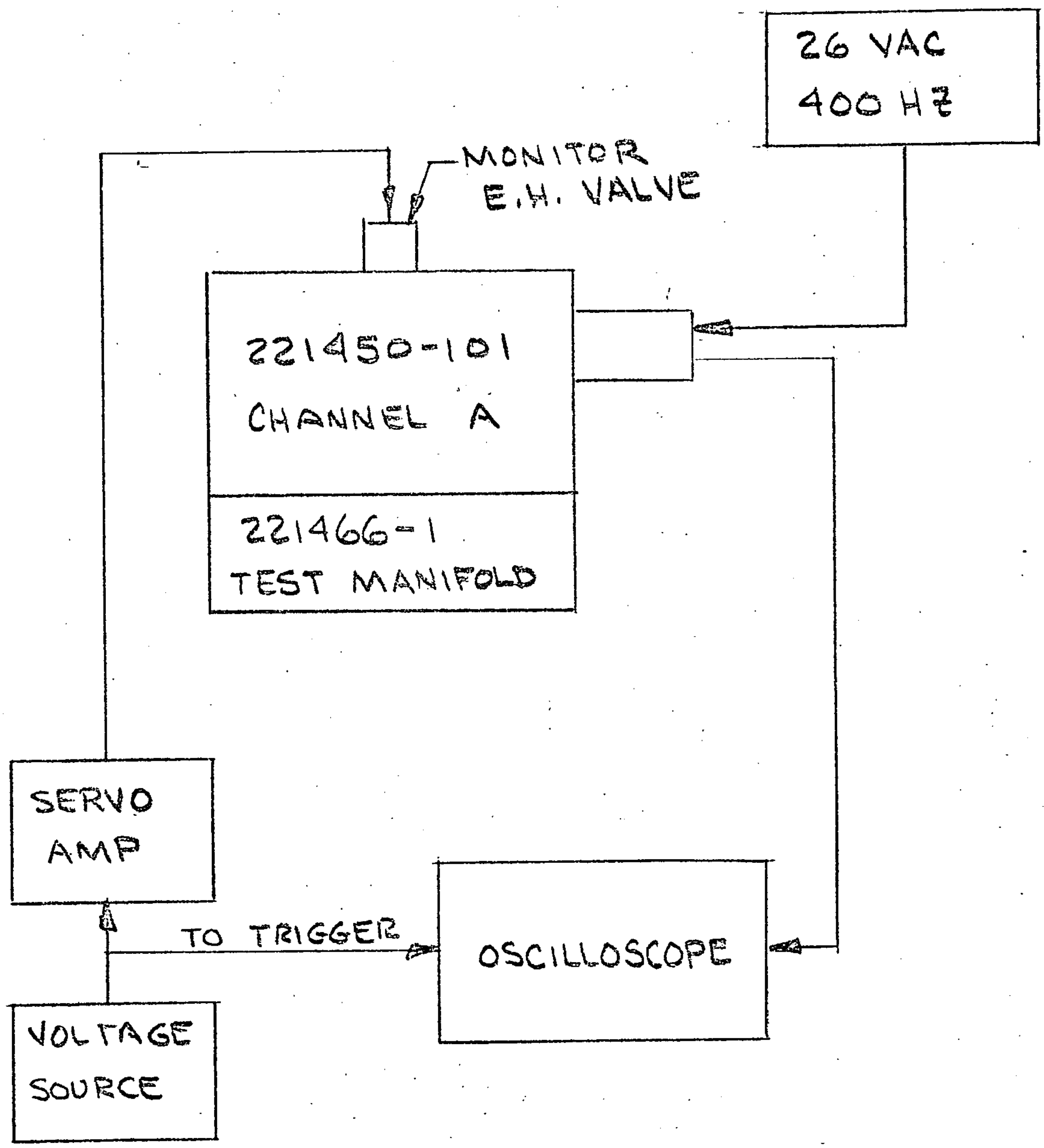
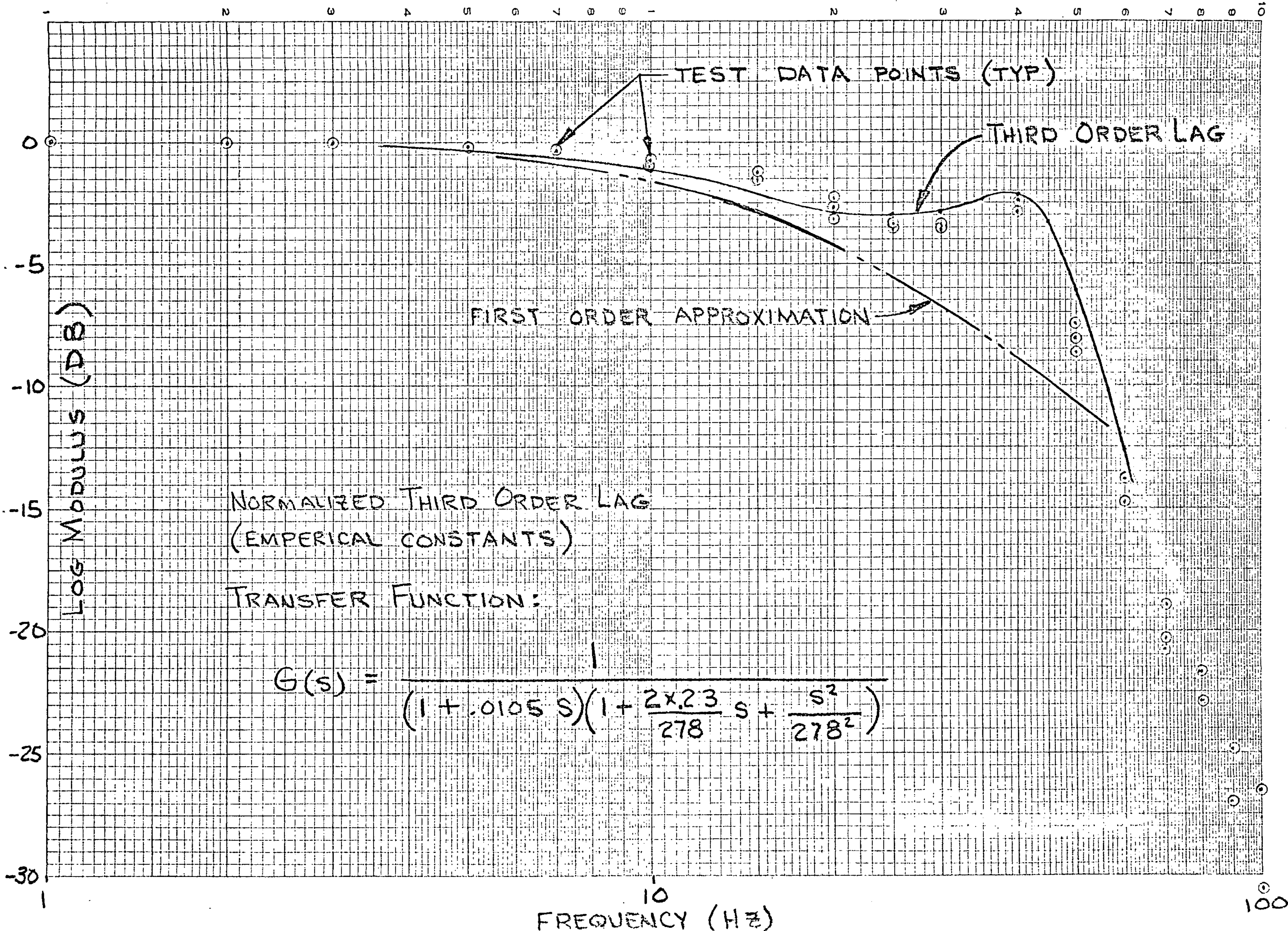



FIG. 2

3½

3,2


TEST DATA POINTS (TYP)
THIRD ORDER LAG
FIRST ORDER APPROXIMATION
NORMALIZED THIRD ORDER LAG
(EMPERICAL CONSTANTS)
TRANSFER FUNCTION:
$$G(s) = \frac{1}{(1 + .0105\,s)\left(1 + \frac{2 \times .23}{278}\,s + \frac{s^2}{278^2}\right)}$$
LOG MODULUS (DB)
FREQUENCY (HZ)
0
-5
-10
-15
-20
-25
-30
1
10
100

4

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| PAGE | TEST 1 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE INNER LOOP RESPONSE (BY STEP INPUT TO THE AMPLIFIER)

3000 P.S.I.

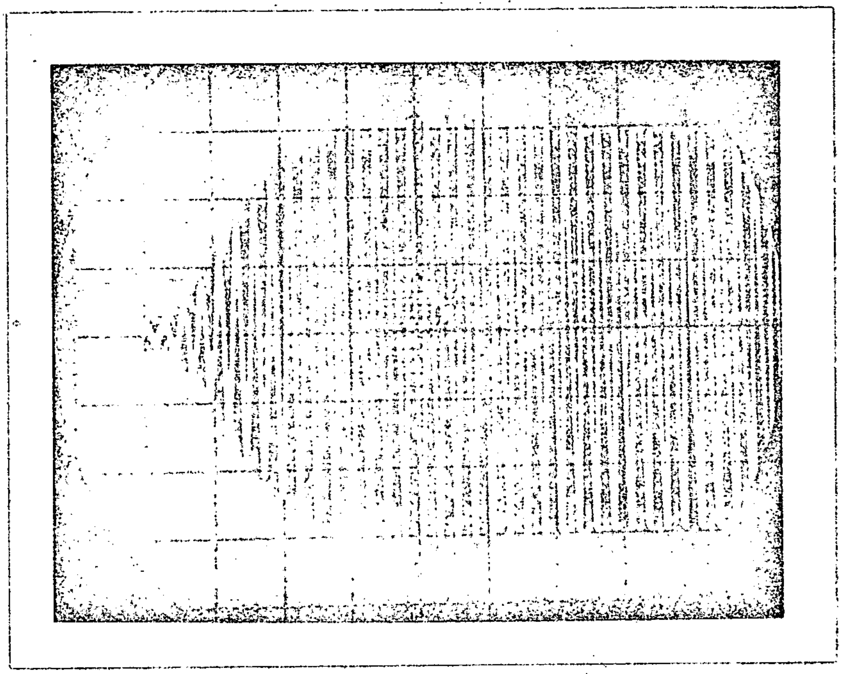
E.H. VALVE S/N 5

FULL STROKE OF THE -3 SLIDE FROM NEUTRAL (.050") = 8 CM TOTAL.

THE E.H. VALVE SIGNAL IS APPROX. 6 MA. TO ACHIEVE 3/4 (.0375).

THE INPUT SIGNAL IS INDUCED TO THE AMPLIFIER ACROSS A SWITCH AND THE SCOPE TRIGGERED TO SWEEP FROM THE SWITCH

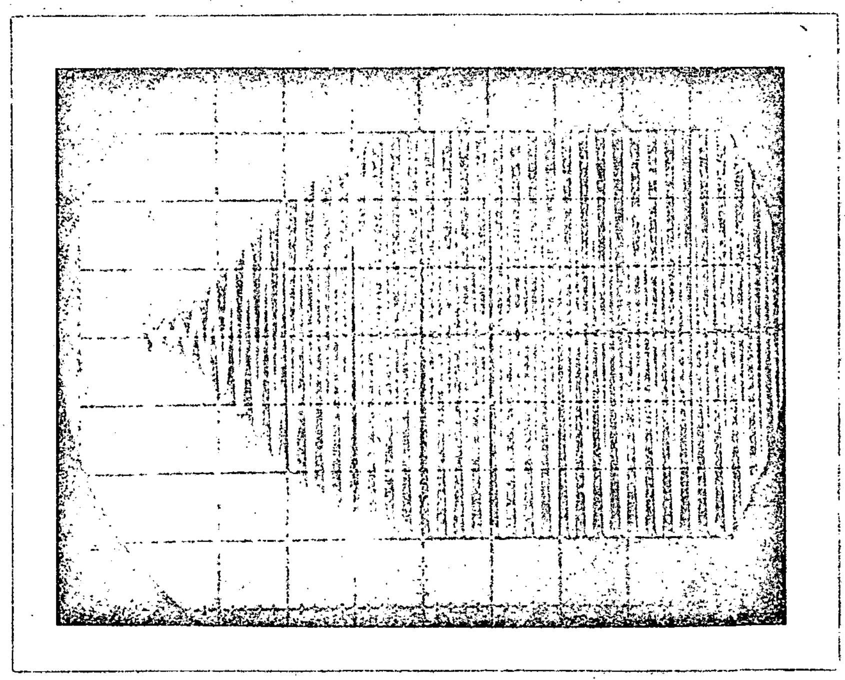
THE SCOPE DISPLAY IS THE SIGNAL FROM THE -3 SERVO MONITOR L.V.D.T. (400 Hz)



+ VOLTAGE INPUT

SWEEP TIME - 10/MS/CM

3000 P.S.I.



− VOLTAGE INPUT

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| PAGE | TEST 1 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE INNER LOOP RESPONSE (BY STEP INPUT TO THE AMPLIFIER)

3000 P.S.I.

E.H. VALVE S/N 5

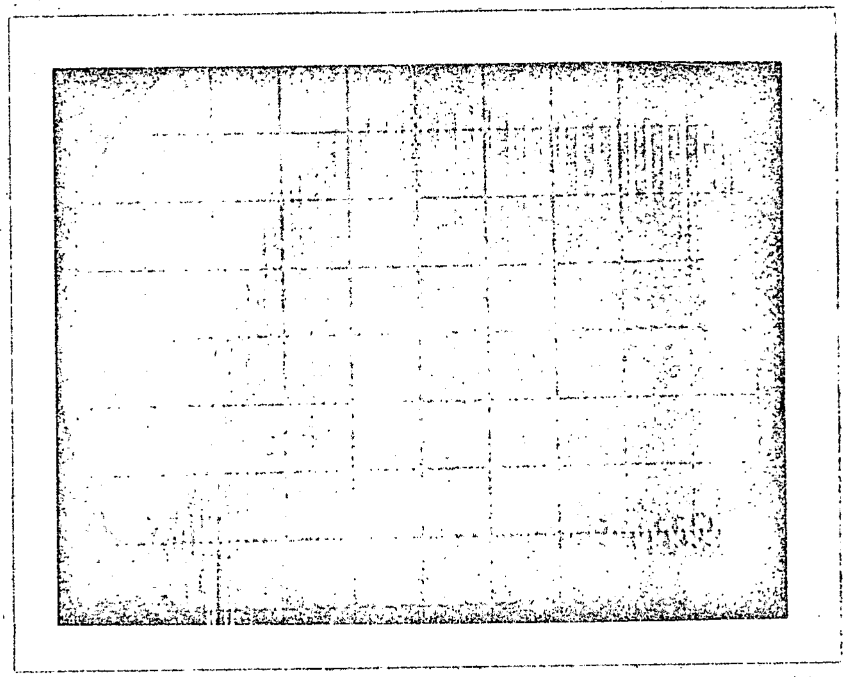
FULL STROKE OF THE -3 SLIDE FROM NEUTRAL (.050") = 7.6 CM TOTAL.

THE E.H. VALVE SIGNAL IS APPROX. 6 MA. TO ACHIEVE 3/4 (.0375).

THE INPUT SIGNAL IS INDUCED TO THE AMPLIFIER ACROSS A SWITCH AND THE SCOPE TRIGGERED TO SWEEP FROM THE SWITCH

THE SCOPE DISPLAY IS THE SIGNAL FROM THE -3 SERVO MONITOR L.V.D.T. (400 Hz)

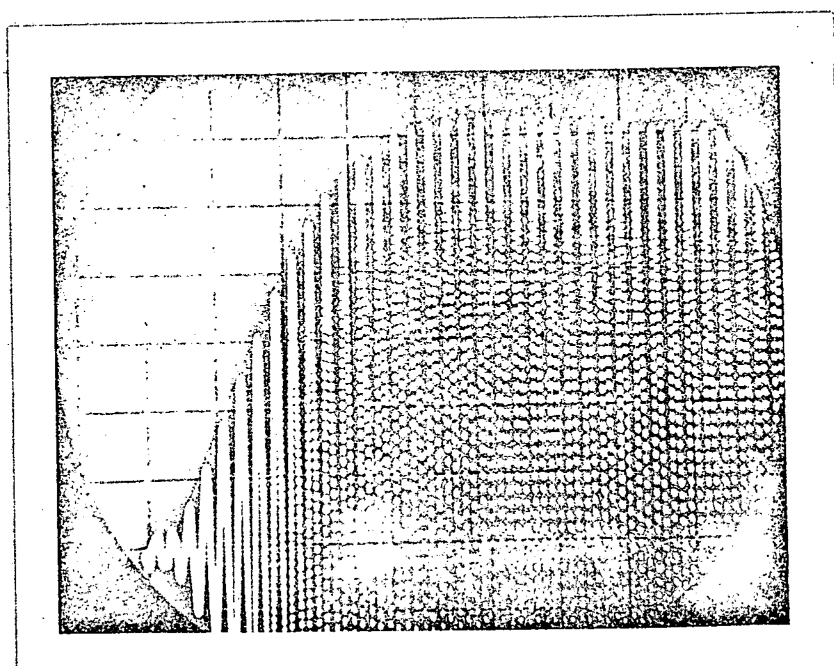
+ VOLTAGE INPUT



SWEEP TIME - 10/MS/CM

3000 P.S.I.

- VOLTAGE INPUT



OUTER LOOP FREQUENCY RESPONSE TEST

DESCRIPTION:

THIS TEST PROVIDES A CORRELATION BETWEEN ELECTRICAL COMMAND TO THE SERVO AMP AND POSITION OF THE ACTUATOR RAM (INERTIA LOADED AND NO-LOAD).

EQUIPMENT REQUIRED:

1. 221400-1003, ACTIVE STANDBY SYSTEM
2. TF221400-1003, ELECTRONIC CONTROLLER
3. INERTIA TEST FIXTURE FOR 747 INBOARD ELEVATOR SERVO ACTUATOR
4. FUNCTION GENERATOR (SINE WAVE)
5. ELECTRONIC ANALYZER, EMR 1410

TEST PROCEDURE

A. SET OPEN LOOP GAIN:

1. CALIBRATE FEEDBACK LVDT:

   a. CONNECT AC VOLT METER TO FEEDBACK LVDT JACKS ON BACK OF BOX.
   b. WITH FEEDBACK LOOP CLOSED, USE "OFFSET" POT TO MOVE MAIN RAM TO FULL EXTEND. RECORD FEEDBACK TRANSDUCER VOLTAGE.
   c. REPEAT FOR RETRACT AND RECORD NULL VOLTAGE.

2. CALCULATE VOLTAGE REQUIRED TO PROVIDE .10 IN ERROR SIGNAL:

$$V_e = \frac{V_{EXTEND} + V_{RETRACT}}{7.53 \text{ IN}} (.10) \text{ IN} + V_{NULL}$$

3. CALIBRATE SCOPE:

   a. CONNECT AC OUTPUT OF FEEDBACK LVDT TO SCOPE.
   b. ADJUST OFFSET POT TO OBTAIN MINIMUM LVDT OUTPUT VOLTAGE. ZERO SCOPE.
   c. MOVE MAIN RAM 1.00 IN (USING "OFFSET" POT) FROM NULL AND CALIBRATE SCOPE AT 4 CM (PEAK TO PEAK). SWEEP = .2 SEC/CM
   d. RETURN ACTUATOR TO NULL AND OPEN FEEDBACK LOOP. CONNECT "HOT" LEAD FROM FEEDBACK LVDT (OUTPUT) TO CONNECTOR LABELED "MONITOR" LEADING TO CONTROL BOX.

4. COMMAND (OR ERROR) SIGNAL:

   a. EXCITE PRIMARY COILS ON EQUIVALENT EXTERNAL LVDT WITH VOLTAGE FROM ELECTRONIC CONTROLLER: 26 VAC ON BACK OF BOX.
   b USING AC METER MOVE PROBE ON EXTERNAL LVDT UNTIL OUTPUT VOLTAGE IS EQUIVALENT TO .10 IN ERROR SIGNAL = $V_e$ SEE (2.) ABOVE.

## OUTER LOOP FREQUENCY RESPONSE TEST (Continued)

TEST PROCEDURE (Continued)

A. SET OPEN LOOP GAIN: (Continued)

5. CHECK OPEN LOOP GAIN:

a. CONNECT ERROR SIGNAL TO FEEDBACK LVDT TAP ON BACK OF CONTROLLER.
b. VIEW LVDT OUTPUT VS TIME ON SCOPE.
c. REVERSE POLARITY OF VOLTAGE ON PRIMARY COILS OF ERROR SIGNAL LVDT.
d. RECORD TIME TO MOVE 1 IN FROM NEUTRAL IN BOTH EXTEND ($T_1$) AND RETRACT ($T_2$).
e. CALCULATE OPEN LOOP GAIN:

$$\text{O.L.G.} = \frac{1 \text{ IN}}{\frac{T_1 + T_2}{2} \text{ SEC}} \times \frac{1}{.1 \text{ IN}}$$

f. O.L.G. MUST BE 40 $\pm$ 2 RAD/SEC, IF NOT, ADJUST POT THROUGH HOLE IN BOTTOM OF BOX AND RECHECK.
g. WHEN REQUIRED O.L.G. IS OBTAINED, PHOTOGRAPH VAC VS TIME ON SCOPE. (BOTH DIRECTIONS)

B. NO LOAD FREQUENCY RESPONSE:

USING THE SETUP SHOWN IN FIGURE 1, PERFORM THE FOLLOWING TESTS IN SEQUENCE.

1. CALIBRATE EMR 1410 FOR 10 DB/IN AND 40$^{o}$ PHASE LAB/IN.
2. COMMAND THE ACTUATOR .20" DOUBLE AMP.
   DRIVE THE ACTUATOR WITH CHANNEL 'A'.
   RECORD THE LOG MODULUS IN DB AND PHASE ANGLE IN DEGRESS FOR THE FOLLOWING COMMAND FREQUENCIES: .1, .2, .3, .4, .5 ---- ---- 20 CPS.

C. FREQUENCY RESPONSE WITH INERTIA LOAD:

USING THE TEST SETUP SHOWN IN FIGURE 1 INCLUDING THE INERTIA LOAD, PERFORM THE SAME TESTS DESCRIBED IN B-2 ABOVE.

8

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**PRODUCTION TEST PROCEDURE**

DRAWN BY -A FACKRELL DATE 7-20-72

CHECK BY DATE

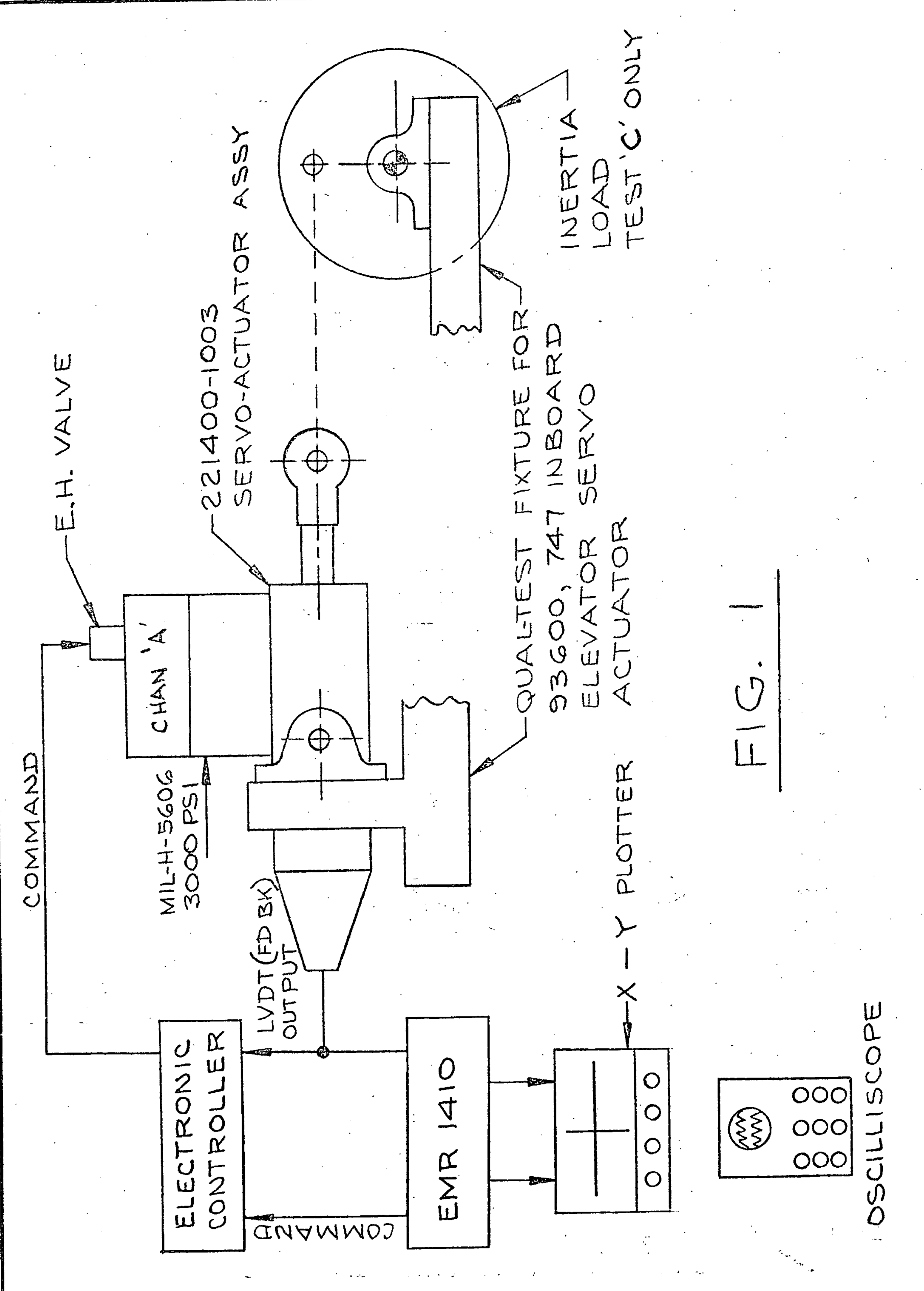
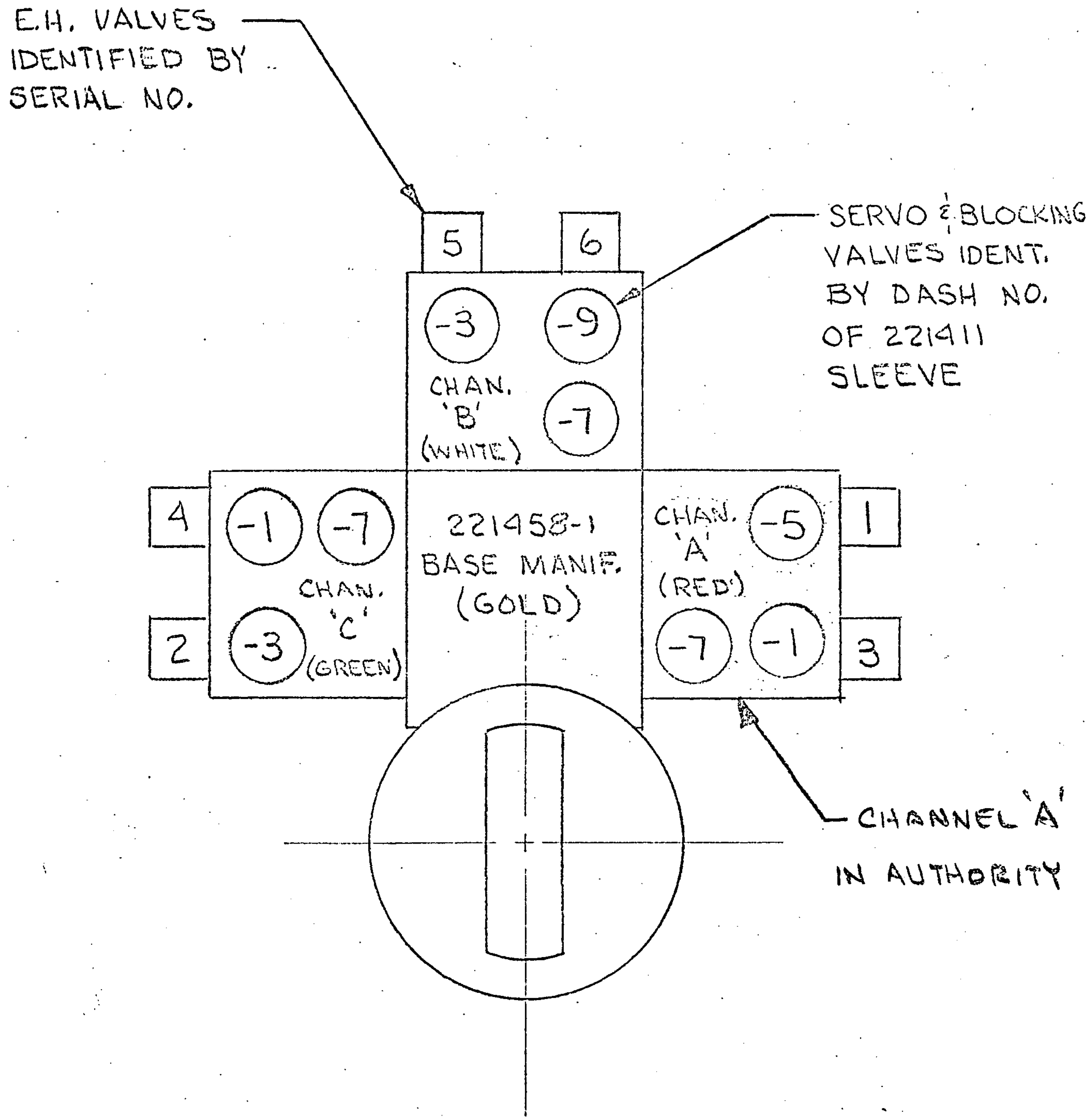



FIG. 1

TEST № 2

PG. 3 OF 3

A



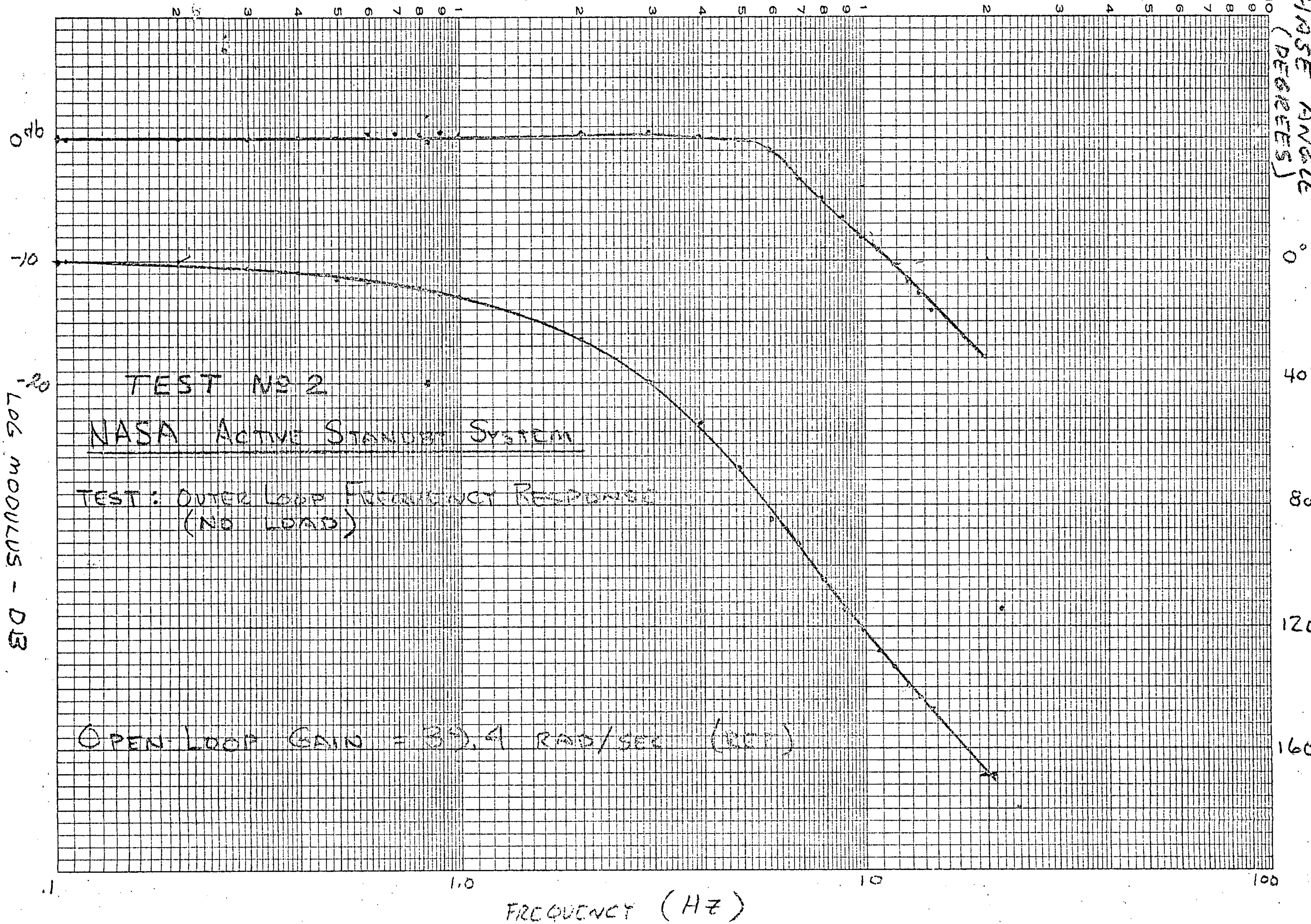

VIEW LOOKING AT MAIN RAM END OF ACTUATOR

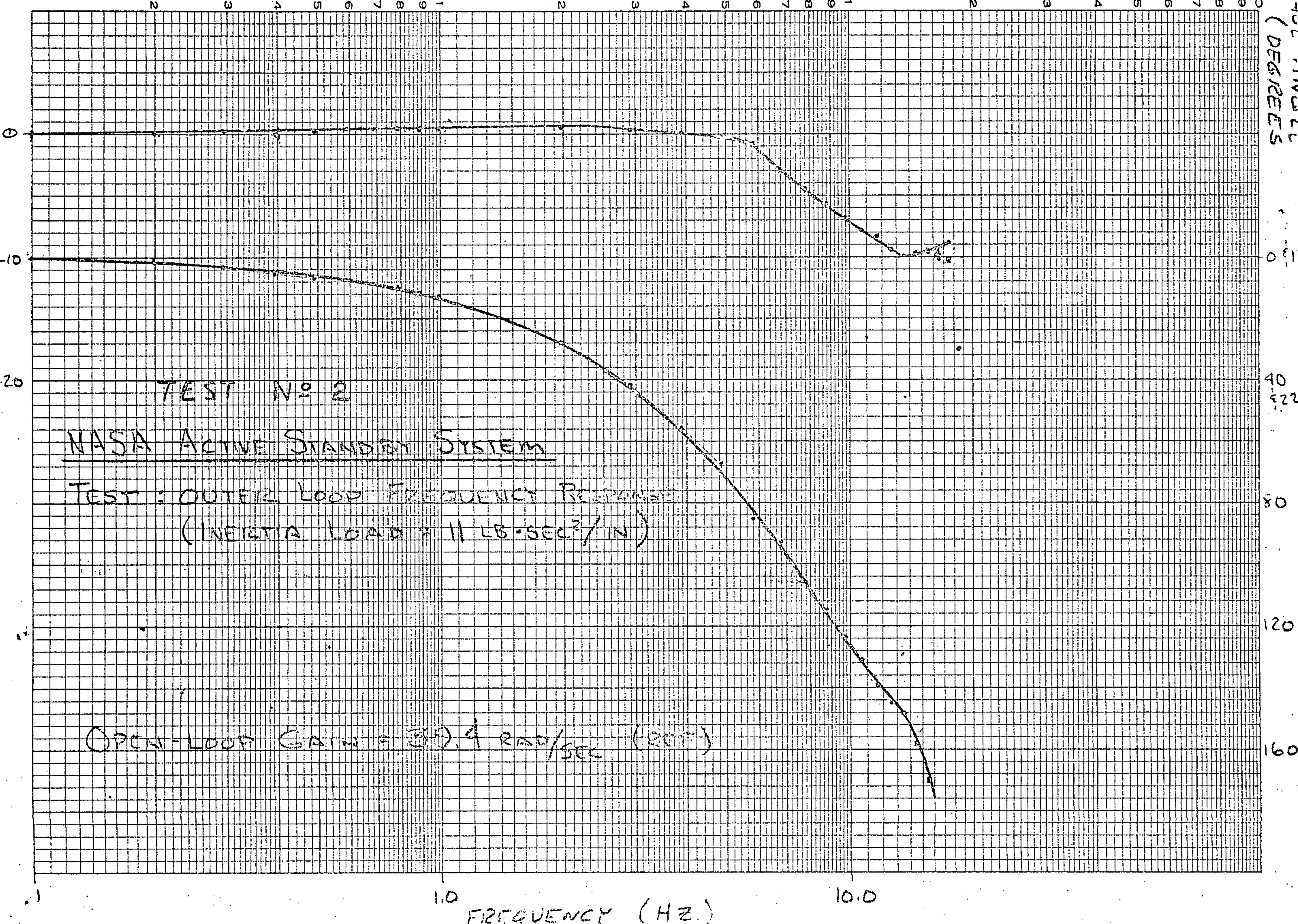
# VALVE LOCATIONS

OUTER LOOP FREQ. RESPONSE TESTS

NO. 340-L310 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
3 CYCLES X 10 DIVISIONS PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.




TEST No 2
NASA ACTIVE STANDBY SYSTEM
TEST: OUTER LOOP FREQUENCY RESPONSE
(INERTIA LOAD = 11 LB·SEC²/IN)
OPEN-LOOP GAIN = 30.4 RAD/SEC
LOG MODULUS - DB
0
-10
-20
PHASE ANGLE (DEGREES
0
40
80
120
160
.1
1.0
10.0
FREQUENCY (HZ)

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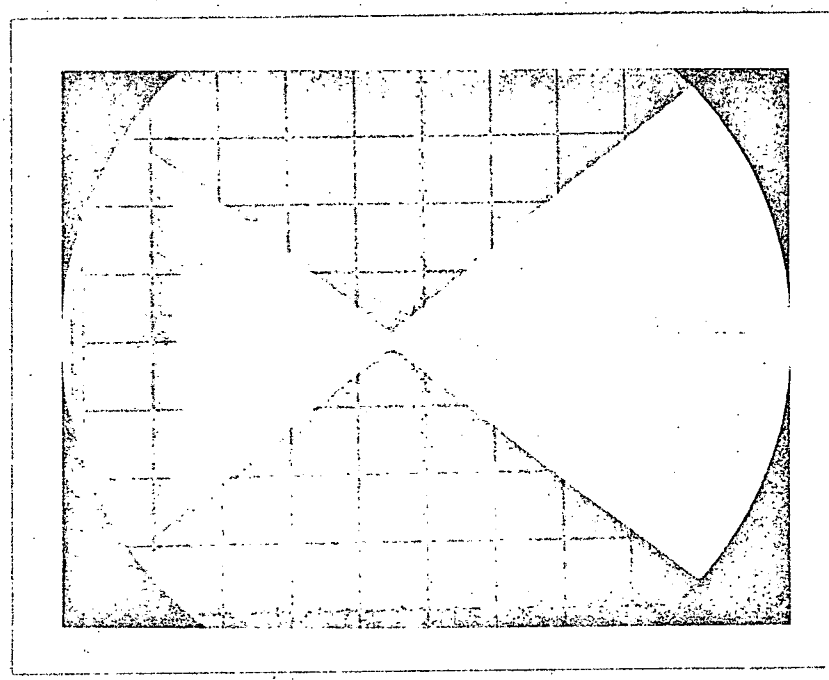
| PAGE 12 | TEST 2 | REV. |
|---|---|---|
| ORIG. DATE | ~~REV.~~ DATE 4-13-72 | |

TITLE OPEN LOOP GAIN (CALIBRATION) FOR OUTER-LOOP FREQ. RESPONSE TEST

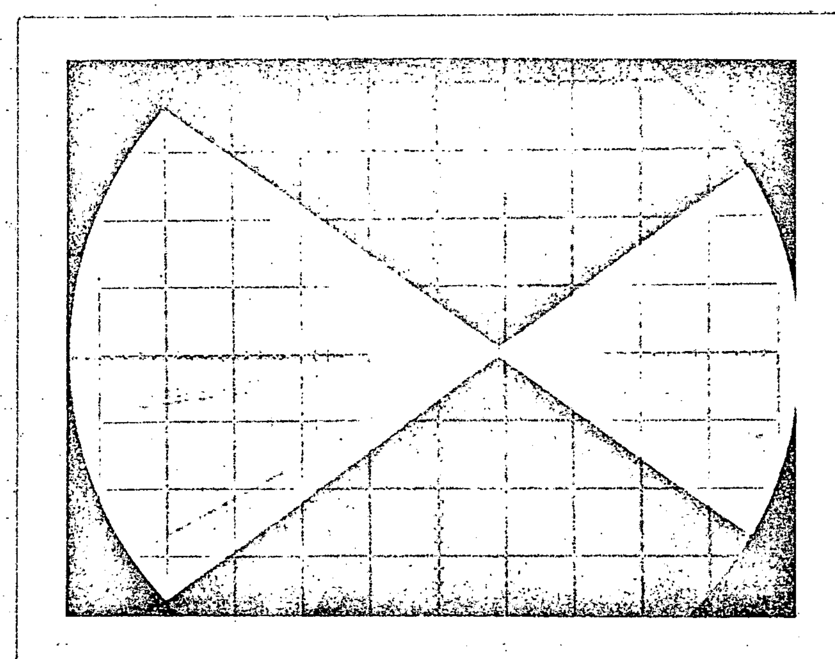
X AXIS = 100/MS/CM
Y AXIS = 1.0 ACTUATOR IN.
= 4/CM.

COMMAND = 0.1 V.A.C.

± SIGNAL CONTROLLED FROM A POLARITY SWITCH.



EXTEND



RETRACT

NOISE FREQUENCY VS. AMPLITUDE TEST
NASA ACTIVE STANDBY SYSTEM

DESCRIPTION: THIS TEST PROVIDES A CORRELATION BETWEEN NOISE LEVEL (FREQUENCY AND AMPLITUDE) AND AUTHORITY FOR VARIOUS FAILURE DETECTION MECHANISMS.

