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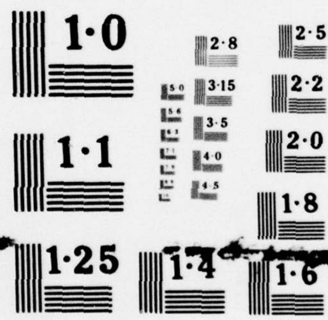

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Final Technical Report
June 1979

MILES PRESSURE/SEISMIC RESPONSE (EVALUATION OF ADVANCED DEVELOPMENT MODEL OF MILES TEST FIXTURE)

Honeywell, Inc.

Kerry J. Sutherland
Scott D. Crist

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ROME AIR DEVELOPMENT CENTER
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In Phase I of this contract, a concept was developed for performing in-factory quality assurance tests of the Transducer, Motional Pickup TR-299/G ( ), hereafter referred to as MILES. Under this, Phase II of the work, test procedures and an advanced development model of the test fixture were developed and successfully evaluated. It was demonstrated that the seismic and magnetic stimuli experienced in the field could be simulated in the test fixture with sufficient accuracy and repeatability to provide the baseline for evaluating the performance of the MILES. The performance data combined with other statistical information

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generated with the fixtures will provide a complete dossier on each MILES as it is manufactured. This insures that the transducer is performing satisfactorily prior to its actual deployment. In the next phase of the work, two engineering development models of the test fixture will be developed with their configuration based upon the Phase II prototype plus the addition of automated sequence control and data processing equipment to minimize operator interface.

EVALUATION

This effort is directed toward the development of a test fixture and procedure for performing in-plant evaluation of the as manufactured performance characteristics of the MILES transducer. Currently, there is no satisfactory technique for monitoring the quality of MILES cables being fabricated in production quantities. Therefore, if anomalous behavior of a cable occurs in the field, both its deployment and original condition must be considered suspect. With the test fixture, the original condition of the cable is a matter of record and field performance anomalies can be attributed to some facet of its installation. This work is being conducted under TPO-6 in support of the Base and Installation Security System Program Office.

Robert B Curtis

ROBERT B. CURTIS
Center Program Manager

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SECTION I

SUMMARY

This project, which was Phase II of a 3-phase development program, involved the development of a prototype Test Device for use in in-factory measurement of the response characteristics of MILES transducers. The design development approach was based on the Phase I design concept and analytical results presented in reference (1). A series of tests was conducted to verify the Phase II design and the test procedures. The Phase II Test Device was successfully demonstrated, and approved for use in Phase III as a design baseline for development of an automatic facility for testing MILES transducers in the factory environment.

The basic design problem that was solved on this project was the development of a device that accurately and consistently applies a test environment that closely simulates the environment experienced by an emplaced (buried) transducer. This was done by applying appropriate magnetic and mechanical stresses to a specific 84-inch section of the transducer, measuring the response, and then repeating the process until the total 100-meter length of the transducer has been tested. The magnetic stresses consist of a bias field that represents the earth's magnetic field, and a 1 Hz time-varying field that represents changes in the earth's field caused by a metal object in proximity to the transducer. The mechanical stresses consists of a longitudinal bias force and a longitudinal, 1 Hz time-varying force, which approximates the actual stresses experienced by a buried transducer subjected to surface pressure stimuli.

A major design objective was repeatability of the mechanical forces applied by the Test Device to the transducer section under test. It was agreed that Test Device mechanical repeatability would be demonstrated by transducer response signals that showed a standard deviation σ = 10%, with the transducer average output taken as the mean. Test results showed σ = 8%. An instrumented test rod was developed for use as a Test Device calibration standard, but its use was abandoned due to the inability to obtain consistent results.

An important design consideration was minimization of Test Device sensitivity to the magnetic and electrical noise present in the industrial

1. Starr, J.B., "MILES Pressure/Seismic Response; Initial Study and Analysis," Final Technical Report, USAF Contract F30602-76-C-0385, Phase I.

production environment, and isolation of the transducer under test from earth's magnetic field. To do this, the Test Device incorporates cross-correlation signal processing techniques, signal averaging, and an electromagnetic shield. Tests indicated that proper Test Device installation combined with the use of cross-correlation and signal averaging techniques will virtually eliminate any noise interference. Test results indicate that the electromagnetic shield, which is constructed of ARMCO iron, may not be necessary for reliable performance. Additional tests will be conducted in Phase III to verify these results, or define a specific requirement for electromagnetic shielding.