EQUIPMENT REQUIRED:

1. 221400-1003, ACTIVE STANDBY SYSTEM WITH THE FOLLOWING COMPARATOR CONFIGURATIONS:

| CHANNEL | COMPARATOR SLIDE OVERLAP |
|---|---|
| A | .0396 |
| B | .0396 |
| C | .0032 |

2. TF221400-1003, ELECTRONIC CONTROLLER

3. PULSE GENERATOR (TRIANGLE PULSE)

4. OSCILLOSCOPE

5. DIGITAL VOLT METER

NOISE FREQUENCY VS. AMPLITUDE TEST (Continued)
NASA ACTIVE STANDBY SYSTEM

PROCEDURE:

OUTLINE OF TEST SEQUENCE:

1. INSTALL REQUIRED COMPARATOR SLIDES
2. SET APPROXIMATELY NEUTRAL MECHANICALLY
3. FINE-TUNE NULL WITH ELECTRONICS
4. NULL COMPARATOR LVDT
5. SET CLOSED-LOOP GAIN OF #2 BUFFER AMP
6. CHECK COMPARATOR TRIP POSITION.
7. PLOT FREQUENCY VS. MINIMUM AMPLITUDE TO CAUSE SWITCHING FOR TRIANGLE PULSE TO MONITOR

NOTES: ALL TESTS TO BE RUN WITH THE RESET SOLENOIDS ENERGIZED AND WITH THE FAIL SIMULATING SOLENOIDS DE-ENERGIZED EXCEPT AS NOTED.

| TEST NO. | TEST DESCRIPTION | PROCEDURE |
|---|---|---|
| 1 | COMPARATOR SLIDE INSTALLATION | INSTALL COMPARATOR SLIDES. OVERLAP SHOWN IN "EQUIPMENT REQUIRED" SECTION ABOVE.<br><br>VISUALLY INSPECT TEST CONFIGURATION AND VERIFY COMPLETENESS AND CORRECTNESS. |

NOISE FREQUENCY VS. AMPLITUDE TEST (Continued)
NASA ACTIVE STANDBY SYSTEM





| TEST NO. | TEST DESCRIPTION | PROCEDURE |
|---|---|---|
| 2 | MECHANICAL NULL | DISCONNECT ELECTRICAL CONNECTIONS FROM ELECTRO-HYDRAULIC VALVES. USING REDUCED PRESSURE, ADJUST ELECTROHYDRAULIC VALVES ON POWER SLIDES AS CLOSE TO NULL AS PRACTICAL. |
| 3 | ELECTRICAL NULL CHANNEL "A" | RECONNECT ELECTRICAL CABLE TO ALL ELECTRO-HYDRAULIC VALVES. DISCONNECT ACTUATOR FEEDBACK LVDT OUTPUT. ADD OFF-SET THROUGH STEP FUNCTION JACK TO #1 BUFFER AMP. TO ACHIEVE ZERO DRIFT AT ACTUATOR.<br><br>APPLY VOLTAGE TO NOISE INPUT JACKS ON FRONT OF CONTROLLER TO DRIVE MONITOR ELECTROHYDRAULIC VALVE ONE DIRECTION UNTIL INTERLOCK VALVE TRIPS. RECORD COMMAND VOLTAGE (USE DIGITAL VOLT METER). RESET SYSTEM AND DETERMINE TRIP VOLTAGE IN OPPOSITE DIRECTION. ADJUST NULL BIAS TO MONITOR ELECTROHYDRAULIC VALVE UNTIL TRIP VOLTAGE IS THE SAME (IN MAGNITUDE) IN BOTH DIRECTIONS. |

BERTEA CORPORATION IRVINE • CALIFORNIA

**PRODUCTION TEST PROCEDURE**

DRAWN BY W. Covell DATE

CHECK BY DATE

NOISE FREQUENCY VS. AMPLITUDE TEST (Continued)
NASA ACTIVE STANDBY SYSTEM

| TEST NO. | TEST DESCRIPTION | PROCEDURE |
|---|---|---|
| 4 | LVDT NULL (COMPARATOR AND MONITOR SLIDE) | SET NULL VOLTAGE ON COMPARATOR AND MONITOR LVDT'S TO LOWEST LEVEL BY ADJUSTING POSITION OF PROBE OR COILS AS APPLICABLE. (CHANNEL "A") |
| 5 | #2 BUFFER AMPLIFIER GAIN (CLOSED LOOP) | APPLY NOTED VOLTAGES TO #2 BUFFER AMPLIFIER (THRU NOISE INPUT) RECORD RESULTANT COIL CURRENT IN ELECTROHYDRAULIC VALVE.<br><br>INPUT VOLTAGES: .1, .5, 1.0, AND 5 VDC<br><br>ADJUST POT., IF REQUIRED, TO OBTAIN A CLOSED LOOP GAIN OF 1 MA/VDC $\pm$5% AT 1 VDC COMMAND. |
| 6 | COMPARATOR TRIP POSITION CHANNEL "A" | APPLY COMMAND VOLTAGE TO NOISE INPUT JACKS. DRIVE MONITOR WITH POSITIVE VOLTAGE COMMAND UNTIL INTERLOCK TRIPS. RECORD COMPARATOR LVDT OUTPUT VOLTAGE AND COMMAND VOLTAGE AT TRIP POINT. REPEAT FOR NEGATIVE COMMAND VOLTAGE. |

BERTEA CORPORATION IRVINE • CALIFORNIA

**PRODUCTION TEST PROCEDURE**

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CHECK BY DATE



NOISE FREQUENCY VS. AMPLITUDE TEST (Continued)
NASA ACTIVE STANDBY SYSTEM

| TEST NO. | TEST DESCRIPTION | PROCEDURE |
|---|---|---|
| 7 | NOISE REJECTION TEST CHANNEL "A" | SET UP PER FIG. 1 SCHEMATIC. DRIVE MONITOR ELECTROHYDRAULIC VALVE BY APPLYING TRIANGLE PULSE INPUT TO #2 BUFFER AMP. (NOISE INPUT JACKS ON FRONT OF CONTROL BOX)<br><br>DETERMINE MINIMUM AMPLITUDE OF PULSE, IN EQUIVALENT INCHES, AT COMPARATOR WHICH WILL TRIP INTERLOCK FOR THE FOLLOWING PULSE FREQUENCIES:<br>.1, .2, .3, .4, .5, .7, .9<br>1.0, 2.0, 3.0, 4.0, 5.0, 7.0, 9.0<br>10, 11, 12, . . . 30<br><br>REPEAT WITH NOISE INPUT TO POWER VALVE (APPLY NOISE TO "STEP INPUT" JACKS). MONITOR AND RECORD ACTUATOR TRANSIENTS AT TRIP LEVEL. |
| 8 | ELECTRICAL NULL CHANNEL "B" | MOVE COMPARATOR LVDT TO CHANNEL "B" CONNECT #1 AND #2 BUFFER AMPS TO CHANNEL "B" POWER AND MONITOR ELECTROHYDRAULIC VALVES (S/N'S 6 & 5) RESPECTIVELY. REPEAT TEST NO. 3 FOR CHANNEL "B" IN AUTHORITY. |

B

BERTEA CORPORATION IRVINE • CALIFORNIA

PRODUCTION TEST PROCEDURE

DRAWN BY W. Coven DATE

CHECK BY DATE

NOISE FREQUENCY VS. AMPLITUDE TEST (Continued)
NASA ACTIVE STANDBY SYSTEM

| TEST NO. | TEST DESCRIPTION | PROCEDURE |
|---|---|---|
| 9 | COMPARATOR LVDT NULL CHANNEL "B" | WITH ZERO INPUT COMMAND, SET NULL VOLTAGE ON COMPARATOR LVDT TO ITS MINIMUM LEVEL. |
| 10 | #2 BUFFER AMPLIFIER GAIN CHECK | RECHECK CLOSED LOOP GAIN OF #2 BUFFER AMPLIFIER. |
| 11 | COMPARATOR TRIP POSITION CHANNEL "B" | REPEAT TEST NO. 6 FOR CHANNEL "B". |
| 12 | NOISE REJECTION TEST CHANNEL "B" | REPEAT TEST NO. 7 FOR CHANNEL "B". |

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**PRODUCTION TEST PROCEDURE**

DRAWN BY N. Cover DATE

CHECK BY DATE

NOISE FREQUENCY VS. AMPLITUDE TEST (Continued)
NASA ACTIVE STANDBY SYSTEM

| TEST NO. | TEST DESCRIPTION | PROCEDURE |
|---|---|---|
| 13 | | MOVE COMPARATOR LVDT TO CHANNEL "B" AND REPEAT TEST #3 FOR CHANNEL "B" USING BUFFER AMPS NO'S 1 & 2. |
| 14 | | REPEAT TESTS 9 FOR CHANNEL "C". |
| 15 | | REPEAT TESTS 10 FOR CHANNEL "C". |
| 16 | | REPEAT TESTS 11 FOR CHANNEL "C". |
| 17 | | REPEAT TESTS 12 FOR CHANNEL "C". |

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**PRODUCTION TEST PROCEDURE**

DRAWN BY A FACKRELL DATE 7-20-72
CHECK BY DATE



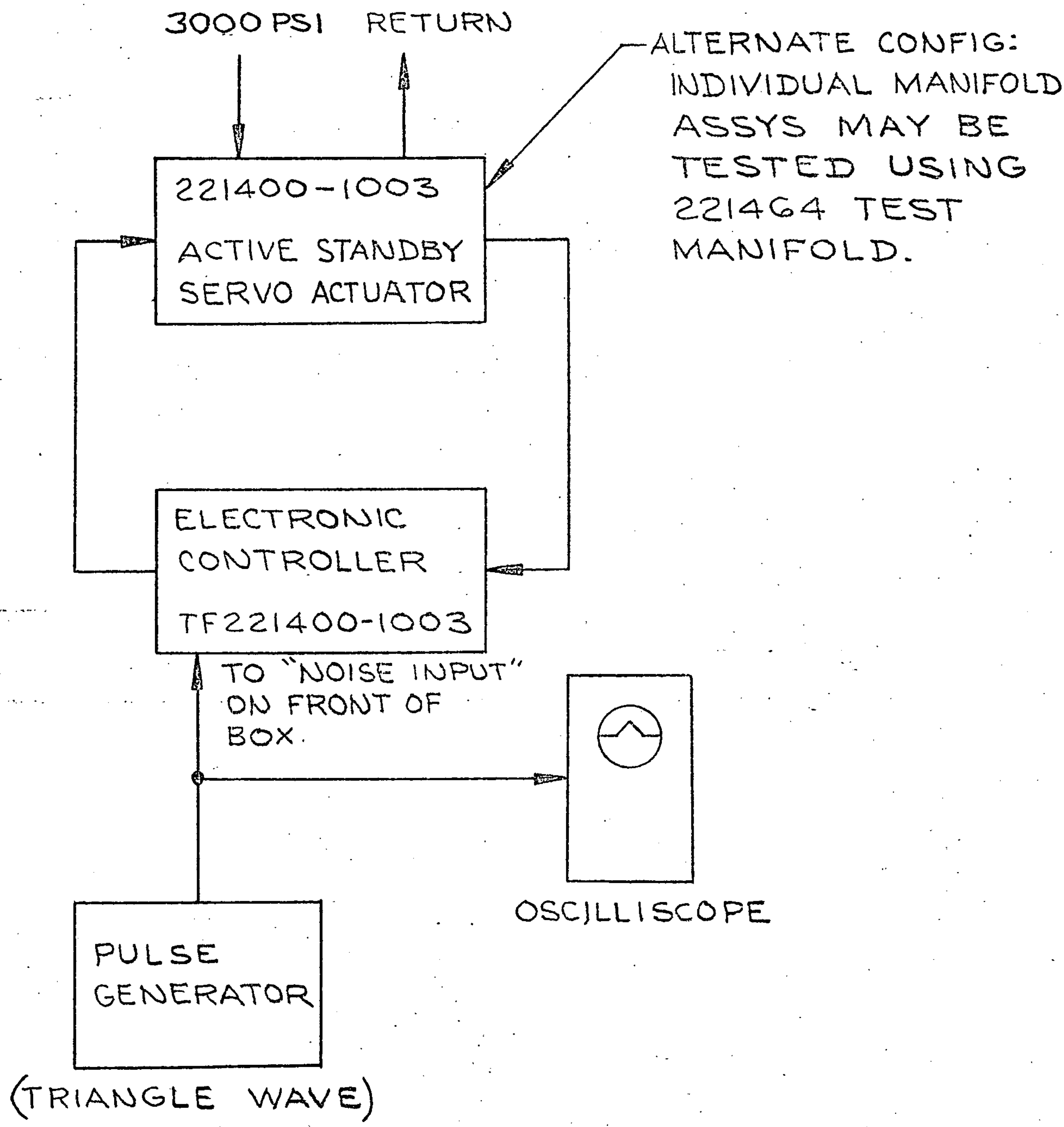


FIG. 1, SCHEMATIC TEST SETUP

21/22

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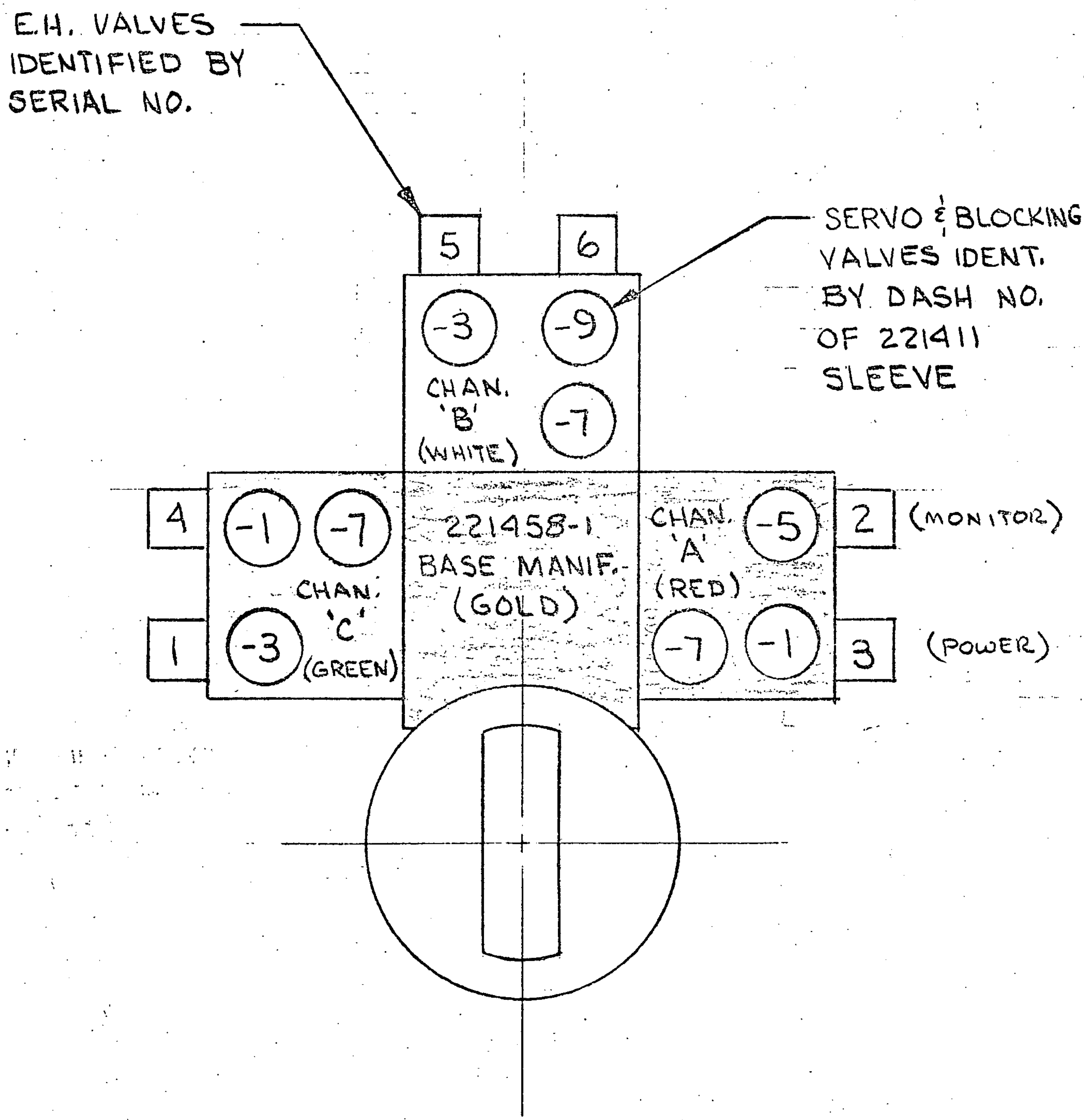
**PRODUCTION TEST PROCEDURE**

DRAWN BY ______ DATE ______

CHECK BY ______ DATE ______

TESTS 3, 4, 5 PG. OF

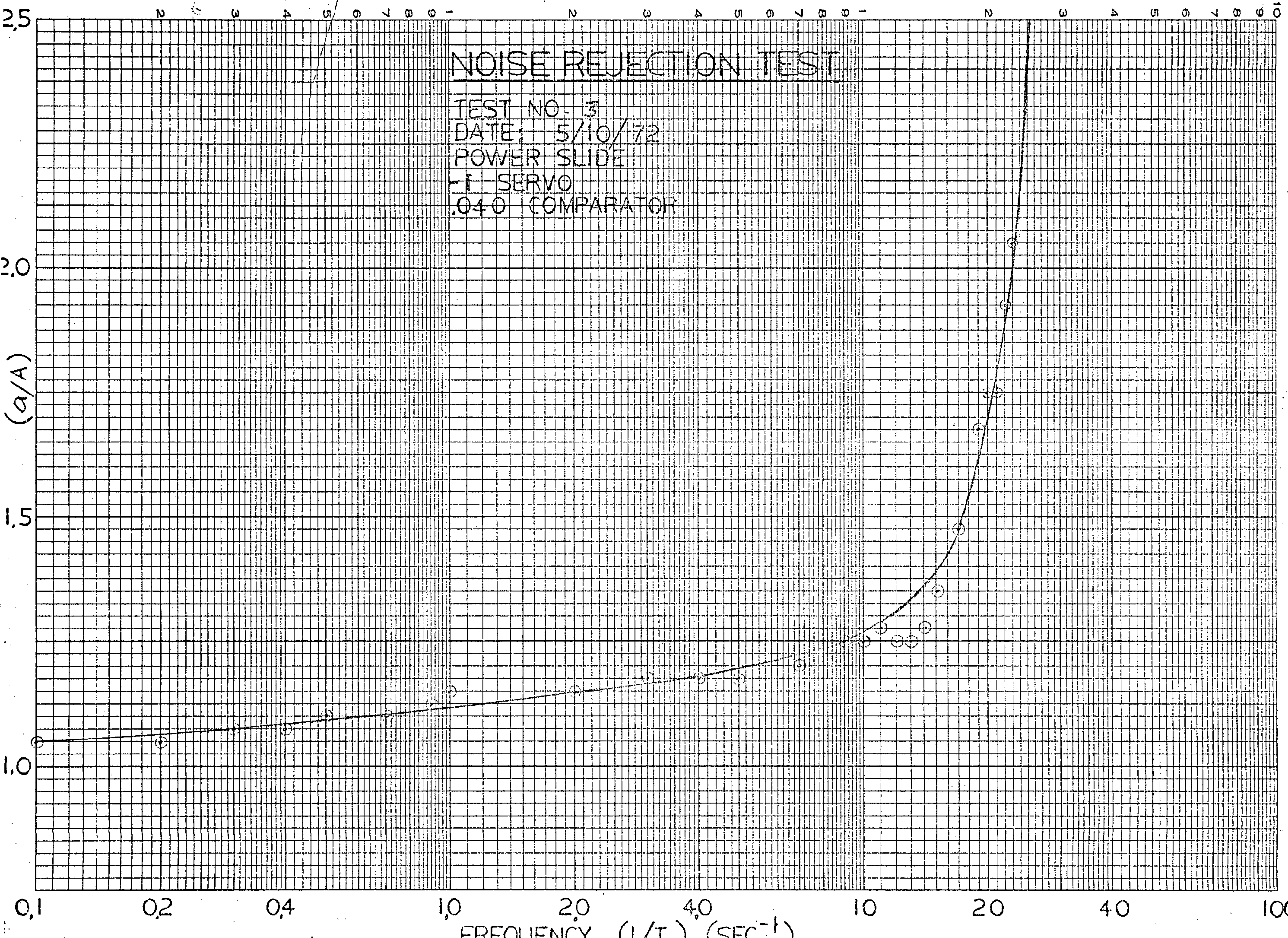



VIEW LOOKING AT MAIN RAM END OF ACTUATOR

# VALVE LOCATIONS

A POWER
5-10-72



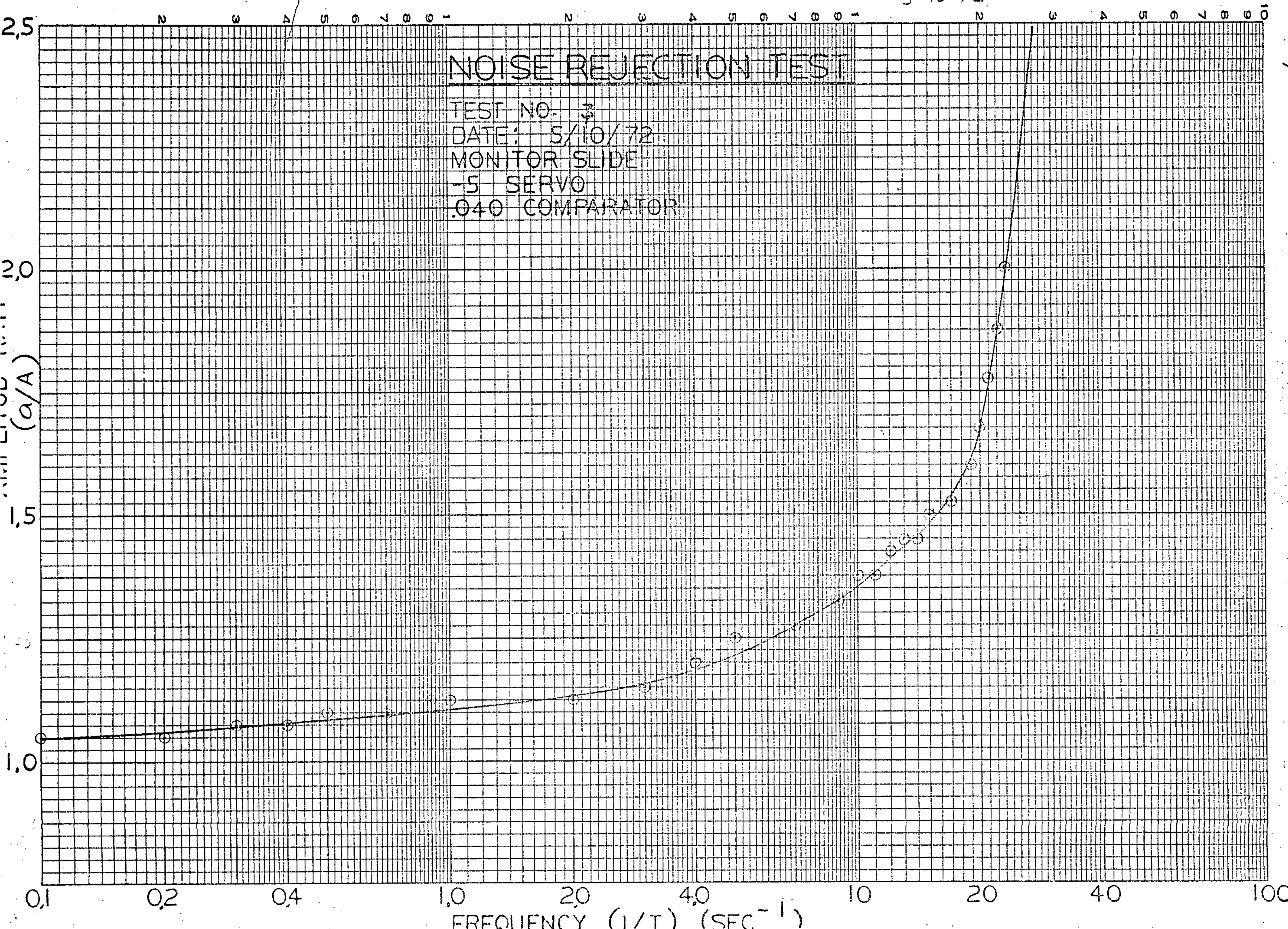


NO. 340-L310 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
3 CYCLES X 10 DIVISIONS PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

A MON
-5 SERVO
5-10-72

24/26

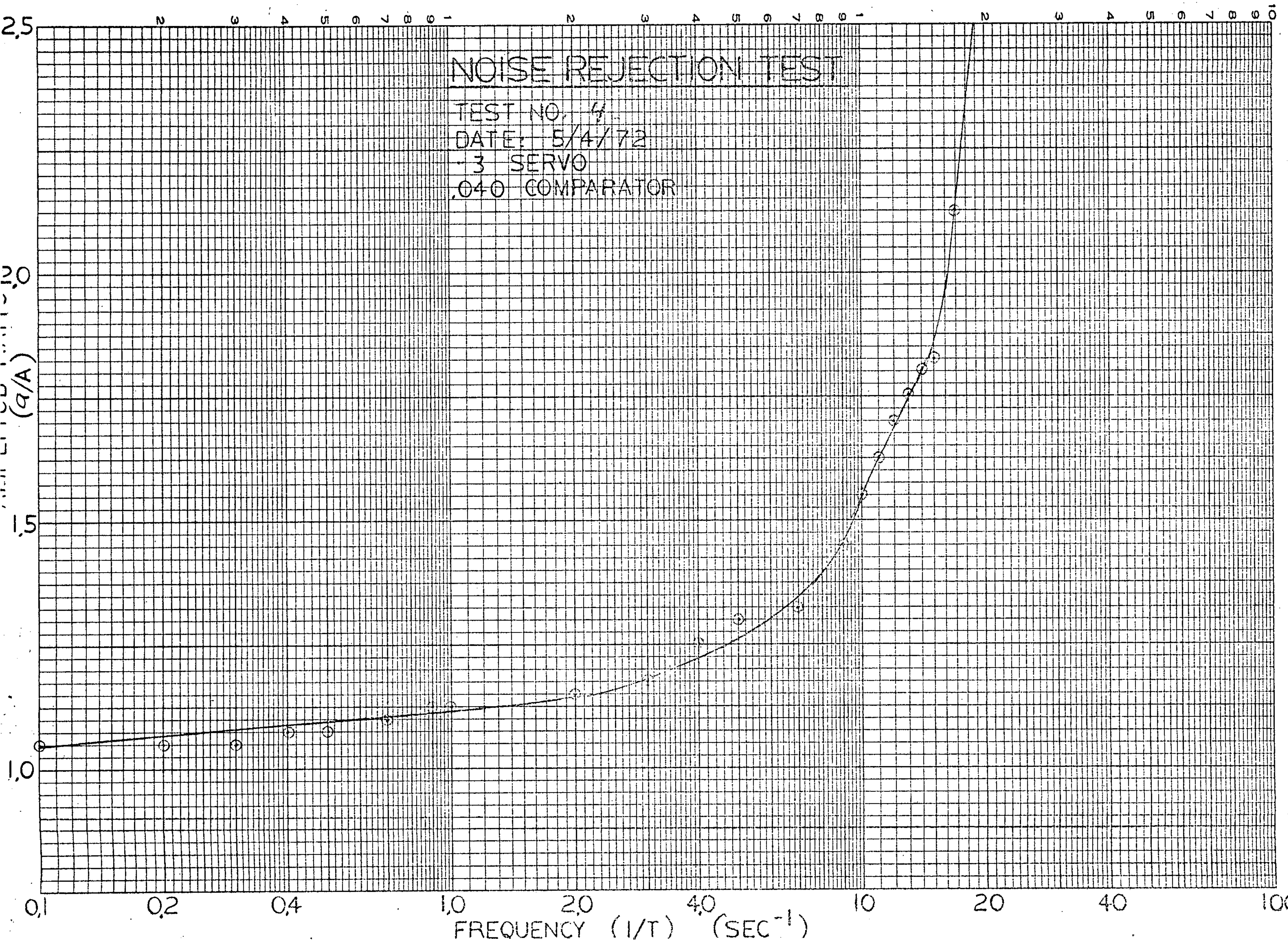


CHAN B
-3

5-4-72

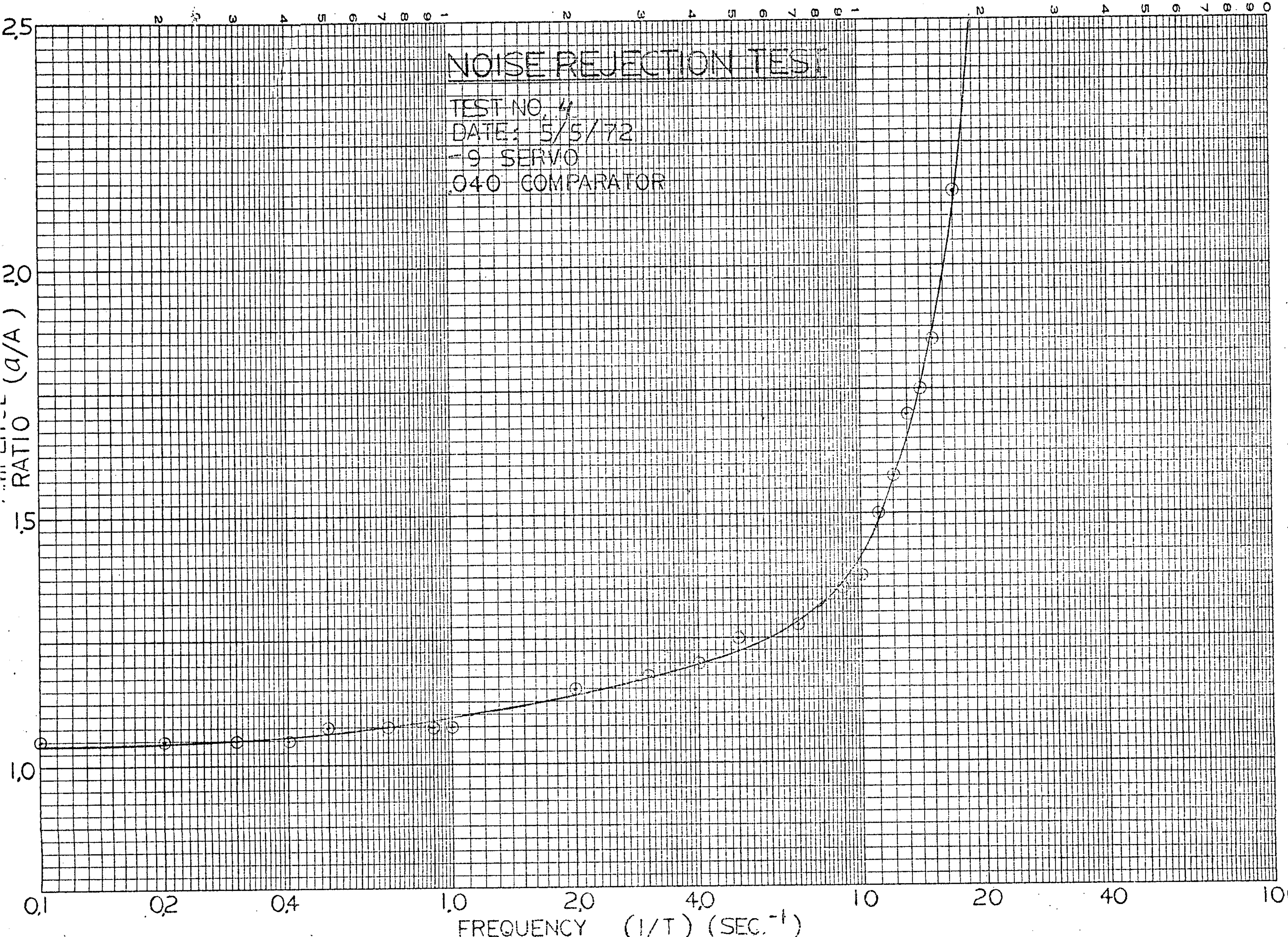
No 25826

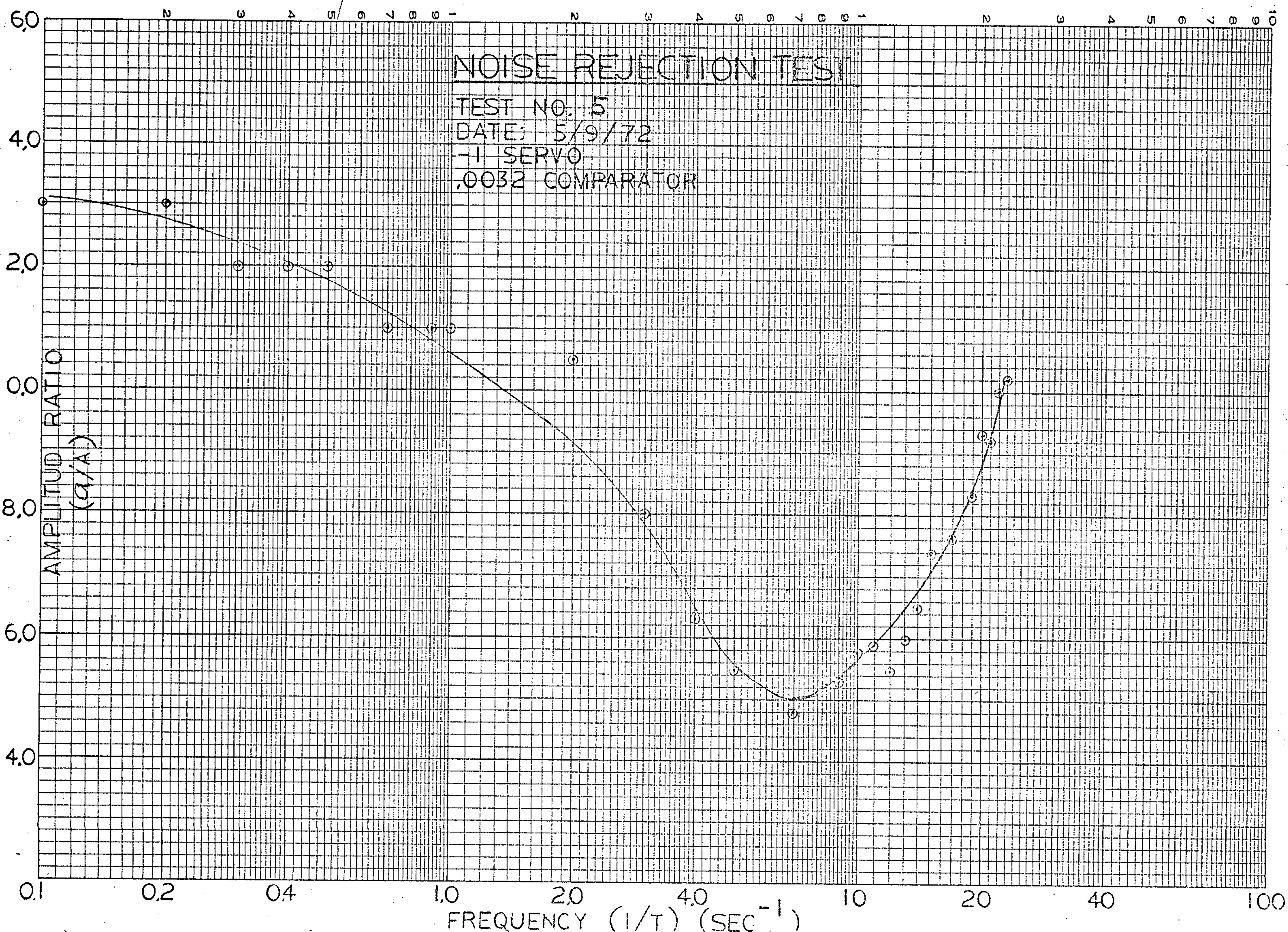




CHAN B
-9 SIV,
5-5






NOISE REJECTION TEST
TEST NO. 5
DATE: 5/9/72
-1 SERVO
.0032 COMPARATOR
AMPLITUD RATIO
(a/A)
6.0
4.0
2.0
0.0
8.0
6.0
4.0
0.1
0.2
0.4
1.0
2.0
4.0
10
20
40
100
FREQUENCY (1/T) (SEC$^{-1}$)

## SUPPLY AND RETURN TRANSIENT TEST

DESCRIPTION:

THIS TEST DETERMINES THE EFFECT OF 1000 PSI TRANSIENTS IN THE SUPPLY AND RETURN LINES ON THE FAULT CORRECTING MECHANISM.

EQUIPMENT REQUIRED:

1. 221400-1003, ACTIVE STANDBY SYSTEM
2. TF221400-1003, ELECTRONIC CONTROLLER
3. STRIP CHART RECORDER OR OSCILLOSCOPE
4. 0-3000 PSI TRANSDUCER
5. 2-WAY SOLENOID VALVE

NOTES:

1. TEST TO BE CONDUCTED WITH CHANNEL "A" IN AUTHORITY.
2. ALL TESTS TO BE RUN WITH RESET SOLENOIDS ENERGIZED AND WITH FAIL SIMULATING SOLENOIDS DE-ENERGIZED EXCEPT AS NOTED.

PROCEDURE:

1. USING TEST SETUP SHOWN SCHEMATICALLY IN FIGURE 1, PERFORM THE FOLLOWING TESTS IN SEQUENCE.
2. REGULATOR, SOLENOID, AND PRESS TRANSDUCER USED FOR PRESSURE TRANSIENT TEST MAY BE RELOCATED FOR RETURN TRANSIENT TEST.

| TEST NO. | TEST DESCRIPTION | PROCEDURE |
|---|---|---|
| 1 | CALIBRATION | SET GALVO DEFLECTION FOR 1.00" ON STRIP CHART = .020" COMPARATOR SLIDE MOTION.<br><br>SET 1000 PSI = 1.0" ON STRIP CHART.<br><br>NO SCALE REQUIRED FOR SOLENOID VOLTAGE.<br><br>IF OSCILLOSCOPE IS USED: SET 2 CM ON SCOPE (PEAK TO PEAK) = .005" COMPARATOR SLIDE MOTION. SET 1000 PSI = 2 CM ON SCOPE |

## SUPPLY AND RETURN TRANSIENT TEST (Continued)

| TEST NO. | TEST DESCRIPTION | PROCEDURE |
|---|---|---|
| 2 | PRESSURE LINE TRANSIENTS WITH NO COMMAND | INDUCE 1000 ± 100 PSI PRESSURE LINE TRANSIENTS BY ADJUSTING HIGH PRESSURE REGULATOR AND SWITCHING SOLENOID VALVE OFF AND ON (MANUALLY OPERATED SWITCH). RECORD PRESSURE FLUCTUATION AND COMPARATOR MOTION ON STRIP CHART.<br><br>DO NOT COMMAND ACTUATOR DURING THIS TEST. |
| 3 | PRESSURE LINE TRANSIENTS (ACTUATOR CYCLING) | COMMAND ACTUATOR TO CYCLE ±.100 AT NOTED FREQUENCIES.<br><br>REPEAT TEST 2 WITH THE ABOVE EXCEPTION.<br><br>COMMAND FREQUENCIES: .1, 1, 10 CPS |
| 4 | RETURN LINE TRANSIENTS WITH NO COMMAND | REPEAT TEST 2 EXCEPT INDUCE 0-1000 ± 100 PSI TRANSIENTS IN THE RETURN LINE. |
| 5 | RETURN LINE TRANSIENTS (ACTUATOR CYCLING) | REPEAT TEST 3 EXCEPT INDUCE 0-1000 ± 100 PSI TRANSIENTS IN THE RETURN LINE. |

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**PRODUCTION TEST PROCEDURE**

DRAWN BY A FACKRELL DATE 7-20-72

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TESTS No 6-7

PG. 3 OF 3

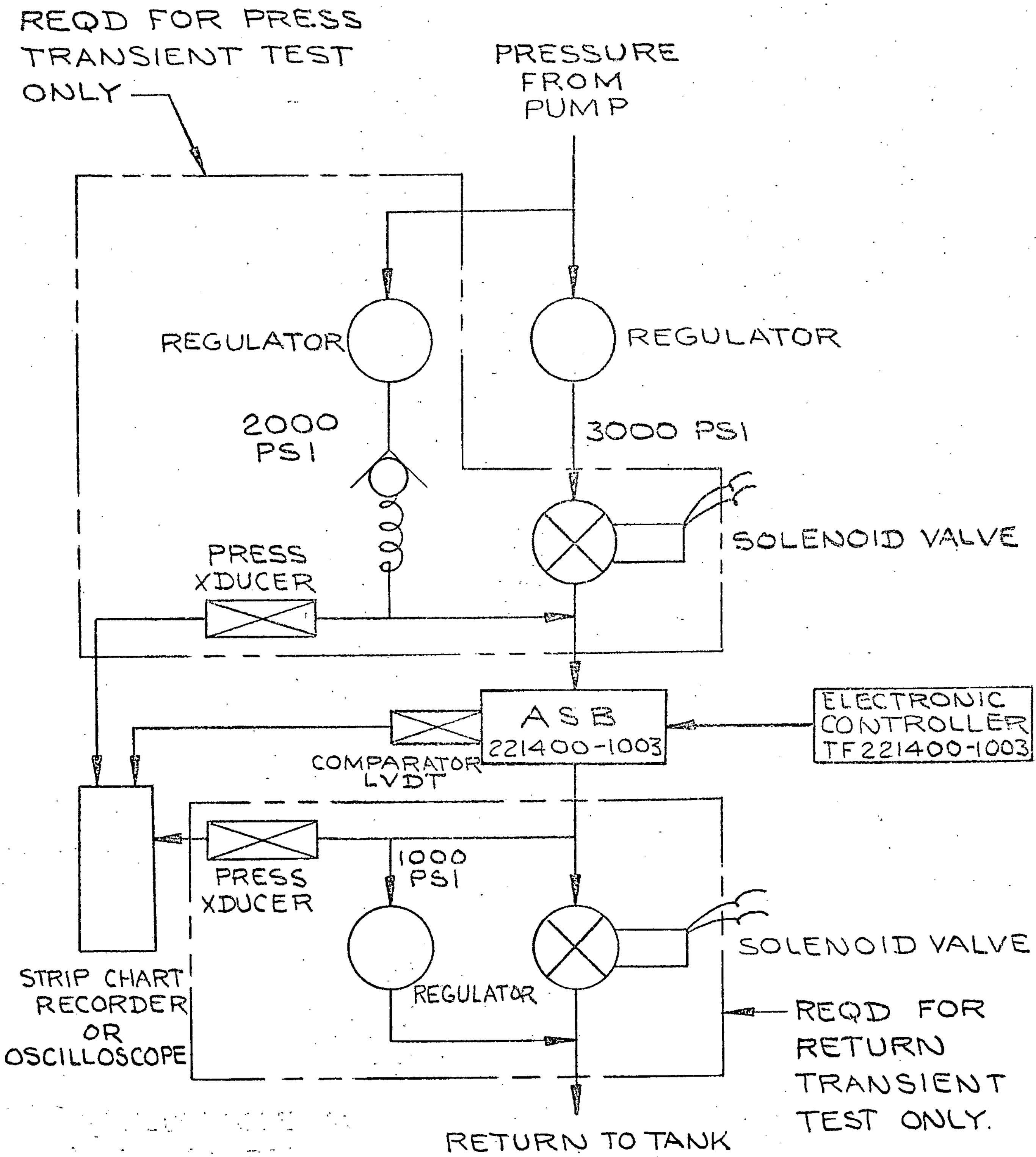
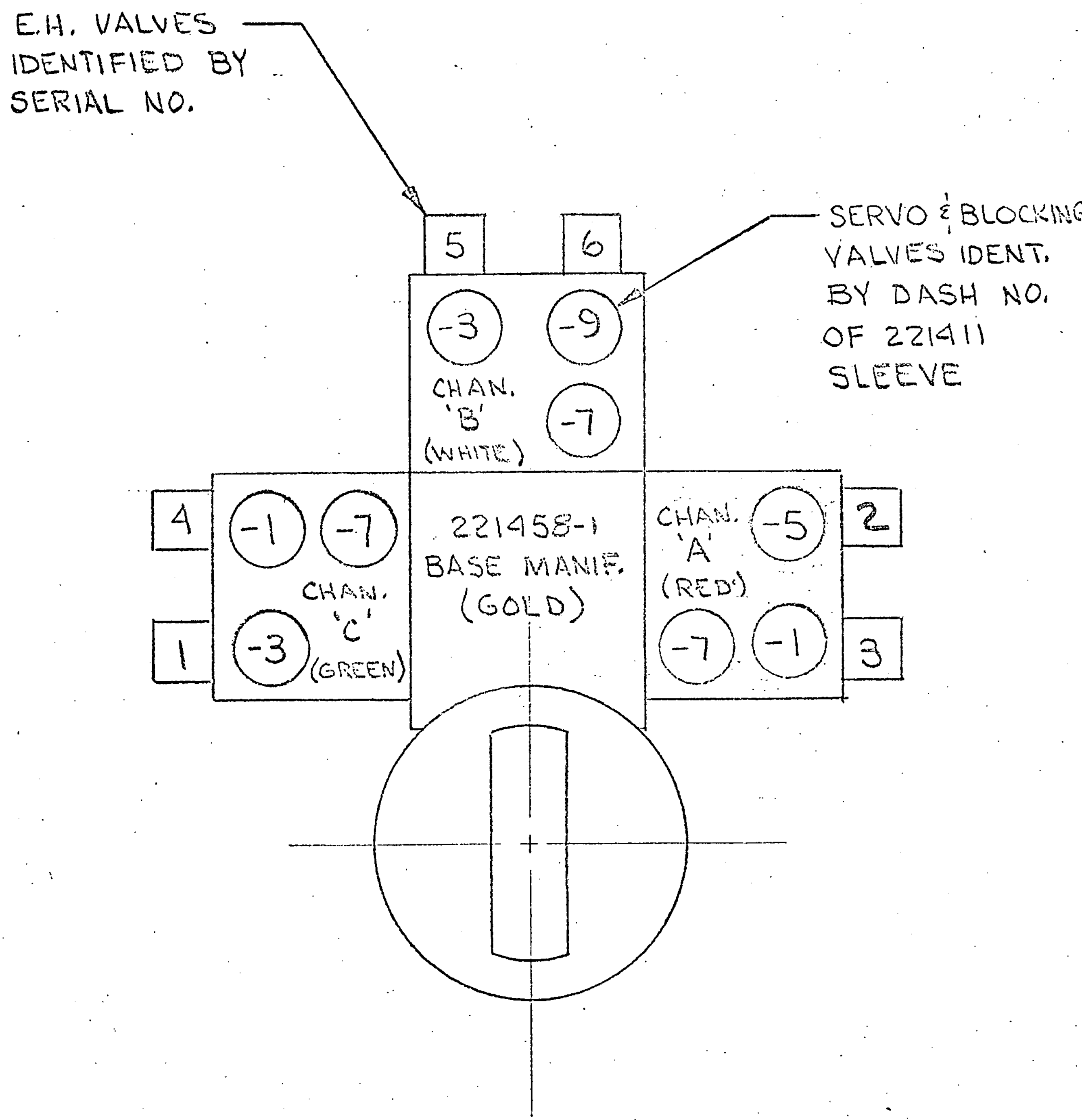



FIGURE 1

TEST SET-UP – SCHEMATIC

A




VIEW LOOKING AT MAIN RAM END OF ACTUATOR

# VALVE LOCATIONS

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| PAGE 34 | ~~DOCUMENT NO.~~ TESTS 6 - 7 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE SUPPLY & RETURN TRANSIENT TEST (221400)

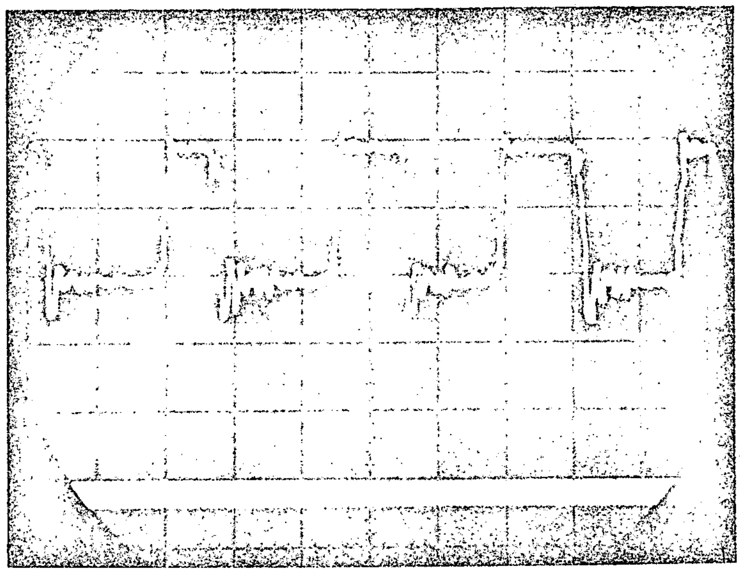
SINE WAVE INPUT & .050"
D.A. OUTPUT @ 1.0 Hz

3000 P.S.I.

SYSTEM INLET PRESS

2000 P.S.I.

COMPARATOR SLIDE POSITION .005"



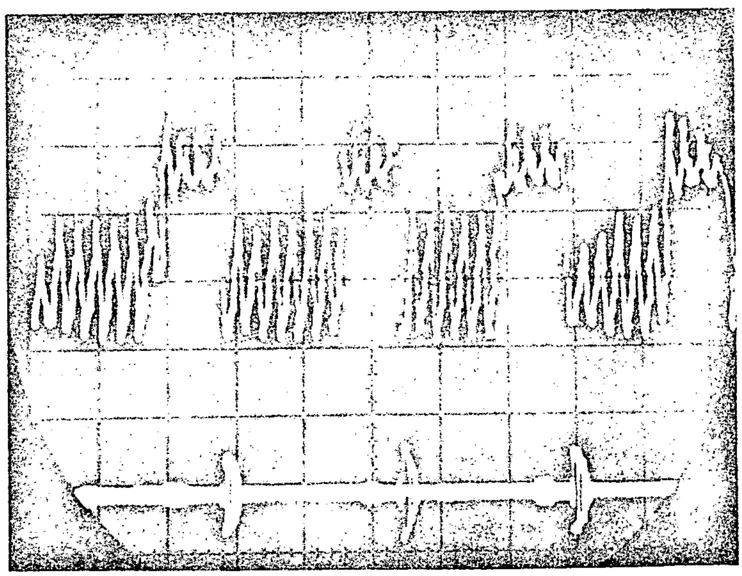
SINE WAVE INPUT & .050"
D.A. OUTPUT @ 10.0 Hz

SLOW PRESSURE REGULATOR RESPONSE IS CAUSE FOR OVERSHOOT

NOTE

THE .1 Hz SINE WAVE INPUT DEVELOPES NO MOTION AT THE COMPARATOR SLIDE, AS DOES THE 1.0 INPUT.

PRESSURE TRANSIENTS INDUCED WITH THE SYSTEM IN A STEADY STATE NEUTRAL CONDITION HAVE THE SAME RESULTS AS WHEN IN THE DYNAMIC CONDITION



TITLE SUPPLY & RETURN TRANSIENT TEST (221400)

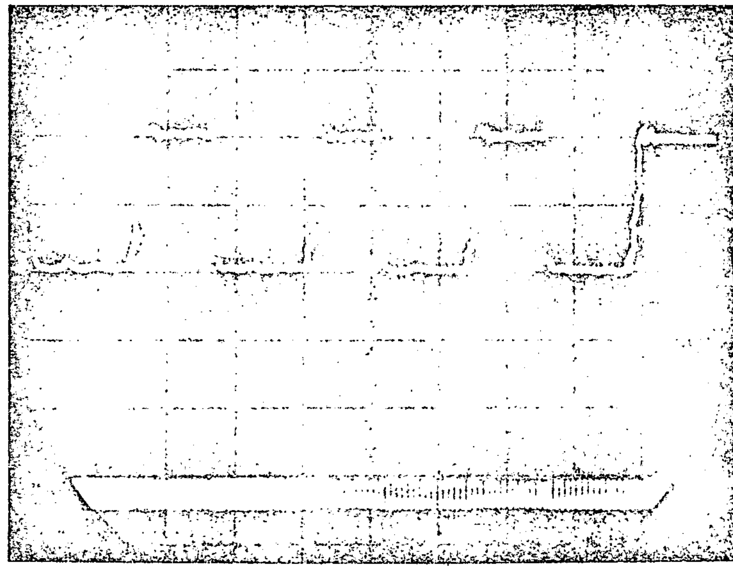
SINE WAVE INPUT & .050" D.A. OUTPUT @ 1.0 Hz

1000 P.S.I.

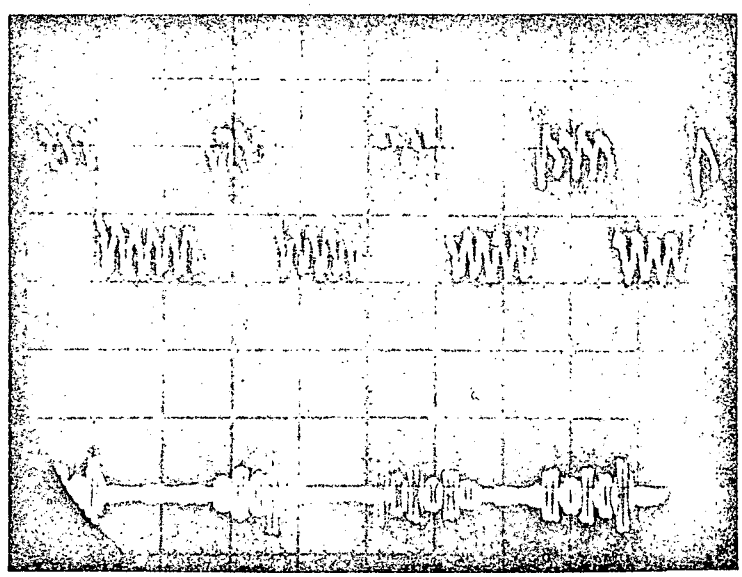
SYSTEM RETURN PRESS.

0 P.S.I.

COMPARATOR SLIDE POSITION .005"



SINE WAVE INPUT & .050" D.A. OUTPUT @ 10.0 Hz



STANDARD TEST SERIES

DESCRIPTION:

THIS TEST PROVIDES INFORMATION ABOUT SWITCHING TRANSIENTS FOR VARIOUS FAILURE DETECTING CONFIGURATIONS.

EQUIPMENT REQUIRED:

1. 221400-1003, ACTIVE STANDBY SYSTEM
2. TF221400-1003, ELECTRONIC CONTROLLER
3. FUNCTION GENERATOR (SINE WAVE)
4. 2 OSCILLOSCOPES
5. CAMERA FOR OSCILLOSCOPE

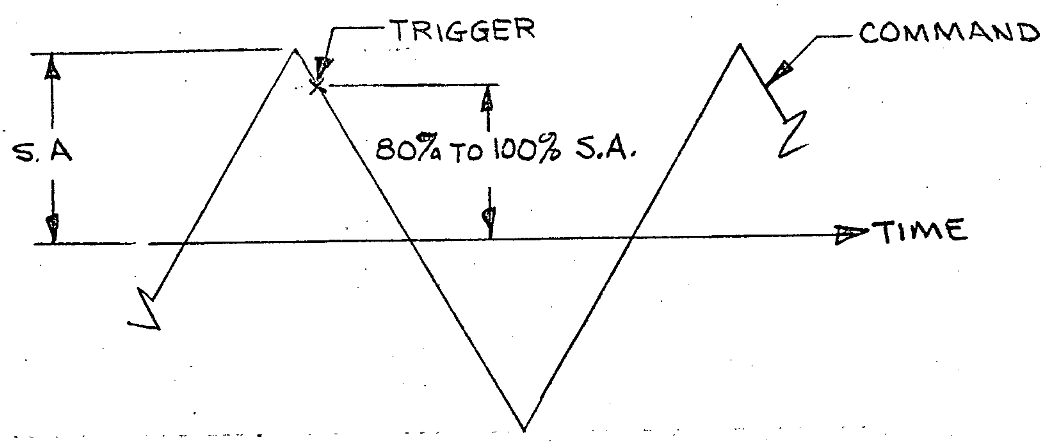
TEST PROCEDURE:

A. HARD OVER FAILURE:

1. CALIBRATE SCOPE TO .6 IN FROM NULL (AT ACTUATOR) EQUALS 6 CM ON SCOPE, USE LVDT OUTPUT AS AC (DO NOT DEMODULATE).
2. ADJUST OFFSET POT TO OBTAIN NULL POSITION ON FEEDBACK LVDT.
3. INTRODUCE STEP VOLTAGE INTO JACKS LABLED "STEP INPUT" TO PRODUCE 10 ± 1 MA AT ELECTROHYDRAULIC VALVE.
4. RECORD AND STORE ACTUATOR POSITION VS TIME ON SCOPE AND PHOTOGRAPH RESULTS.

B. PASSIVE FAILURE:

1. CYCLE ACTUATOR .75 IN D.A. TRIANGLE WAVE AT 2 CPS
2. VIEW COMMAND VS. TIME ON OSCILLOSCOPE. SET TRIGGER AT APPROXIMATE POSITION SHOWN:



STANDARD TEST SERIES (Continued)

TEST PROCEDURE: (Continued)

B. PASSIVE FAILURE: (Continued)

3. VIEW AC OUTPUT OF FEEDBACK TRANSDUCER VS TIME ON SECOND SCOPE. CONNECT TRIGGER FROM FIRST SCOPE TO "OPEN TRANSFER VALVE: JACK ON FRONT OF ELECTRICAL CONTROLLER.
4. RECORD ACTUATOR POSITION TRANSIENTS BY STORING AND PHOTOGRAPHING ACTUATOR POSITION VS TIME ON SCOPE.
5. SWITCH CONNECTORS TO ELECTROHYDRAULIC VALVES AND REPEAT 3 AND 4 ABOVE FOR MONITOR VALVE.

C. SOFT FAILURE:

1. CHECK GAIN OF #1 BUFFER AMP. BY APPLYING 4 VDC TO "STEP INPUT" JACK AFTER NULLING CURRENT. GAIN SHOULD BE .9 TO 1.1 MA/VDC. ADJUST "GAIN 2" POT. IN BUFFER AMP FEEDBACK LOOP TO CHANGE TO ½ ORIGINAL GAIN WHEN VOLTAGE IS APPLIED TO "GAIN CHANGE" JACKS.
2. REPEAT PASSIVE FAILURE TEST EXCEPT CONNECT TRIGGER FROM FIRST SCOPE TO "GAIN CHANGE" ON FRONT OF BOX. (BOTH POWER AND MONITOR VALVES)

STANDARD TEST SERIES (Continued)

THE FOLLOWING CONFIGURATIONS SHALL BE TESTED USING THE "STANDARD TEST SERIES" (TEST ALL VALVES WITH ALL THREE TESTS)

| TEST # | CHANNEL | TIME DELAY ORIFICE | COMPARATOR VALVE OVERLAP (INCHES) | OPEN LOOP GAIN (RAD/SEC) | COMMENTS |
|---|---|---|---|---|---|
| 8 | A | N/A | .040 | 40 | NO DATA REQUIRED "PASSIVE" OR "SOFT" FAILURES ON MONITOR VALVE |
| 9 | B | NONE | .040 | 40 | NO DATA REQUIRED "PASSIVE" OR "SOFT" FAILURES ON MONITOR VALVE (MONITOR = .060 OVERLAP VALVE) |
| 10 | C | N/A | .003 | 40 | |
| 11 | A | N/A | .040 | 40 | SAME AS #8 EXCEPT SUPPLY PRESS = 2000 PSI |
| 12 | A | N/A | .040 | 40 | SAME AS #8 EXCEPT ORIFICE IN POWER STAGE T-VALVE LINE |
| 13 | A | N/A | .008 | 40 | |
| 14 | A | N/A | .040 | 20 | SEE TEST PROCEDURE FOR "OUTER LOOP FREQUENCY RESPONSE" FOR PROCEDURE TO SET OPEN LOOP GAIN |
| 15 | A | N/A | .008 | 20 | |
| 16 | B | LEE JET 187-"T"-04000-0808 (FOR "T"= ANY NO.) | .040 | 40 | |

STANDARD TEST SERIES (Continued)

| TEST # | CHANNEL | TIME DELAY ORIFICE | COMPARATOR VALVE OVERLAP (INCHES) | OPEN LOOP GAIN (RAD/SEC) | COMMENTS |
|---|---|---|---|---|---|
| 17 | B | LEE JET 187-"T"-10000-0808 (FOR "T" = ANY NO.) | .040 | 40 | |
| 18 | B | LEE JET 187-"T"-10000-0808 (FOR "T" = ANY NO.) | .008 | 40 | |
| 19 | C | N/A | .016 | 40 | |
| 20 | C | N/A | .016 | 20 | |
| 21 | C | N/A | .003 | 20 | |

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**PRODUCTION TEST PROCEDURE**

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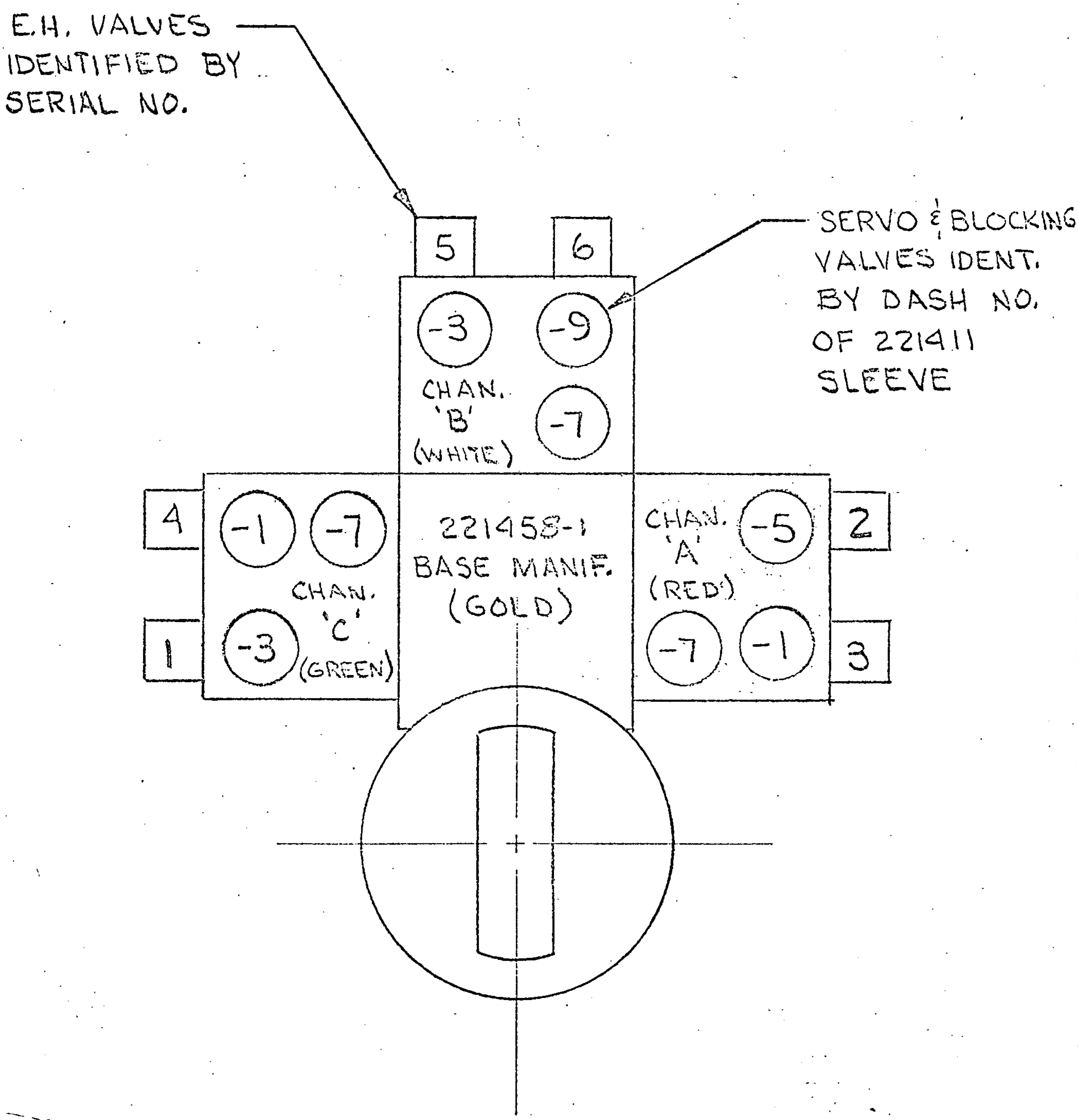
CHECK BY ______ DATE ______






VIEW LOOKING AT MAIN RAM END OF ACTUATOR

## VALVE LOCATIONS

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

HARD OVER SIGNAL @ ≈ 1 SERVO (CHAN. "A")

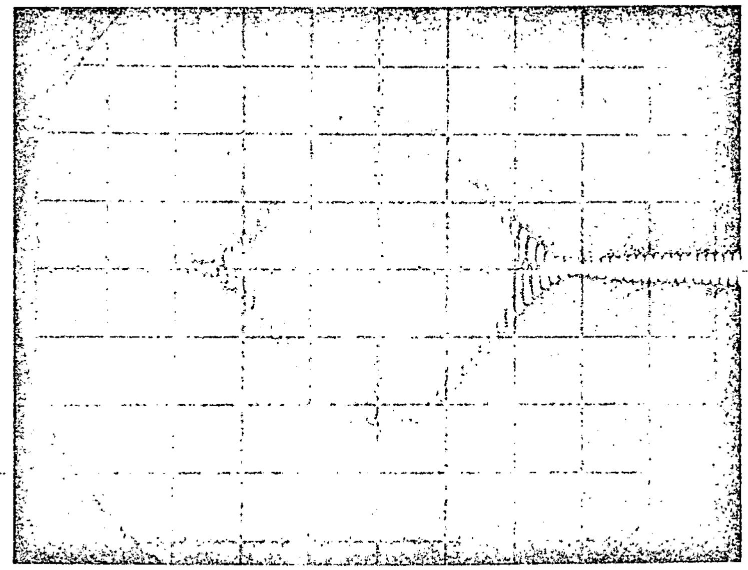
.6 CM = 0.3" STROKE FROM N @ ACTUATOR

0.3 IN

10 V.D.C. (10/MA) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH.

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

FAILED & ACTIVATED CHANNEL "B"

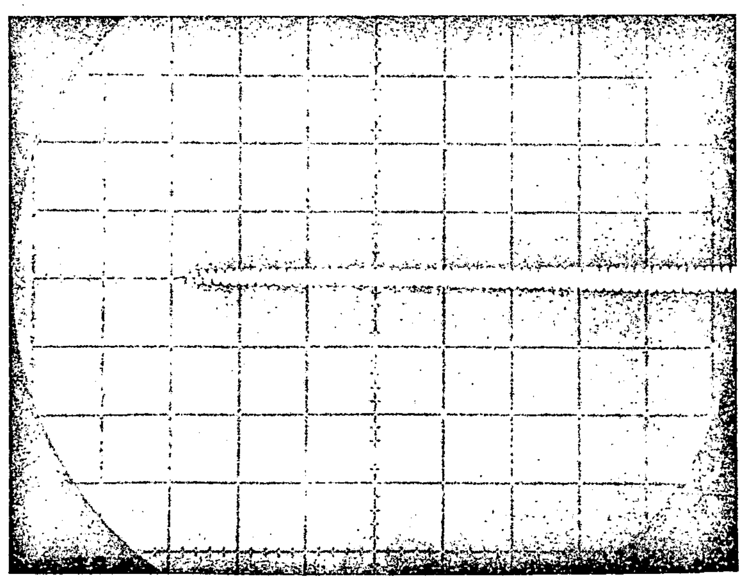


SWEEP TIME = 20 MS/CM

HARD OVER SIGNAL @ ≈ 5 SERVO (CHAN. "A")

FAILED & ACTIVATED CHANNEL "B"

A



TRIGGER

.0396" COMPARATOR O. LAP

GAIN = 40 RAD./SEC

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| PAGE 42 | DOCUMENT NO. TEST 8 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL)

2000 P.S.I.

HARD OVER SIGNAL @ -1 SERVO (CHAN "A")

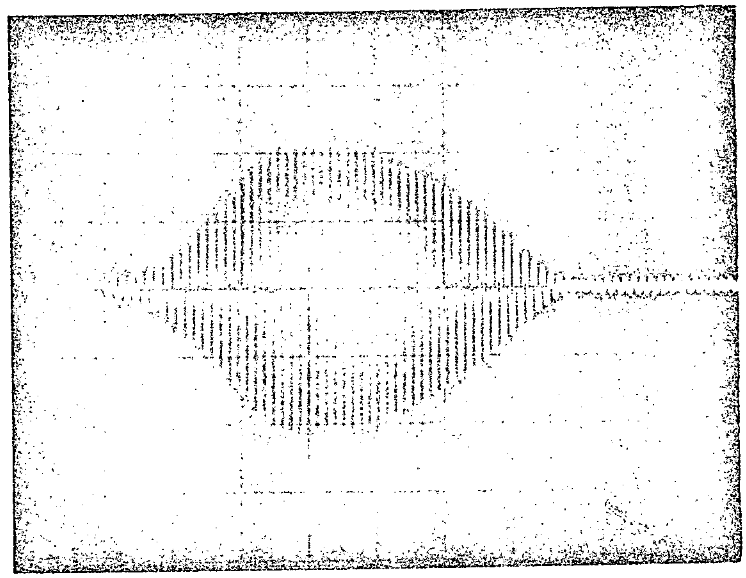
6 CM = 0.3" STROKE FROM N @ ACTUATOR

0.3 IN.

10 V.D.C. (10/MA) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT, & SWITCH

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

FAILED & ACTIVATED CHANNEL "B"

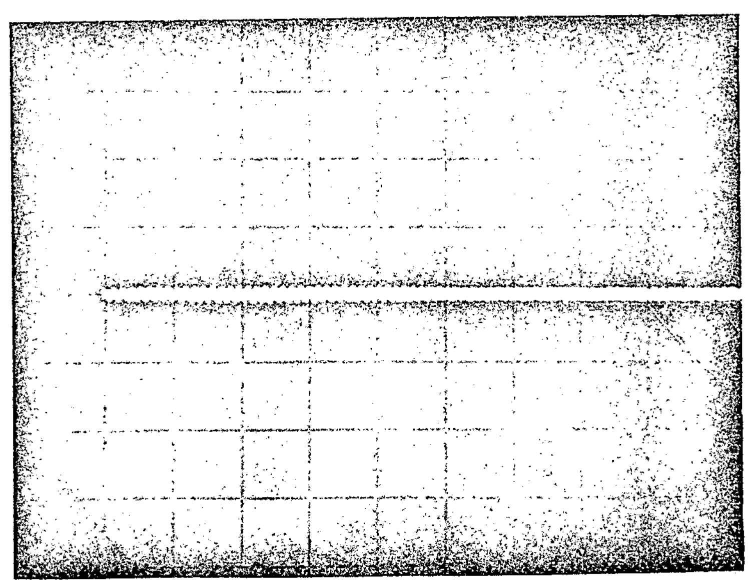


SWEEP TIME = 20 MS/CM

HARD OVER SIGNAL @ -5 SERVO (CHAN "A")

FAILED & ACTIVATED CHANNEL "B"

A



TRIGGER

.0396" COMPARATOR O. LAP

GAIN = 40 RAD./SEC

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| PAGE 43 | DOCUMENT NO. TEST 8 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE PASSIVE FAILURE (∿ INPUT TO AMPLIFIER @ 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED OPEN TO THE -1 SERVO (CHANNEL "A")

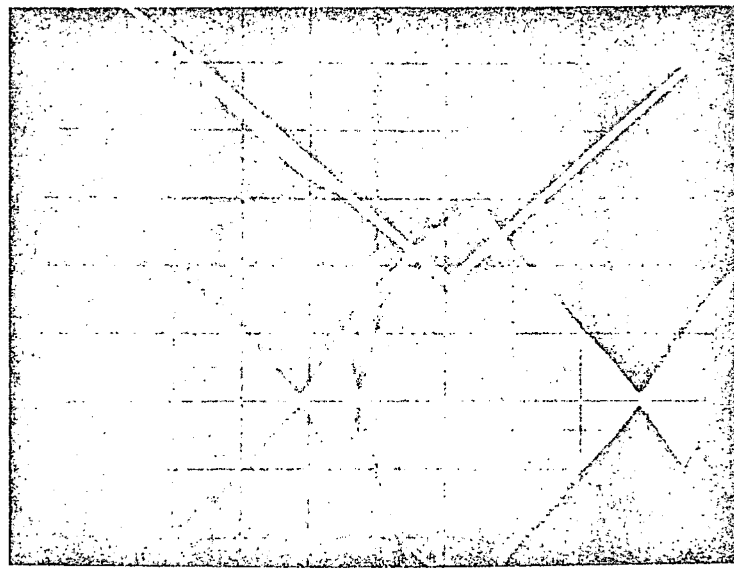
6 CM = .375" STROKE FROM N @ ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

DOUBLE SWEEP PHOTO EXPOSURE TO DISPLAY NORMAL & SWITCHING OUTPUT PATTERNS

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

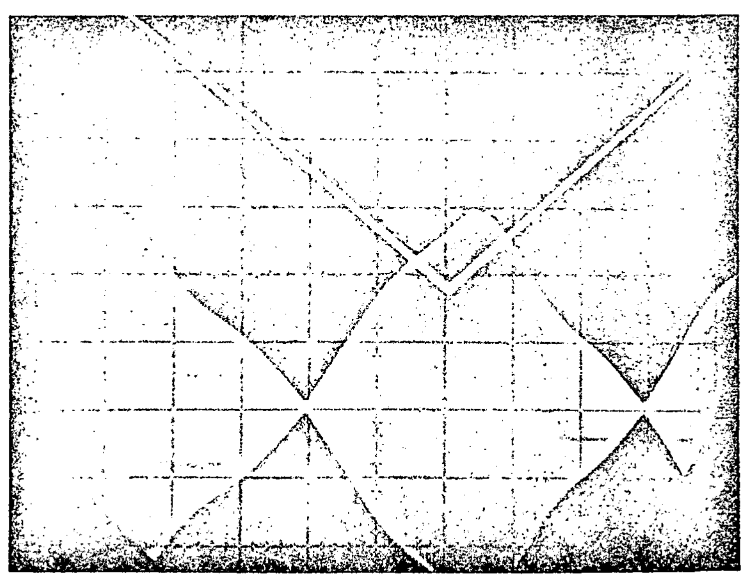
FAILED & ACTIVATED CHANNEL "B"



SWEEP TIME = 50 MS/CM

E.H. VALVE TRIGGERED OPEN TO THE -3 SERVO (CHANNEL "A")

NO FAIL



A

GAIN = 40 RAD./SEC

.0396" COMPARATOR O. LAP

Form 310-01

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| PAGE 44 | DOCUMENT NO. TEST 8 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE PASSIVE FAILURE (∿ INPUT TO AMPLIFIER @ 2 Hz)

2000 P.S.I.

TRIGGER TIME = .001/SEC.

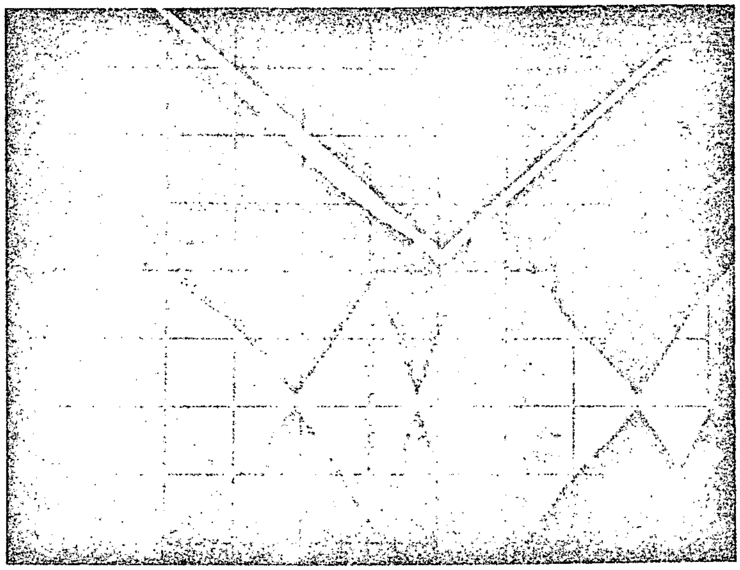
E.H. VALVE TRIGGERED OPEN TO THE -1 SERVO CHANNEL "A"

6 CM = .375" STROKE FROM NEUTRAL @ THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

DOUBLE SWEEP PHOTO EXPOSURE TO DISPLAY NORMAL & SWITCHING OUTPUT PATTERNS.

THE UPPER TRACE DISPLAYS THE INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

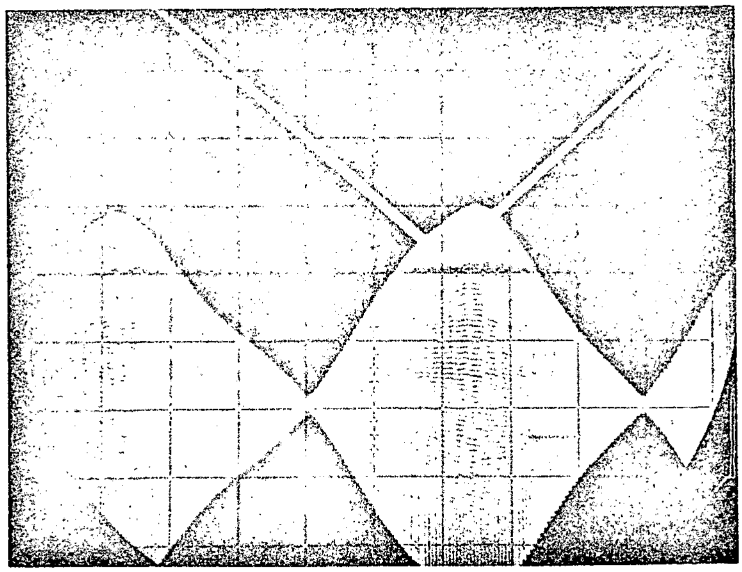
THE LOWER TRACE DISPLAYS THE ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME = 50 MS/CM

E.H. VALVE TRIGGERED OPEN TO THE -3 SERVO (CHANNEL "A")



NO FAIL

A

GAIN = 40 RAD./SEC

.0396 COMPARATOR O'LAP

Form 310-01

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| PAGE 45 | DOCUMENT NO. TEST 8 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE SOFT FAILURE (1 INPUT TO THE AMPLIFIER @ 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

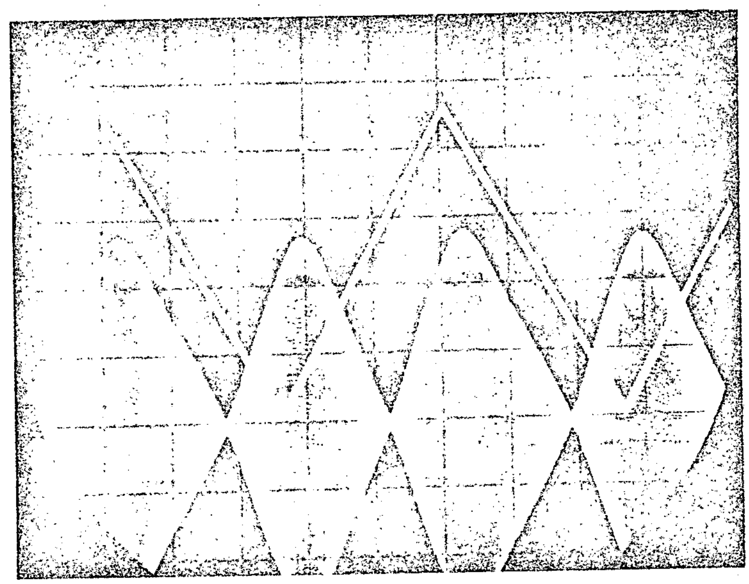
E.H. VALVE TRIGGERED TO HALF GAIN AT THE -1 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

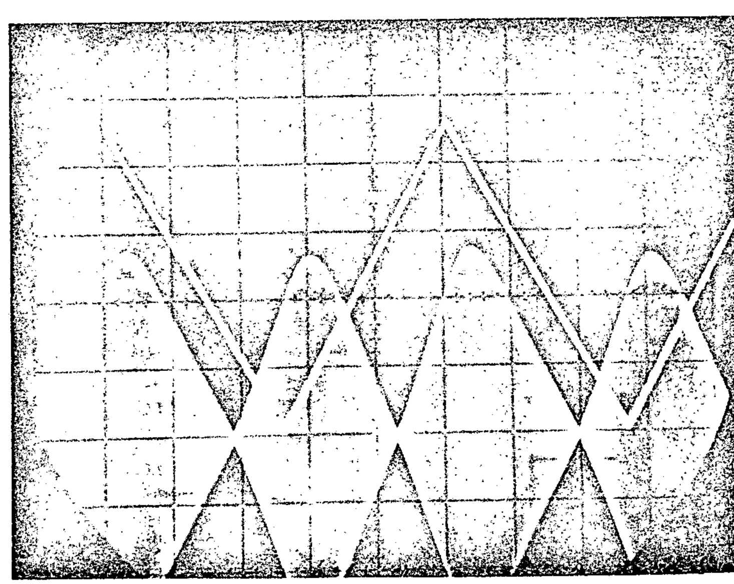
LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL



SWEEP TIME = 100/MS/CM

2000 P.S.I.



A

GAIN = 40 RAD

.0396 COMPARATOR O'LAP

TITLE SOFT FAILURE (1 INPUT TO THE AMPLIFIER @ 2 Hz)

3000 P.S.I.

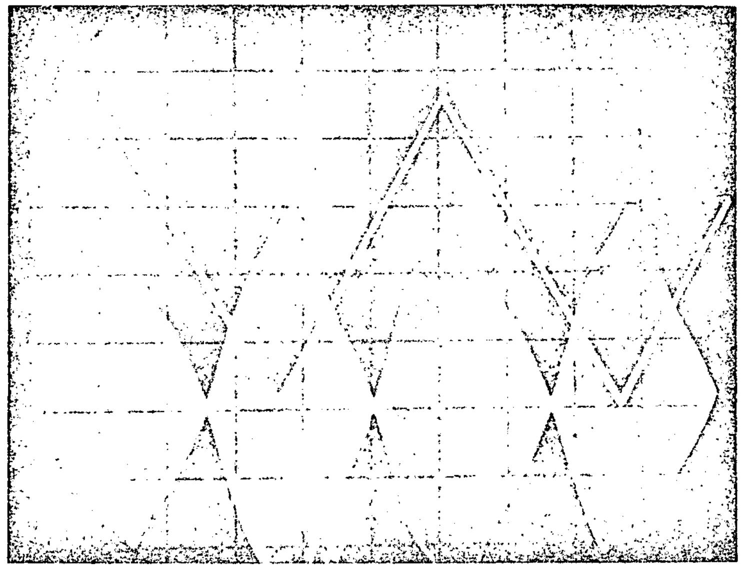
TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -3 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

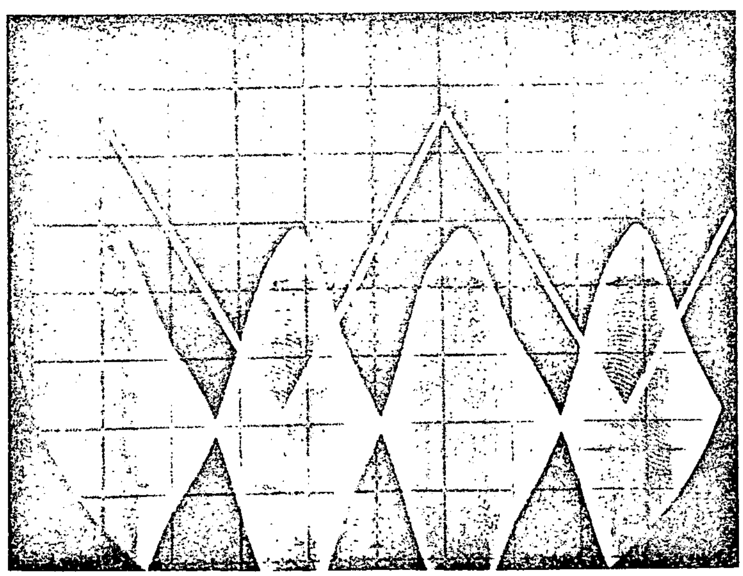
LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)



NO FAIL

SWEEP TIME = 100/MS/CM

2000 P.S.I.



A

GAIN = 40 RAD

.0396 COMPARATOR O. LAP

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

HARD OVER SIGNAL @ -3 SERVO (CHAN "B")

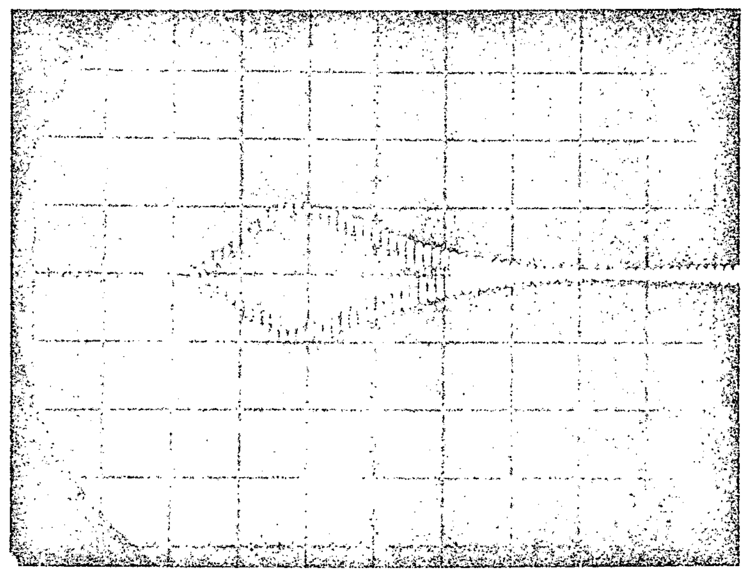
6 CM = 0.3" STROKE FROM N @ ACTUATOR

0.3 IN.

10 V.D.C. (10/MA) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

FAILED & ACTIVATED CHANNEL "C"

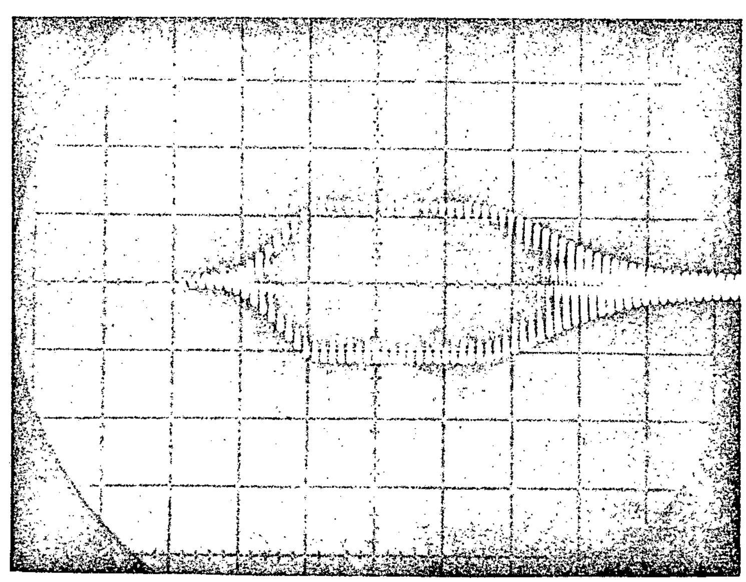


SWEEP TIME - 20 MS/CM

HARD OVER SIGNAL @ -9 SERVO (CHAN "B")

FAILED & ACTIVATED CHANNEL "C"

B



TRIGGER

.0396" COMPARATOR O'LAP

GAIN = 40 RAD/SEC

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL)

2000 P.S.I.

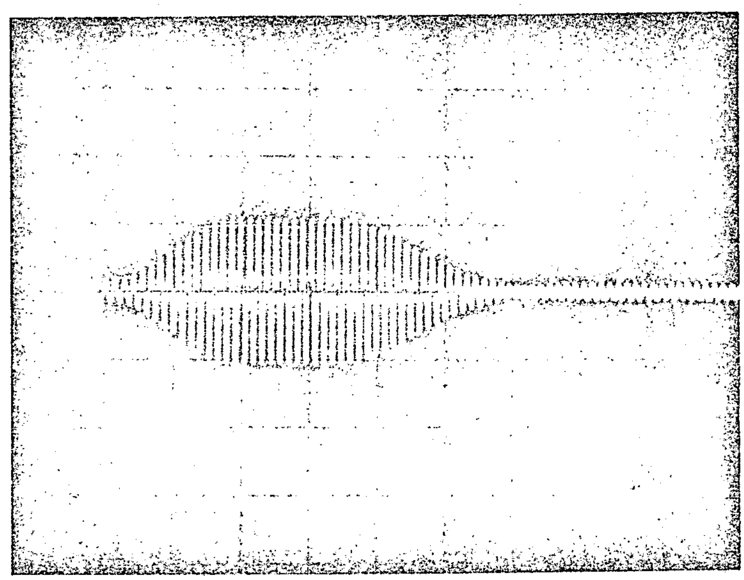
HARD OVER SIGNAL @ -3 SERVO (CHAN. "B")

6 CM = 0.3" STROKE FROM N @ ACTUATOR

0.3 IN.

10 V.D.C. (10/MA) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT, & SWITCH.

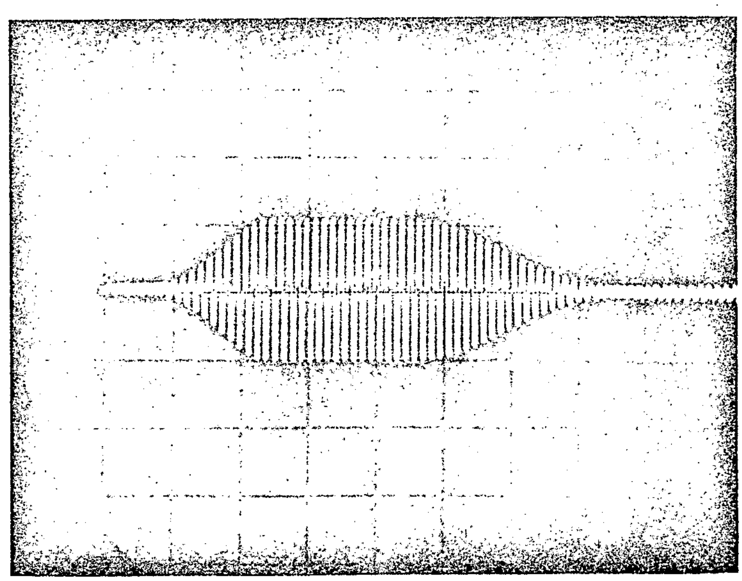
SCOPE TRIGGERED FROM THE BATTERY SWITCH



FAILED & ACTIVATED CHANNEL "C"

SWEEP TIME = 20 MS/CM

HARD OVER SIGNAL @ -9 SERVO (CHAN. "B")



FAILED & ACTIVATED CHANNEL "C"

B

TRIGGER

.0396" COMPARATOR O'LAP

GAIN = 40 RAD/SEC



D

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| PAGE 49 | DOCUMENT NO. TEST 9 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE PASSIVE FAILURE (∿ INPUT TO AMPLIFIER @ 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED OPEN TO THE -3 SERVO (CHANNEL "B")

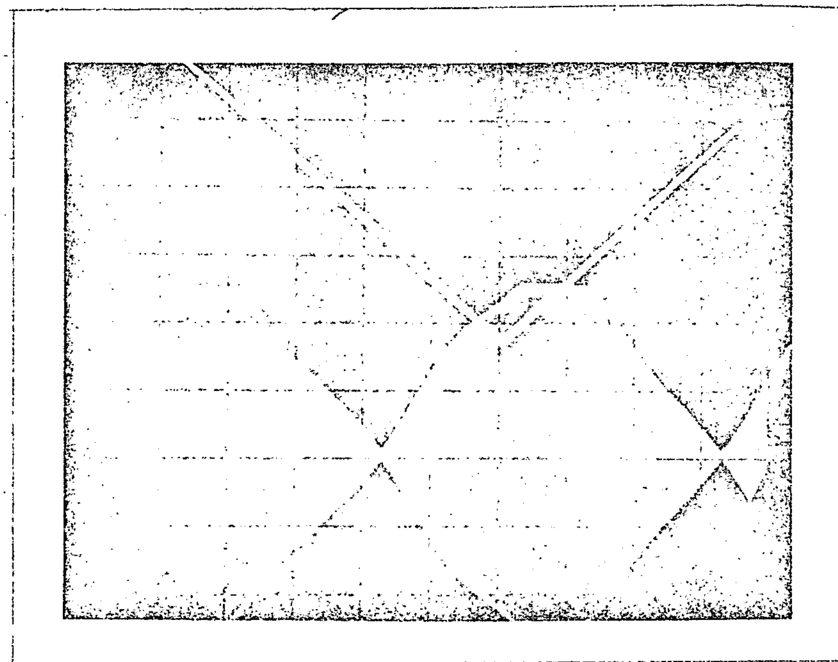
6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

DOUBLE SWEEP PHOTO EXPOSURE TO DISPLAY THE NORMAL & SWITCHING OUTPUT PATTERNS

THE UPPER TRACE DISPLAYS THE INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

THE LOWER TRACE DISPLAYS THE ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

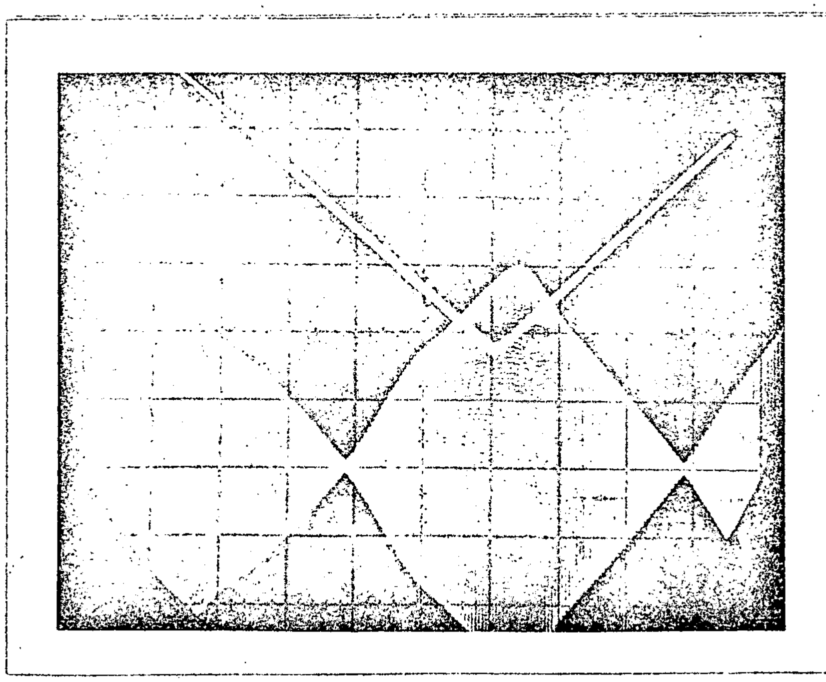
NO FAIL
OUTPUT SHOWS DECREASE IN AMPLITUDE OF APPROX. 15 %



SWEEP TIME - 50/MS/CM

E.H. VALVE TRIGGERED OPEN TO THE -9 SERVO (CHANNEL "B")

NO FAIL



(B)

GAIN = 40 RAD.

.0396" COMPARATOR O. LAP

BERTEA CORPORATION
IRVINE · CALIFORNIA

| PAGE 50 | DOCUMENT NO. TEST 9 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE PASSIVE FAILURE (1) INPUT TO AMPLIFIER @ 2 Hz

2000 P.S.I.

TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED OPEN TO THE -3 SERVO ("CHANNEL "B")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

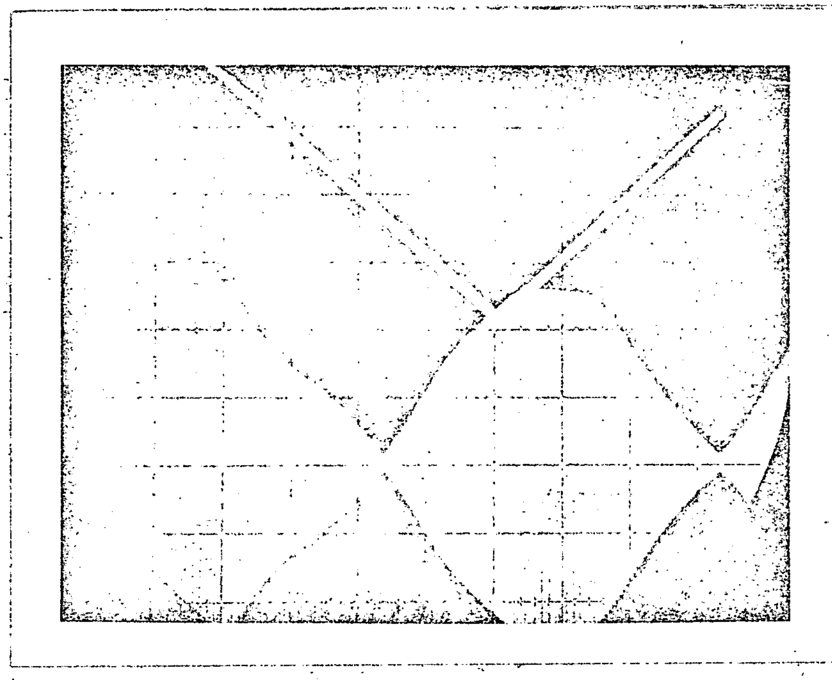
DOUBLE SWEEP PHOTO EXPOSURE TO DISPLAY THE NORMAL & SWITCHING OUTPUT PATTERNS.

THE UPPER TRACE DISPLAYS THE INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

THE LOWER TRACE DISPLAYS THE ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

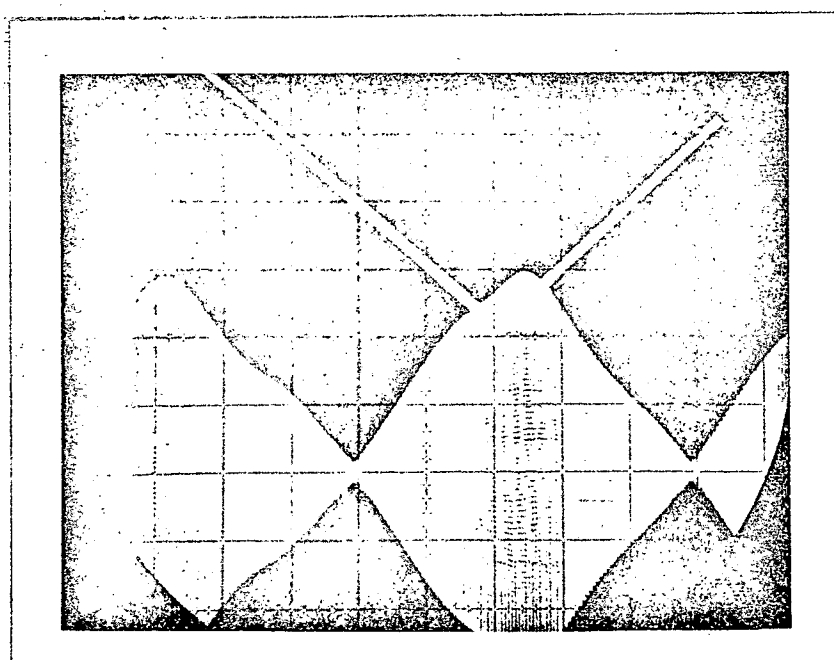
NO FAIL

OUTPUT SHOWS DECREASE IN AMPLITUDE OF APPROX. 15%



SWEEP TIME - 50/MS/CM

E.H. VALVE TRIGGERED OPEN TO THE -9 SERVO (CHANNEL "B")



NO FAIL

B

GAIN = 40 RAD.

.0396" COMPARATOR O'LAP

Form 310-01

BERTEA / CORPORATION IRVINE · CALIFORNIA

| PAGE 51 | DOCUMENT NO. TEST 9 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE SOFT FAILURE (1V INPUT TO THE AMPLIFIER @ 2 Hz).

3000 P.S.I.

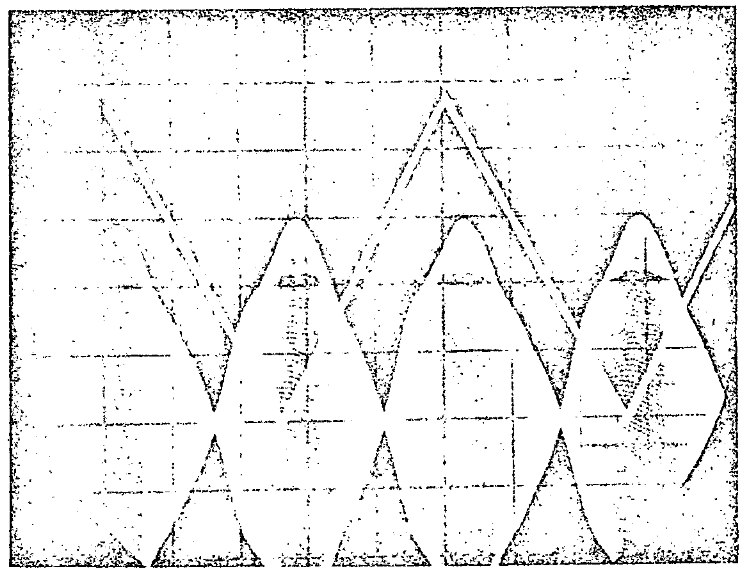
TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -3 SERVO CHANNEL "B"

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

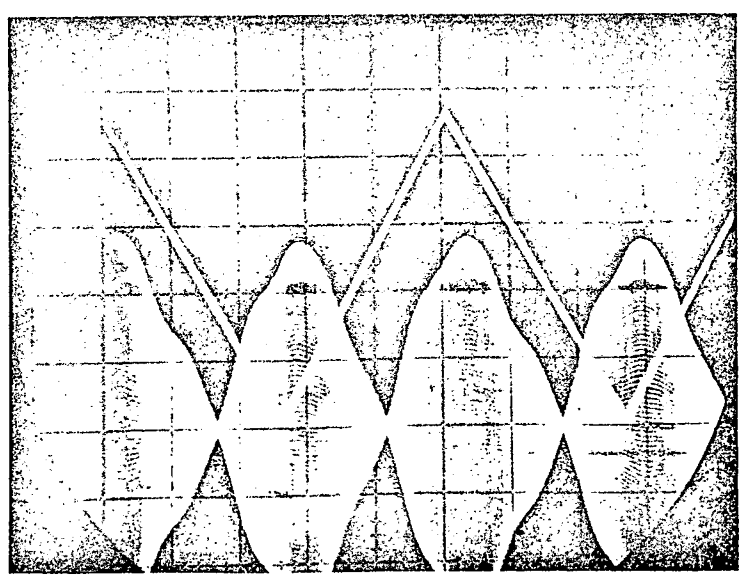
LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)



NO FAIL

SWEEP TIME - 100/MS/CM

2000 P.S.I.



NO FAIL

(B)

GAIN = 40 RAD

.0396 COMPARATOR O'LAP

Form 310-01

TITLE SOFT FAILURE (∿ INPUT TO THE AMPLIFIER @ 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

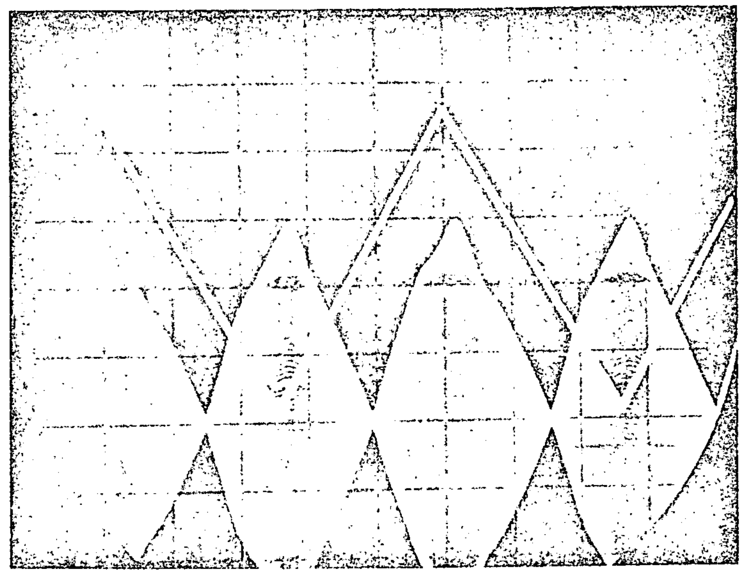
E.H. VALVE TRIGGERED TO HALF GAIN A THE -θ SERVO CHANNEL "B"

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

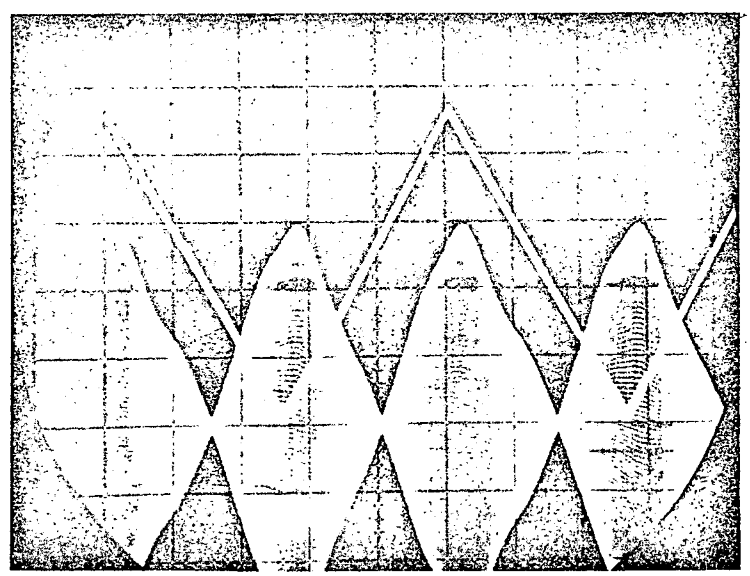
LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL



SWEEP TIME - 100/MS/CM

2000 P.S.I.



B

GAIN = 40 RAD.