The work performed under Phase II has defined a Test Device and procedures for measurement of MILES transducer response in the factory environment. This work has verified the basic design concept and procedures defined in Phase I, and provides a sound basis for development of an automatic MILES transducer test facility in a follow-on Phase III effort. It is expected that performance improvements over the Phase II design will be realized through replacement of the manual test setup procedures used in Phase II by automatic (computer controlled) procedures for transporting and centering the transducer within the Test Device.

SECTION II

INTRODUCTION

This final report covers the work accomplished under Phase II of Contract F30602-76-C-0385 for development of a Test Device for use in in-factory testing of MILES transducers. The project was performed under direction of Rome Air Development Center (RADC). The contract period extended from 20 September 1977 to 20 January 1979.

Background

The MILES transducer provides an effective means for intrusion detection in perimeter security systems. The transducer is essentially a cable, 100-meters in length, that is usually buried at a depth of nine (9) inches, but may be buried as deep as 18 inches. The transducer core is a permalloy material possessing high permeability and magnetostrictive properties. A sense winding is wrapped about the core. The winding direction is reversed periodically to provide a gradiometer configuration that results in rejection of far-field disturbances. By virtue of the high permeability of the core, the transducer is sensitive to anomalies produced within the earth's magnetic field, as for example, by an armed intruder. The magnetostrictive properties of the core material make the transducer sensitive to the small soil displacements caused by the passage of an intruder.

The MILES transducer has been widely deployed in a "round" configuration in which the core is a stranded bundle of permalloy material, and an outer layer of thermoplastic material provides a protective covering.

Although MILES transducers have been used successfully in security systems, variations in sensitivity have been observed. The cause of these variations may be either the burial environment or the specific transducer characteristics. Currently, no information or technique is available for assessing either the magnetic or pressure/seismic sensitivity. Consequently, little or no guidance can be provided to assist in the optimization of a specific installation or the correction of performance anomalies.

To provide a solution to this problem, RADC is conducting a program that will provide a test facility for in-factory measurement of the magnetic and pressure/seismic sensitivity of MILES transducers. The use of this test facility will assure satisfactory transducer performance before its installation in a security system.

Project Objectives

The following objectives were established for Phase II of the project:

1. Develop a prototype Test Device for in-factory measurement of the response characteristics of MILES transducers. The Test Device design will be based on the analytical results of Phase I, and will provide a sound basis for development of an automatic Test Device under a follow-on Phase III.

2. Conduct tests to verify Test Device mechanical repeatability, as demonstrated by test results that show a standard deviation $\sigma = 10\%$ or better, with the transducer average output taken as the mean.

Achievement of these objectives will provide the design basis for proceeding into Phase III.

SECTION III

TEST DEVICE DESCRIPTION

The MILES Transducer Test Device that was developed under this project is illustrated in Figures 1a and 1b. The Test Device applies magnetic and mechanical stresses to the MILES transducer under test. The magnetic stresses consist of a bias field that represents the earth's magnetic field, and a 1 Hz time-varying field that represents changes in the earth's field caused by a metal object in proximity to the transducer. The mechanical stresses consist of a longitudinal bias force and a longitudinal, 1 Hz time-varying force. These longitudinal stresses approximate the actual stresses experienced by a buried transducer subjected to a surface pressure stimuli.

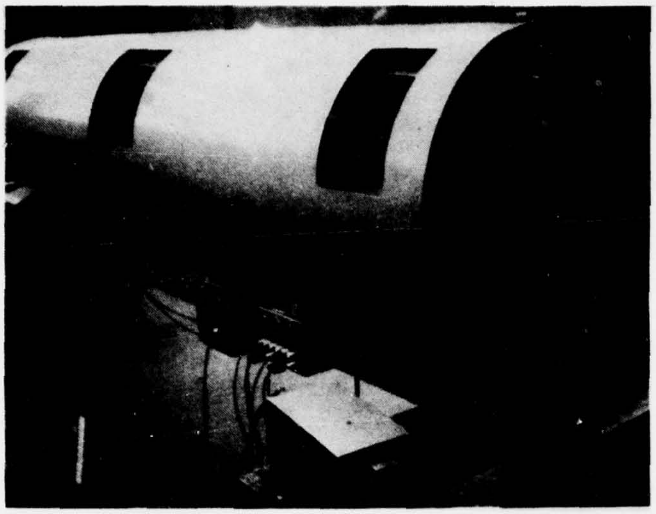
The Test Device design concept is illustrated in Figure 2. To perform a test, the connector end of a MILES transducer, as stored on the supply reel, is threaded through the Test Device and onto the takeup reel. At the takeup reel, the transducer connector is tied into the test instrumentation via a mating connector. Key component functions are described below.