.0396 COMPARATOR O'LAP

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| PAGE 53 | DOCUMENT NO. TEST 1D | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

HARD OVER SIGNAL @ -1 SERVO (CHAN "C")

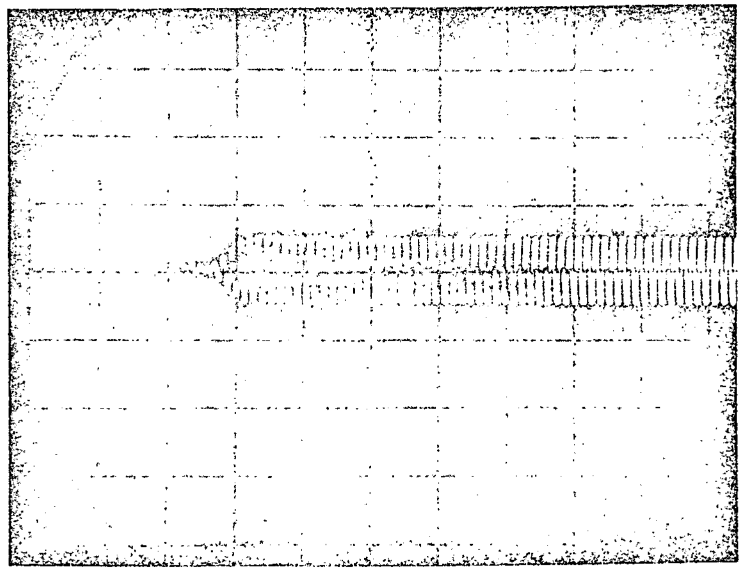
6 CM = 0.3" STROKE FROM N @ ACTUATOR

0.3 IN.

10 V.D.C. (10/MA) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

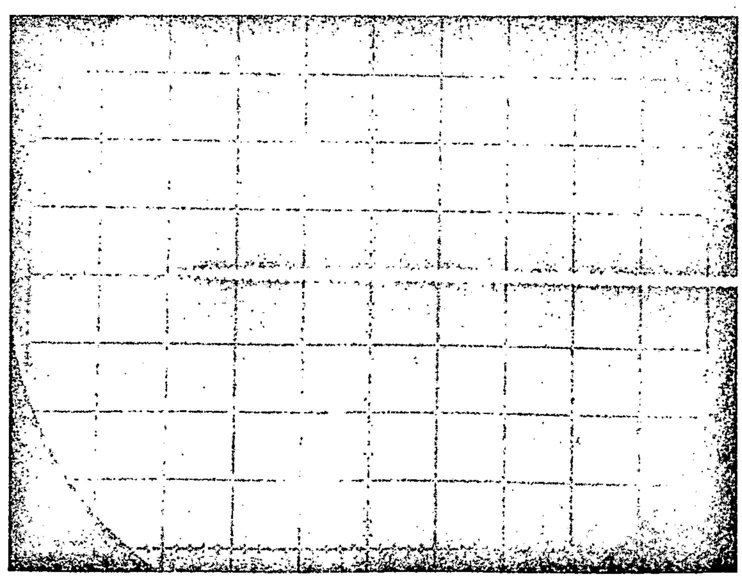
FAILED



SWEEP TIME - 20 MS/CM

HARD OVER SIGNAL @ -3 SERVO (CHAN "C")

NO FAIL



TRIGGER

.0032" COMPARATOR O'LAP

GAIN = 40 RAD./SEC

Form 310-01

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL)

2000 P.S.I.

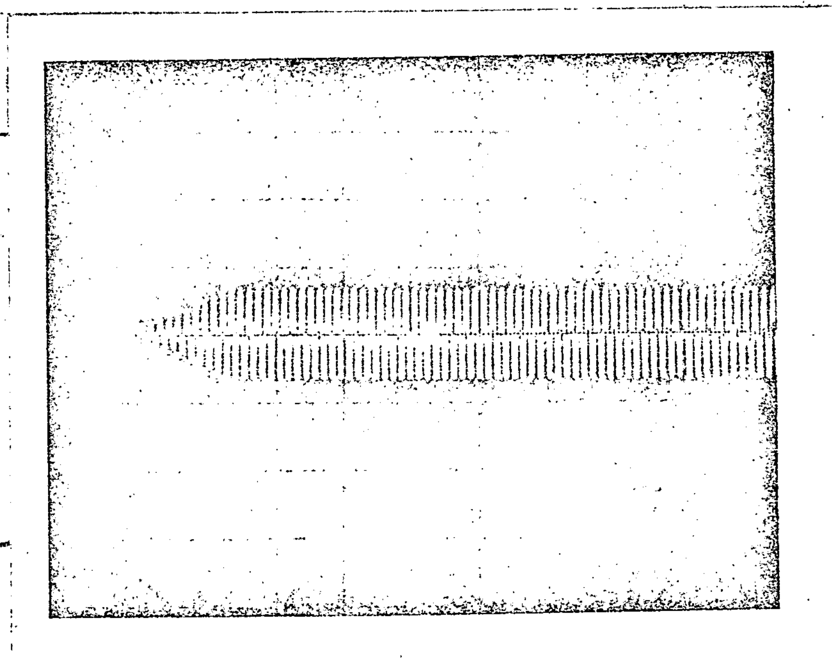
HARD OVER SIGNAL @ -1 SERVO (CHAN "C")

6 CM = 0.3" STROKE FROM N @ ACTUATOR

0.3 IN.

10 V.D.C. (10/MA) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT, & SWITCH

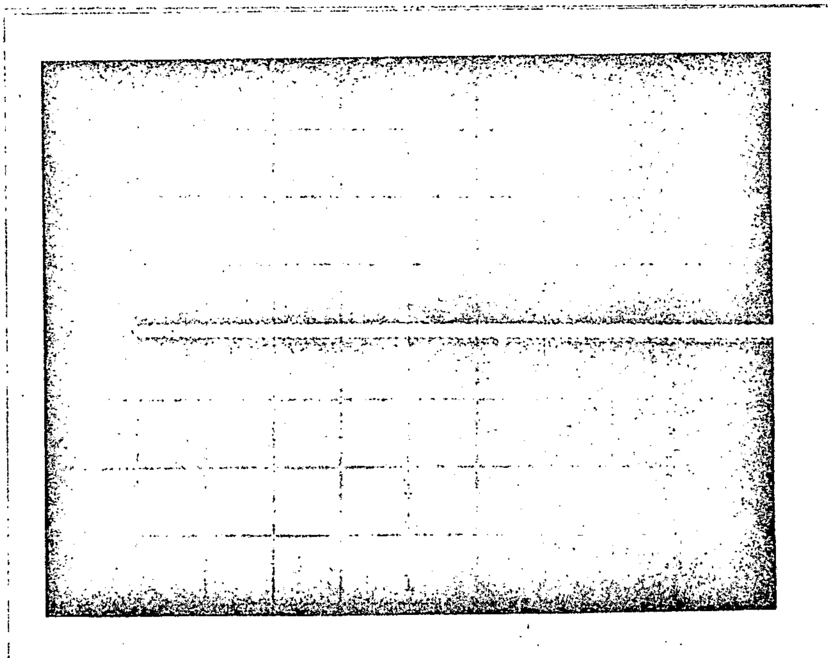
SCOPE TRIGGERED FROM THE BATTERY SWITCH



FAILED

SWEEP TIME - 20 MS/CM

HARD OVER SIGNAL @ -3 SERVO (CHAN "C")



NO FAIL

TRIGGER

.0032" COMPARATOR O'LAP

GAIN = 40 RAD/SEC

TITLE PASSIVE FAILURE (∿ INPUT TO THE AMPLIFIER @ 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

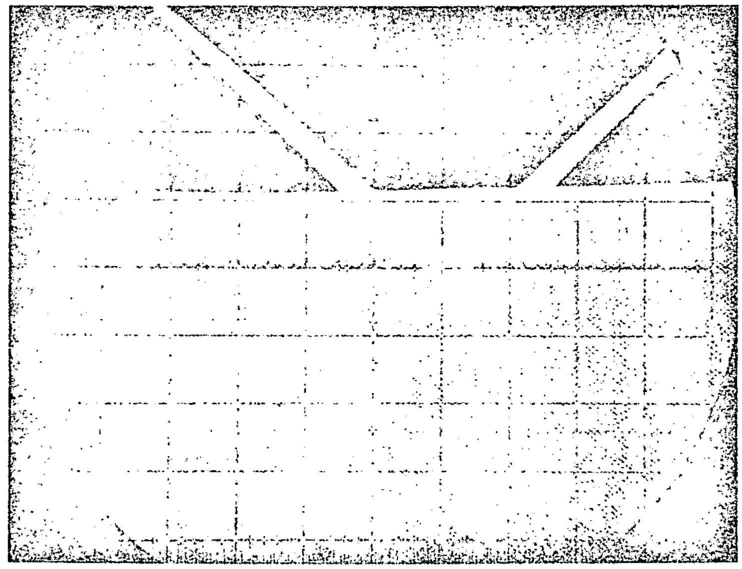
E.H. VALVE TRIGGERED OPEN TO THE -1 SERVO (CHANNEL "C")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS

THE UPPER TRACE DISPLAYS THE INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

THE LOWER TRACE DISPLAYS THE ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

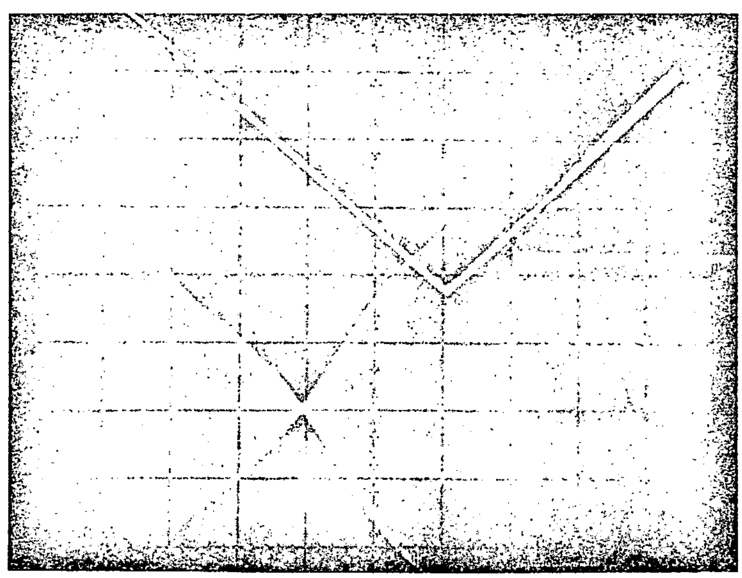
FAILED



SWEEP TIME - 50 MS/CM

E.H. VALVE TRIGGERED OPEN TO THE - 5 SERVO CHANNEL "C"

FAILED



GAIN = 40 RAD./SEC

.0032" COMPARATOR O. LAP

©

TITLE PASSIVE FAILURE (⋀ INPUT TO THE AMPLIFIER @ 2 Hz)

2000 P.S.I.

TRIGGER TIME = .001/SEC.

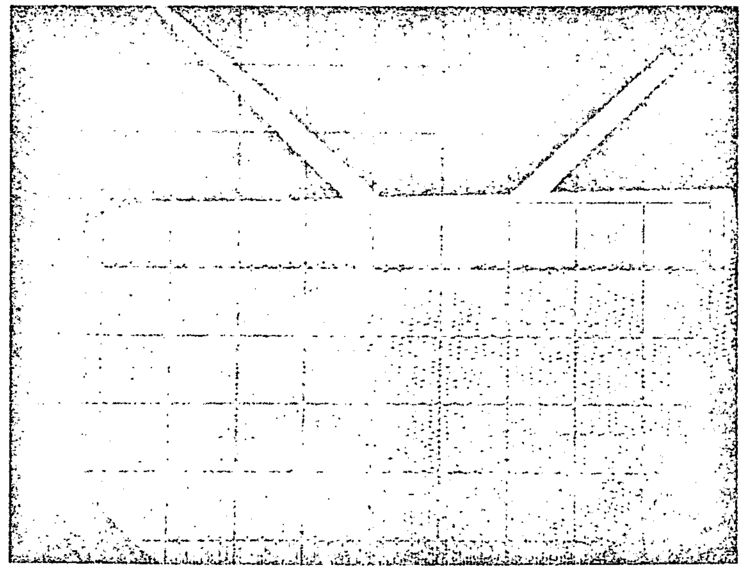
E.H. VALVE TRIGGERED OPEN TO THE -1 SERVO (CHANNEL "C")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

THE UPPER TRACE DISPLAYS THE INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

THE LOWER TRACE DISPLAYS THE ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

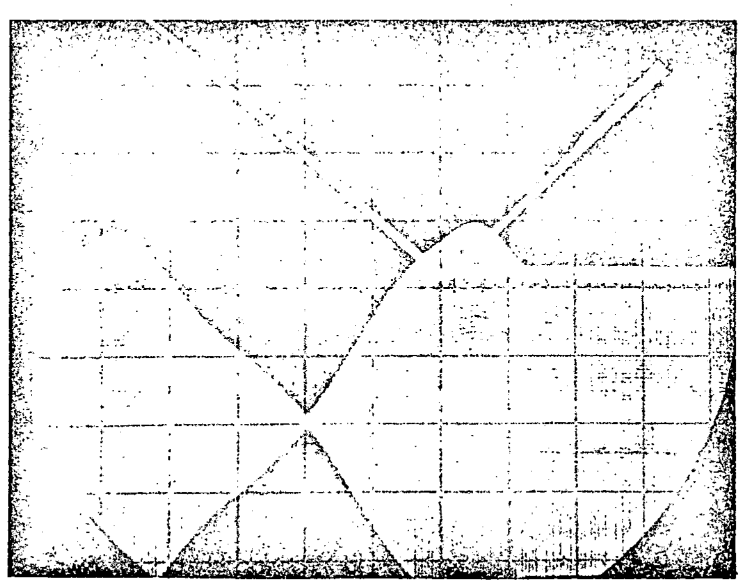
FAILED



SWEEP TIME - 50 MS/CM

E.H. VALVE TRIGGERED OPEN TO THE -5 SERVO (CHANNEL "C"

FAILED



GAIN = 40 RAD./SEC

.0032 COMPARATOR O.LAP

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| PAGE 57 | DOCUMENT NO. TEST 10 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE SOFT FAILURE (1 INPUT TO THE AMPLIFIER @ 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC

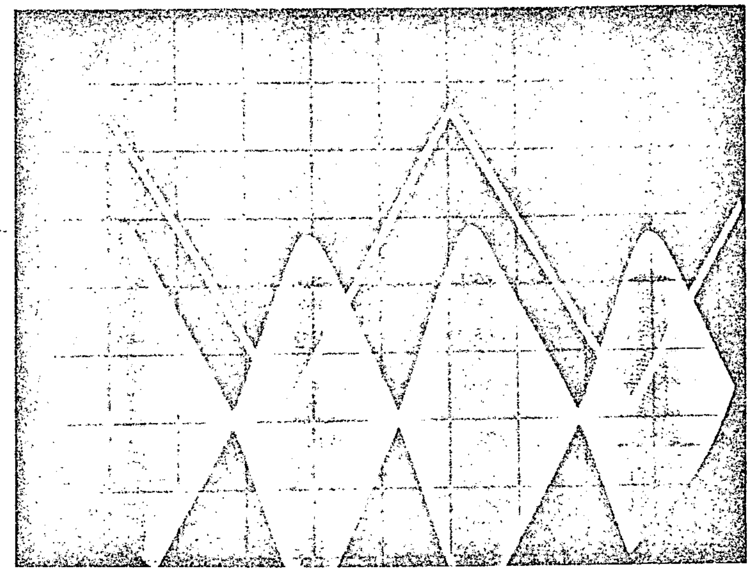
E.H. VALVE TRIGGERED TO HALF GAIN AT THE -1 SERVO CHANNEL "C"

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

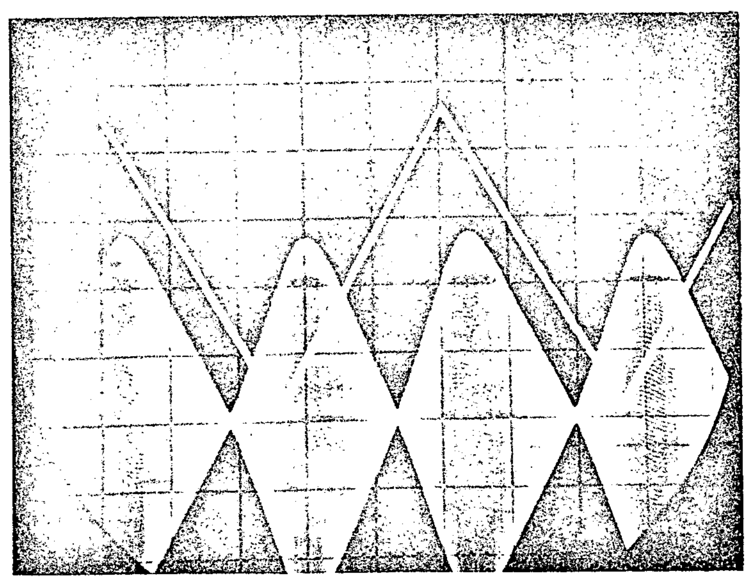
LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL



SWEEP TIME = 100/MS/CM

2000 P.S.I.



©

GAIN = 40 RAD.

.0032 COMPARATOR O'LAP

Form 310-01

TITLE SOFT FAILURE (∿ INPUT TO THE AMPLIFIER @ 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC

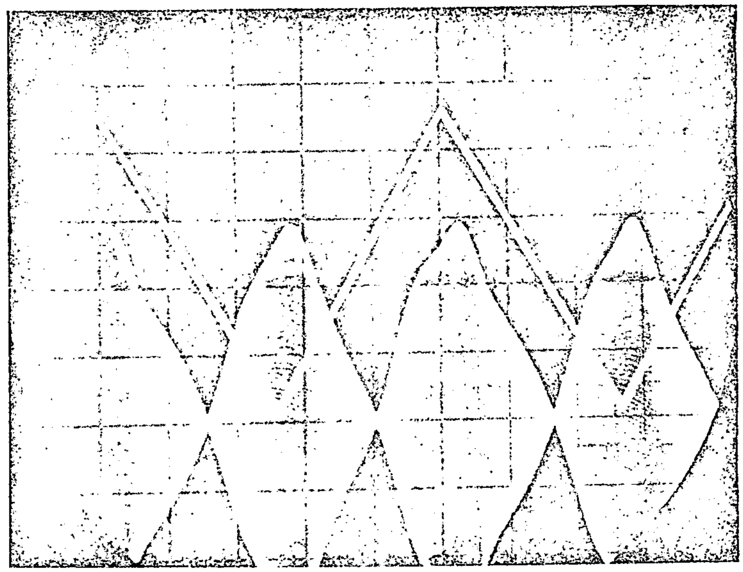
E.H. VALVE TRIGGERED TO TO HALF GAIN AT THE -5 SERVO CHANNEL "C"

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERN'S.

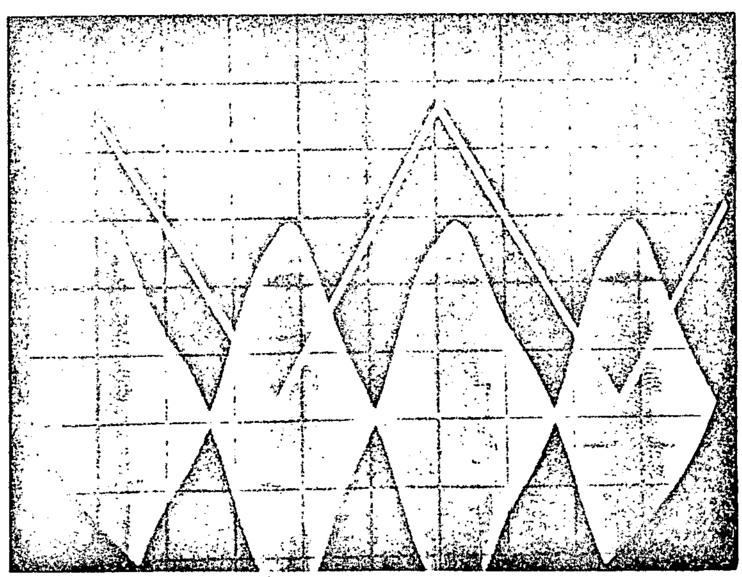
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

THE LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL



SWEEP TIME 100/MS/CM



©

GAIN = 40 RAD.

.0032 COMPARATOR O'LAP

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

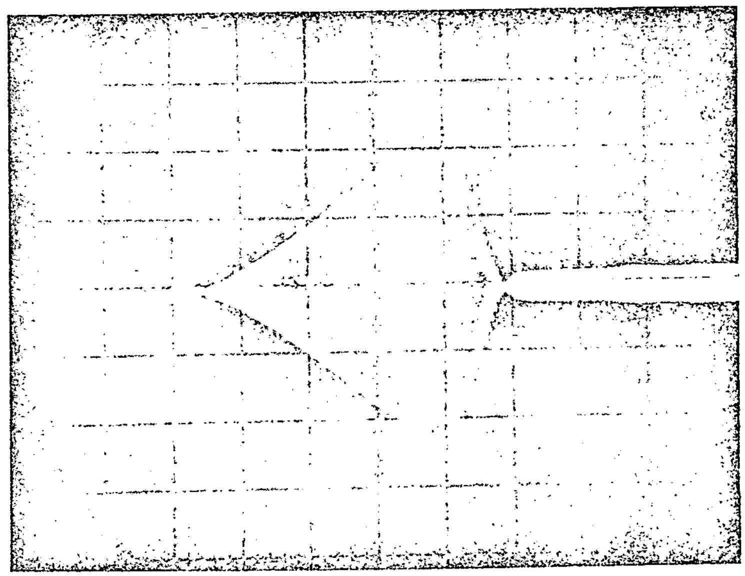
HARD OVER SIGNAL AT -1 SERVO (CHAN. "A")
.0075" ORFICE INSTALLED IN THE E.H. VALVE INLET.

6 CM = 0.3" STROKE FROM NJ @ ACTUATOR

0.3 IN.

10 V.D.C. (10 MA) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, PCT, & SWITCH

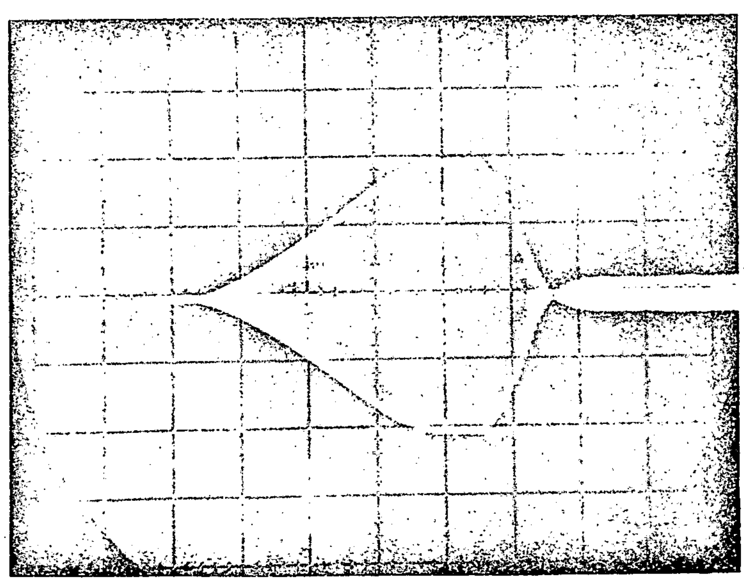
SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH.



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 50 MS/CM

2000 P.S.I.



TRIGGER

A

.0396" COMPARATOR O' LAP
GAIN = 40 RAD./SEC

TITLE PASSIVE FAILURE (1 INPUT TO AMPLIFIER @ 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

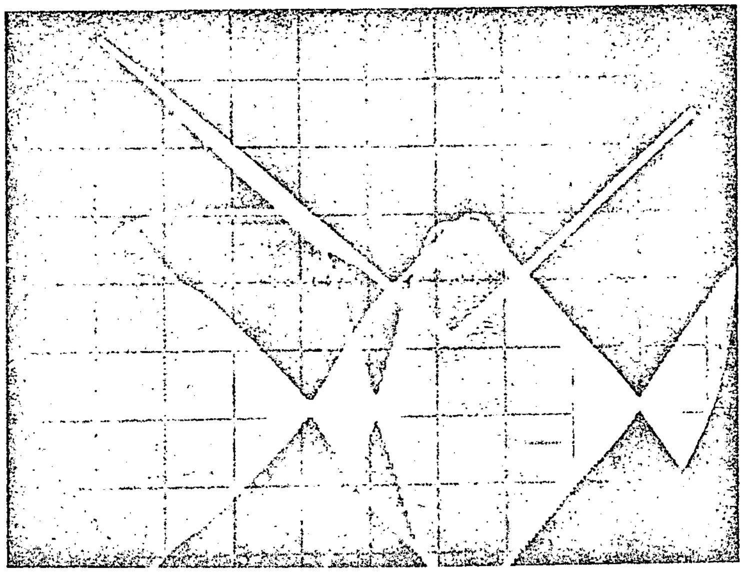
E.H. VALVE TRIGGERED OPEN TO THE -1 SERVO WITH A .0075 ORFICE IN THE INLET TO THE VALVE. (CHANNEL "A")

6 CM = .375 STROKE FROM NEUTRAL AT THE ACTUATOR DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

DOUBLE SWEEP PHOTO EXPOSURE TO DISPLAY A NORMAL & SWITCHING OUTPUT PATTERN.

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

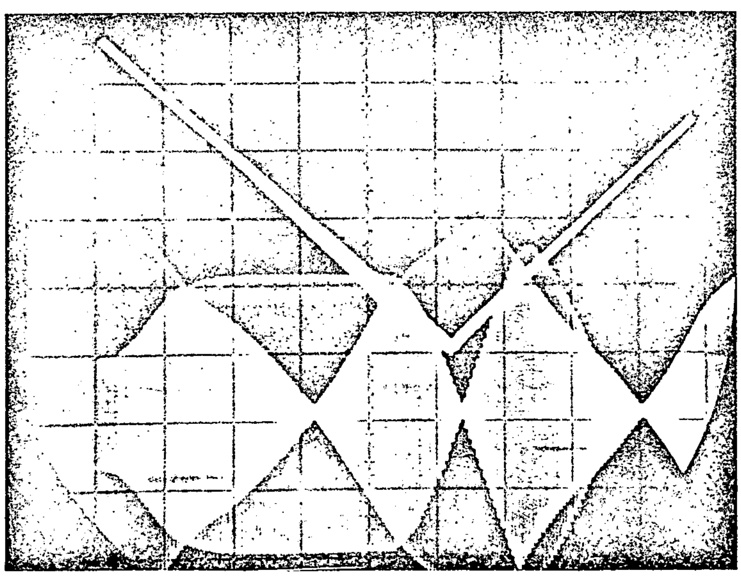
LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 50 MS/CM

2000 P.S.I.



A

GAIN = 40 RAD./SEC

.0396 COMPARATOR O'LAP

TITLE SOFT FAILURE (1 INPUT TO THE AMPLIFIER @ 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

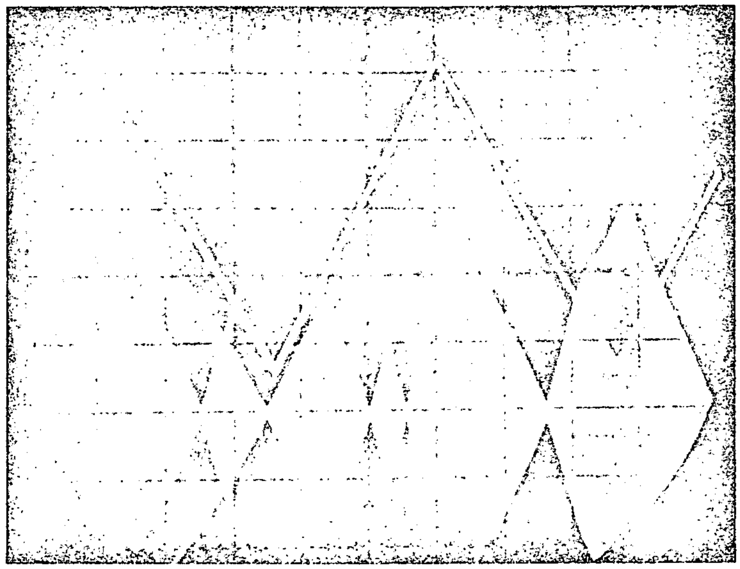
E.H. VALVE TRIGGERED TO HALF GAIN AT THE -1 SERVO WITH A .0075 ORFICE IN THE INLET TO THE VALVE. CHANNEL "A"

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

DOUBLE SWEEP PHOTO EXPOSURE TO DISPLAY A NORMAL, & SWITCHING OUTPUT PATTERN.

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

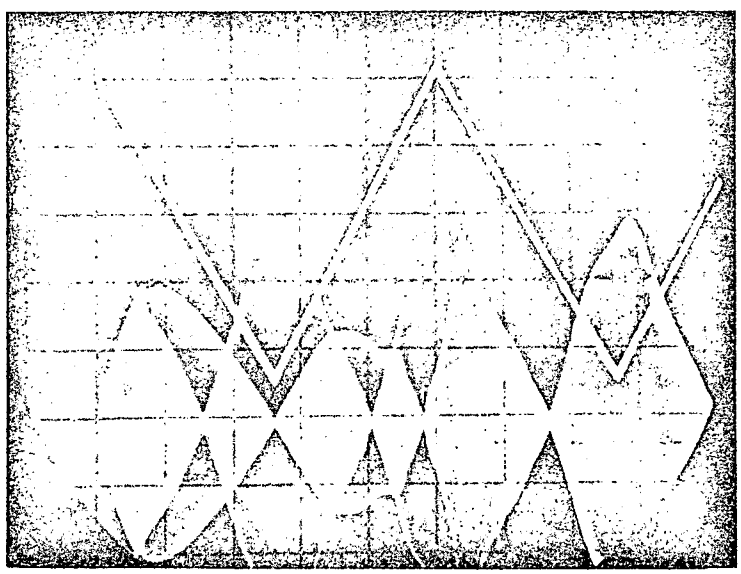
LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME = 100 MS/CM

2000 P.S.I.



A

GAIN = 40 RAD.

.0396 COMPARATOR O'LAP

TITLE SOFT FAILURE (∿ INPUT TO AMPLIFIER @ 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

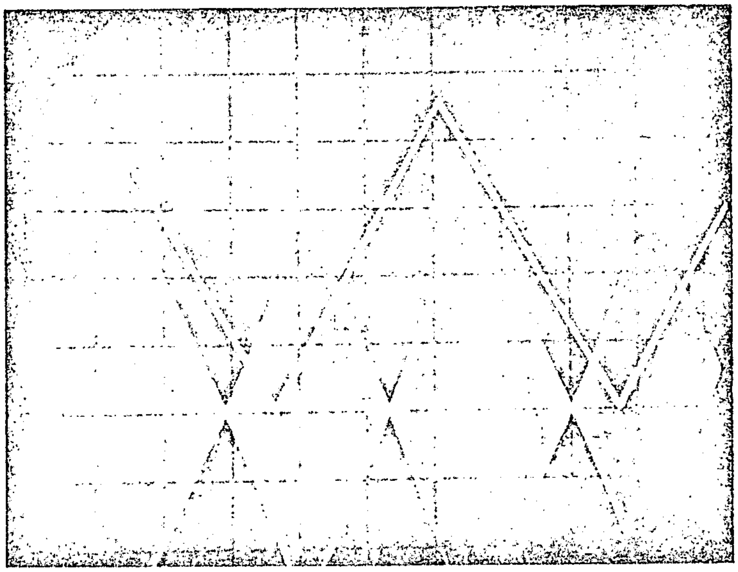
E.H. VALVE TRIGGERED TO HALF GAIN AT THE -3 SERVO WITH A .0075 ORFICE IN THE INLET TO THE -3 E.H. VALVE CHANNEL "A"

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

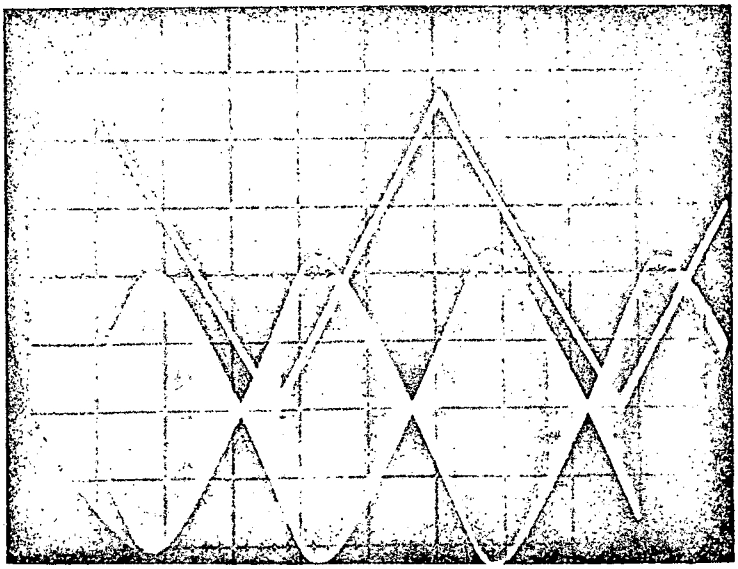
LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL



SWEEP TIME - 100/MS/CM

2000 P.S.I.



A

GAIN = 40 RAD.
.0396 COMPARATOR 0' LAP

BERTEA / CORPORATION IRVINE · CALIFORNIA

| PAGE 63 | TEST 13 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

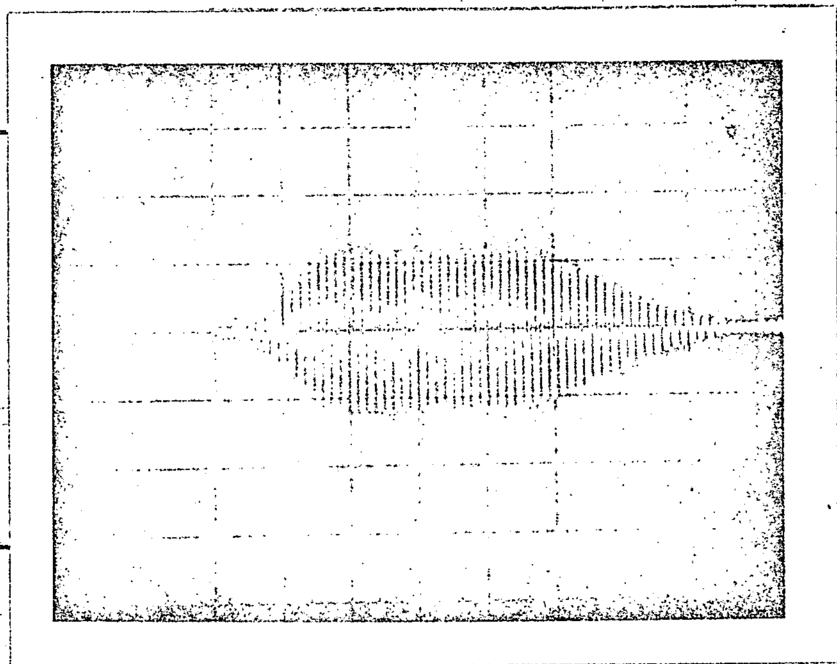
HARD OVER SIGNAL AT THE -1 SERVO (CHANNEL "A")

6 CM = .300" STROKE FROM NEUTRAL AT THE ACTUATOR

10 V.D.C. (10 MA.) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH.

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

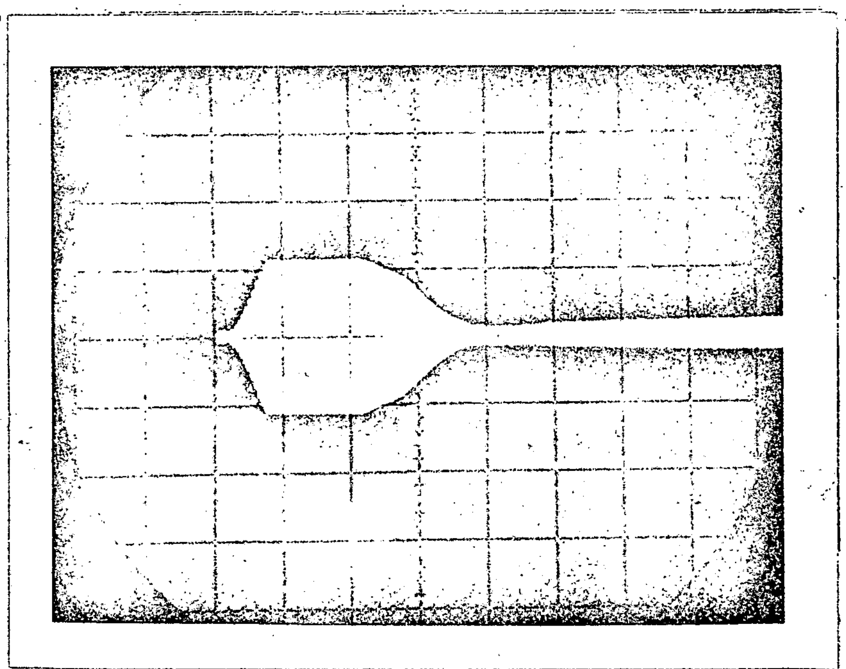
0.3 IN



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 20 MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

A

SWEEP TIME - 50 MS/CM

GAIN = 40 RAD/SEC

.0079 COMPARATOR O LAP

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

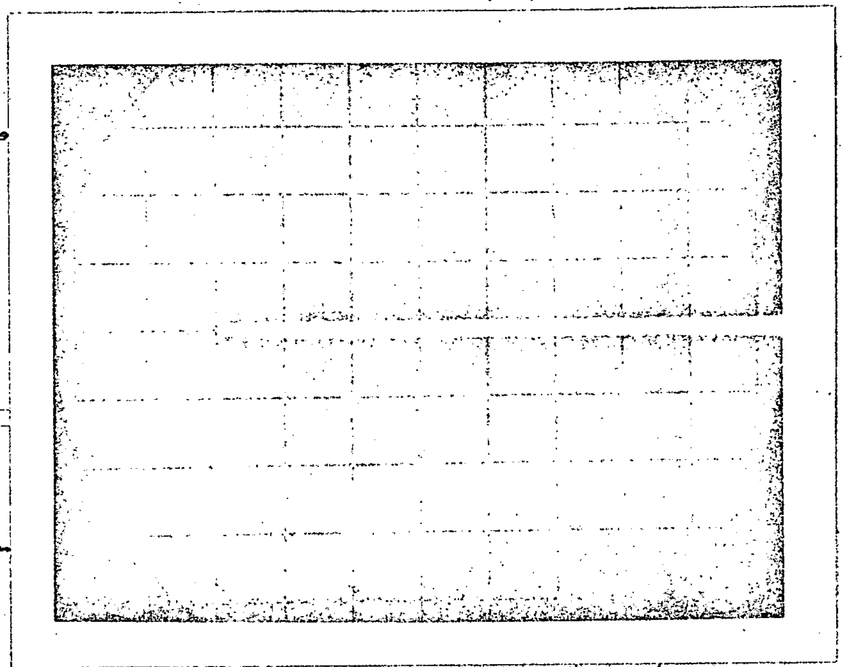
HARD OVER SIGNAL AT THE -5 "SERVO (CHANNEL "A")

6 CM = .300" STROKE FROM NEUTRAL AT THE ACTUATOR

10 V.D.C. (10 MA.) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH.

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

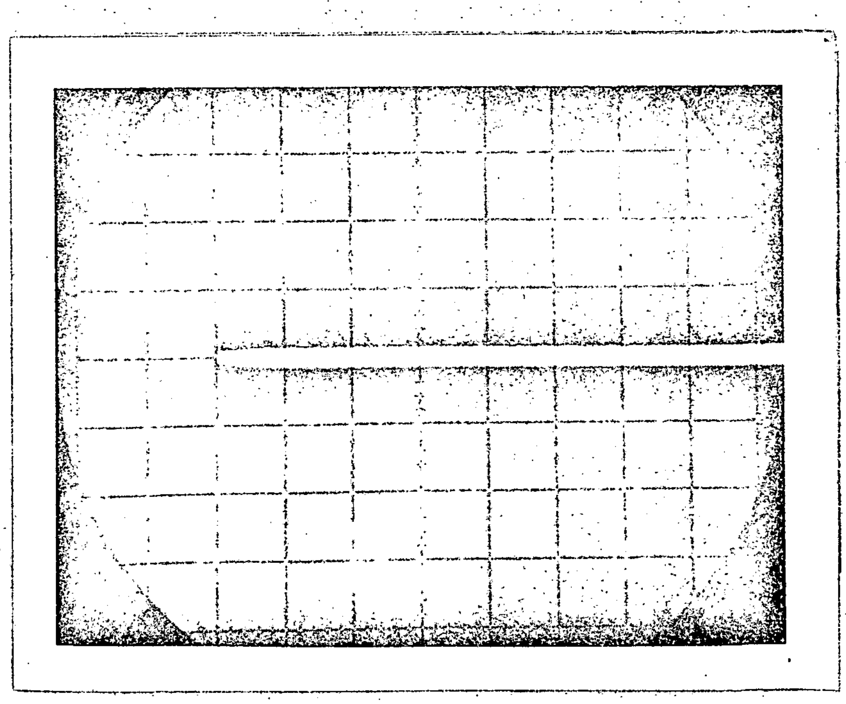
0.3 IN



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 50 MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

A

SWEEP TIME = 50 MS/CM

GAIN = 40 RAD/SEC

.0079 COMPARATOR O'LAP

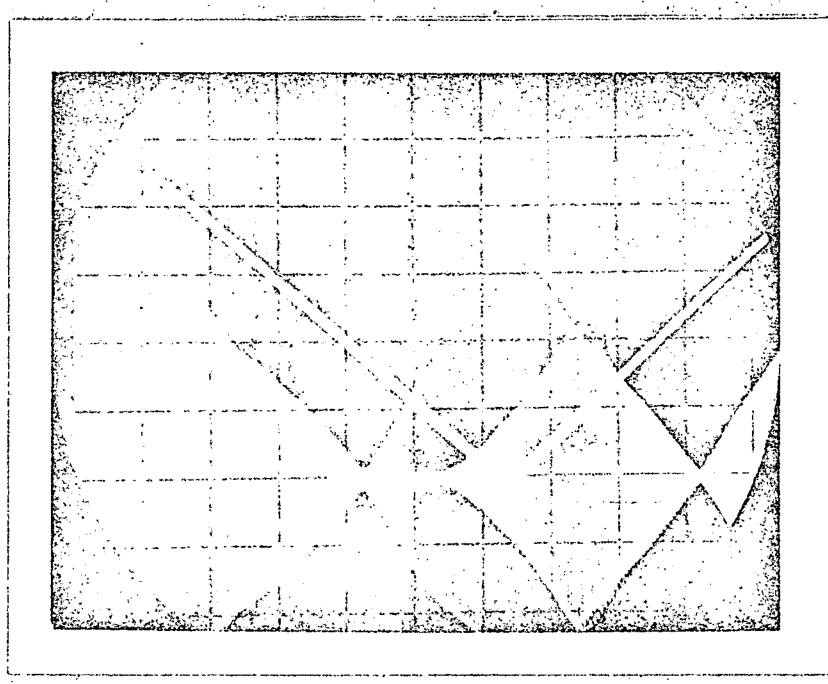
TITLE PASSIVE FAILURE (1 INPUT TO THE AMPLIFURE AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC

E.H. VALVE TRIGGERED OPEN TO THE -3 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM #1 @ ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



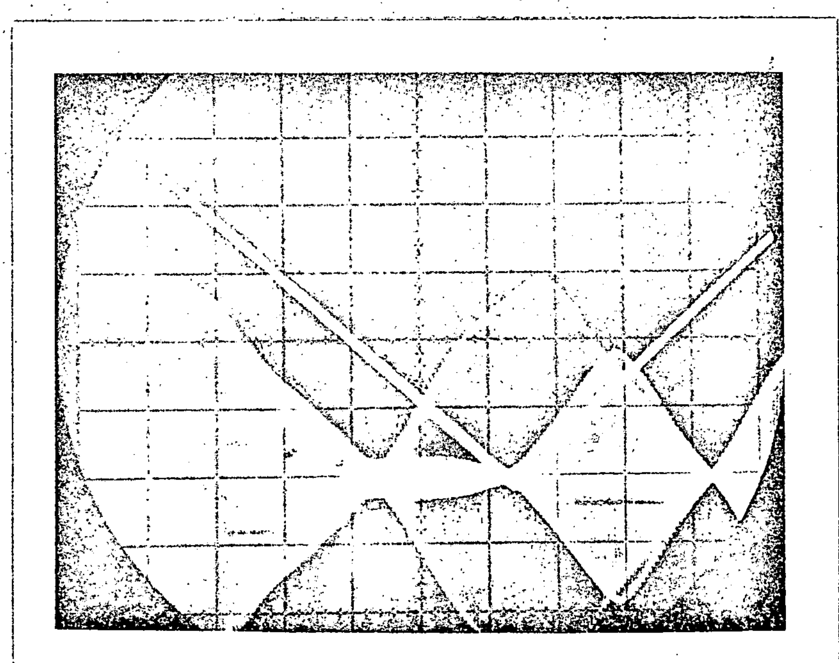
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 50 MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 50 MS/CM

A

GAIN = 40 RAD/SEC

.0079 COMPARATOR O'LAP

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| PAGE 66 | TEST 13 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

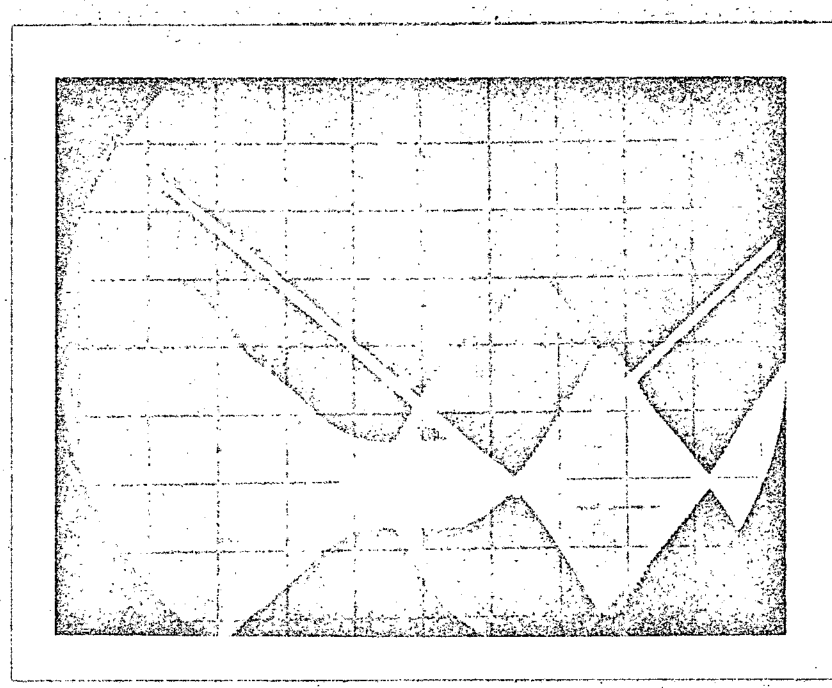
TITLE PASSIVE FAILURE (1 INPUT TO THE AMPLIFURE AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC

E.H. VALVE TRIGGERED OPEN TO THE -1 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM ℄ @ ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



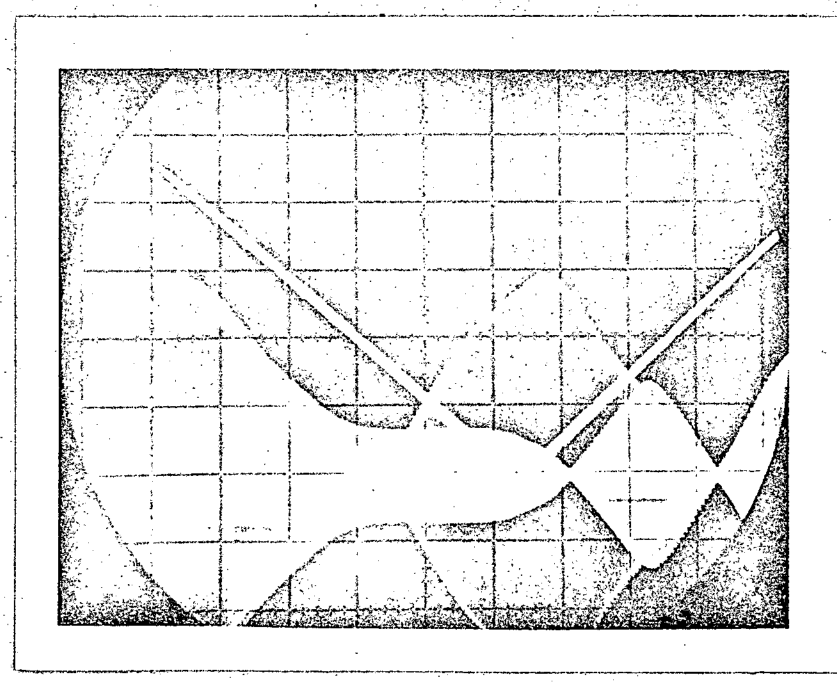
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 50 MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 50 MS/CM

A

GAIN = 40 RAD./SEC

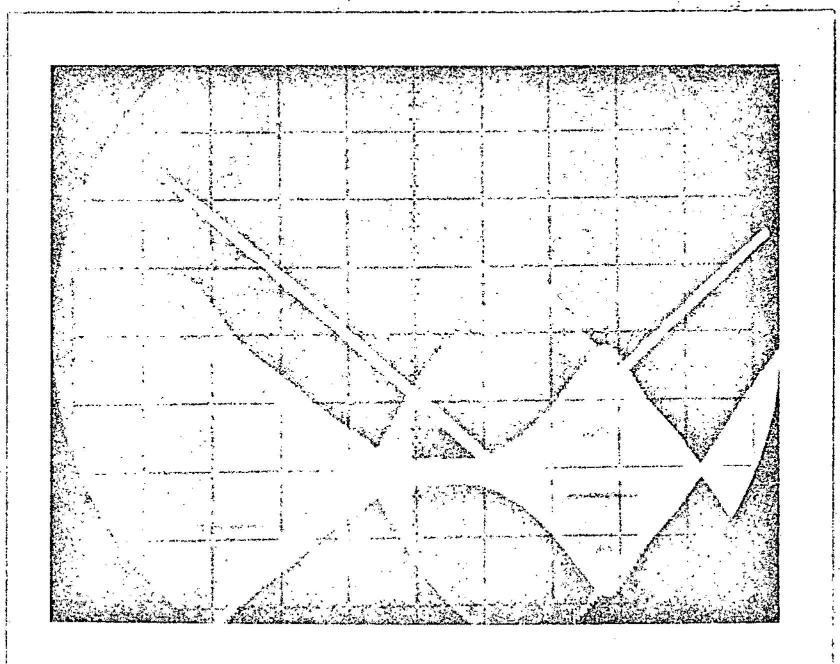
.0079 COMPARATOR O'LAP

TITLE SOFT FAILURE (1 INPUT TO AMPLIFIER AT 2 Hz)

3000 P.S.I. TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -1 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



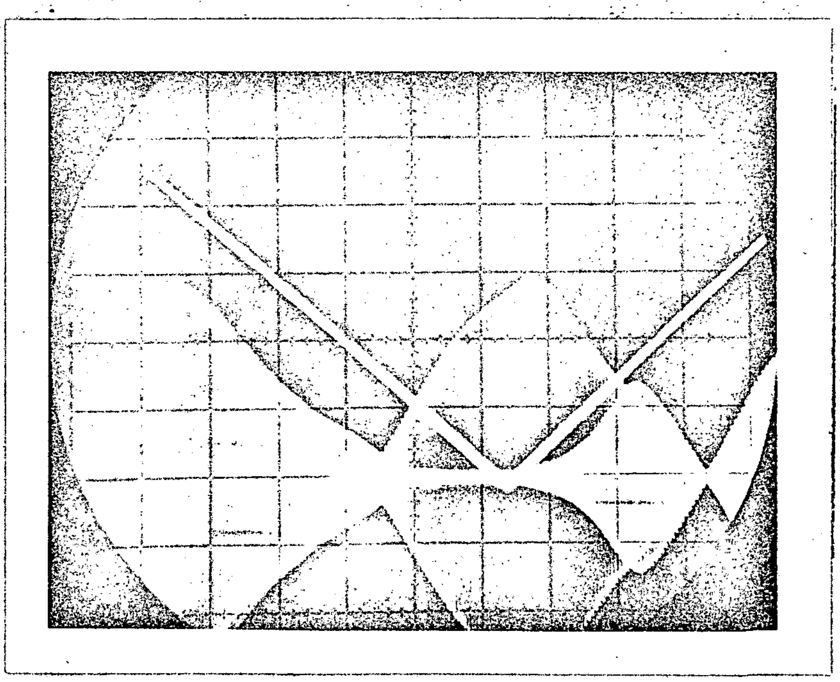
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 50 /MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

A

SWEEP TIME - 50 /MS/CM

GAIN = 40 RAD.

.0079 COMPARATOR O'LAP

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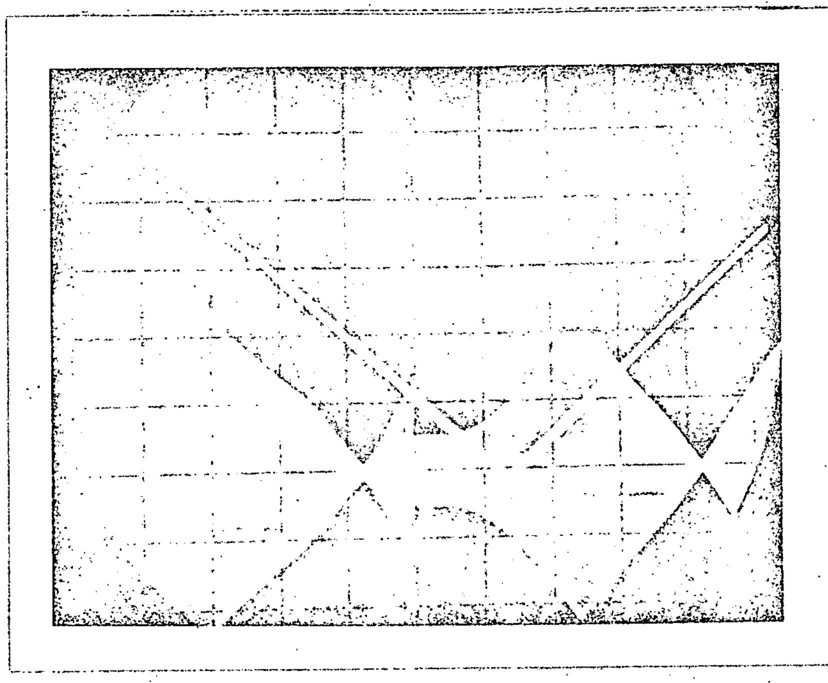
| PAGE 68 | TEST 13 | REV. |
| --- | --- | --- |
| ORIG. DATE | REV. DATE | |

TITLE SOFT FAILURE (✓ INPUT TO AMPLIFIER AT 2 Hz)

3000 P.S.I. TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -3 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



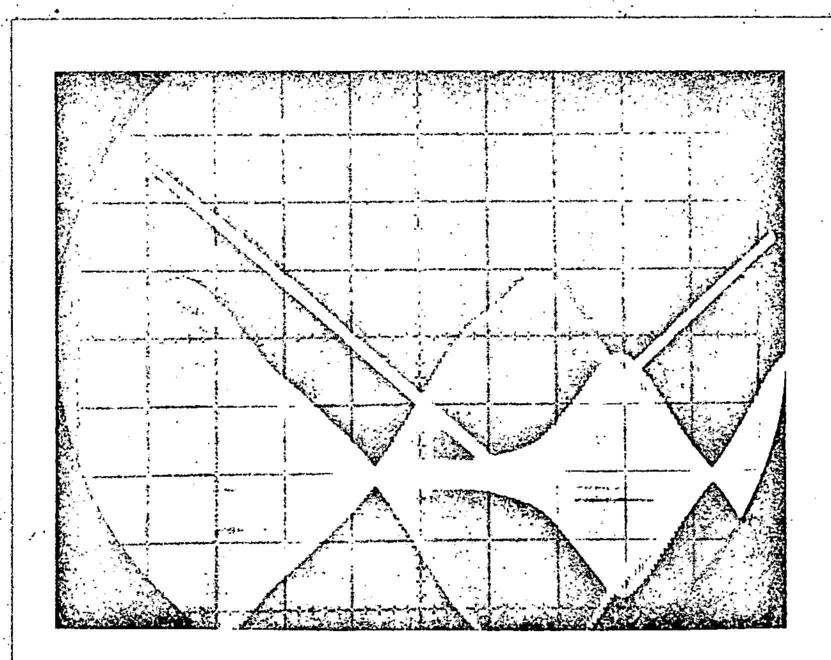
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 50/MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

A

SWEEP TIME - 50/MS/CM

GAIN = 40 RAD. .0079 COMPARATOR O'LAP

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| PAGE 69 | TEST 14 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

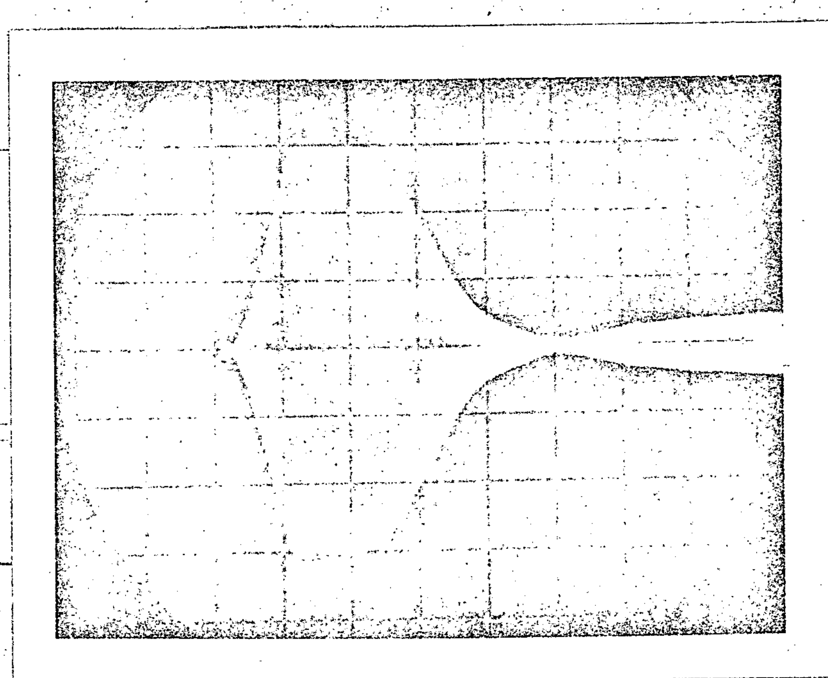
HARD OVER SIGNAL AT THE -1 SERVO (CHANNEL "A")

6 CM = .300" STROKE FROM NEUTRAL AT THE ACTUATOR

10 V.D.C. (10 MA.) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH.

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

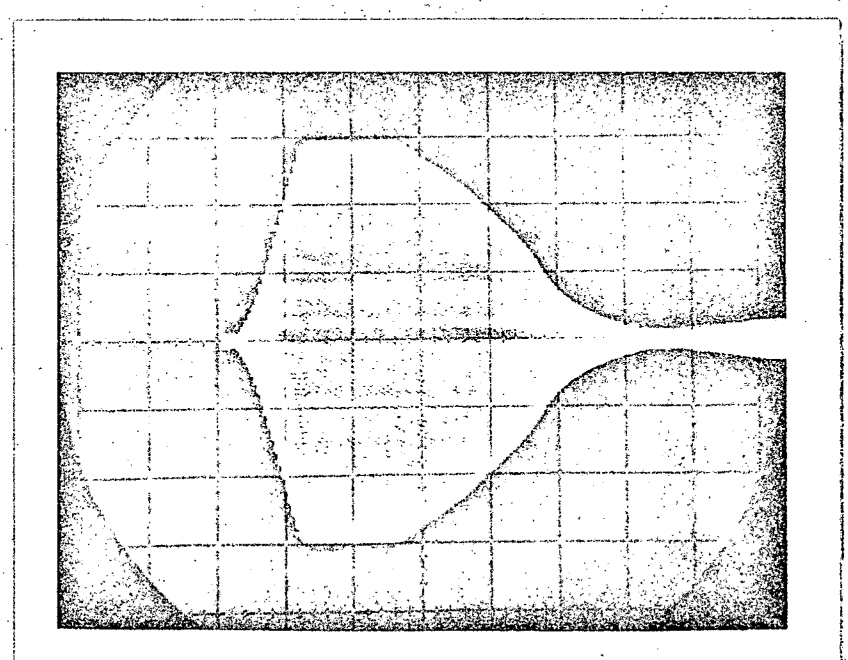
0.3 IN



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 50 MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

A

SWEEP TIME - 50 MS/CM

GAIN = 20 RAD/SEC

.0396 COMPARATOR O LAP

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

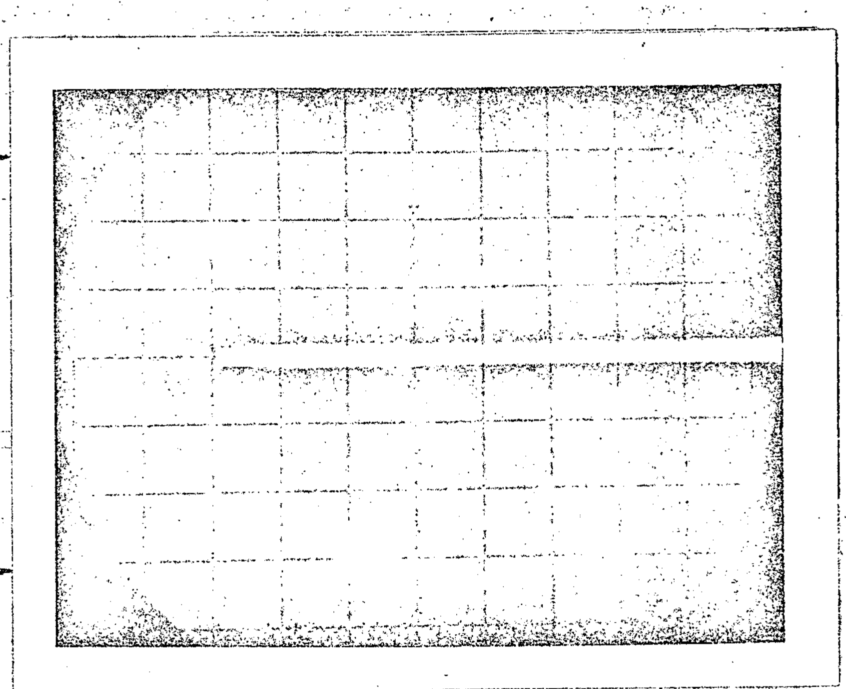
HARD OVER SIGNAL AT THE -5 SERVO (CHANNEL "A")

6 CM = .300" STROKE FROM NEUTRAL AT THE ACTUATOR

10 V.D.C. (10 MA.) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH.

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

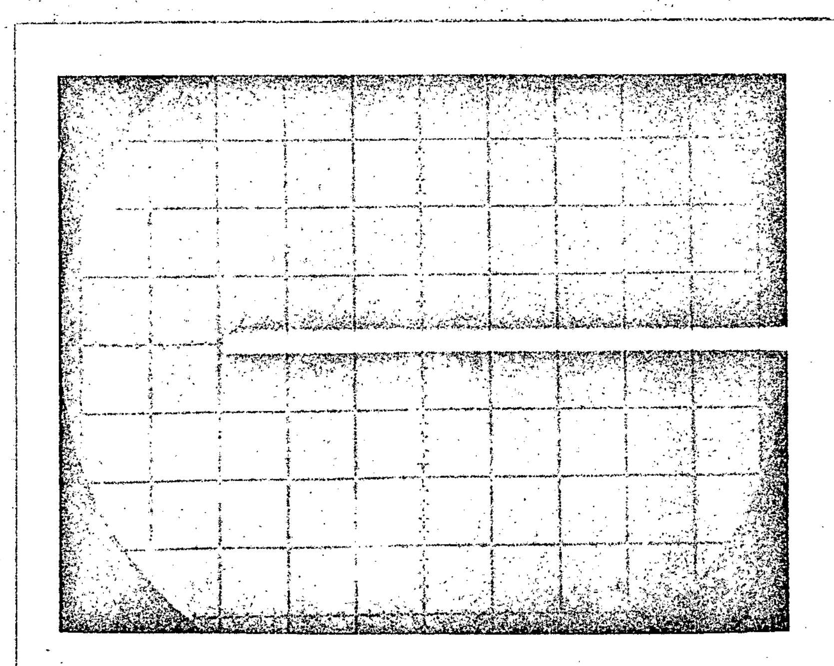
0.3 IN



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 50 MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

A

SWEEP TIME - 50 MS/CM

GAIN = 20 RAD/SEC

.0396 COMPARATOR O LAP

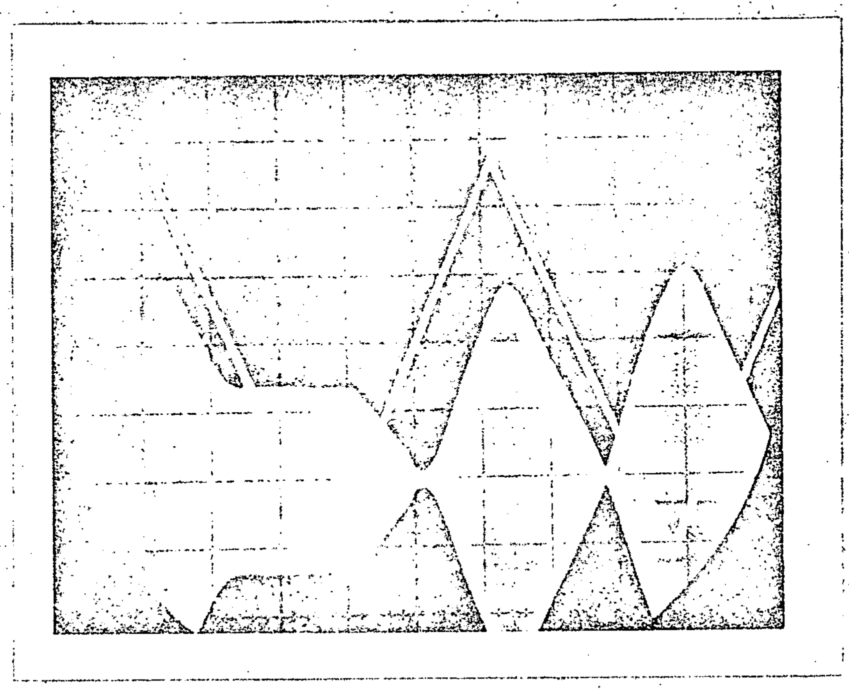
TITLE PASSIVE FAILURE (1 INPUT TO THE AMPLIFURE AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC

E.H. VALVE TRIGGERED OPEN TO THE #1 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM ℄ @ ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



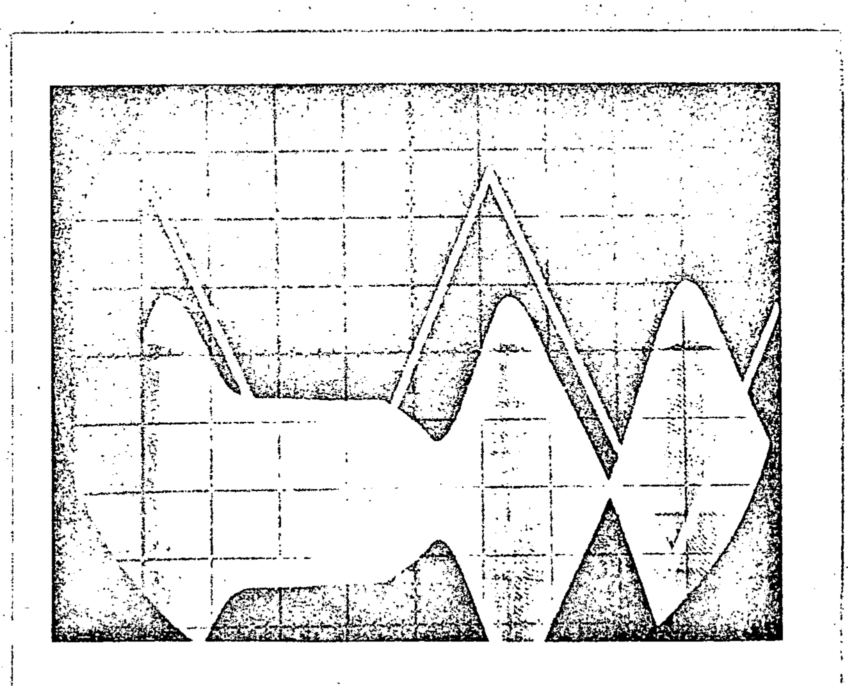
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 100 MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 100 MS/CM

A

GAIN = 20 RAD.

.0396 COMPARATOR O'LAP

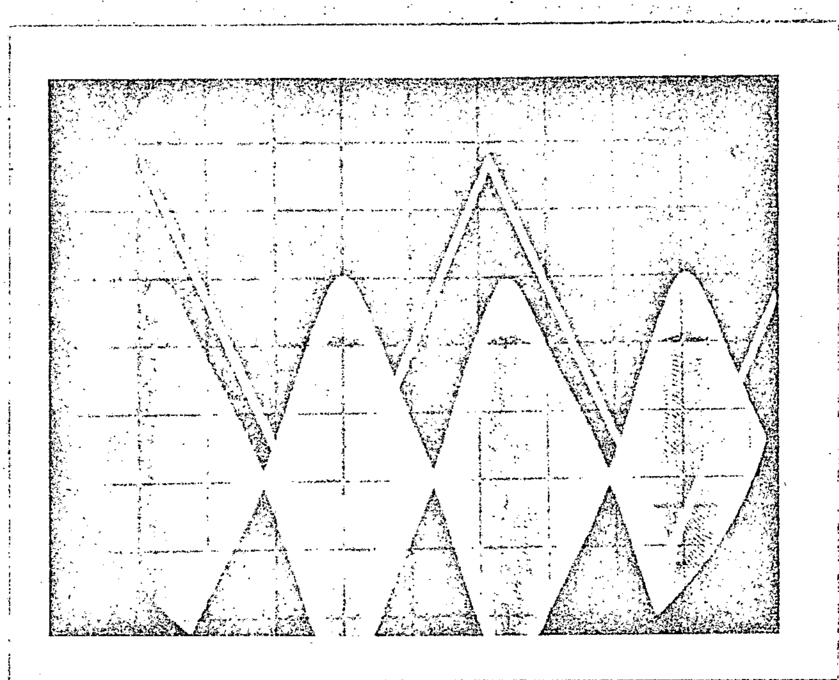
TITLE PASSIVE FAILURE (1 INPUT TO THE AMPLIFURE AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC

E.H. VALVE TRIGGERED OPEN TO THE -3 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM ℄ @ ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



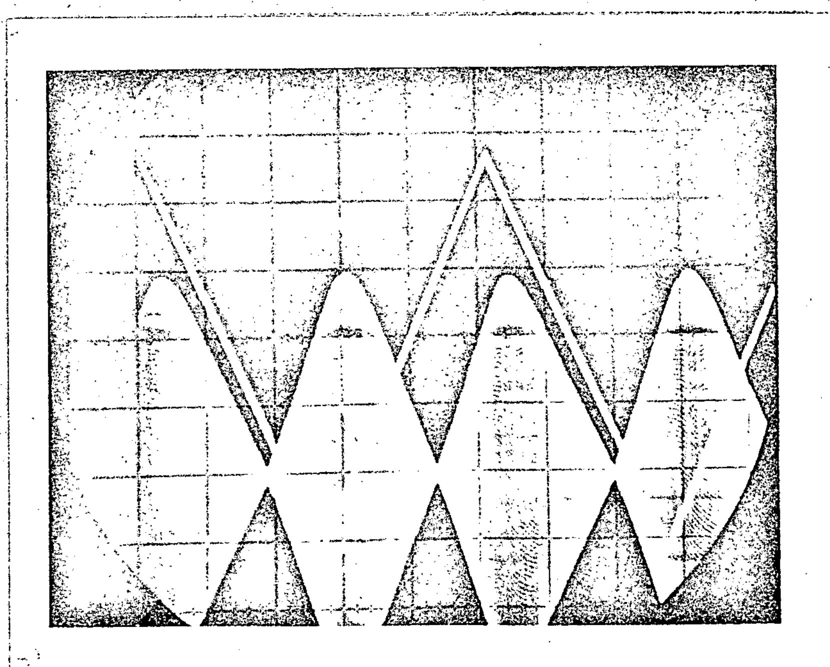
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL

SWEEP TIME - 100 MS/CM

2000 P.S.I.



NO FAIL

SWEEP TIME - 100 MS/CM

A

GAIN = 20 RAD./SEC

.0396 COMPARATOR O'LAP

BERTEA CORPORATION IRVINE · CALIFORNIA

| PAGE 73 | TEST 14 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

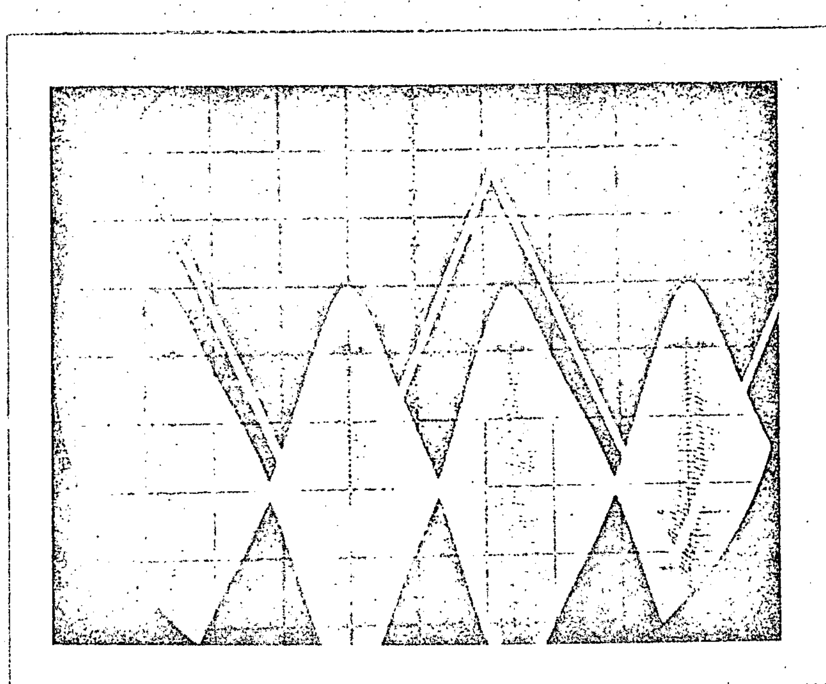
TITLE SOFT FAILURE (1 INPUT TO AMPLIFIER AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -3 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



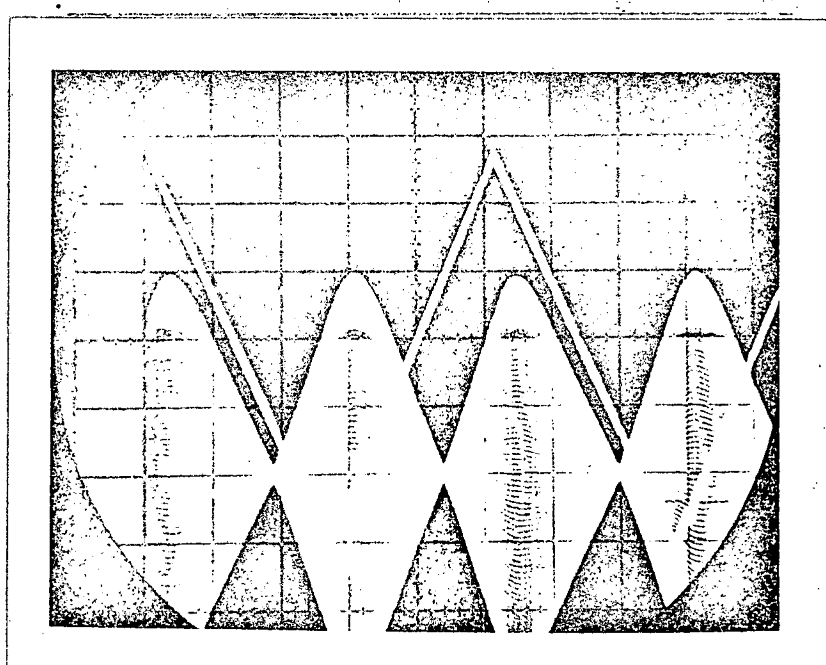
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL

SWEEP TIME - 100/MS/CM

2000 P.S.I.



NO FAIL

A

SWEEP TIME - 100/MS/CM

GAIN = 20 RAD.

.0396 COMPARATOR O'LAP

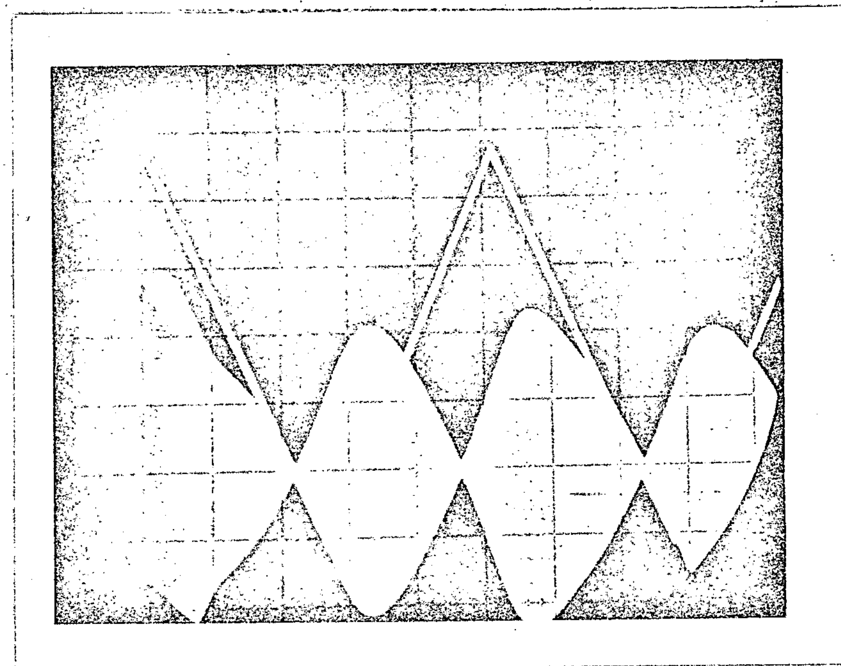
TITLE SOFT FAILURE (∿ INPUT TO AMPLIFIER AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -1 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



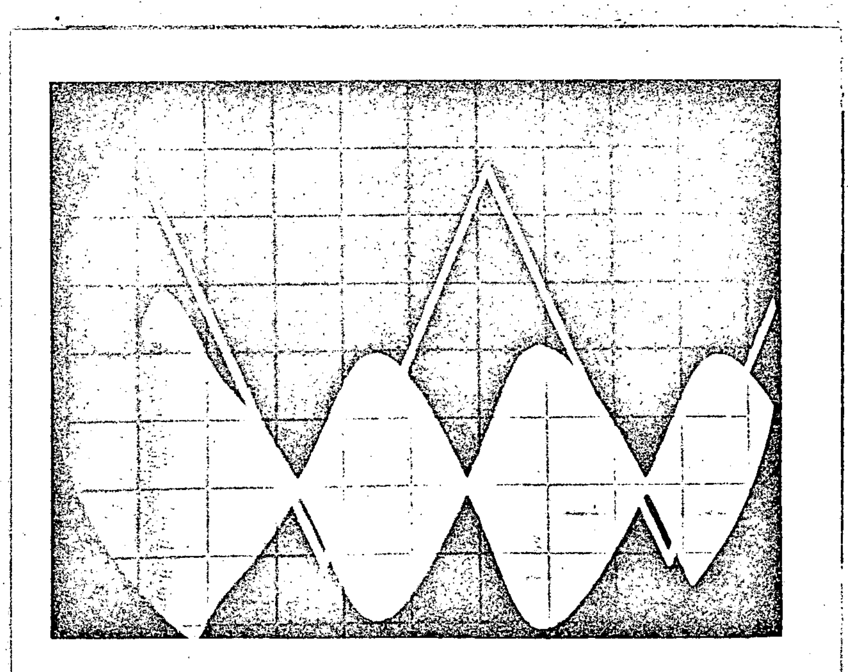
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL

SWEEP TIME - 100/MS/CM

2000 P.S.I.



NO FAIL

A

SWEEP TIME - 100/MS/CM

GAIN = 20 RAD.

.0396 COMPARATOR O'LAP

BERTEA / CORPORATION IRVINE · CALIFORNIA

| PAGE 75 | TEST 15 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

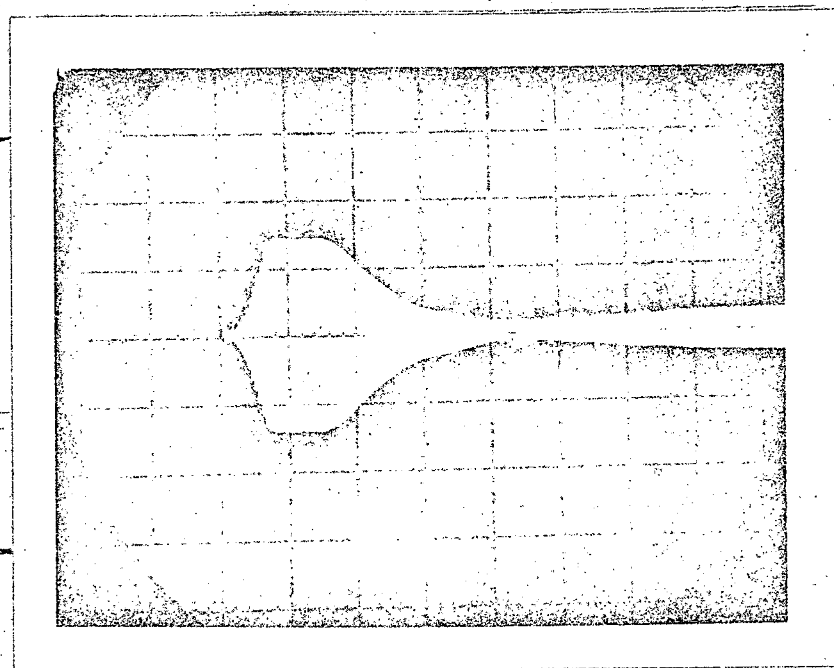
HARD OVER SIGNAL AT THE -1 SERVO (CHANNEL "A")

6 CM = .300" STROKE FROM NEUTRAL AT THE ACTUATOR

10 V.D.C. (10 MA.) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH.

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

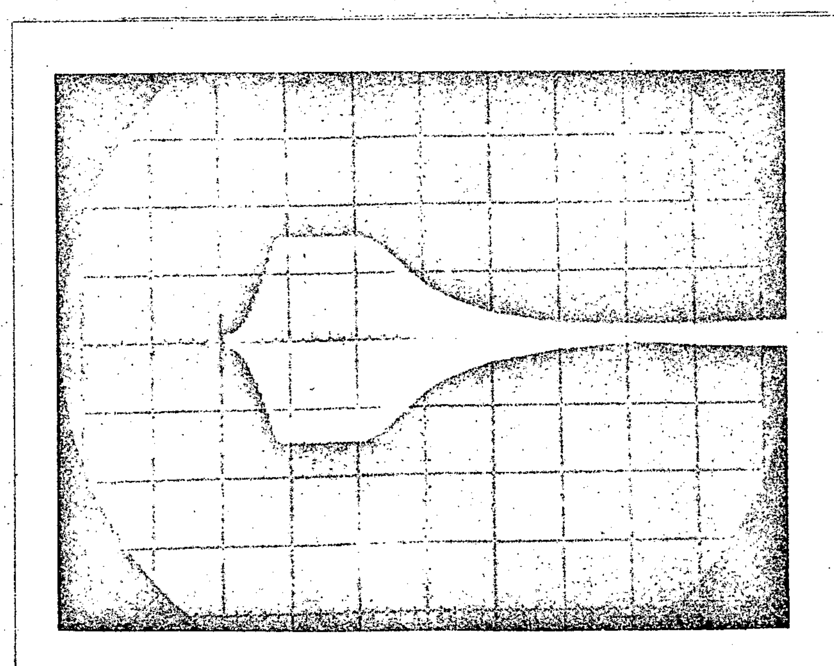
0.3 IN



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 50 MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

A

SWEEP TIME = 50 MS/CM

GAIN = 20 RAD/SEC

.0079 COMPARATOR O LAP

| BERTEA CORPORATION IRVINE · CALIFORNIA | PAGE 26 | TEST 15 | REV. |
|---|---|---|---|
| | ORIG. DATE | REV. DATE | |

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

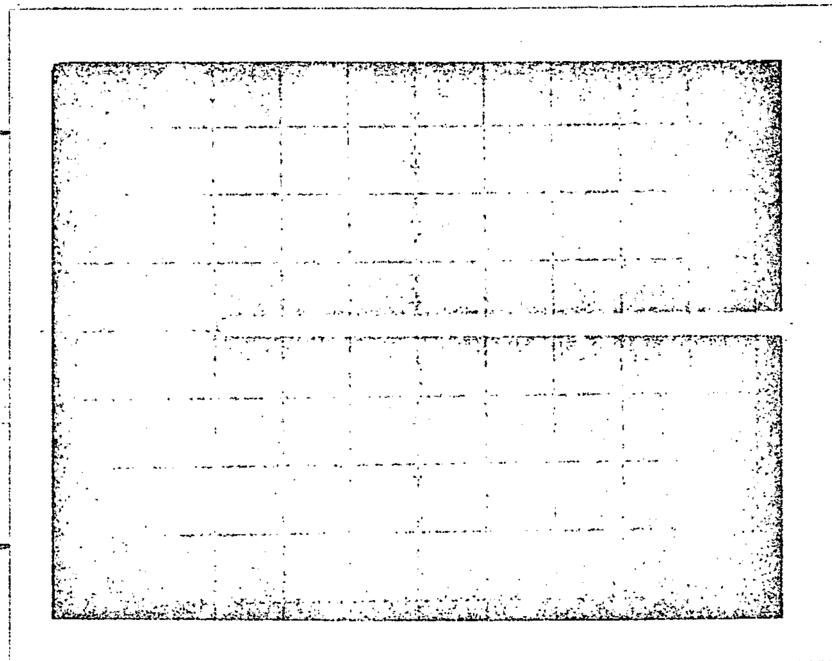
HARD OVER SIGNAL AT THE -5 SERVO (CHANNEL "A")

6 CM = .300" STROKE FROM NEUTRAL AT THE ACTUATOR

10 V.D.C. (10 MA.) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH.

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

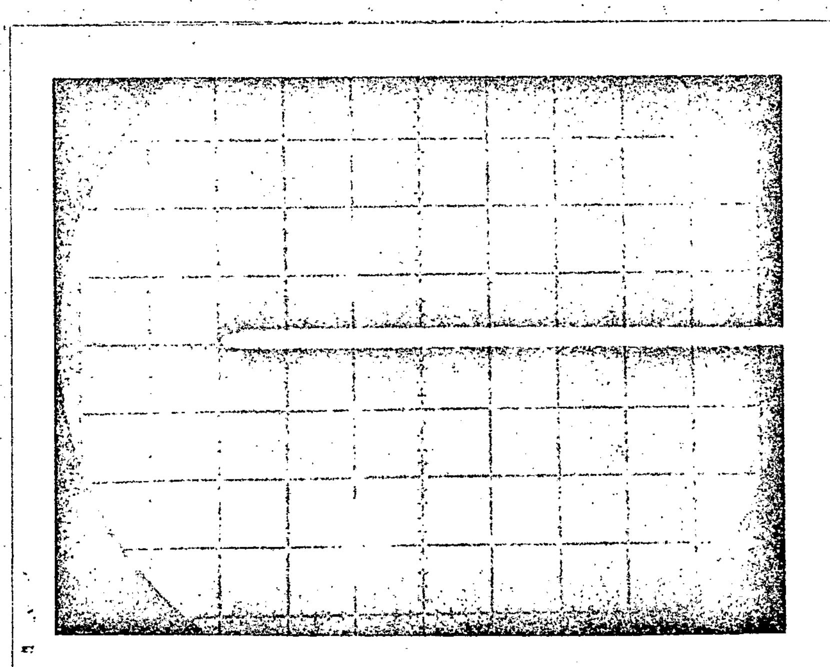
0.3 IN



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME = 50 /MS /CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

A

SWEEP TIME = 50 /MS /CM

GAIN = 20 RAD /SEC

.0019 COMPARATOR O LAP

TITLE PASSIVE FAILURE (1 INPUT TO THE AMPLIFURE AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC

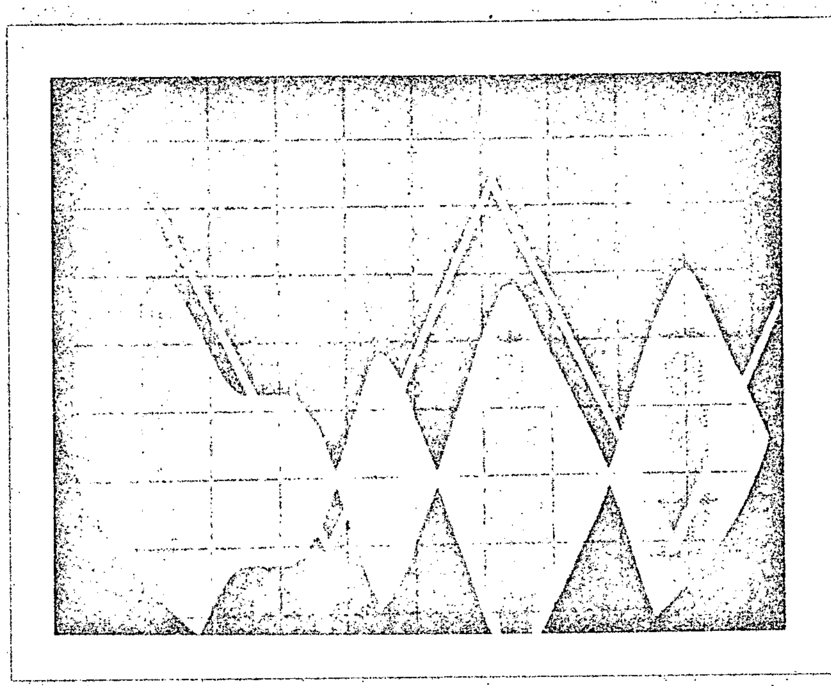
E.H. VALVE TRIGGERED OPEN TO THE =1 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM #1 @ ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

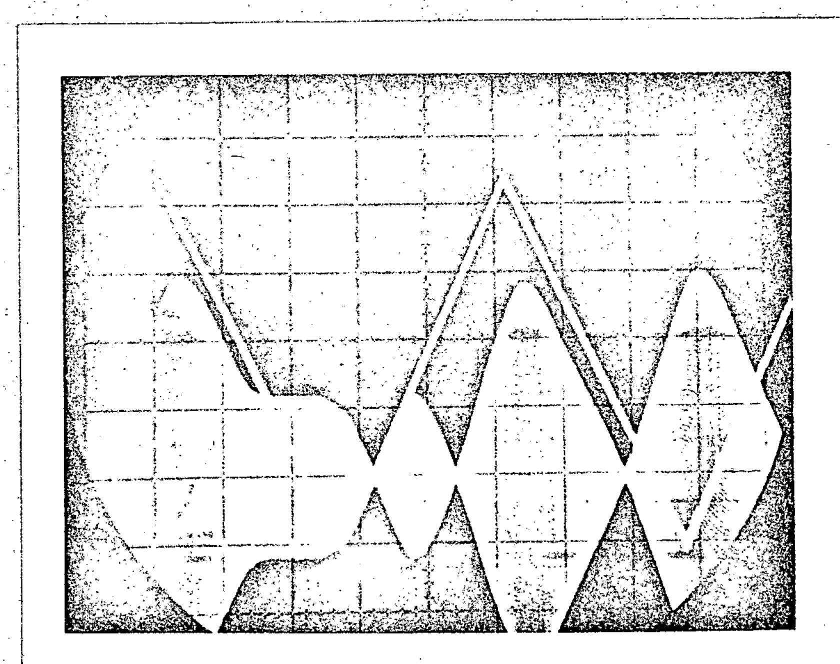
FAILED & ACTIVATED CHANNEL "B"



SWEEP TIME - 100 MS/CM

2000 P.S.I.

FAILED & ACTIVATED CHANNEL "B"



SWEEP TIME - 100 MS/CM

A

GAIN = 20 RAD./SEC

.0079 COMPARATOR O'LAP

BERTEA CORPORATION
IRVINE · CALIFORNIA

| PAGE 78 | TEST 15 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

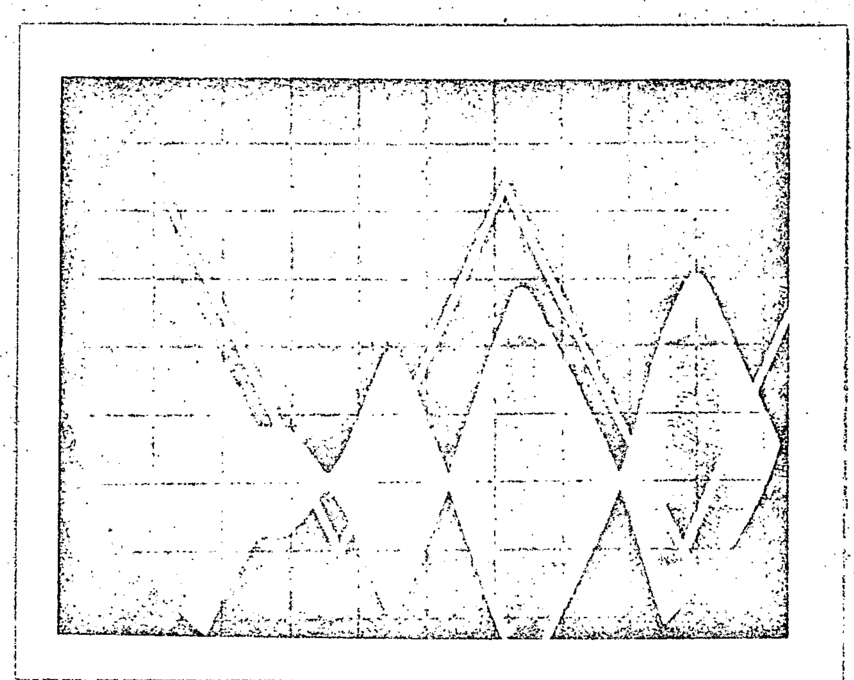
TITLE PASSIVE FAILURE (1 INPUT TO THE AMPLIFURE AT 2 Hz.)

3000 P.S.I.

TRIGGER TIME = .001/SEC

E.H. VALVE TRIGGERED OPEN TO THE -3 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM ℄ @ ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



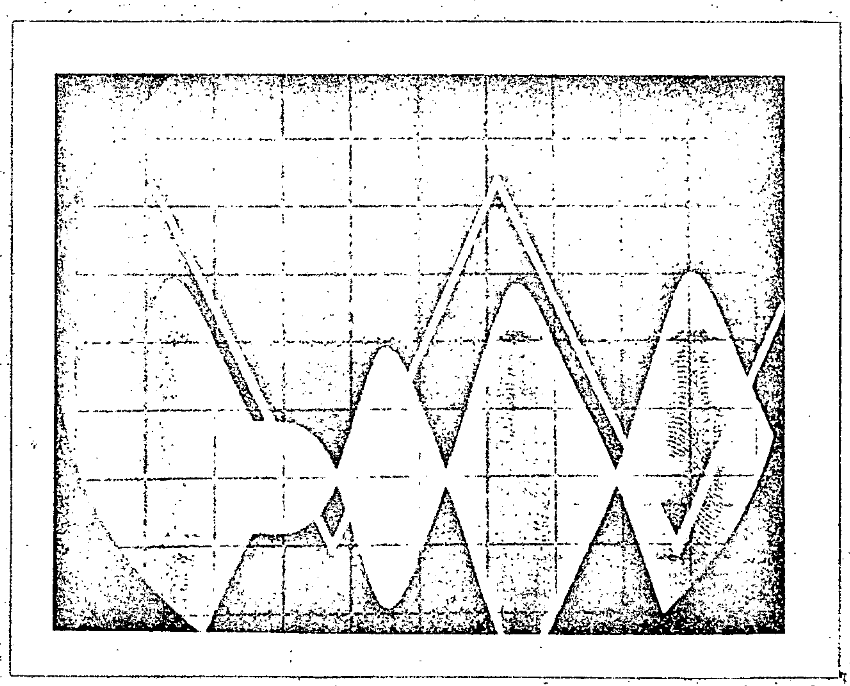
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 100 MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 100 MS/CM

A

GAIN = 20 RAD./SEC

.0079 COMPARATOR O'LAP

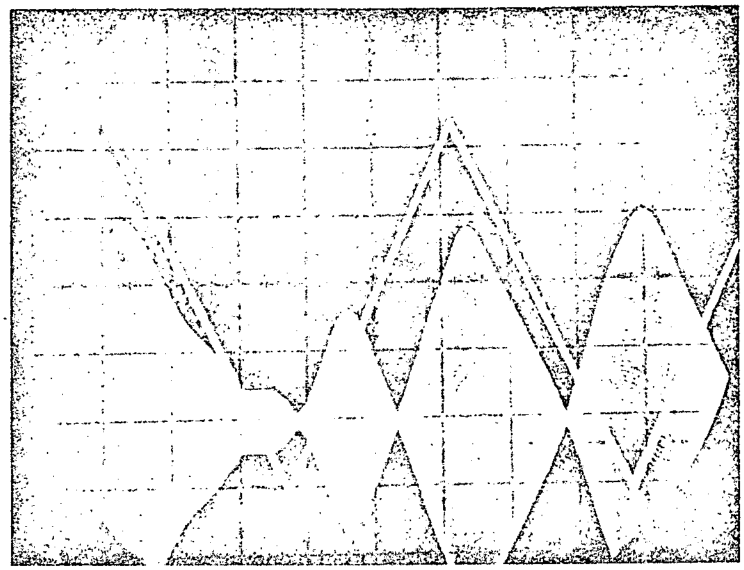
TITLE SOFT FAILURE (∿ INPUT TO AMPLIFIER AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -1 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



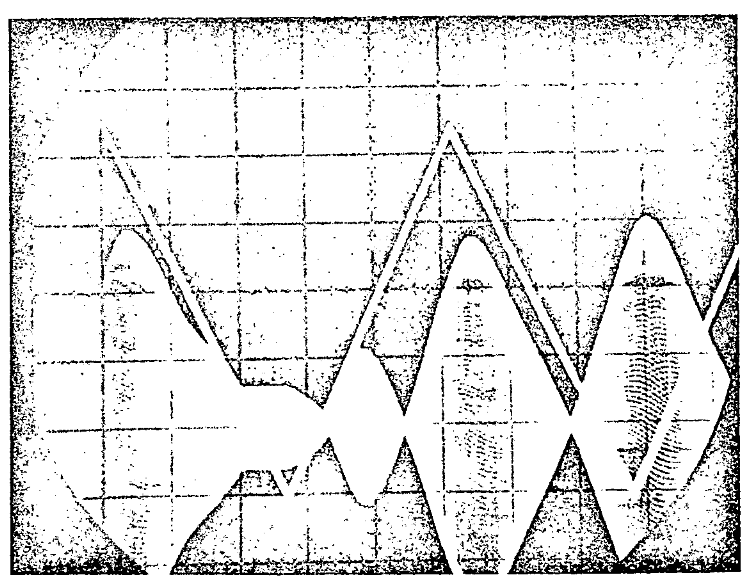
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME - 100/MS/CM.