Nulling Coils

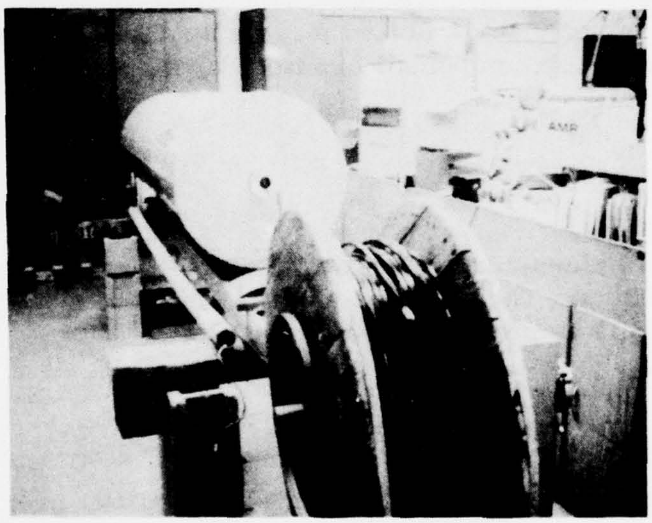
These coils generate 10-hertz sinusoidal magnetic fields that are detected via the transducer sense winding. The detected signal is minimum when a sense winding transposition is centered between the coils.

Clamps

Pneumatically controlled clamps provide for mechanical isolation, preloading, and sinusoidal mechanical loading of the transducer section under test. The stationary tension clamps are activated first, after which a pneumatic cylinder produces a tension preload of 10 pounds. The tension lock maintains the preload and prevents movement of the tension clamp during testing. The stress clamp, located midway between the stationary and tension clamps, is the means by which a sinusoidal load is imparted to the transducer. Such loads are produced by a motor-driven spring linkage. The pneumatic lines which control the clamps and the tension lock are actuated by electrically controlled solenoid valves.

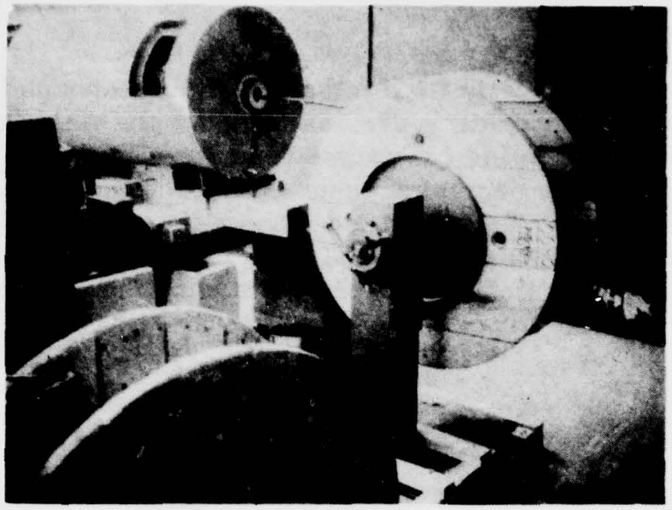


TEST CHAMBER

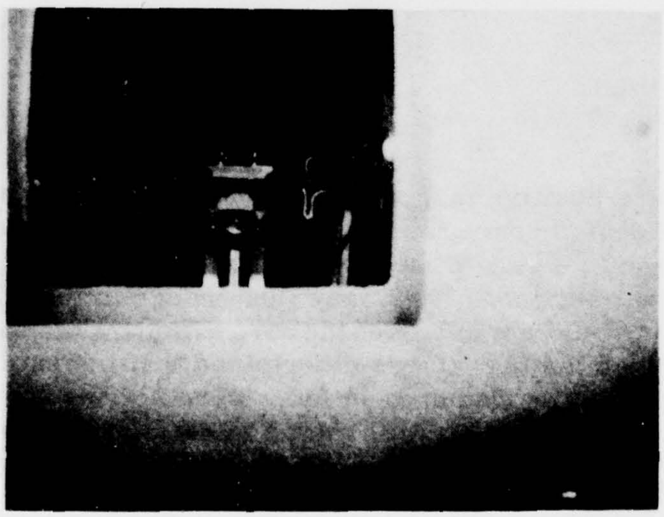


END VIEW

Figure 1a. MILES Transducer Test Device



REEL STAND



TRANSDUCER
CLAMP

Figure 1b. MILES Transducer Test Device

Field Coils

The field coils are driven to magnetic field intensities large enough to saturate the transducer core material. After saturation, the field intensity is returned to a prescribed value for magnetic and mechanical sensitivity measurements. This provision ensures that the magnetic state of the transducer is at the prescribed location on the magnetic hysteresis loop during testing. Magnetic sensitivity is determined by producing a specified sinusoidal field within the coils, and then measuring the line response signal.

Electromagnetic Shield

This shield was designed to minimize Test Device sensitivity to magnetic and electrical noise fields in the production environment, and also isolate the transducer under test from earth's magnetic field.

The results of tests conducted during the program provide substantial evidence that this shield may not be required for reliable Test Device operation, and that the shield now in place may not be performing an isolation function as originally intended. Further analysis and testing will be conducted under Phase III to verify any requirement for an electromagnetic shield.

Saturating Coils

These coils were to assure positive magnetic isolation of the transducer section under test. The design concept was that the coils would produce a steady field large enough to saturate the transducer core material located just beyond the test section. Thus, any flux change in the core outside of the test section could not influence the core within the test section. However, during acceptance testing, it was determined that the saturating coils were not functioning as intended and, in fact, were not necessary if normal care was taken to prevent ferrous metal objects from being carried into the test area.

Distance Measuring Device

This device, which consists of a roller driving a counter, is used to measure the physical length of the transducer.

Reel Stands

The supply and takeup reels are each mounted on an independent stand (not part of the Test Device chassis). The supply reel containing the transducer is manually loaded onto the supply reel stand, and an empty takeup reel is manually loaded onto the takeup reel stand. Feeding the transducer through the Test Device is accomplished by manually rotating the reels. Each reel stand has a hand brake.

SECTION IV

DEVICE APPLICATION

The MILES Transducer Test Device is designed for use in a normal factory or laboratory environment. Proper operation of the pneumatic components requires a source of 100 psig air. The following sequence for testing a MILES transducer is typical.

A supply reel containing a 100-meter transducer is manually mounted on the stand provided. Turning the reel manually, the transducer is threaded through the Test Device and onto the takeup reel (see Figure 2).

Prior to transducer positioning and clamping, the resistance of the transducer conductors is checked. Leakage resistance is also checked using a megohmeter.

After the resistance checks are completed, the transducer is positioned such that the point of winding transportation of the transducer section under test is exactly centered between the nulling coils (see Figure 2). Then the pneumatically controlled clamps are engaged by setting the appropriate toggle switches, and a 10-pound preload is applied to the transducer section under test.

Prior to measuring mechanical or magnetic sensitivity, the field coils are energized to a level sufficient to saturate the transducer core material. Thereafter, the magnitude of the field is reduced to a level representative of the earth's field in the direction of the line, e.g., between zero and 0.25 Oersteds. (A drive motor is then energized, which applies a 1-hertz mechanical load to the transducer via the stress clamp. The response of the transducer is then measured to determine pressure/seismic sensitivity.) Magnetic sensitivity is determined by measuring the transducer response to a small sinusoidal field generated by the field coils.

After tests on this transducer section are complete, the excitation currents to the field coils are removed, and the pneumatic clamps are released. The transducer is then advanced through the Test Device (by manual rotation of the takeup reel), until the point of winding transposition of the next transducer section to be tested is properly located between the nulling coils, after which the procedure outlined above is repeated.

After the desired number of transducer sections have been tested, the transducer is rewound manually onto the supply reel, which is then removed from the Test Device in preparation for testing another MILES transducer.