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

A

SWEEP TIME - 100/MS/CM

GAIN = 20 RAD.

.0079 COMPARATOR O'LAP

BERTEA CORPORATION IRVINE • CALIFORNIA

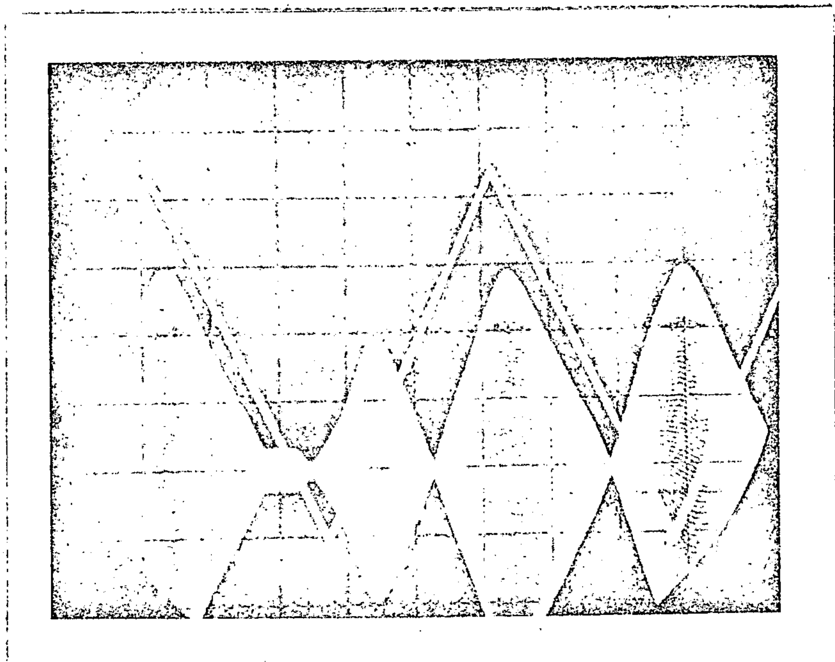
| PAGE 80 | TEST 15 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE SOFT FAILURE (1 INPUT TO AMPLIFIER AT 2 Hz)

3000 P.S.I. TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -3 SERVO (CHANNEL "A")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



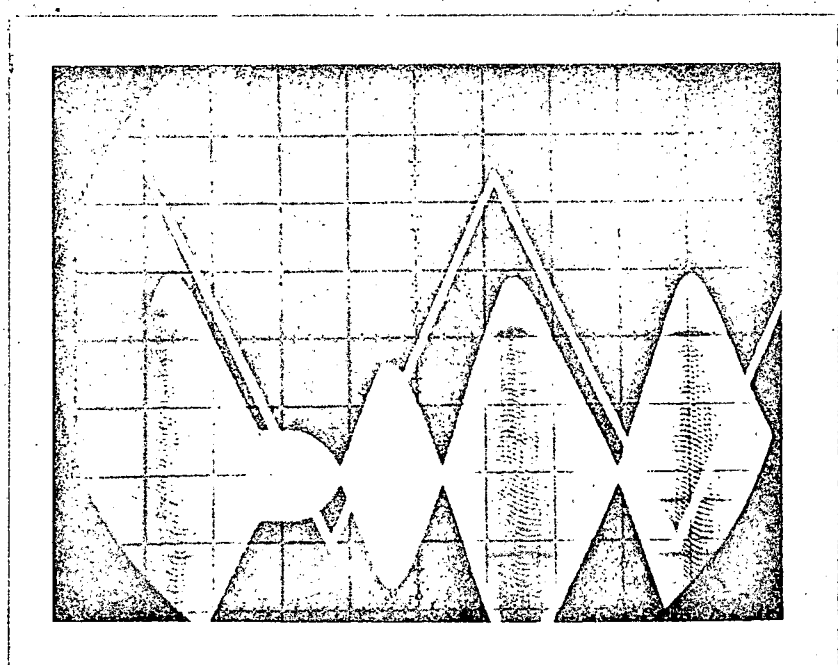
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz).

FAILED & ACTIVATED CHANNEL "B"

SWEEP TIME -100/MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "B"

A

SWEEP TIME -100/MS/CM.

GAIN = 20 RAD.

.0079 COMPARATOR O'LAP

BERTEA CORPORATION IRVINE · CALIFORNIA

| PAGE 81 | DOCUMENT NO. TEST 16 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I. LEE JET (187-0-04000-0808 INSTALLED IN THE TIME DELAY VALVE)

HARD OVER SIGNAL AT -3 SERVO (CHAN. "B")

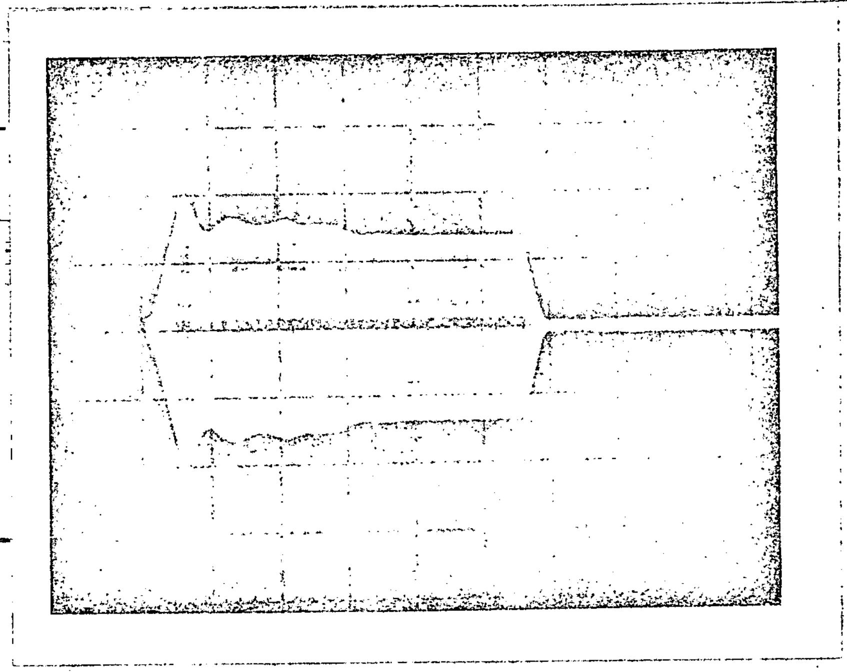
6 CM = 0.3" STROKE FROM N. AT ACTUATOR

0.3 IN.

10 V.D.C. (10 MA.) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT, & SWITCH

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

FAILED & ACTIVATED CHANNEL "C"



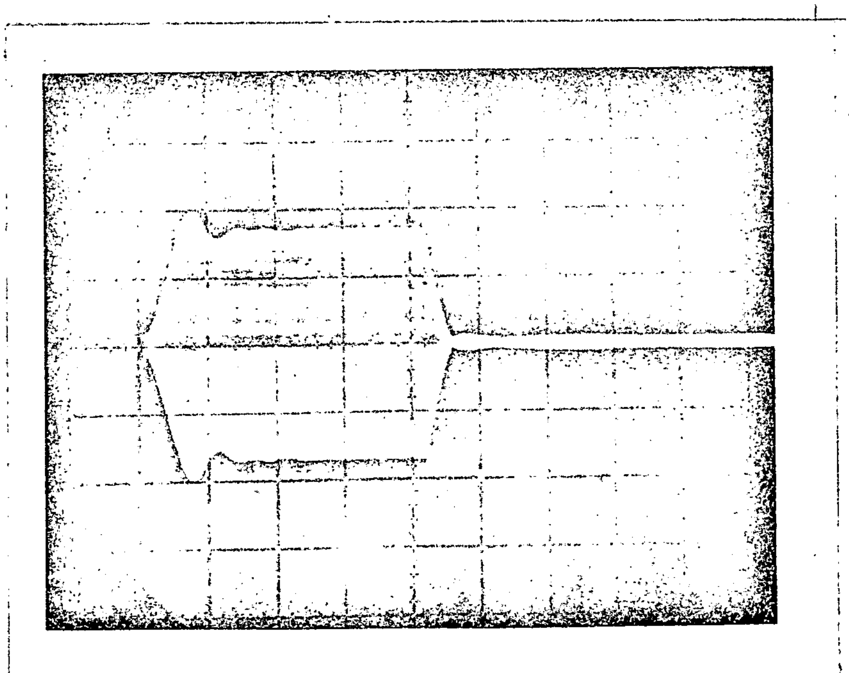
SWEEP TIME - .1 SEC/CM

2000 P.S.I.

HARD OVER SIGNAL AT -3 SERVO (CHAN "B")

FAILED & ACTIVATED CHANNEL "C"

B



TRIGGER

GAIN = 40 RAD./SEC .0396 COMPARATOR O'LAP

Form 310-01

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I. LEE JET (187-0-04000-0808 INSTALLED IN THE TIME DELAY VALVE)

HARD OVER SIGNAL AT -9 SERVO (CHAN "B")

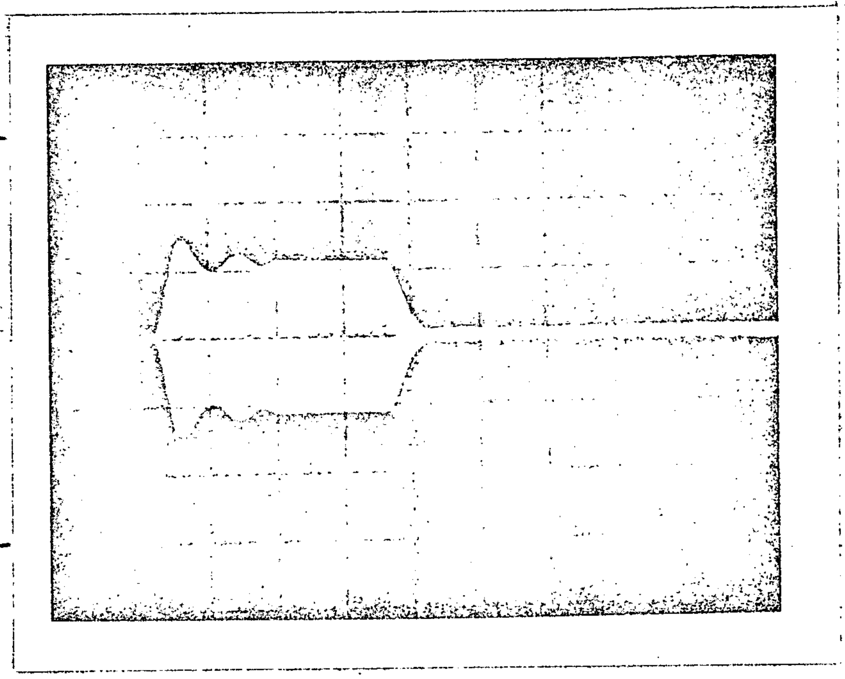
6 CM = 0.3" STROKE FROM N AT ACTUATOR

0.3 IN.

10 V.D.C. (10 MA) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH

SCOPE TRACE TRIGGERED FROM BATTERY SWITCH.

FAILED & ACTIVATED CHANNEL "C"

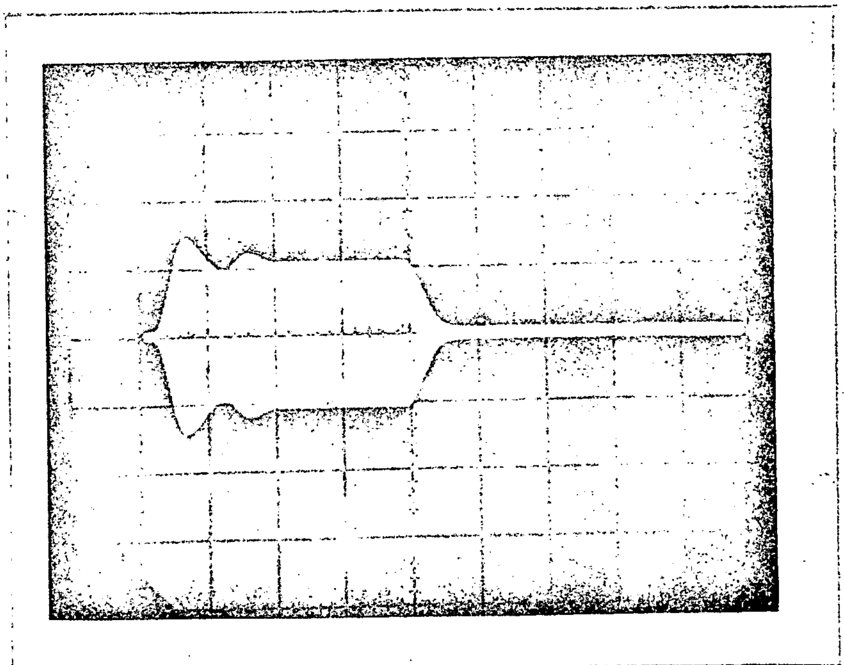


SWEEP TIME = .1 SEC/CM

2000 P.S.I.

HARD OVER SIGNAL AT -9 SERVO (CHAN "B")

FAILED & ACTIVATED CHANNEL "C"



B

TRIGGER

GAIN = 40 RAD./SEC

.0396 COMPARATOR O'LAP

| BERTEA CORPORATION IRVINE • CALIFORNIA | PAGE 33 | DOCUMENT NO. TEST 16 | REV. |
|---|---|---|---|
| | ORIG. DATE | REV. DATE | |

TITLE PASSIVE FAILURE (V INPUT TO AMPLIFIER @ 2 Hz)

3000 P.S.I. LEE JET = 187-0-04000-0808 INSTALLED IN THE TIME DELAY VALVE

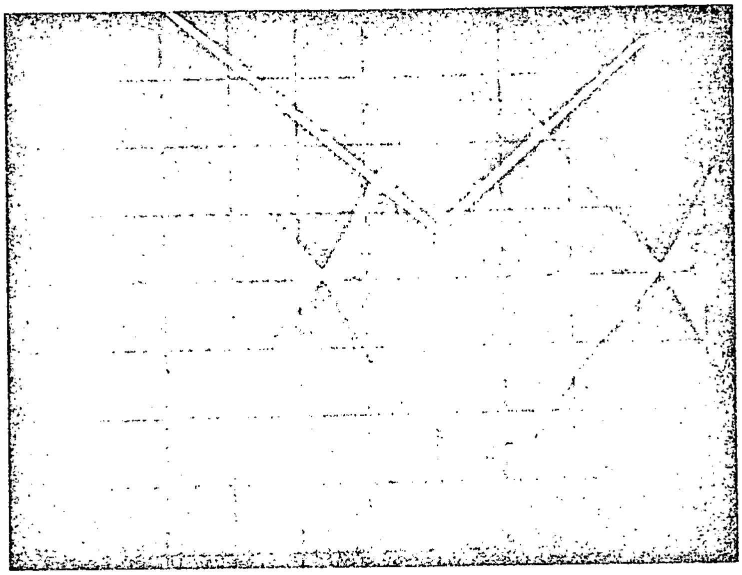
E.H. VALVE TRIGGERED OPEN TO THE -3 SERVO CHANNEL "B"

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

THE UPPER TRACE DISPLAYS THE INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

THE LOWER TRACE DISPLAYS THE ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

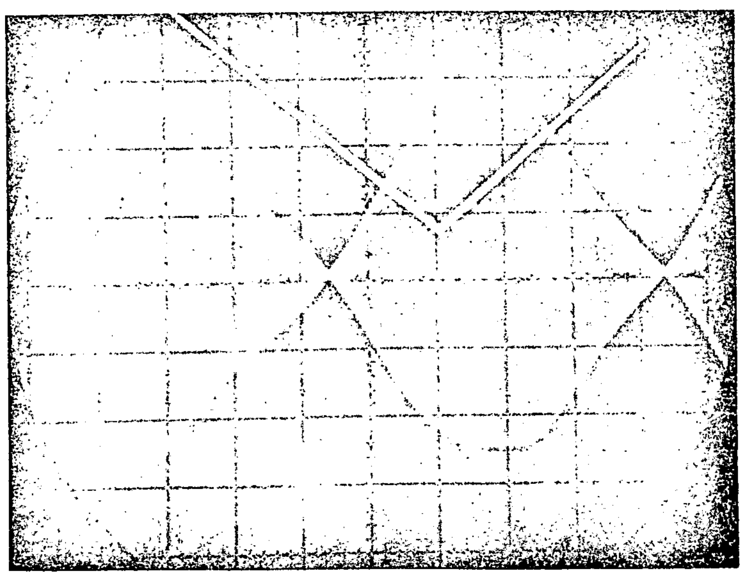
NO FAIL
ACTUATOR OUTPUT SHOWS DECREASE IN AMPLITUDE



SWEEP TIME - 50 MS/CM

2000 P.S.I.

TRIGGER TIME = .001/SEC.



NO FAIL

B

GAIN = 40 RAD/SEC
.0396 COMPARATOR O LAP

BERTEA / CORPORATION IRVINE · CALIFORNIA

| PAGE 84 | DOCUMENT NO. TEST 16 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE PASSIVE FAILURE (1 INPUT TO THE AMPLIFIER @ 2 Hz)

3000 P.S.I. LEE JET 187-0-04000-0808 INSTALLED IN THE TIME DELAY VALVE

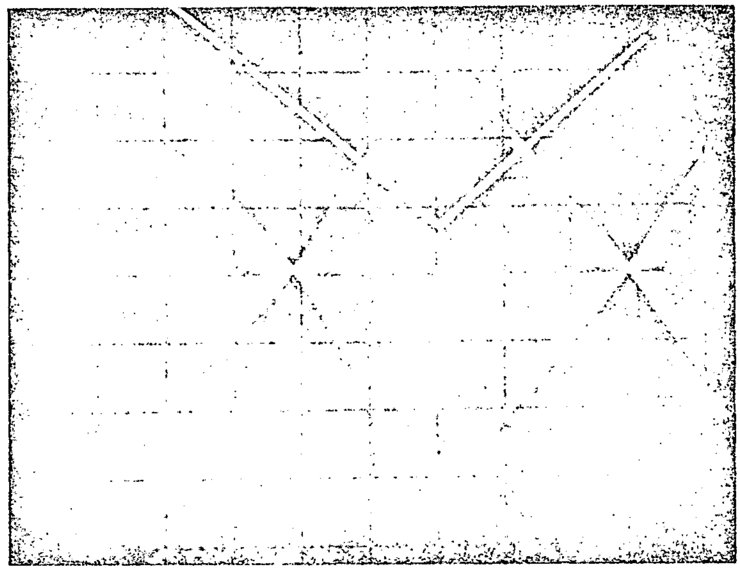
E.H. VALVE TRIGGERED OPEN TO THE -9 SERVO CHANNEL "B"

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS

THE UPPER TRACE DISPLAYS THE INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

THE LOWER TRACE DISPLAYS THE ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

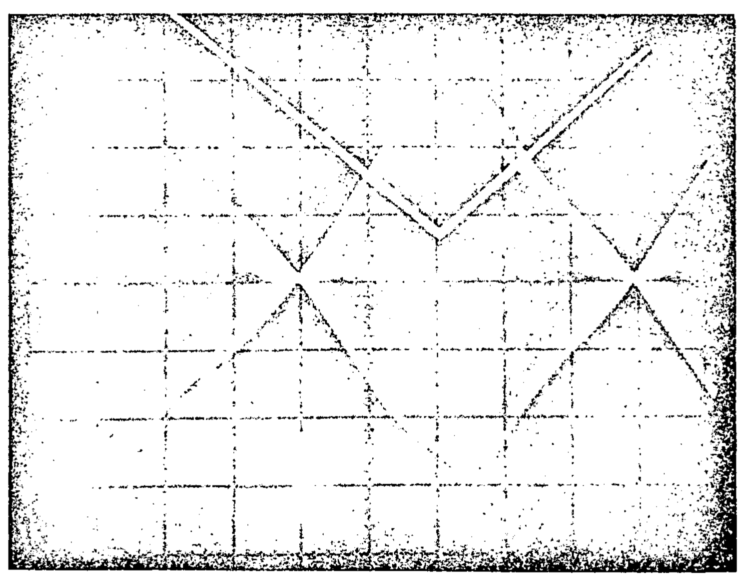
NO FAIL



SWEEP TIME = 50 MS/CM

2000 P.S.I.

TRIGGER TIME = .001/SEC.



NO FAIL

B

GAIN = 40 RAD/SEC

.0396 COMPARATOR O'LAP

Form 310-01

TITLE SOFT FAILURE (∿ INPUT TO AMPLIFIER @ 2 Hz)

3000 P.S.I.

LEE JET 187-0-04000-0808 INSTALLED IN THE TIME DELAY VALVE

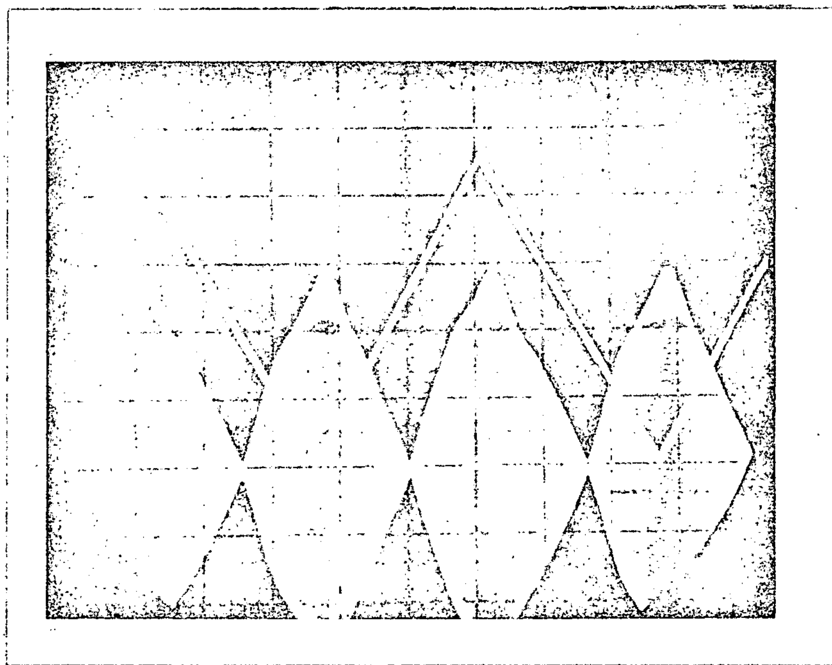
E.H. VALVE TRIGGERED TO HALF GAIN AT THE -9 SERVO CHANNEL "B"

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL

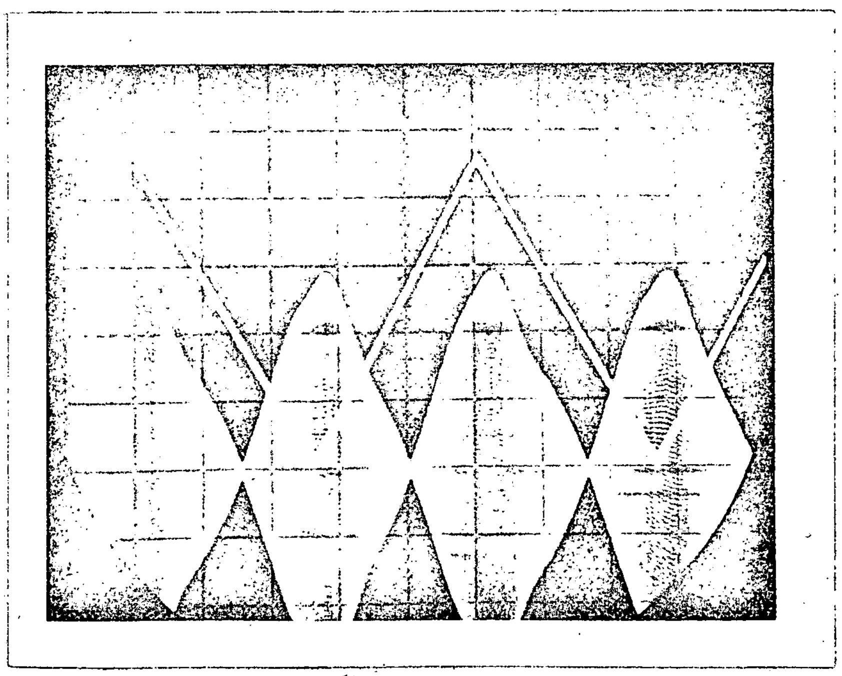


SWEEP TIME - 100/MS/CM

2000 P.S.I.

TRIGGER TIME .001/SEC.

NO FAIL



B

GAIN = 40 RAD.

.0396 COMPARATOR O'LAP

BERTEA / CORPORATION IRVINE · CALIFORNIA

| PAGE 86 | DOCUMENT NO. TEST 16 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE SOFT FAILURE (1V INPUT TO AMPLIFIER @ 2 Hz)

3000 P.S.I. LEE JET 1ST-0-04000-0808 INSTALLED IN THE TIME DELAY VALVE

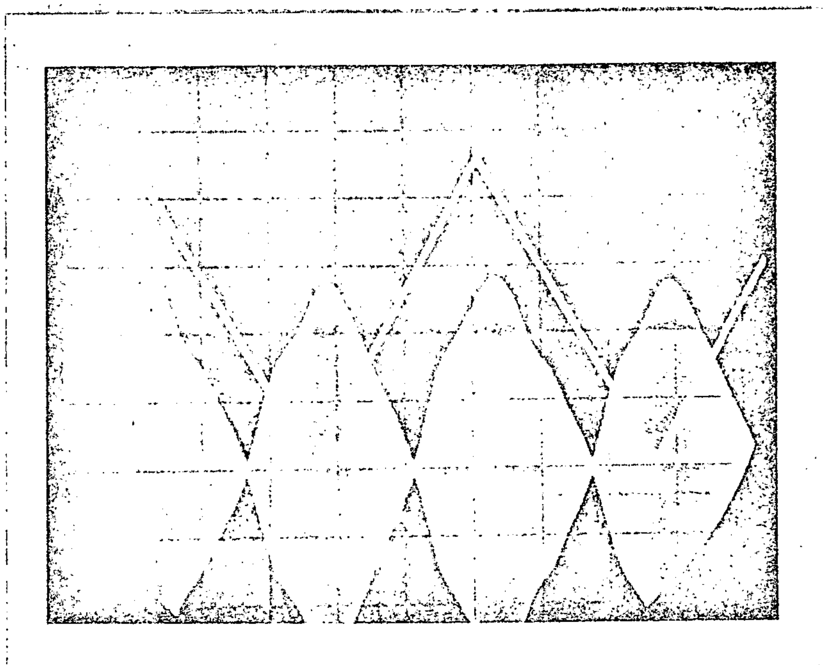
E.H. VALVE TRIGGERED TO HALF GAIN AT THE -3 SERVO CHANNEL "B"

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS

UPPER TRACE DISPLAYS INPUT SIGNAL, & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL

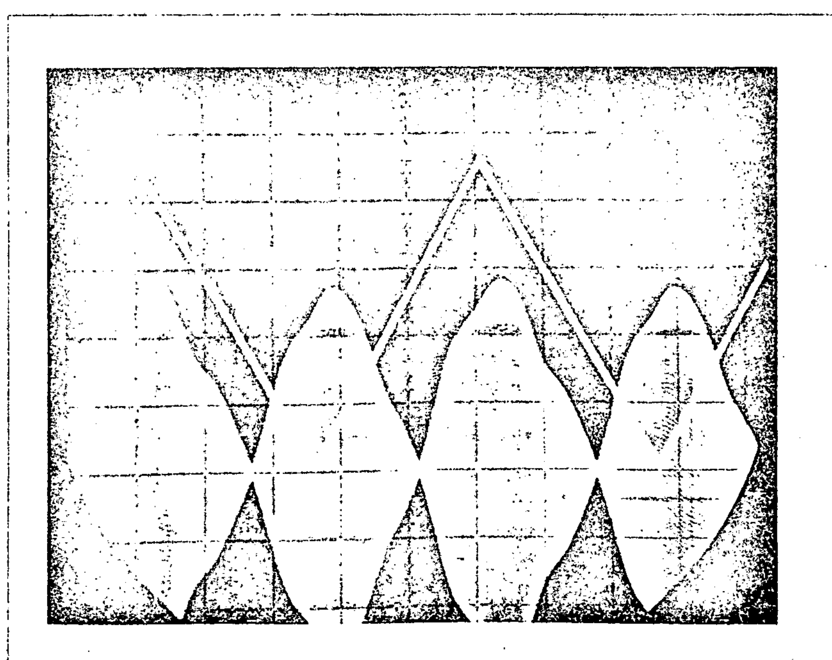


SWEEP TIME = 100/MS/CM →

2000 P.S.I.

TRIGGER TIME = .001/SEC.

NO FAIL



B

GAIN = 40 RAD.

.0396 COMPARATOR O'LAP

Form 310-01

BERTEA CORPORATION IRVINE · CALIFORNIA

| PAGE 87 | DOCUMENT NO. TEST 17 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I. LEE JET (18T-0-010000-0808 INSTALLED IN THE TIME DELAY VALVE)

HARD OVER SIGNAL AT THE -3 SERVO (CHAN "B")

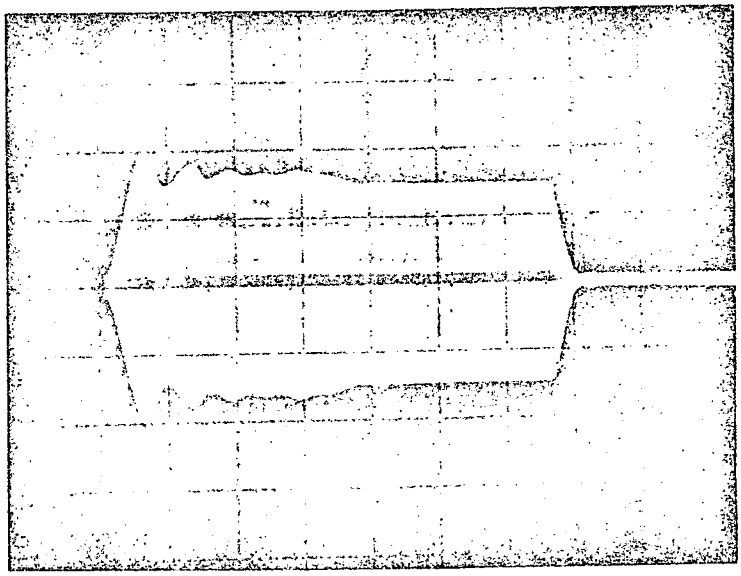
6 CM = 0.3" STROKE FROM N AT ACTUATOR

0.3 IN

10 V.D.C. (10 MA) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT, & SWITCH

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

FAILED & ACTIVATED CHANNEL "C"

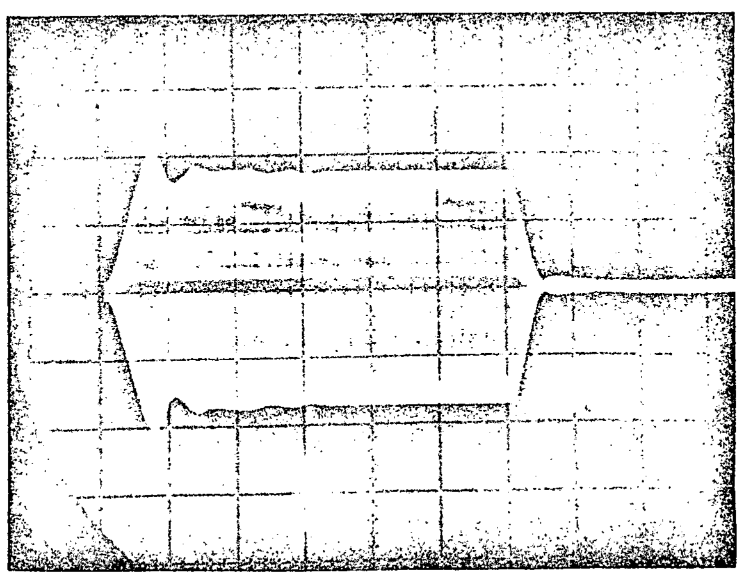


SWEEP TIME = .1 SEC./CM

2000 P.S.I.

HARD OVER SIGNAL AT -3 SERVO (CHAN "B")

FAILED & ACTIVATED CHANNEL "C"



B

TRIGGER

GAIN = 40 RAD/SEC .0396 COMPARATOR O' LAP

Form 310-01

BERTEA / CORPORATION
IRVINE · CALIFORNIA

| PAGE 88 | DOCUMENT NO. TEST 17 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

LEE JET (187-0-010000-0808 INSTALLED IN THE TIME DELAY VALVE)

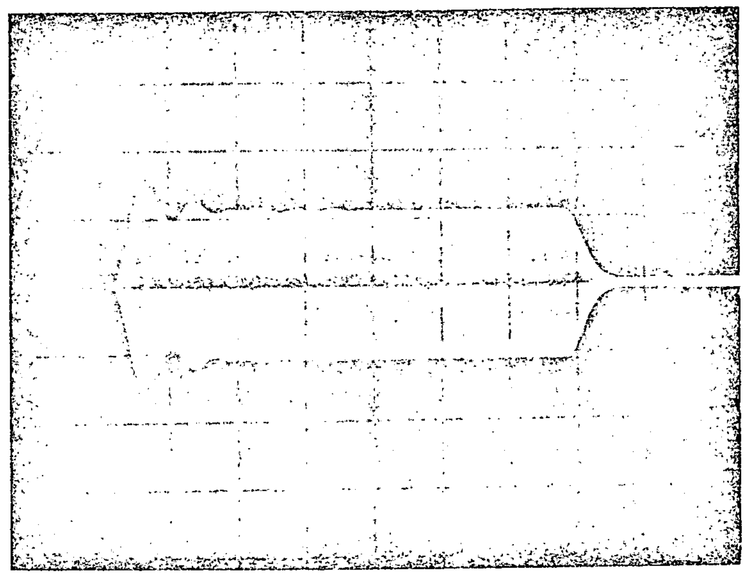
HARD OVER SIGNAL AT THE -9 SERVO (CHAN "B")

6 CM = 0.3" STROKE FROM N/L AT ACTUATOR

0.3 IN.

10 V.D.C. (10 MA) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

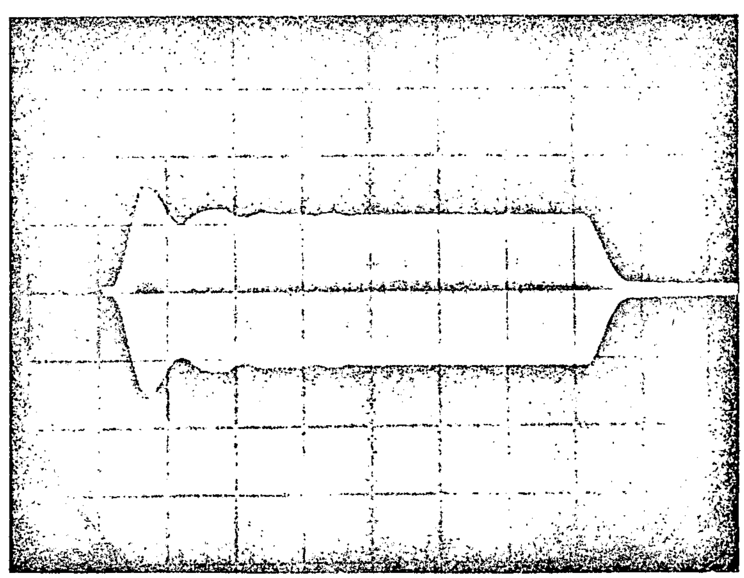


FAILED & ACTIVATED CHANNEL "C"

SWEEP TIME = .1 SEC/CM

2000 P.S.I.

HARD OVER SIGNAL AT THE -9 SERVO (CHAN "B")



FAILED & ACTIVATED CHANNEL "C"

B

TRIGGER

GAIN = 40 RAD./SEC

.0396 COMPARATOR O'LAP

Form 310-01

TITLE PASSIVE FAILURE (I INPUT TO AMPLIFIER @ 2 Hz)

3000 P.S.I.  LEE JET  187-0-010000-0808 INSTALLED IN THE TIME DELAY VALVE

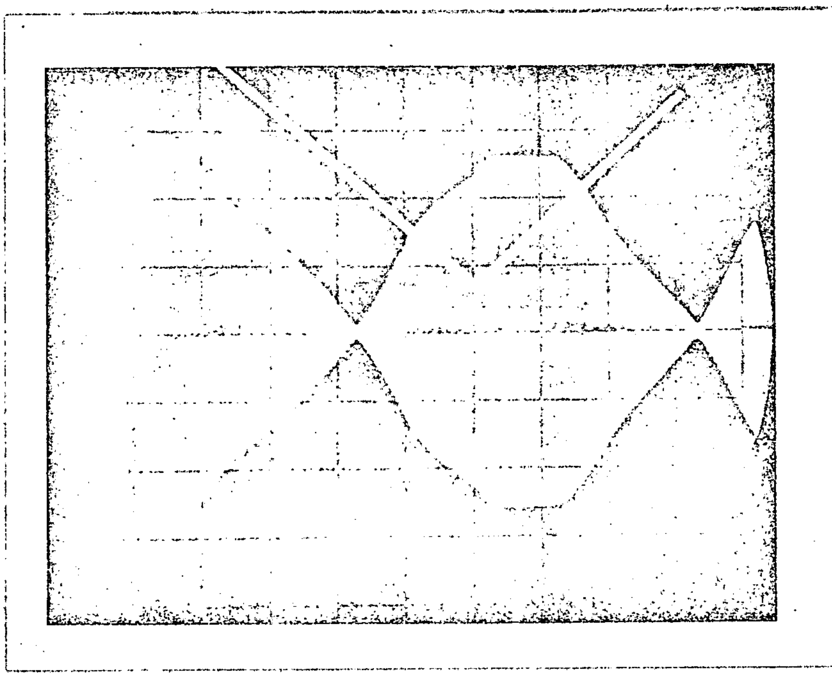
E.H. VALVE TRIGGERED OPEN TO THE -3 SERVO CHANNEL "B"

6 CM = .375 STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

THE UPPER TRACE DISPLAYS THE INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

THE LOWER TRACE DISPLAYS THE ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL
THE ACTUATOR OUTPUT SHOWS A DECREASE IN AMPLITUDE

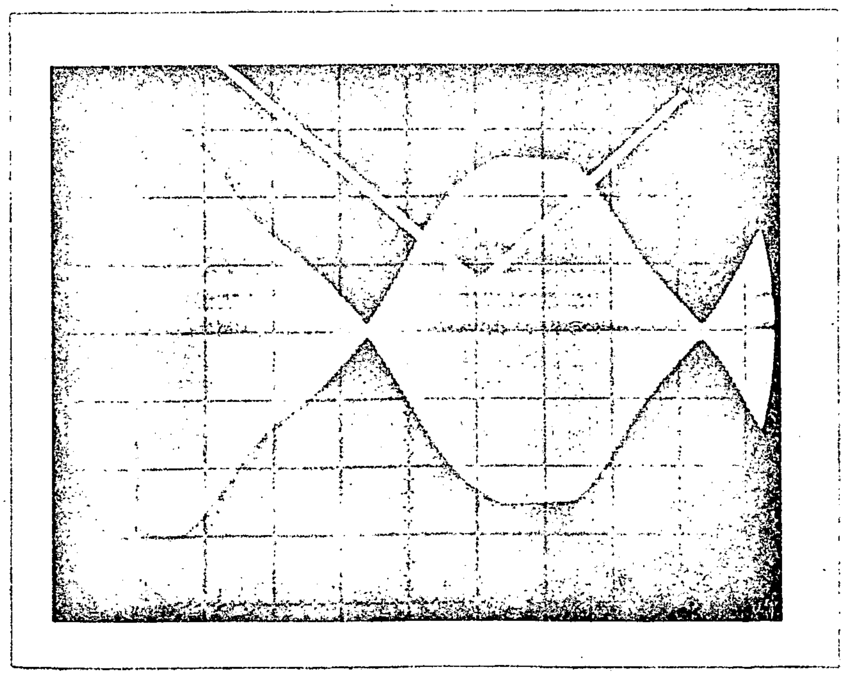


SWEEP TIME = 50 MS/CM

2000 P.S.I.

TRIGGER TIME = .001/SEC.

NO FAIL



(B)

GAIN = 40 RAD./SEC
.0396 COMPARATOR O'LAP

BERTEA CORPORATION IRVINE · CALIFORNIA

| PAGE 90 | DOCUMENT NO. TEST 17 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE PASSIVE FAILURE (1 INPUT TO AMPLIFIER @ 2 Hz)

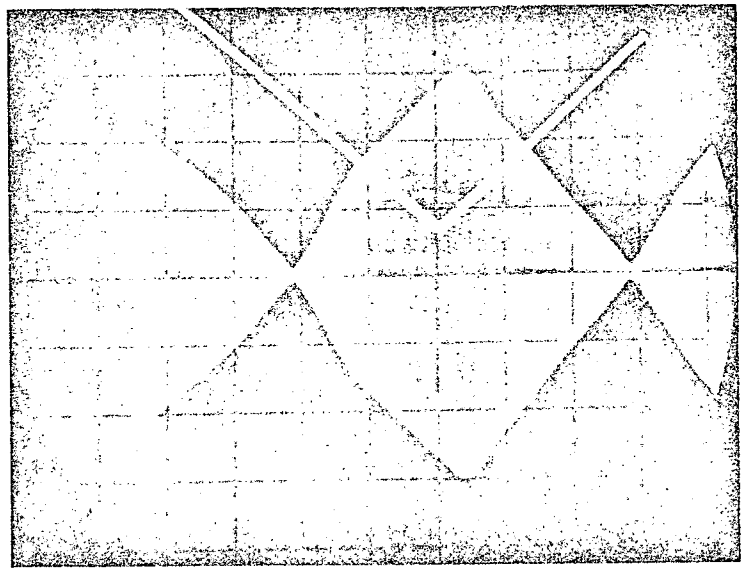
3000 P.S.I. LEE JET JBT-0-010000-0808 INSTALED IN THE TIME DELAY VALVE.

E.H. VALVE TRIGGERED TO OPEN THE -9 SERVO "CHANNEL "B""

6 CM = .375 STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

THE UPPER TRACE DISPLAYS THE INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

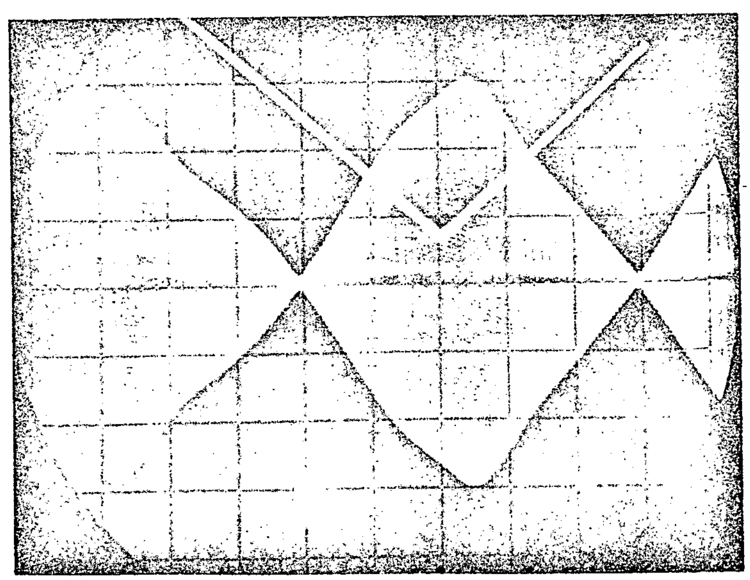
THE LOWER TRACE DISPLAYS THE ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)



NO FAIL

SWEEP TIME = 50 MS/CM

3000 P.S.I. TRIGGER TIME = .001/SEC.



NO FAIL

B

GAIN = 40 RAD/SEC
.0396 COMPARATOR O'LAP

BERTEA CORPORATION IRVINE · CALIFORNIA

| PAGE 91 | TEST 17 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE SOFT FAILURE (∿ INPUT TO THE AMPLIFIER @ 2 Hz)

3000 P.S.I.

LEE JET 187-0-0100000-0808 INSTALLED IN THE TIME DELAY VALVE.

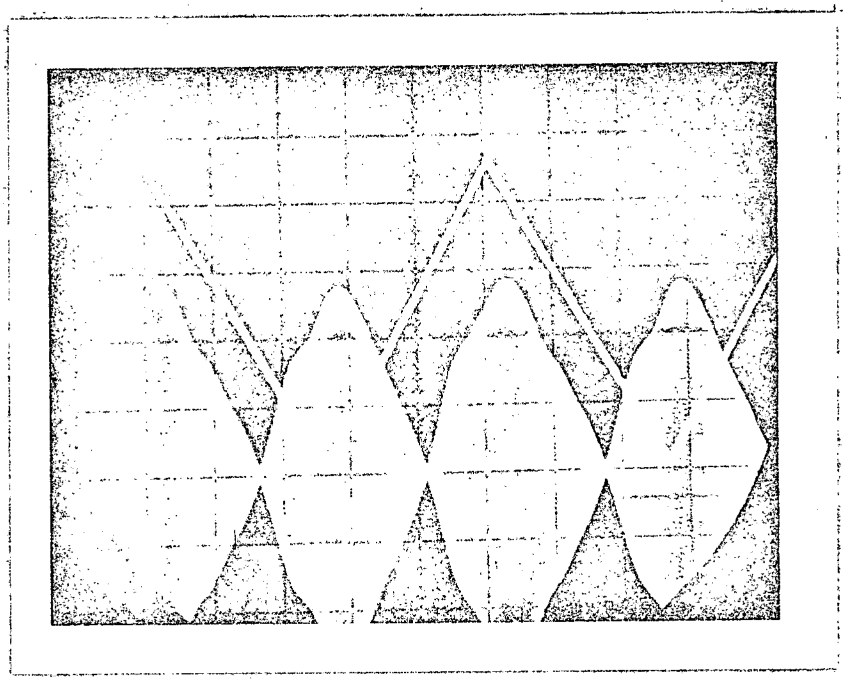
E.H. VALVE TRIGGERED TO HALF GAIN AT THE -3 SERVO CHANNEL "B"

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

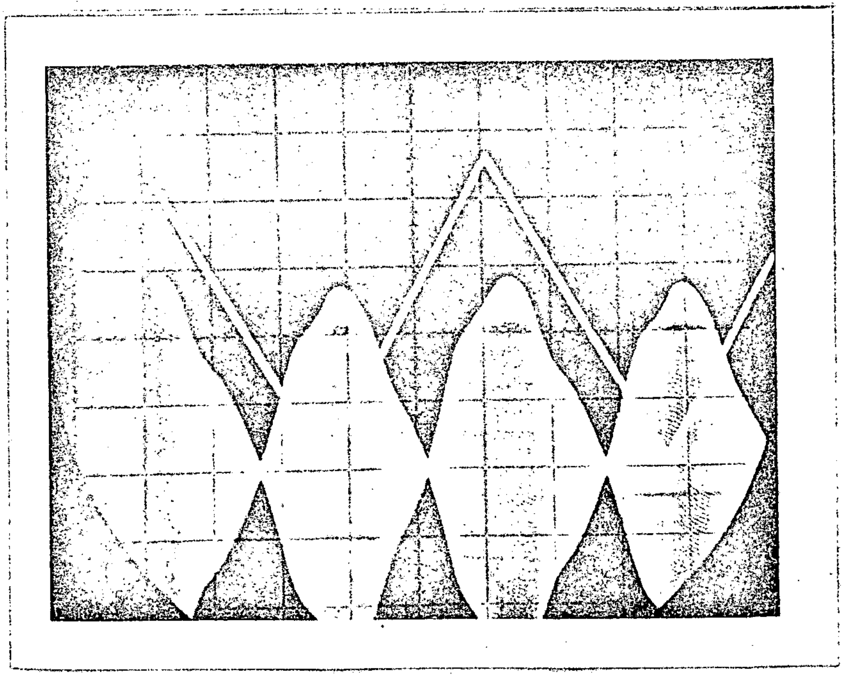
NO FAIL



→ SWEEP TIME - 100/MS/CM ←

2000 P.S.I.

TRIGGER TIME = .001 SEC.



NO FAIL

B

GAIN = 40 RAD.

.0396 COMPARATOR O'LAP

Form 310-01

BERTEA CORPORATION
IRVINE • CALIFORNIA

| PAGE 92 | TEST 17 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE SOFT FAILURE (1 INPUT TO THE AMPLIFIER @ 2 Hz)

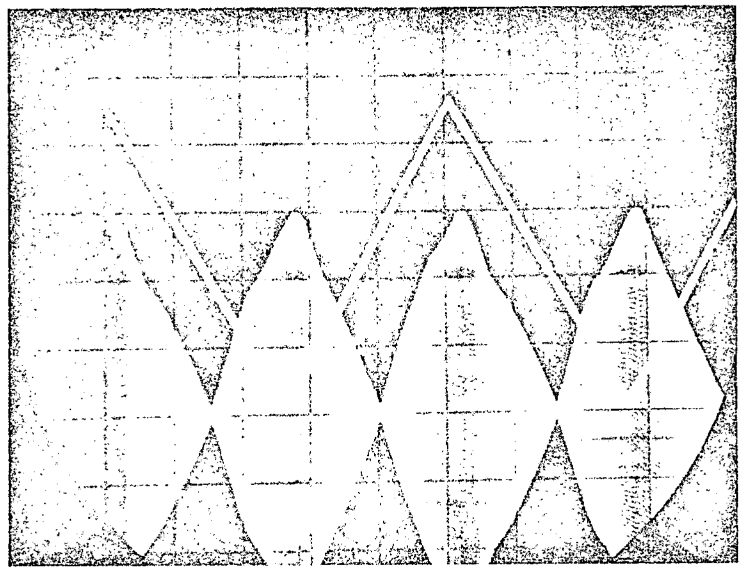
3000 P.S.I. LEE JET 187-0-010000-0808 INSTALED IN THE TIME DELAY VALVE

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -9 SERVO CHANNEL "B"

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

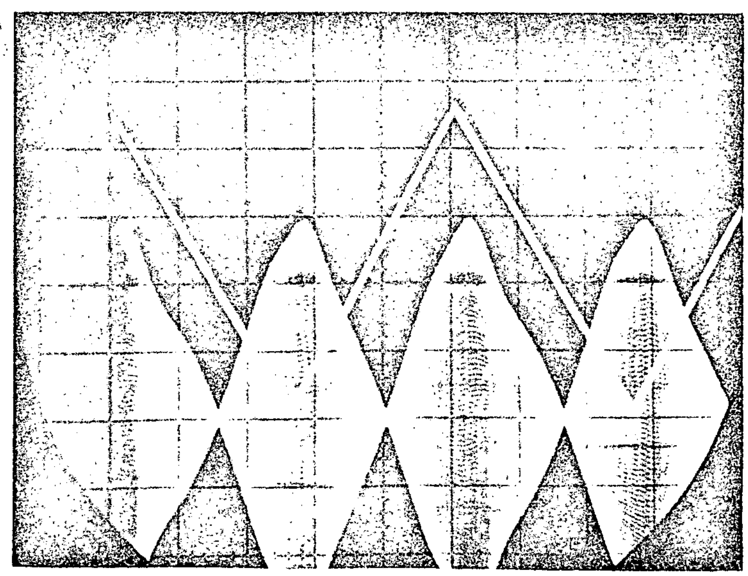
LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)



NO FAIL

SWEEP TIME - 100/MS/CM

2000 P.S.I. TRIGGER TIME = .001/SEC.



NO FAIL

B

GAIN = 40 RAD.
.0396 COMPARATOR O'LAP

Form 310-01

BERTEA CORPORATION IRVINE · CALIFORNIA

| PAGE 93 | TEST 18 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I. LEE JET 181-0-010.000-0808 INSTALLED IN THE TIME DELAY VALVE

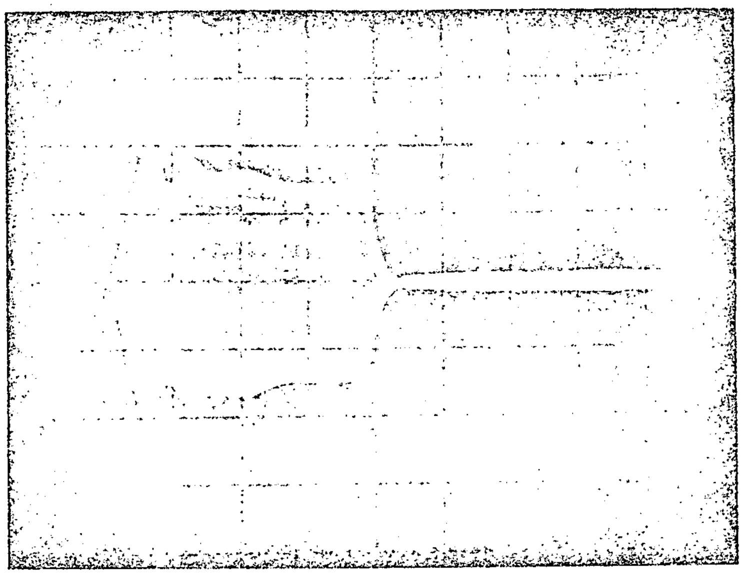
HARD OVER SIGNAL @ -3 SERVO (CHAN. "B")

6 CM = .3" STROKE FROM NEUTRAL AT THE ACTUATOR

10 V.D.C. (10 MA) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT, & SWITCH

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

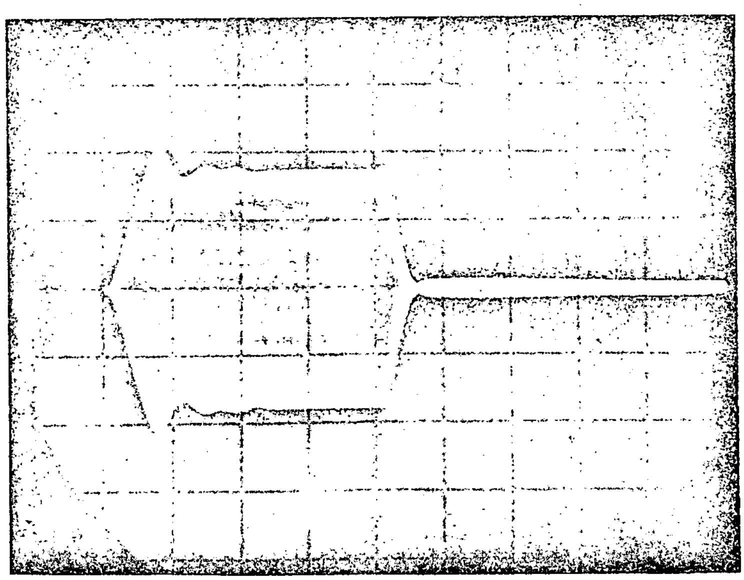
0.3 IN.



FAILED & ACTIVATED CHANNEL "C"

SWEEP TIME = 100 MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "C"

B

SWEEP TIME = 100 MS/CM

GAIN = 40 RAD./SEC

.0079 COMPARATOR O'LAP

Form 310-01

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I. LEE JET 187-0-10000-0808 INSTALLED IN THE TIME DELAY VALVE

HARD OVER SIGNAL @ -9 SERVO (CHAN. "B"

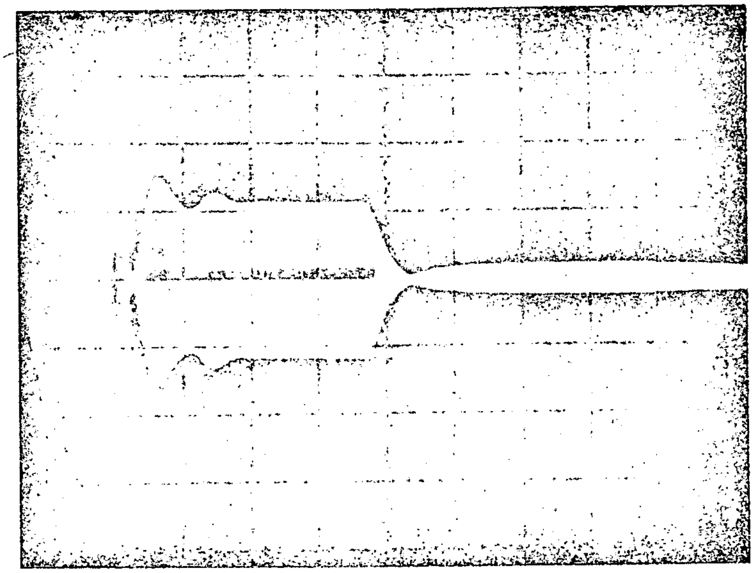
6 CM = .3" STROKE FROM NEUTRAL AT THE ACTUATOR

0.3 IN.

10 V.D.C. (10 MA.) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT, & SWITCH

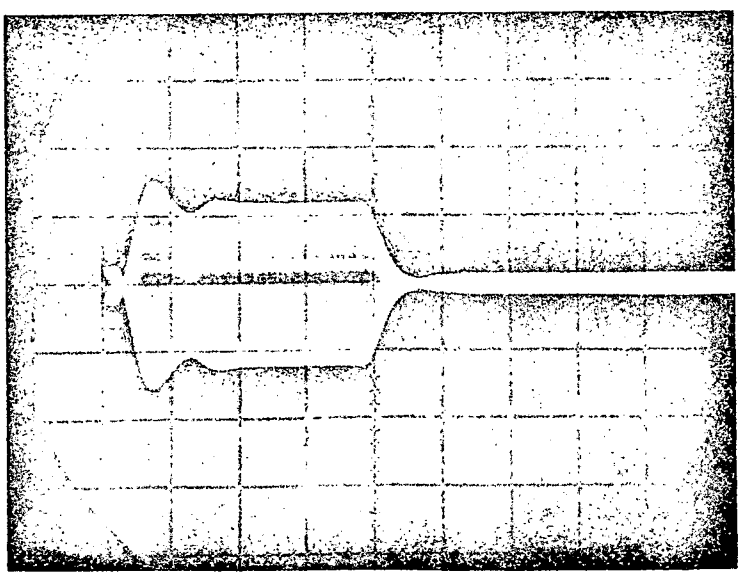
SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

FAILED & ACTIVATED CHANNEL "C"



SWEEP TIME - 100 MS/CM

2000 P.S.I.



FAILED & ACTIVATED CHANNEL "C"

B

GAIN = 40 RAD./SEC

SWEEP TIME - 100 MS/CM
.0079 COMPARATOR O'LAP

BERTEA CORPORATION IRVINE · CALIFORNIA

| PAGE 95 | TEST 18 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE PASSIVE FAILURE (∿ INPUT TO AMPLIFIER @ 2 Hz)

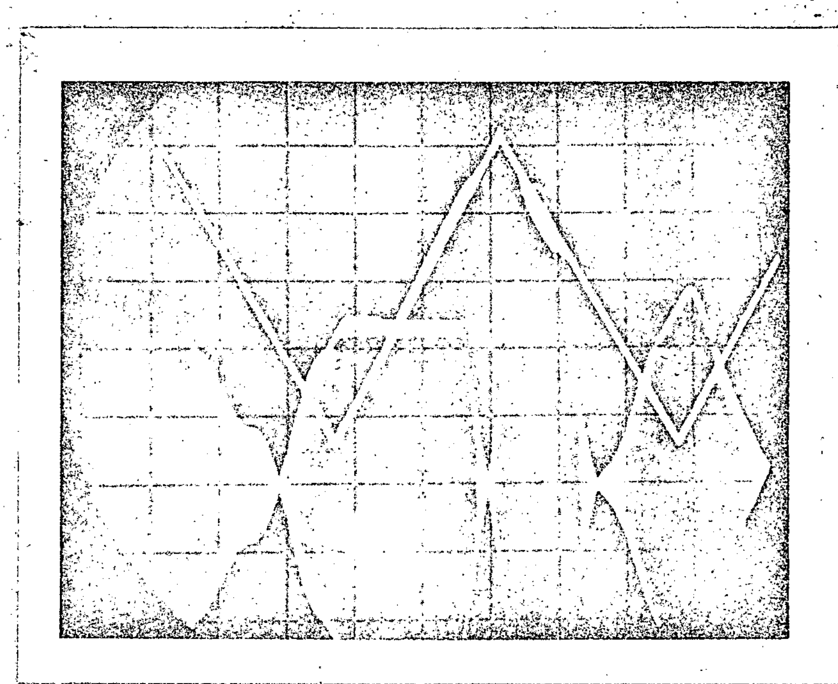
3000 P.S.I. LEE JET 187-0-010000-0808 INSTALLED IN THE TIME DELAY VALVE

E.H. VALVE TRIGGERED OPEN TO THE -3 SERVO CHANNEL "B"

6 CM = .375 STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS

THE UPPER TRACE DISPLAYS THE INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

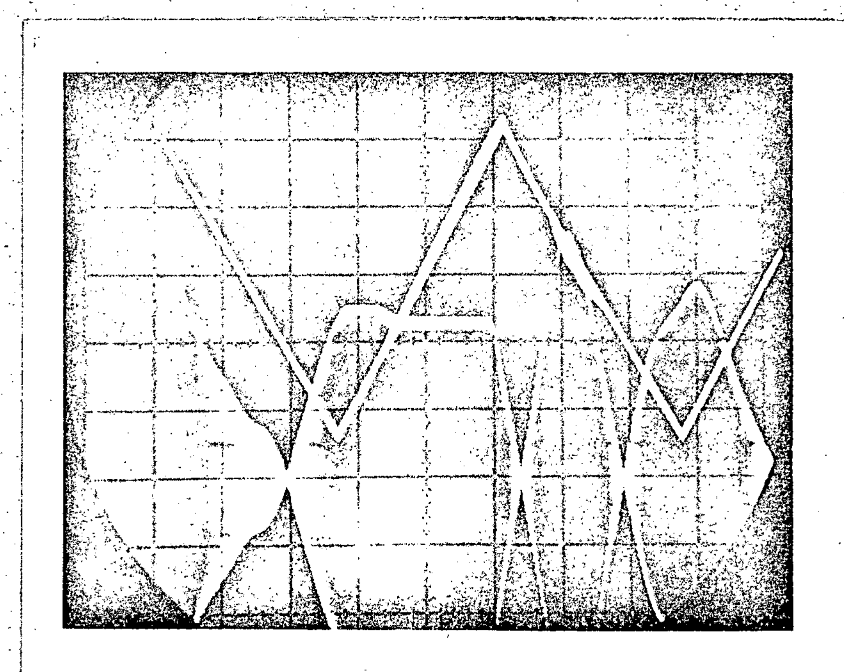
THE LOWER TRACE DISPLAYS THE ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)



FAILED & ACTIVATED CHANNEL "C"

SWEEP TIME - 100 MS/CM

2000 P.S.I. TRIGGER TIME = .001/SEC.



FAILED & ACTIVATED CHANNEL "C"

B

SWEEP TIME - 100 MS/CM

GAIN = 40 RAD./SEC .0079 COMPARATOR O'LAP

BERTEA CORPORATION IRVINE · CALIFORNIA

| PAGE 96 | TEST 18 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE PASSIVE FAILURE (~ INPUT TO AMPLIFIER @ 2 Hz)

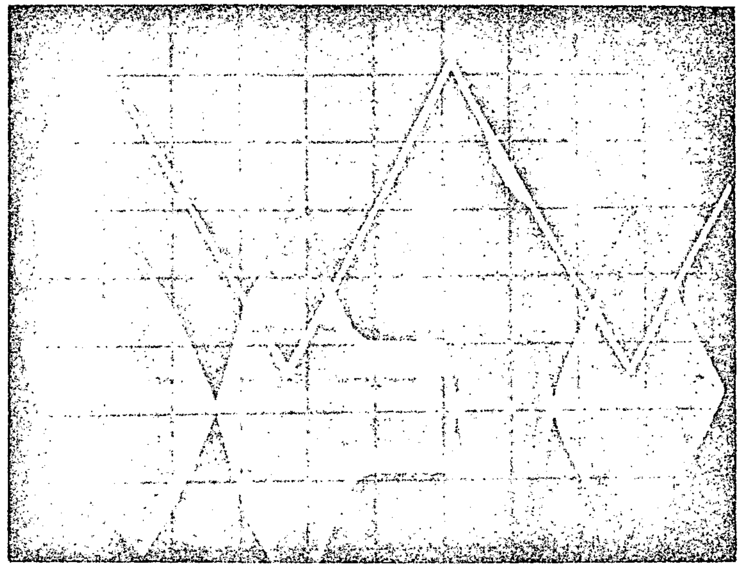
3000 P.S.I.    LEE JET 187-0-010000-0808 INSTALLED IN THE TIME DELAY VALVE

E.H. VALVE TRIGGERED OPEN TO THE -9 SERVO CHANNEL "B"

6 CM = .375 STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS

THE UPPER TRACE DISPLAYS THE INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

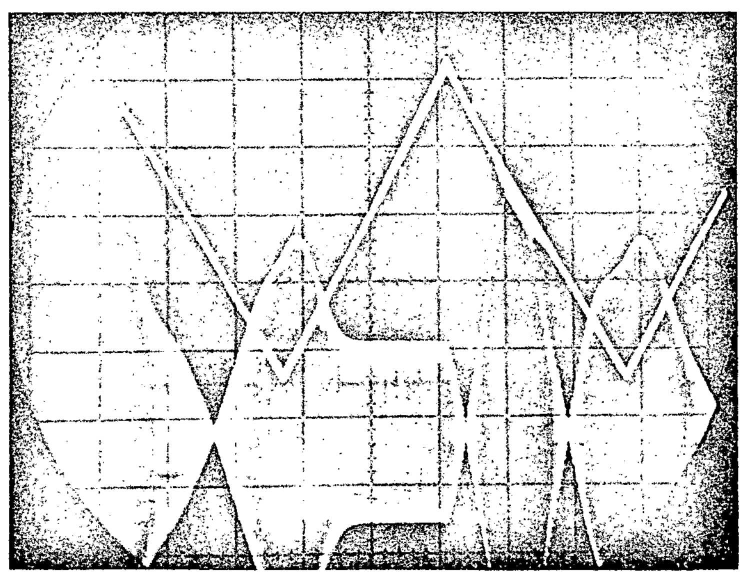
THE LOWER TRACE DISPLAYS THE ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)



FAILED & ACTIVATED CHANNEL "C"

SWEEP TIME - 100 MS/CM

2000 P.S.I.    TRIGGER TIME = .001/SEC.



FAILED & ACTIVATED CHANNEL "C"

B

SWEEP TIME - 100 MS/CM

GAIN = 40 RAD./SEC    .0079 COMPARATOR O'LAP

Form 310-01

BERTEA CORPORATION IRVINE • CALIFORNIA

| PAGE 97 | TEST 18 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE SOFT FAILURE (1 INPUT TO AMPLIFIER @ 2 Hz)

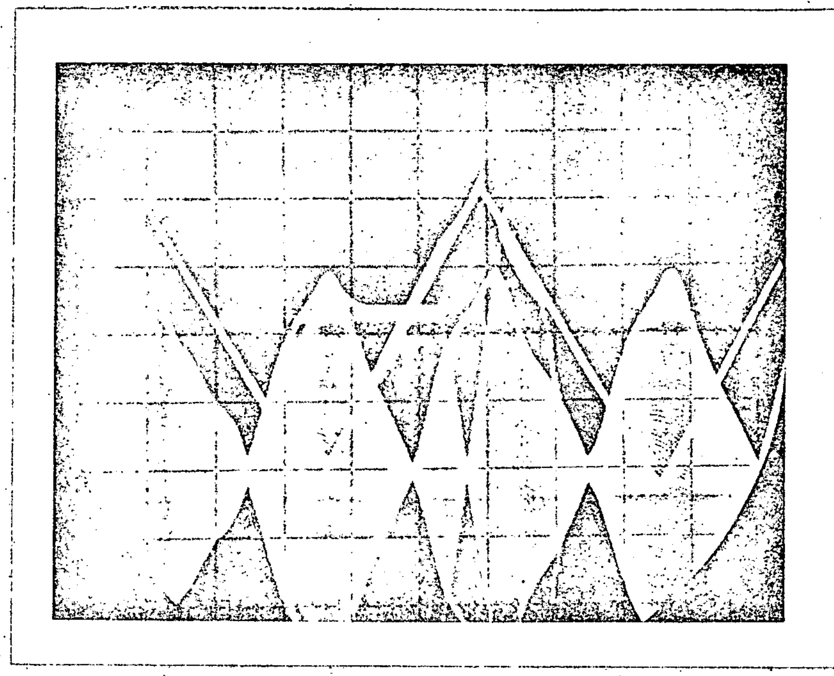
3000 P.S.I. LEE JET 187-0-010000-0808 INSTALLED IN THE TIME DELAY VALVE

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -3 SERVO CHANNEL "B"

6 CM = .375 STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS

THE UPPER TRACE DISPLAYS THE INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

THE LOWER TRACE DISPLAYS THE ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

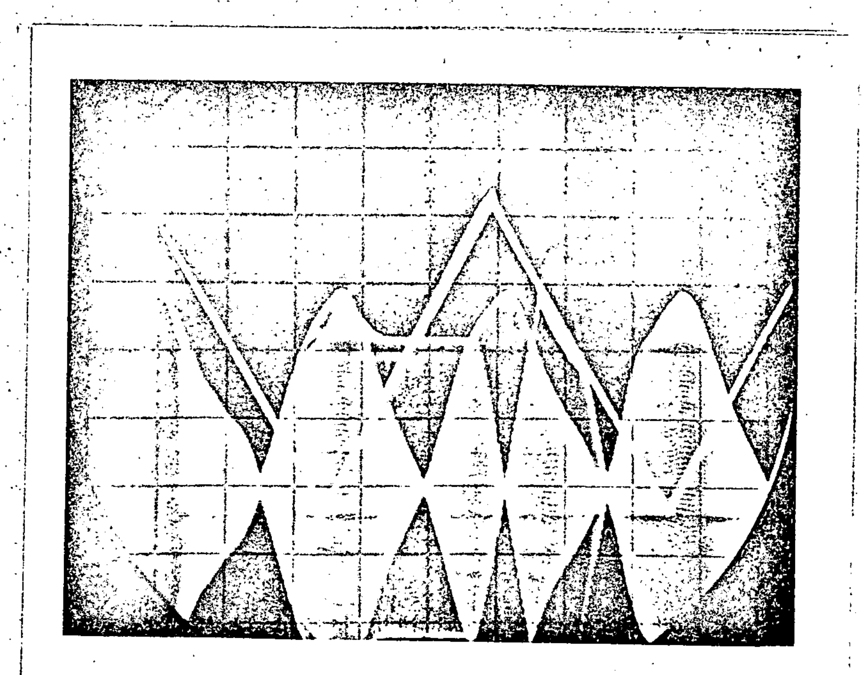


FAILED & ACTIVATED CHANNEL "C"

SWEEP TIME - 100/MS/CM

2000 P.S.I.

TRIGGER TIME = .001/SEC.



FAILED & ACTIVATED CHANNEL "C"

B

SWEEP TIME - 100/MS/CM

GAIN = 40 RAD.

.0079 COMPARATOR O'LAP

Form 310-01

BERTEA CORPORATION IRVINE · CALIFORNIA

| PAGE 98 | TEST 18 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE SOFT FAILURE (∿ INPUT TO AMPLIFIER @ 2 Hz)

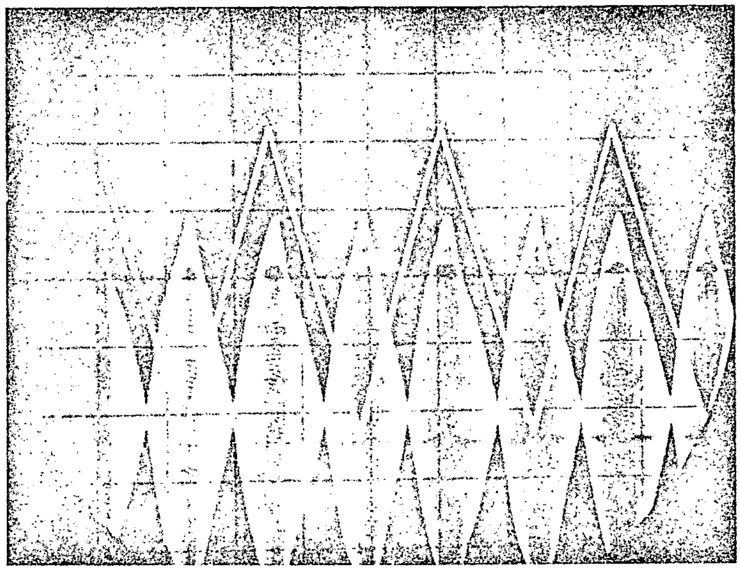
3000 P.S.I. LEE JET 187-0-010000-0808 INSTALLED IN THE TIME DELAY VALVE

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -9 SERVO CHANNEL "B"

6 CM = .375 STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS

THE UPPER TRACE DISPLAYS THE INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

THE LOWER TRACE DISPLAYS THE ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

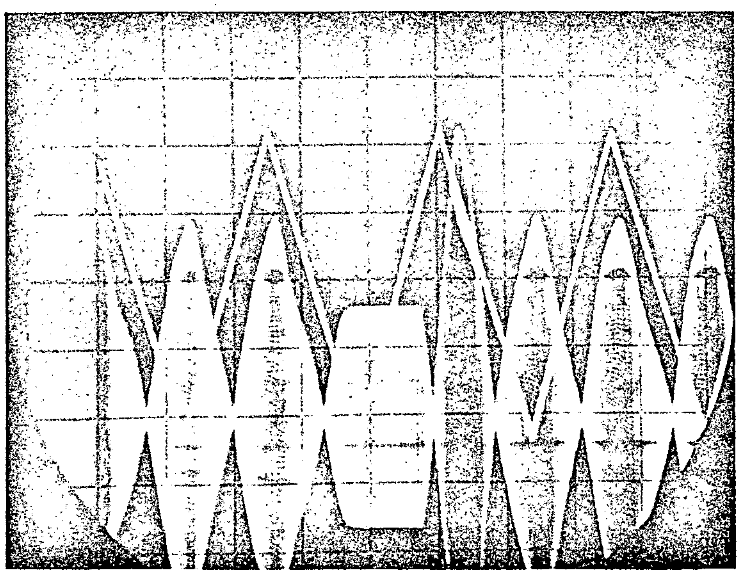


NO FAIL

SWEEP TIME - 200/MS/CM

2000 P.S.I.

TRIGGER TIME = .001/SEC.



FAILED & ACTIVATED CHANNEL "C"

B

SWEEP TIME - 200/MS/CM

GAIN = 40 RAD.

.0079 COMPARATOR O'LAP

Form 310-01

BERTEA CORPORATION
IRVINE · CALIFORNIA

| PAGE 99 | TEST 19 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

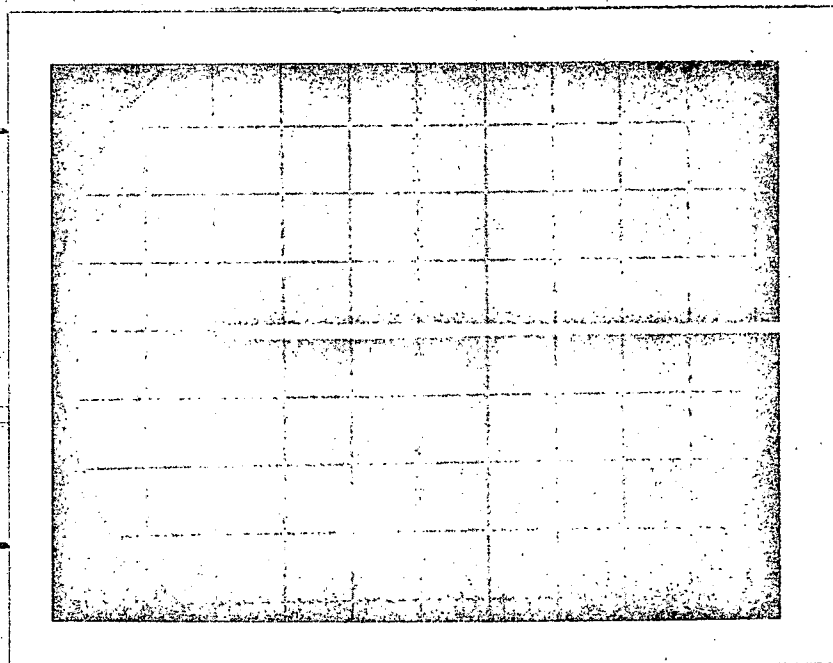
HARD OVER SIGNAL AT THE -3 SERVO (CHANNEL "C")

6 CM = .300" STROKE FROM NEUTRAL AT THE ACTUATOR

10 V.D.C. (10 MA.) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH.

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

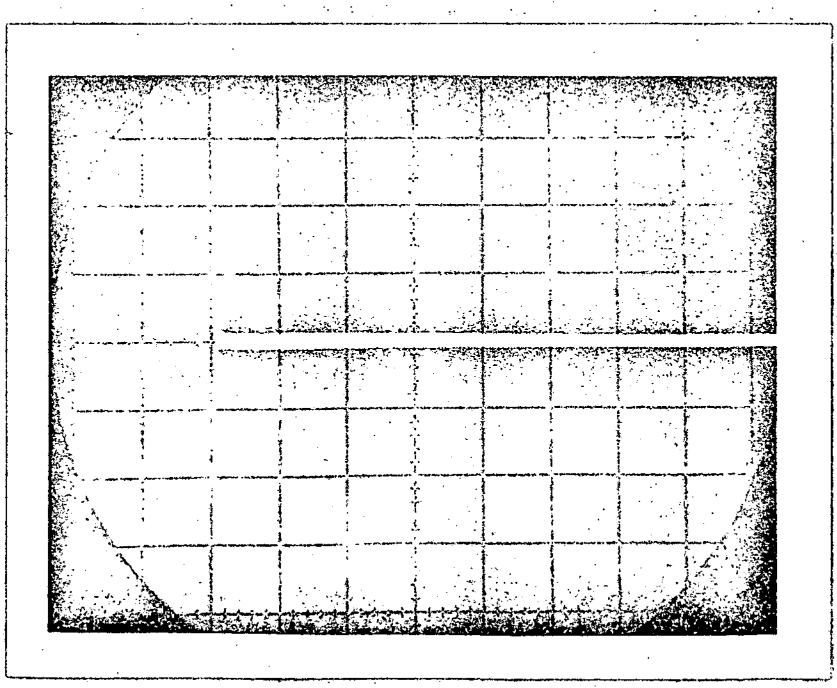
0.3 IN



NO FAIL

SWEEP TIME - 50 MS/CM

2000 P.S.I.



NO FAIL

C

SWEEP TIME - 50 MS/CM

GAIN = 40 RAD/SEC

.0162 COMPARATOR O LAP

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| PAGE 100 | TEST 19 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

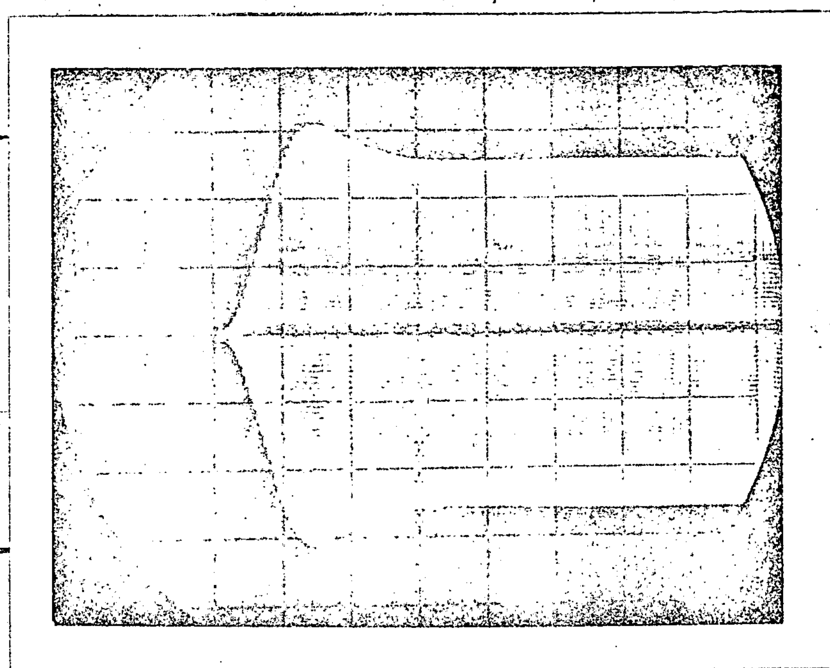
HARD OVER SIGNAL AT THE -1 SERVO (CHANNEL "C")

6 CM = .300" STROKE FROM NEUTRAL AT THE ACTUATOR

10 V.D.C. (10 MA.) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH.

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

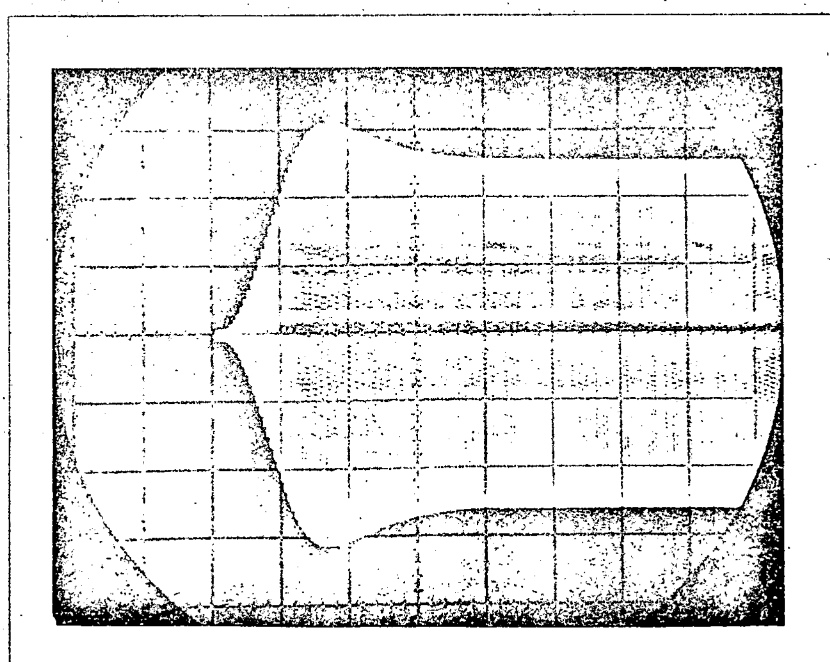
0.3 IN



NO FAIL

SWEEP TIME - 50 MS/CM

2000 P.S.I.



NO FAIL

(C)

SWEEP TIME - 50 MS/CM

GAIN = 40 RAD/SEC

.0162 COMPARATOR O LAP

BERTEA CORPORATION
IRVINE · CALIFORNIA

| PAGE 101 | TEST 19 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

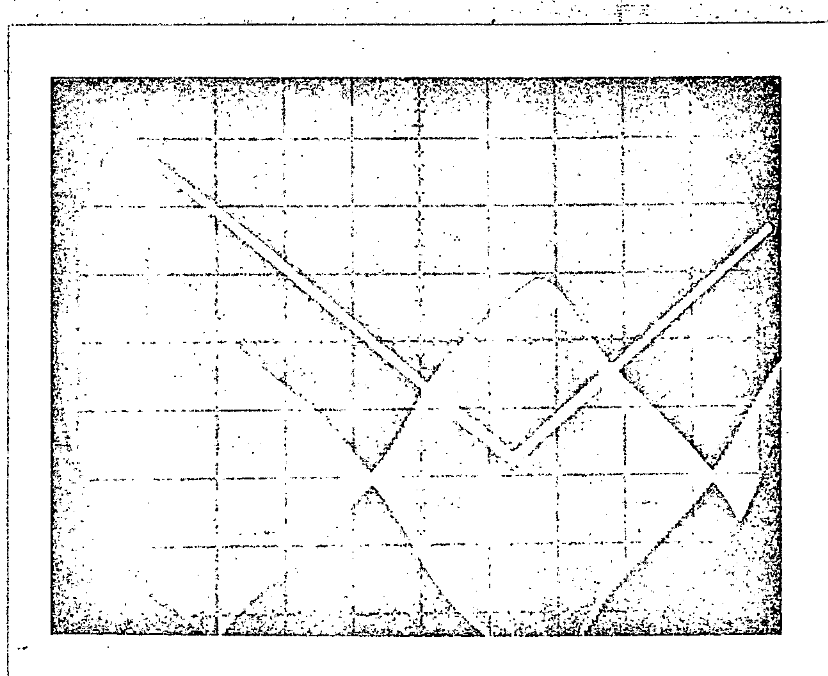
TITLE PASSIVE FAILURE (1 INPUT TO THE AMPLIFURE AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC

E.H. VALVE TRIGGERED OPEN TO THE – 5 SERVO (CHANNEL "C")

6 CM = .375" STROKE FROM N @ ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



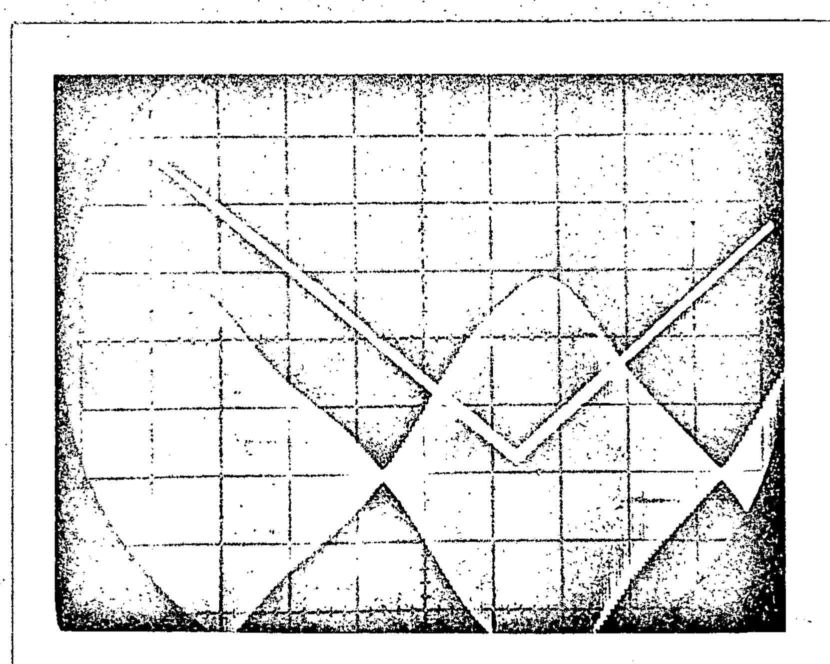
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL

SWEEP TIME - 50 /MS/CM

2000 P.S.I.



NO FAIL

SWEEP TIME - 50 /MS/CM

(C)

GAIN = 40 RAD.

.0162 COMPARATOR O'LAP

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| PAGE 102 | TEST 19 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE: PASSIVE FAILURE (1 INPUT TO THE AMPLIFURE AT 2 Hz)

3000 P.S.I.

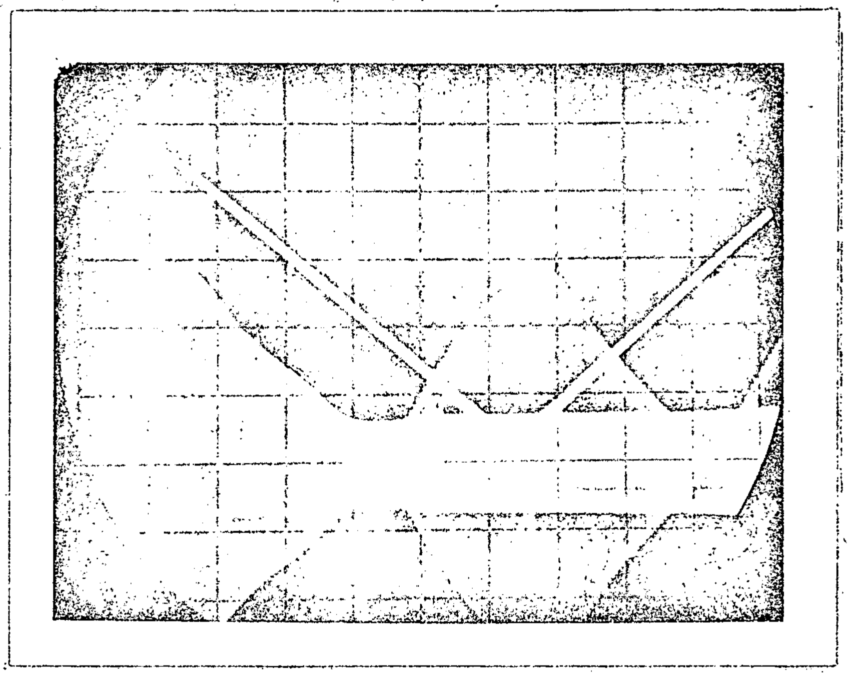
TRIGGER TIME = .001/SEC

E.H. VALVE TRIGGERED OPEN TO THE -1 SERVO (CHANNEL "C")

6 CM = .375" STROKE FROM ℄ @ ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.

UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

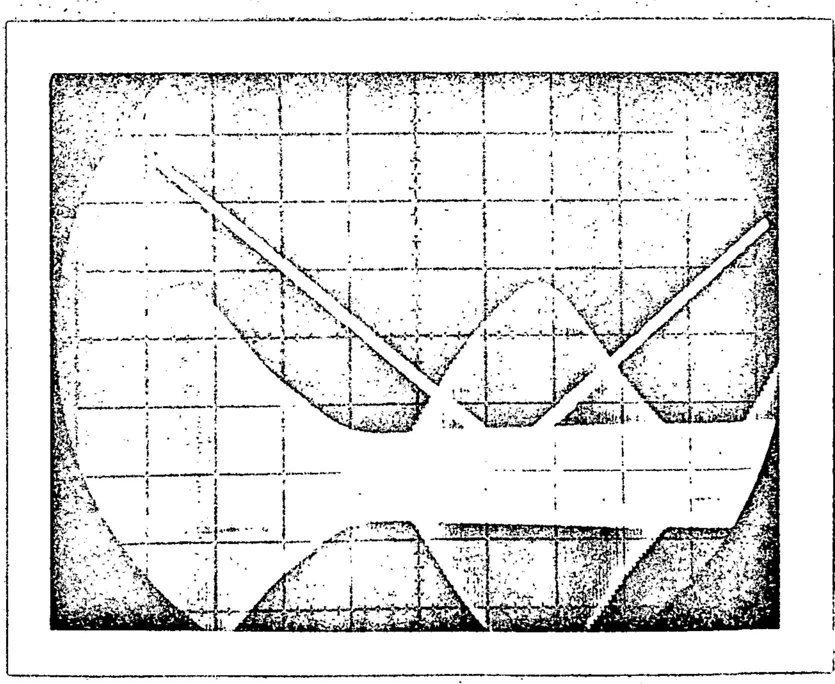
LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)



FAILED

SWEEP TIME - 50/MS/CM

2000 P.S.I.



FAILED

SWEEP TIME - 50 /MS/CM

©

GAIN = 40RAD.

.0162 COMPARATOR O'LAP

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| PAGE 103 | TEST 19 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

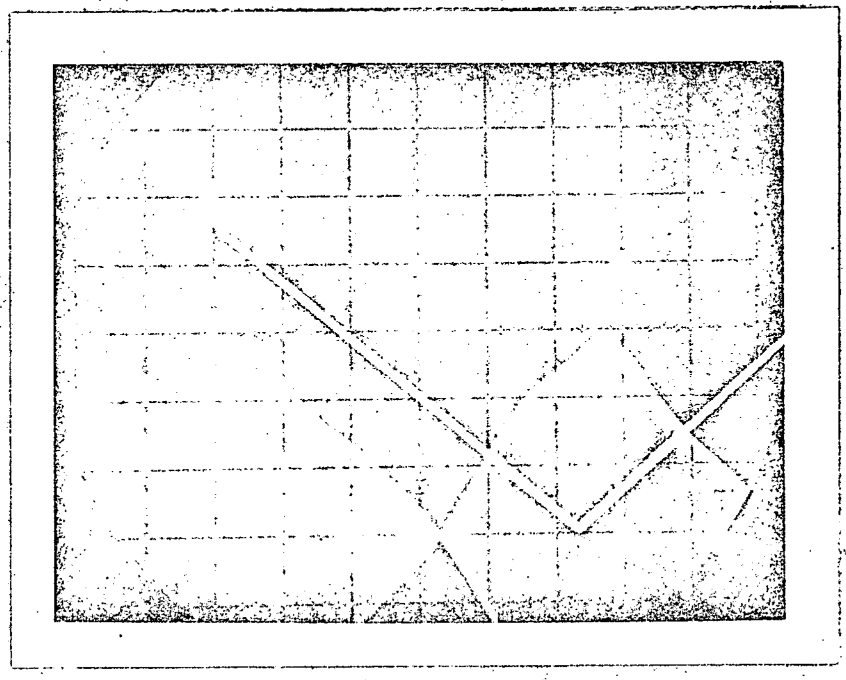
TITLE SOFT FAILURE (∿ INPUT TO AMPLIFIER AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -5 SERVO (CHANNEL "C")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



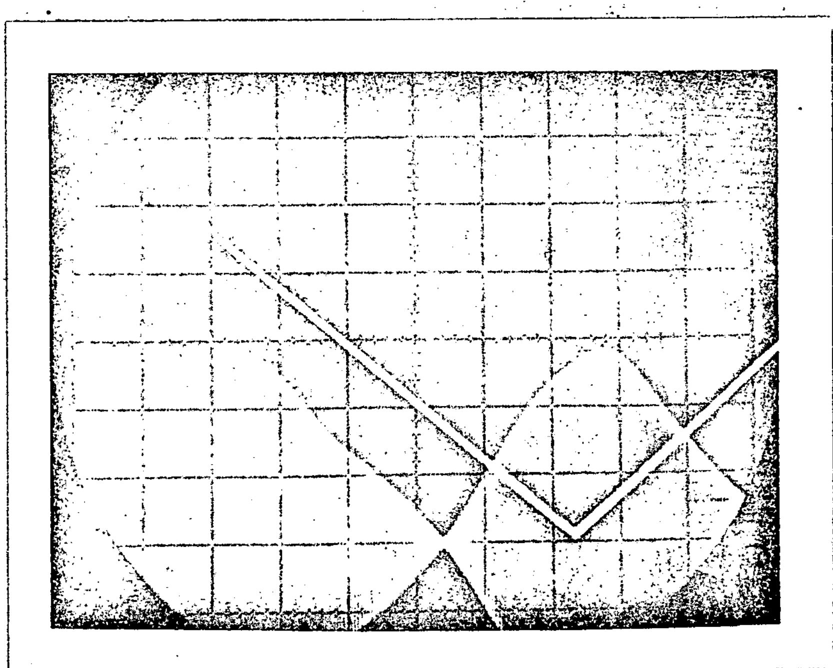
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL

SWEEP TIME - 50/MS/CM

2000 P.S.I.



NO FAIL

Ⓒ

SWEEP TIME - 50/MS/CM

GAIN = 40 RAD.