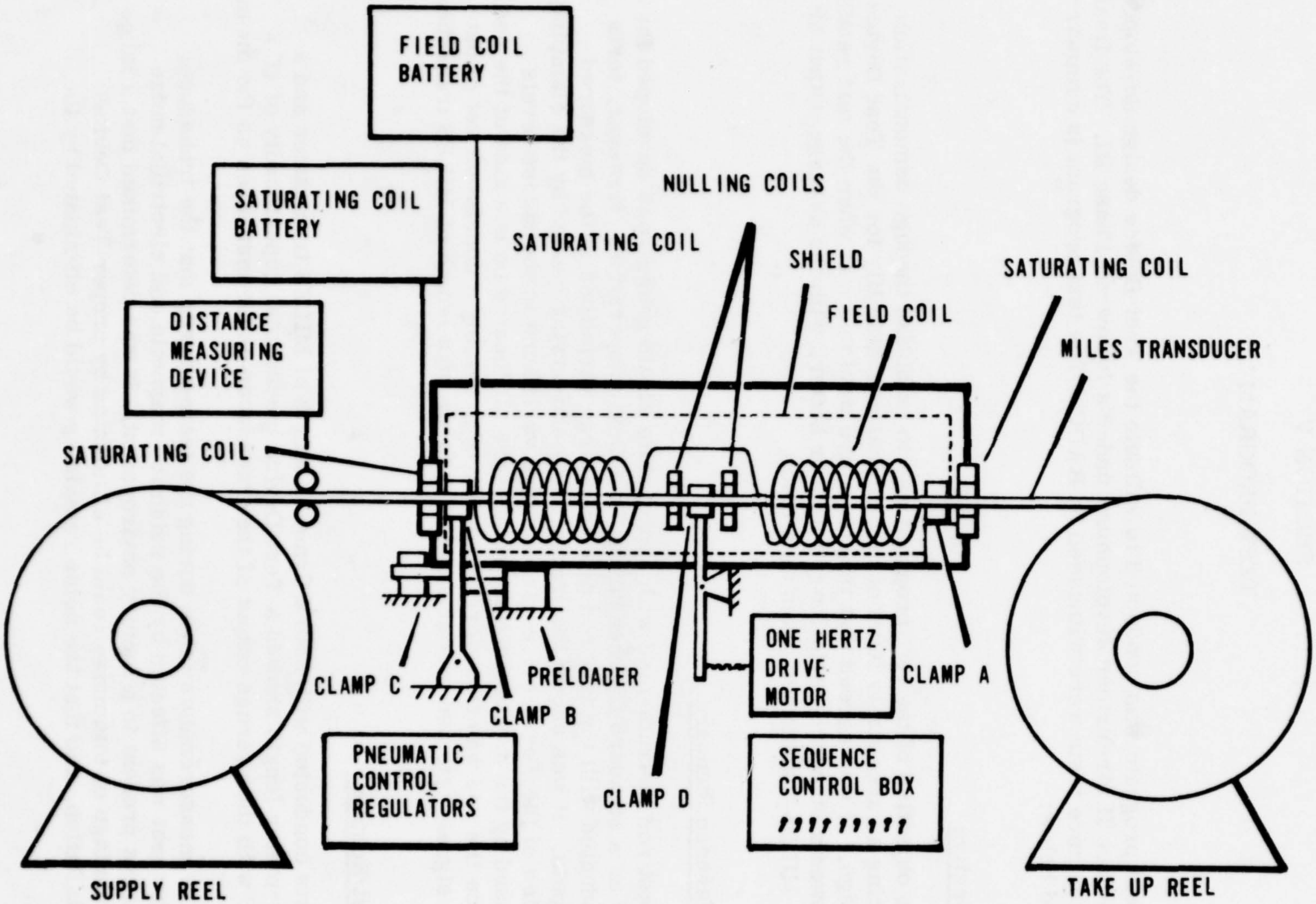


Figure 2
Miles Pressure/Seismic Response Tester

SECTION V

TEST PROGRAM

A test program was conducted to validate the Test Device design developed in Phase II for further development under a follow-on Phase III. The final acceptance tests were witnessed by RADC. The test program is summarized below:

Objective

The objective of the test program was to establish through demonstration testing an acceptable level of mechanical repeatability for the Test Device design. It was agreed that this objective would be met when the test results showed a standard deviation $\sigma = 10\%$ or better, with the average output of the MILES transducer taken as a mean.

Reference Standard

A test rod instrumented with appropriate strain gauges was developed for use as a standard for measuring Test Device operation. However, tests conducted with the test rod produced large variations in the measured outputs. It was shown that rod bending and bowing caused by the clamping action of the Test Device caused large variations in the stress levels sensed by the strain gauges, which were all located on one side of the rod. Since the rod was therefore incapable of providing a consistent set of output signals, its use was abandoned in favor of a length of MILES transducer.

Test Results

Tests conducted with both a 3-meter length of MILES transducer and a 100-meter length showed a Test Device mechanical repeatability of $\sigma =$ 8%, with the average output of the transducer under test taken as the mean.

Noise measurements taken during the tests showed that the transducer under test was affected by the seismic, magnetic and electrical noise sources present in a factory environment. It was determined that a large percentage of this noise could be eliminated by proper Test Device installation, and that the noise remaining would be eliminated by the combination of the 1-Hz low pass filter and cross correlation technique used in the Test Device.