.0162 COMPARATOR O'LAP

BERTEA CORPORATION IRVINE · CALIFORNIA

| PAGE 104 | TEST 19 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

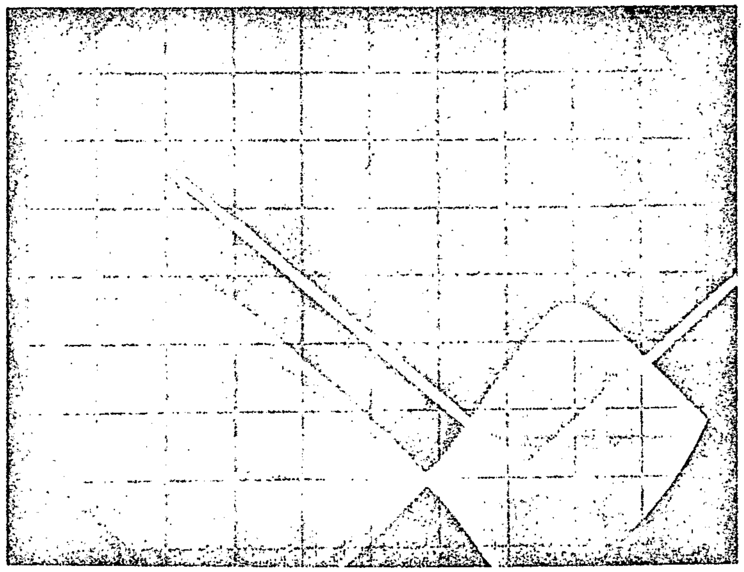
TITLE SOFT FAILURE (1 INPUT TO AMPLIFIER AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -1 SERVO (CHANNEL "C")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



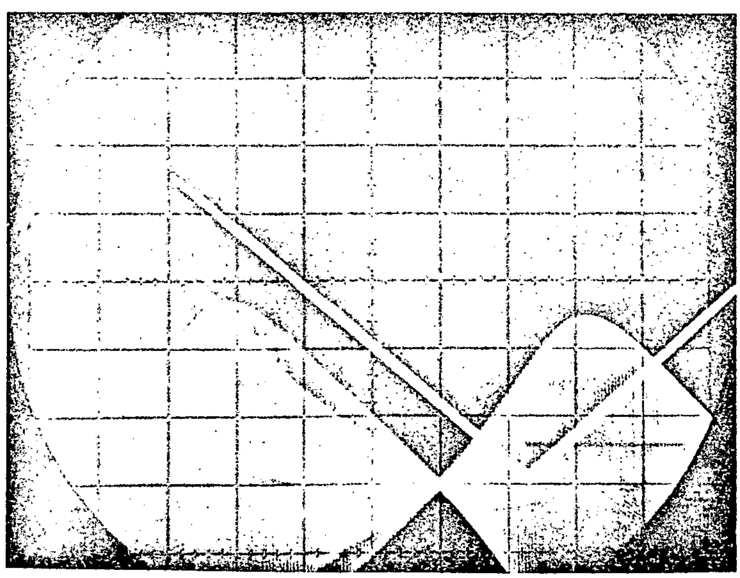
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL

SWEEP TIME - 50/MS/CM

2000 P.S.I.



NO FAIL

(C)

SWEEP TIME - 50/MS/CM

GAIN = 40 RAD.

.0162 COMPARATOR O'LAP

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

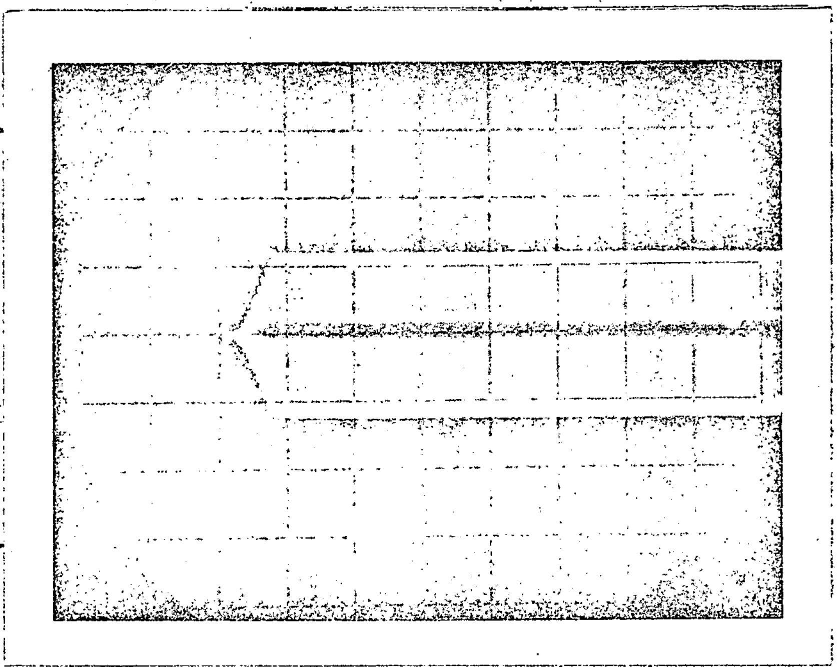
HARD OVER SIGNAL AT THE -1 SERVO (CHANNEL "C")

6 CM = .300" STROKE FROM NEUTRAL AT THE ACTUATOR

10 V.D.C. (10 MA.) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT. & SWITCH.

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

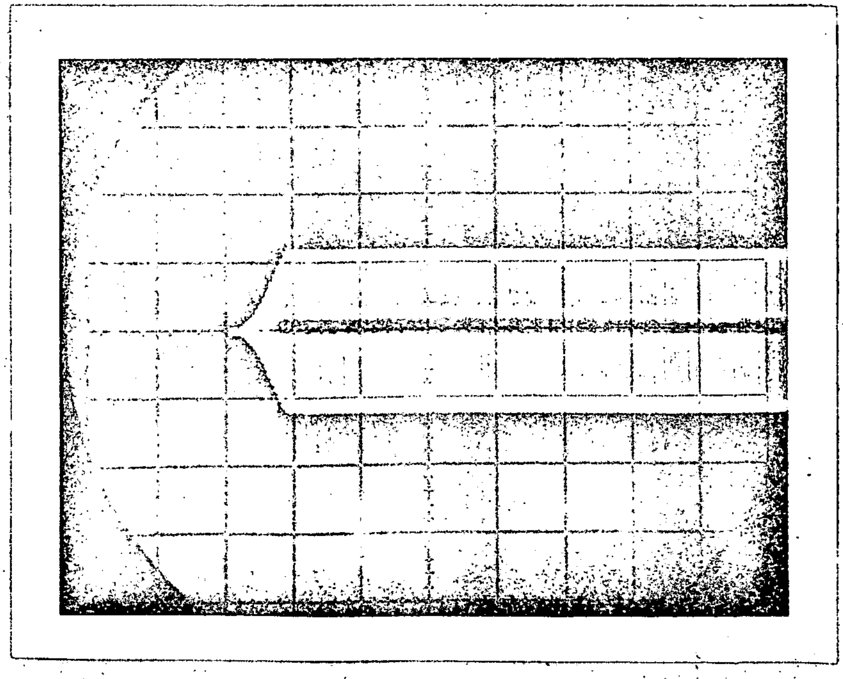
0.3 IN.



NO FAIL

SWEEP TIME - 50 MS/CM

2000 P.S.I.



NO FAIL

SWEEP TIME - 50 MS/CM

GAIN = 20 RAD/SEC

.0162 COMPARATOR O LAP

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

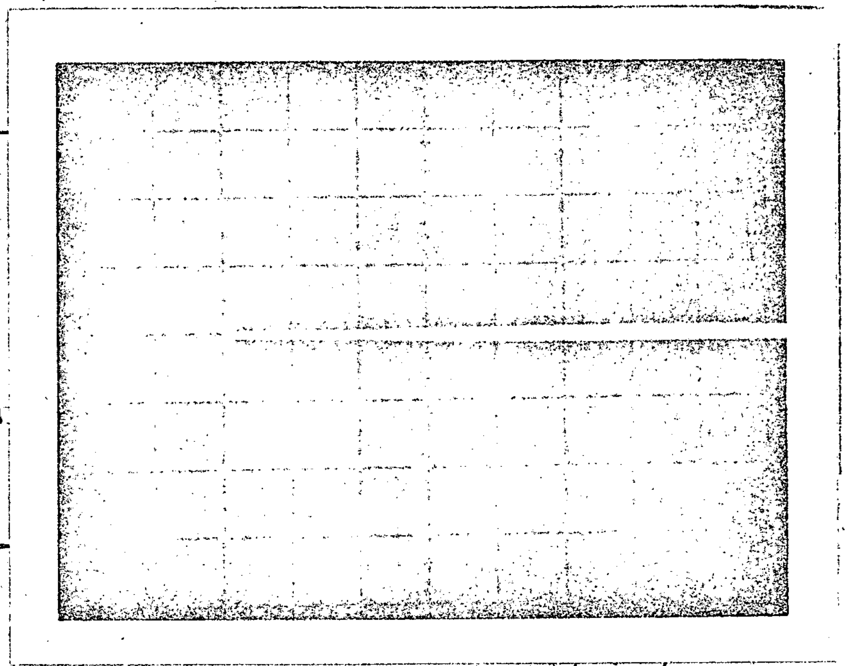
HARD OVER SIGNAL AT THE -3 SERVO (CHANNEL "C")

6 CM = .300" STROKE FROM NEUTRAL AT THE ACTUATOR

10 V.D.C. (10 MA.) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH.

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

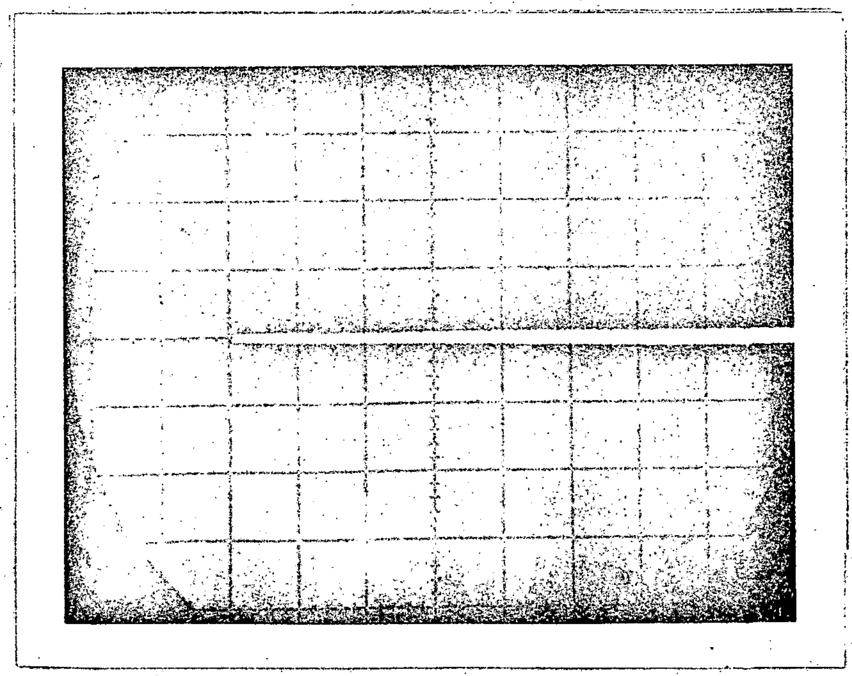
0.3 IN



NO FAIL

SWEEP TIME - 50 MS/CM

2000 P.S.I.



NO FAIL

SWEEP TIME - 50 MS/CM

GAIN = 20 RAD/SEC

.0162 COMPARATOR O'LAP

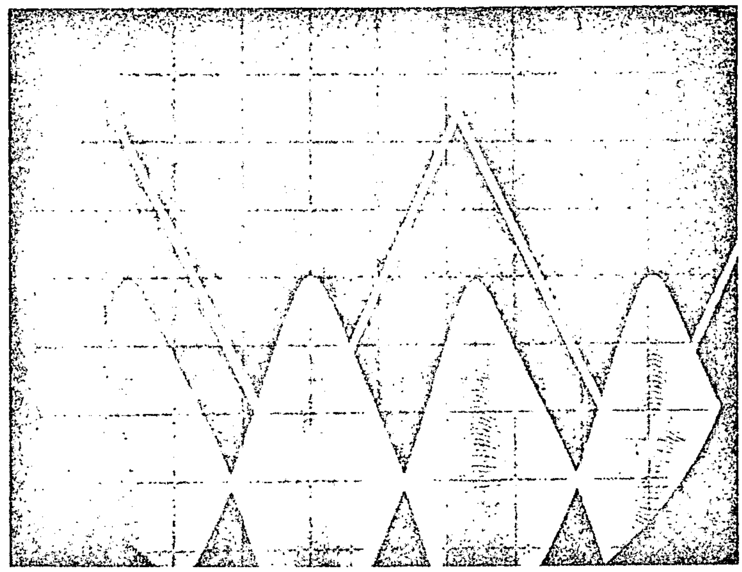
TITLE PASSIVE FAILURE (1 INPUT TO THE AMPLIFURE AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC

E.H. VALVE TRIGGERED OPEN TO THE -5 SERVO (CHANNEL "C")

6 CM = .375" STROKE FROM ℄ @ ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



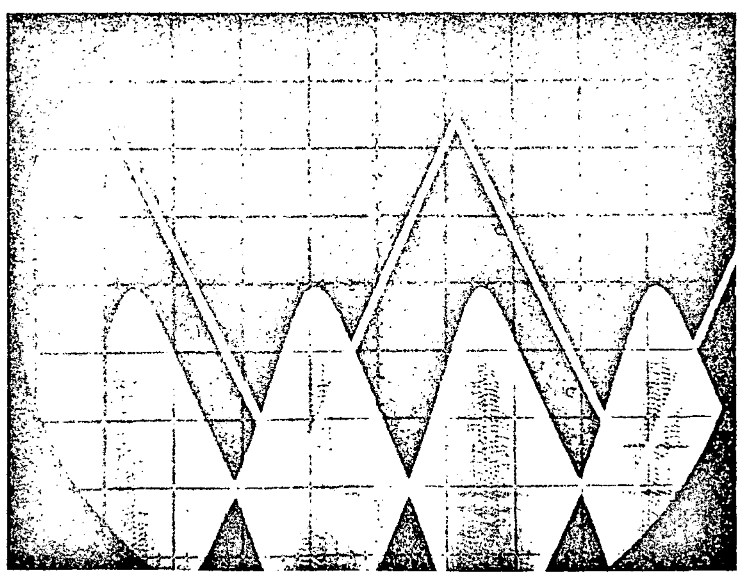
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL

SWEEP TIME - 100 MS/CM

2000 P.S.I.



NO FAIL

SWEEP TIME - 100 MS/CM

©

GAIN = 20 RAD./SEC

.0162 COMPARATOR O'LAP

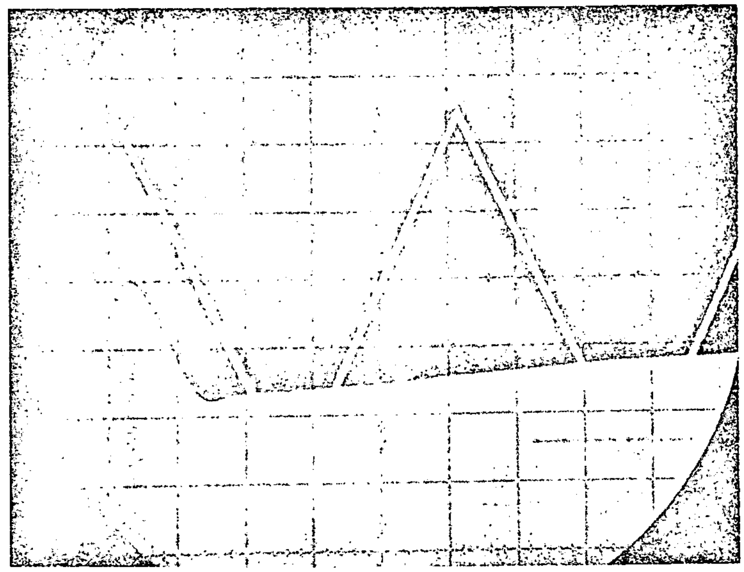
TITLE. PASSIVE FAILURE (1 INPUT TO THE AMPLIFURE AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC

E.H. VALVE TRIGGERED OPEN TO THE -1 SERVO (CHANNEL "C")

6 CM = .375" STROKE FROM ℄ @ ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



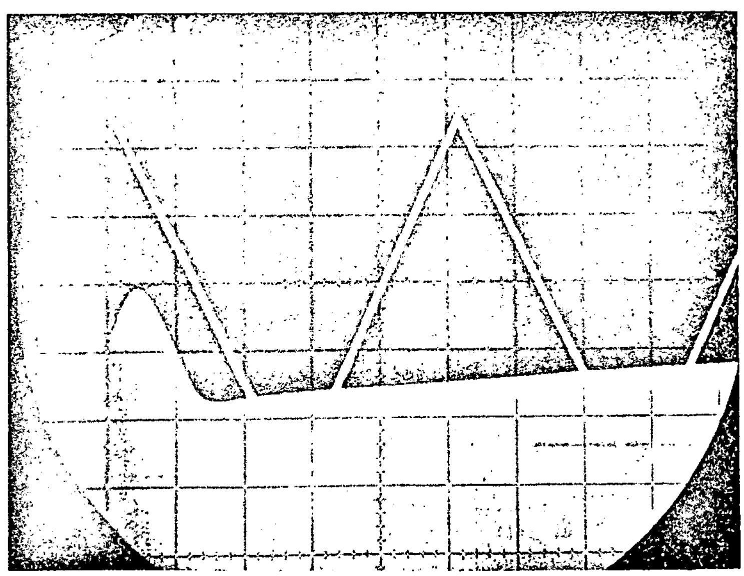
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

FAILED

SWEEP TIME - 100 MS/CM

2000 P.S.I.



FAILED

SWEEP TIME - 100 MS/CM

©

GAIN = 20 RAD./SEC

.0162 COMPARATOR O'LAP

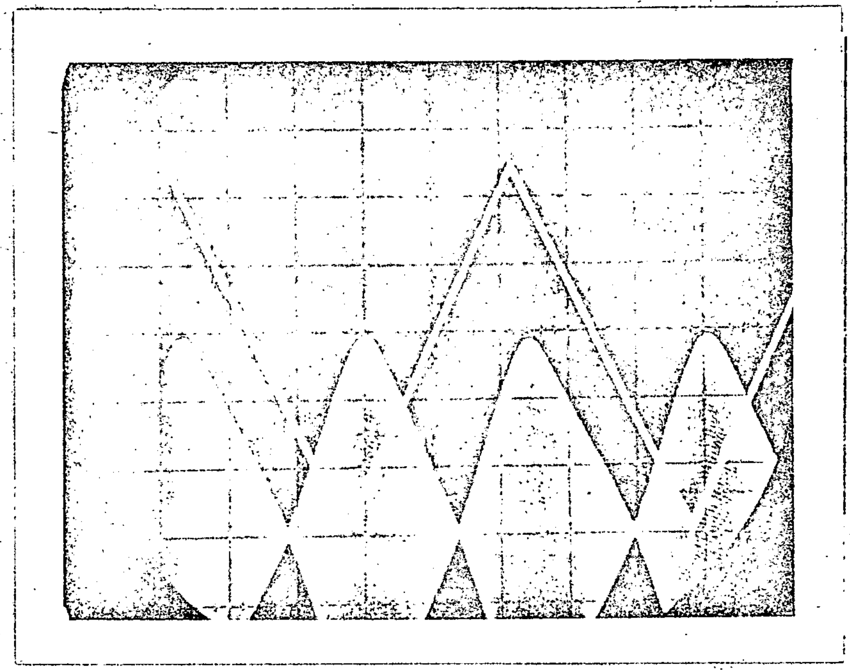
TITLE SOFT FAILURE (1 INPUT TO AMPLIFIER AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -5 SERVO ( CHANNEL "C" )

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



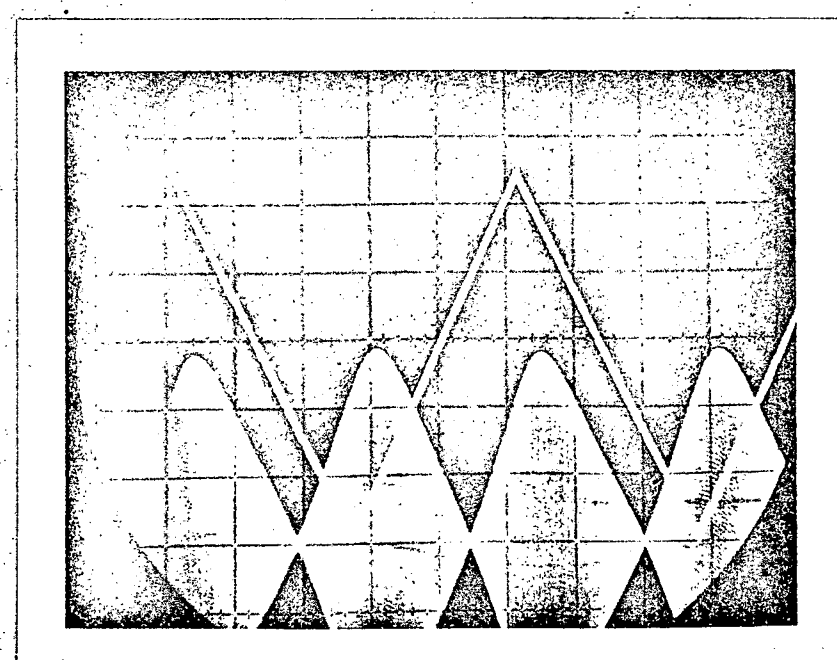
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL

SWEEP TIME - 100/MS/CM

2000 P.S.I.



NO FAIL

C

SWEEP TIME - 100/MS/CM

GAIN = 20 RAD.

.0162 COMPARATOR O'LAP

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| PAGE 110 | TEST 20 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

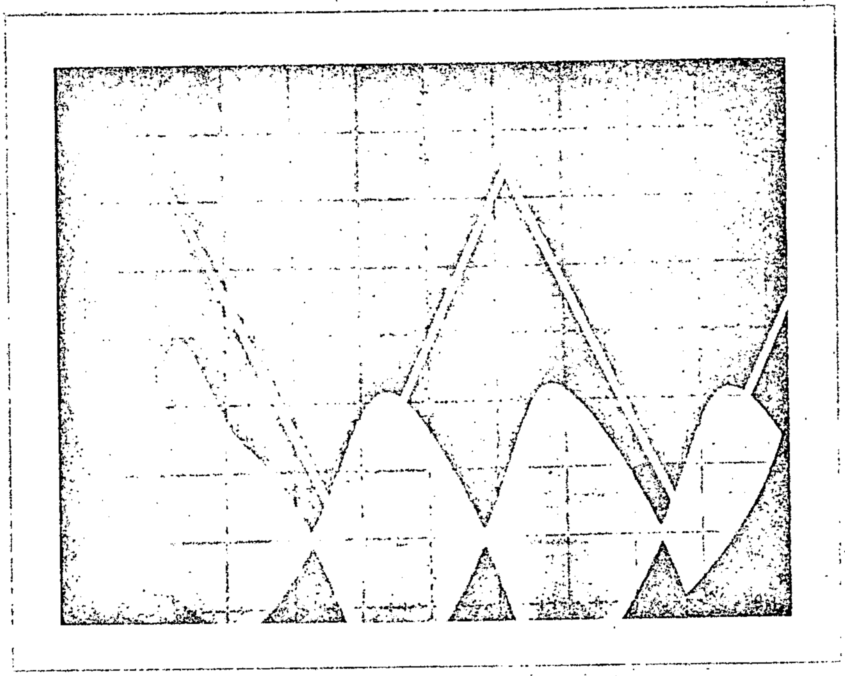
TITLE SOFT FAILURE (∿ INPUT TO AMPLIFIER AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -1 SERVO (CHANNEL "C")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



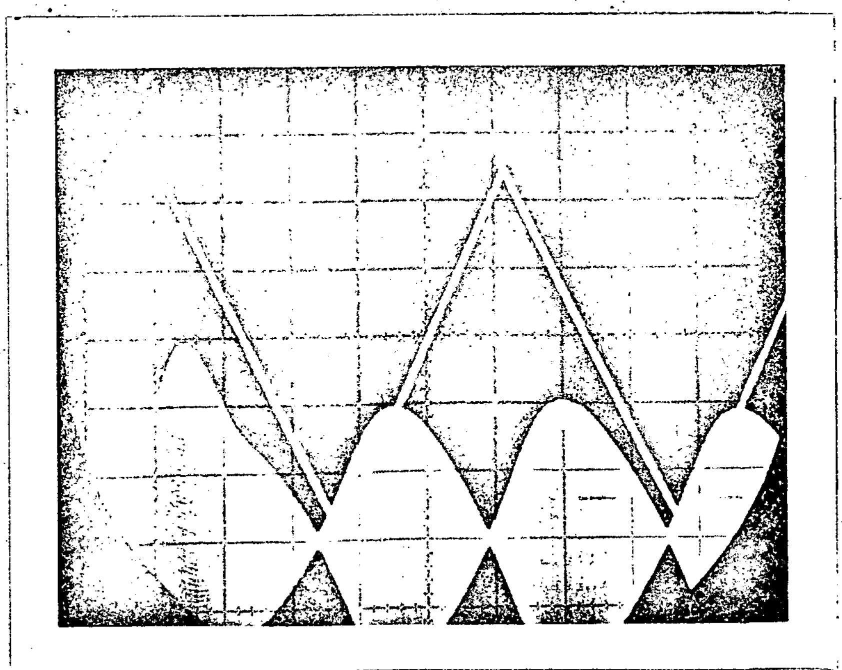
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL

SWEEP TIME -100/MS/CM

2000 P.S.I.



NO FAIL

©

SWEEP TIME -100/MS/CM

GAIN = 20 RAD.

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| PAGE 111 | TEST 21 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

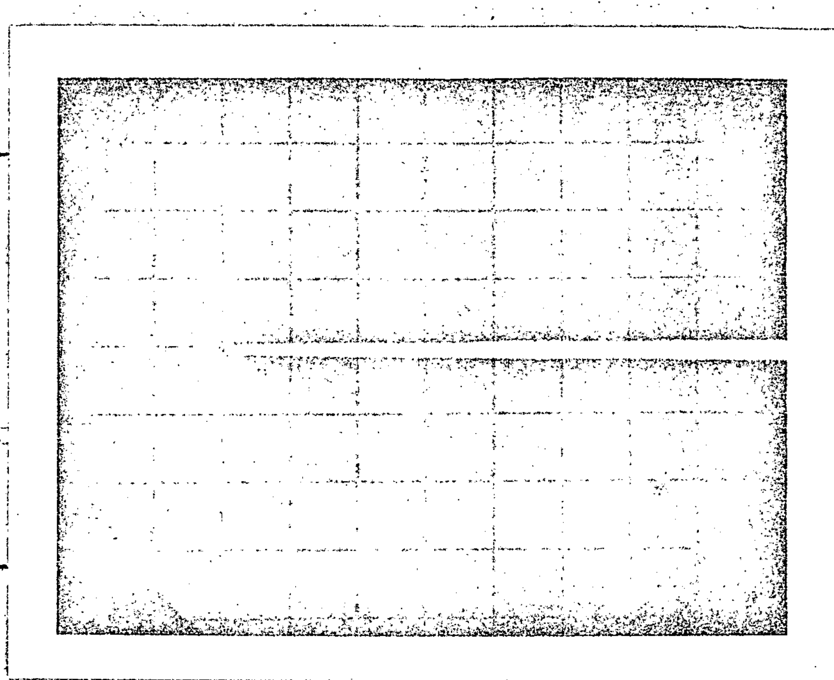
HARD OVER SIGNAL AT THE
-3 SERVO (CHANNEL "C")

6 CM = .300" STROKE FROM
NEUTRAL AT THE ACTUATOR

10 V.D.C. (10 MA.) BIAS SIGNAL
INDUCED TO THE E.H. VALVE
FROM A BATTERY, POT & SWITCH.

SCOPE TRACE TRIGGERED
FROM THE BATTERY SWITCH

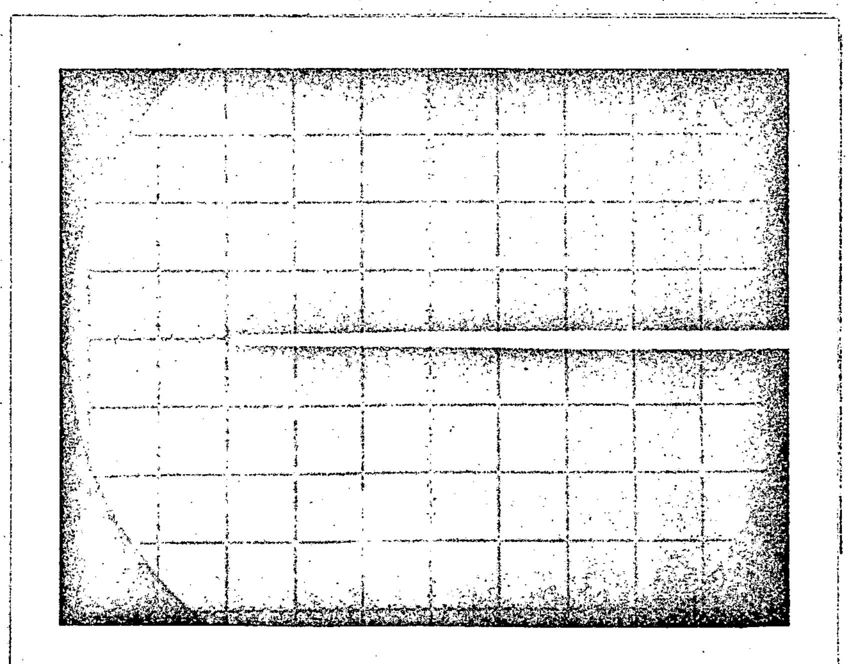
0.3 IN



NO FAIL

SWEEP TIME - 50 MS/CM

2000 P.S.I.



NO FAIL

C

SWEEP TIME - 50 MS/CM

GAIN = 20 RAD/SEC

.0032 COMPARATOR O LAP

TITLE HARD OVER FAILURE (FROM STEADY STATE NEUTRAL POSITION)

3000 P.S.I.

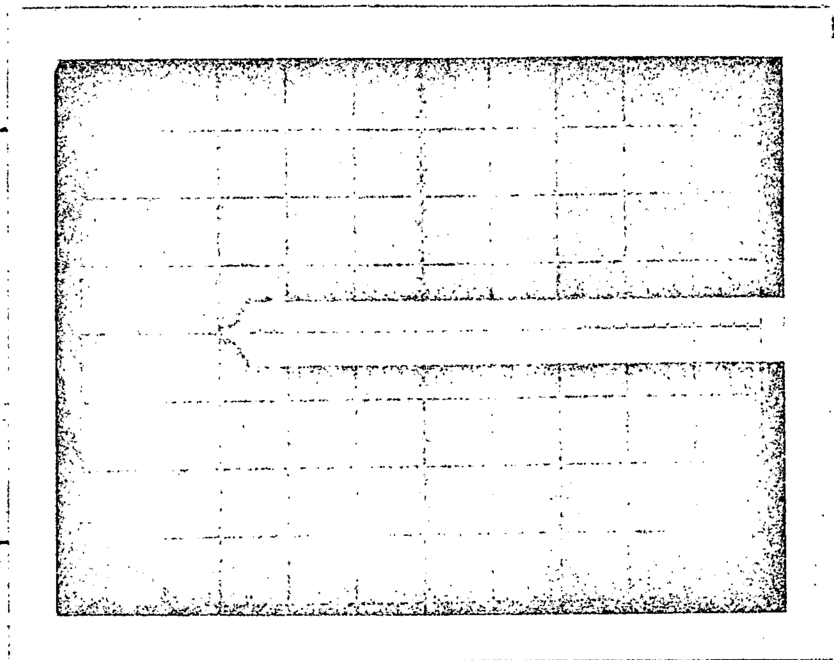
HARD OVER SIGNAL AT THE -1 SERVO (CHANNEL "C")

6 CM = .300" STROKE FROM NEUTRAL AT THE ACTUATOR

10 V.D.C. (10 MA.) BIAS SIGNAL INDUCED TO THE E.H. VALVE FROM A BATTERY, POT & SWITCH.

SCOPE TRACE TRIGGERED FROM THE BATTERY SWITCH

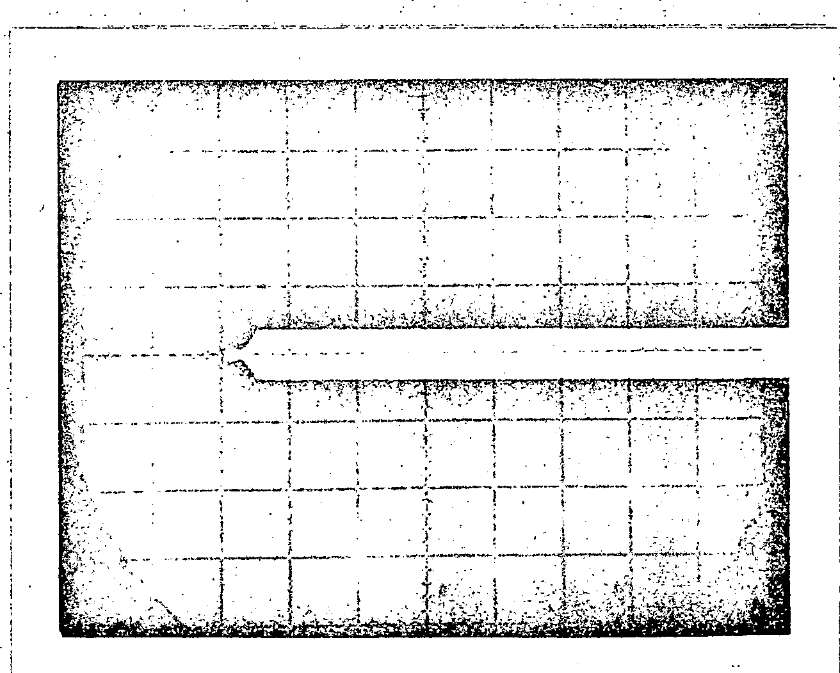
0.3 IN



FAILED

SWEEP TIME - 50 MS/CM

2000 P.S.I.



FAILED

C

SWEEP TIME = 50 MS/CM

GAIN = 20 RAD/SEC

.0032 COMPARATOR O LAP

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| PAGE 113 | TEST 21- | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

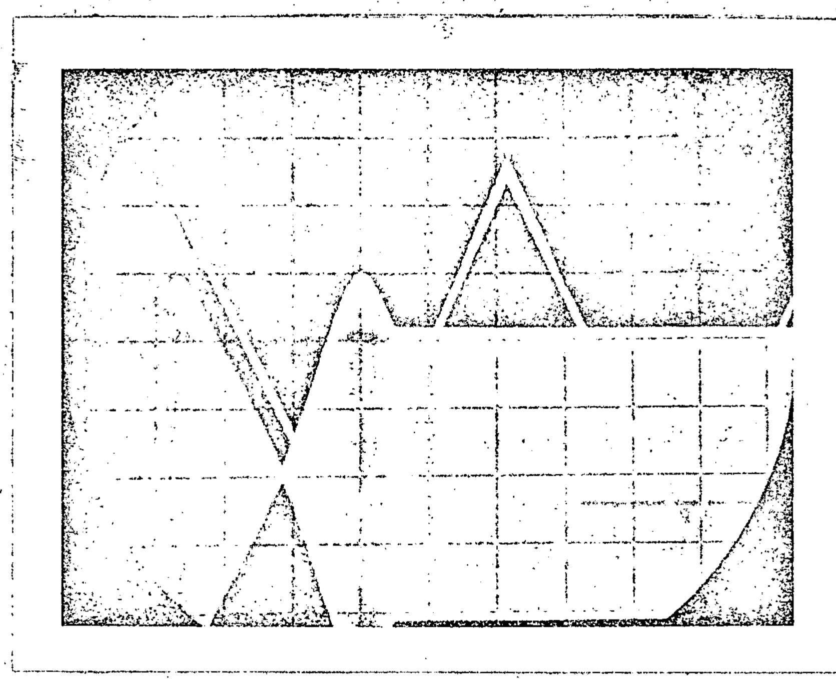
TITLE PASSIVE FAILURE (1 INPUT TO THE AMPLIFURE AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC

E.H. VALVE TRIGGERED OPEN TO THE -5 SERVO (CHANNEL "C")

6 CM = .375" STROKE FROM H1 @ ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



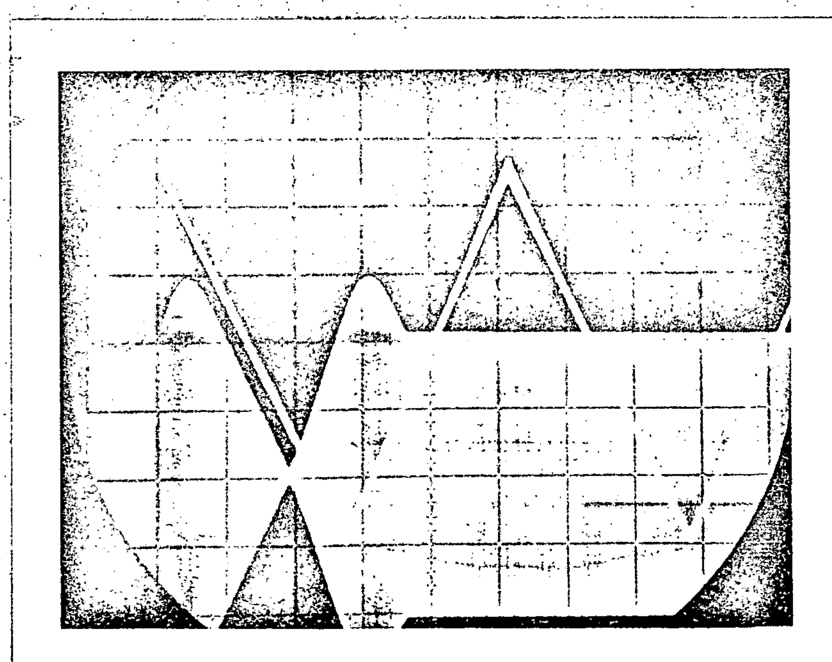
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

FAILED

SWEEP TIME - 100 MS/CM

2000 P.S.I.



FAILED

SWEEP TIME - 100 MS/CM

©

GAIN = 20 RAD./SEC

.0032 COMPARATOR O'LAP

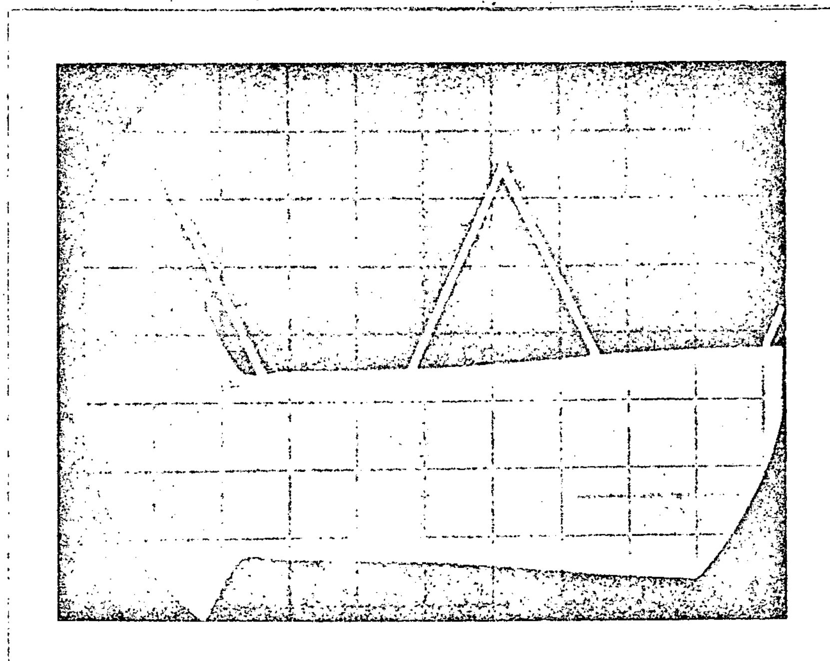
TITLE PASSIVE FAILURE (1 INPUT TO THE AMPLIFURE AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC

E.H. VALVE TRIGGERED OPEN TO THE -1 SERVO (CHANNEL "C")

6 CM = .375" STROKE FROM H @ ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



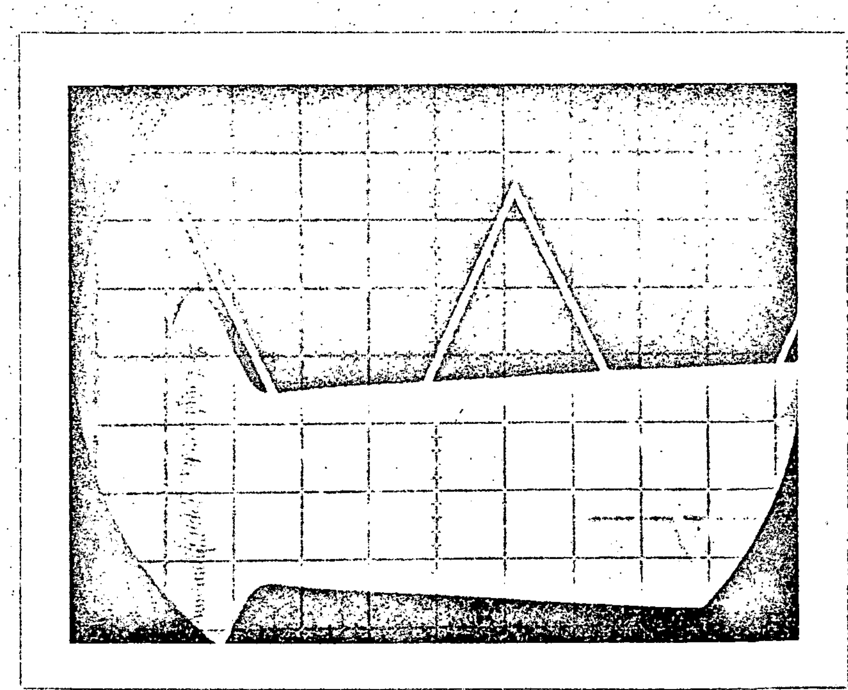
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER.

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

FAILED

SWEEP TIME - 100 MS/CM

2000 P.S.I.



FAILED

SWEEP TIME - 100 MS/CM

©

GAIN = 20 RAD./SEC

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| PAGE 115 | TEST 21 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

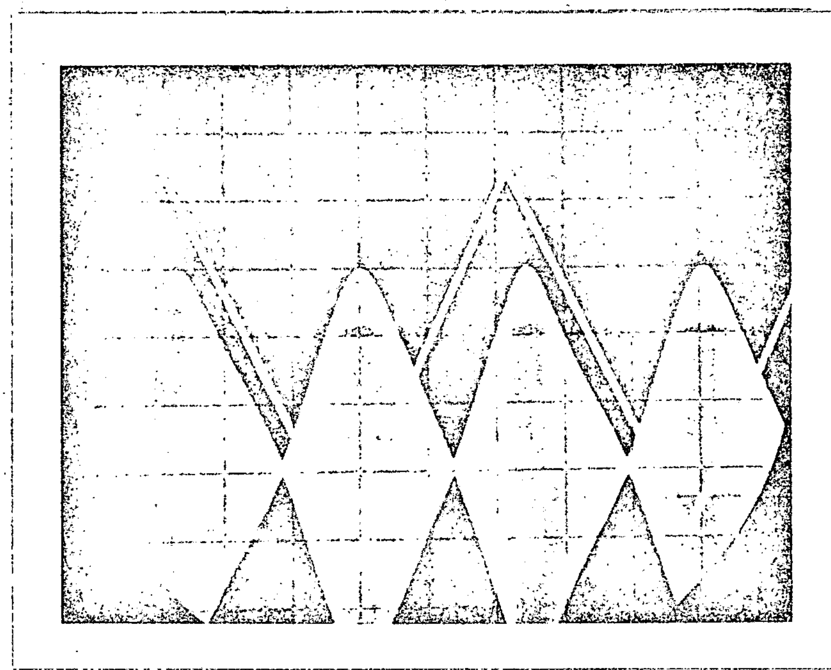
TITLE SOFT FAILURE (∿ INPUT TO AMPLIFIER AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -5 SERVO (CHANNEL "C")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



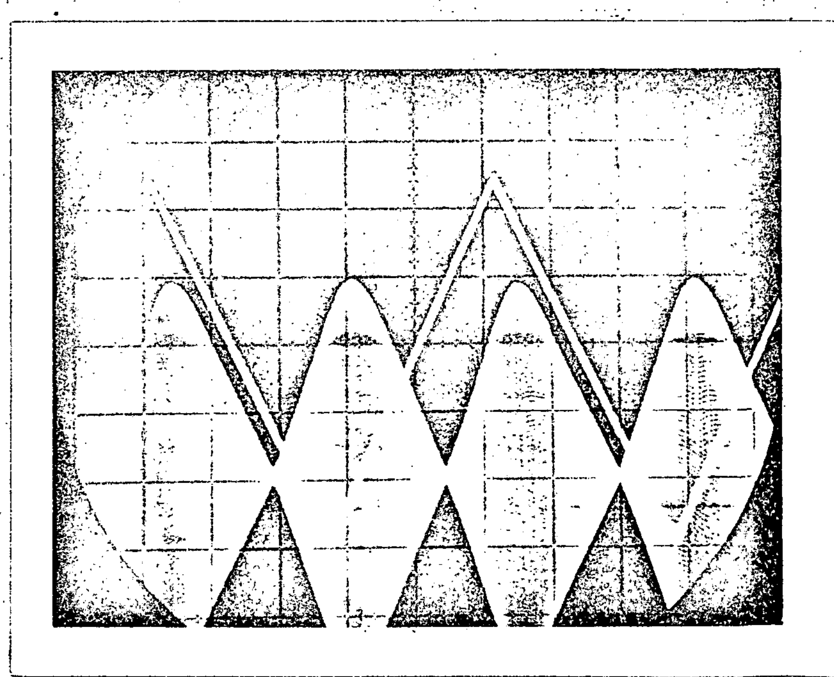
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL

SWEEP TIME - 100/MS/CM

2000 P.S.I.



NO FAIL

SWEEP TIME - 100/MS/CM

GAIN = 20 RAD.

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| PAGE 116 | TEST 21 | REV. |
|---|---|---|
| ORIG. DATE | REV. DATE | |

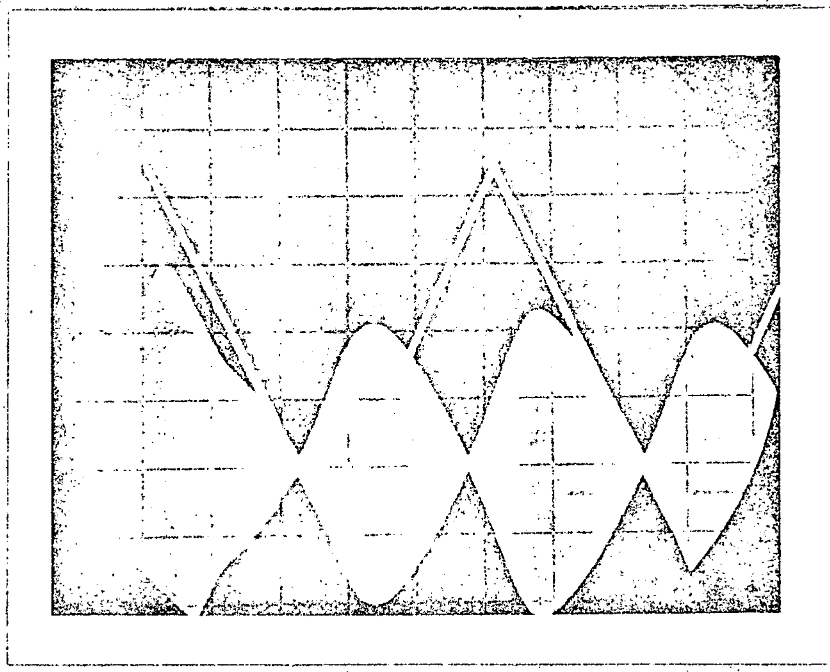
TITLE SOFT FAILURE (1 INPUT TO AMPLIFIER AT 2 Hz)

3000 P.S.I.

TRIGGER TIME = .001/SEC.

E.H. VALVE TRIGGERED TO HALF GAIN AT THE -1 SERVO (CHANNEL "C")

6 CM = .375" STROKE FROM NEUTRAL AT THE ACTUATOR. DOUBLE AMPLITUDE IS A FULL TWO PATTERNS.



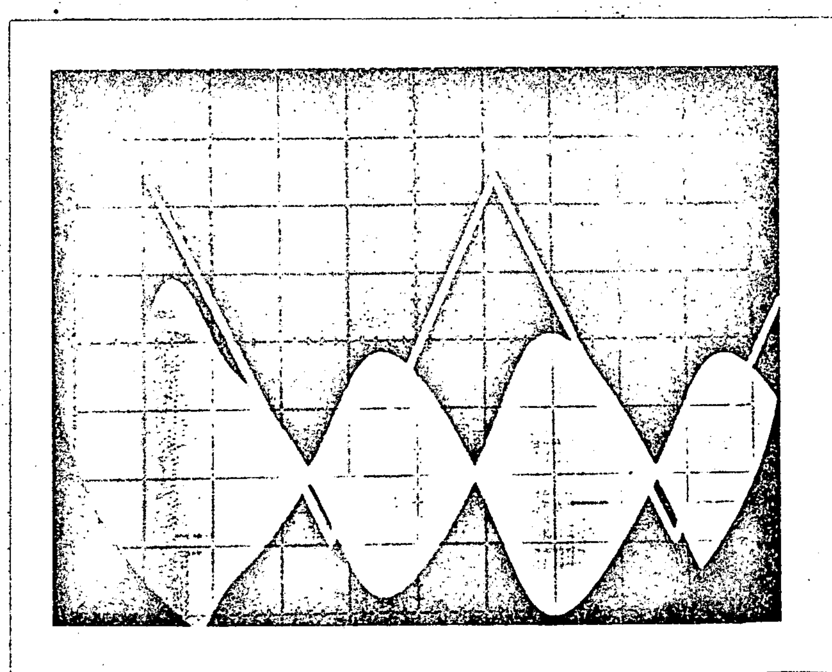
UPPER TRACE DISPLAYS INPUT SIGNAL & TRIGGER TO THE SERVO AMPLIFIER

LOWER TRACE DISPLAYS ACTUATOR L.V.D.T. MONITOR OUTPUT SIGNAL (400 Hz)

NO FAIL

SWEEP TIME -100/MS/CM

2000 P.S.I.



NO FAIL

SWEEP TIME -100/MS/CM

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GAIN = 20 RAD.

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