The following results were obtained in a test conducted at the request of Mr. Robert Curtis of RADC. This test was designed to validate that the Test Device applies a repeatable mechanical load to the transducer under test. A 3-meter MILES transducer was used in this test.

Step	Action	Output
Step 1 -	a) Clamp	
	b) Apply 10 oersted field for 1 second	48
	c) Start 1 Hz motor	
Step 2 -	a) Turn 1 Hz motor off	
	b) Restart 1 Hz motor	48
Step 3 -	a) Turn 1 Hz motor off	
	b) Apply 10 oersted field for 1 second	48
	c) Restart 1 Hz motor	
Step 4 -	a) Turn 1 Hz motor off	
	b) Unclamp center clamp	
	c) Reclamp	49
	d) Apply 10 oersted field for 1 second	
	e) Restart 1 Hz motor	
Step 5 -	a) Repeat Step 4	50
Step 6 -	a) Repeat Step 4	52
Step 7 -	a) Repeat Step 4	51
Step 8 -	a) Repeat Step 4	52
Step 9 -	a) Repeat Step 4	52
Step 10 -	a) Repeat Step 4	52
Step 11 -	a) Repeat Step 4	52
Step 12 -	a) Turn 1 Hz motor off	
	b) Remove tension	
	c) Reapply tension	55
	d) Apply 10 oersted field for 1 second	
	e) Start 1 Hz motor	

Step 13 - a) Repeat Step 12 54

Similar results were obtained in tests with a 100-meter MILES transducer. (See reference (2)).

2. Sutherland, K. J., "MILES Pressure/Seismic Response," Acceptance Test Report, USAF Contract F30602-76-C-0385 Phase II.

SECTION VI

HAZARD ANALYSIS

A hazard analysis was conducted in the following design areas:

- Transportation, handling and storage.
- Test Device operation.

The worst-case hazard was identified as a category II (marginal) hazard. The following design improvements were identified for consideration in any future design development effort.

Transportation, Handling and Storage

Lifting Hooks - The Test Device weighs approximately 650 pounds and is 11 feet long. Lifting hooks should be considered to facilitate transportation and handling.

Roll-Resistant Devices - Reels should be fitted with blocks or some other type of roll resistant device, or otherwise configured to prevent movement during storage.

Reel Mounting on Test Device - A reel is 3 feet in diameter and 1 foot in depth. A fully-loaded reel weighs 125 pounds, and an empty reel weighs 40 pounds. A reel is mounted on the support stand by two men. The lift height is approximately 2 feet. An empty reel presents no problem. However, lifting handles should be considered to facilitate mounting a loaded reel on the Test Device.

To advance or rewind the transducer on a reel, the reel is manually rotated, which raises the possibility of a hand being pinched between the transducer and reel. To minimize this hazard, consideration should be given to a crank for rotating the reels. Note: This hazard may not exist in the automatic Test Device to be developed on Phase III.

Test Device Operation

Pneumatic System Integrity - All pneumatic lines including connectors should be regularly inspected for integrity. With a supply pressure of 100 psig, a rupture in the pneumatic system could jeopardize personnel safety.

Transducer Insertion in Test Device - Caution is required when threading the transducer through the Length Measuring Device to avoid a pinched hand. A "Keep Hands Clear" sign or a cover guard should be affixed to the Length Measuring Device.

Extreme caution should be exercised when centering the transducer between the nulling coils. If the operator inadvertently sets a toggle switch on the Sequence Control Panel during this operation, his hand could become wedged between a clamp and the transducer. As a precaution, a master power control switch should be added to enable the removal of power from all clamp solenoids in the event of an emergency of this nature. Note: These hazards may not exist in the automatic Test Device.

Operator Cautions - Operator instructions should include a caution note to avoid electrical shock when performing insulation resistance checks with the megohmeter. The operator should also be cautioned to avoid electrical shock from the 115 VAC solenoid-operated air valves when centering the transducer between the nulling coils.

Shock Prevention - While the Test Device is operating, 115 VAC is applied to the 1-Hertz drive motor. The operator is exposed to an electrical shock from the motor terminals. These motor terminals should be covered with insulation caps. All solenoid terminals should also be covered with insulation caps.

Drive Motor Hazard - A cover guard should be installed over the junction between the 1-Hertz drive motor shaft and the connecting arm to prevent personnel injury.

SECTION VII

CONCLUSIONS

The work performed under Phase II of Contract F30602-76-C-0385 has concluded the following:

1. The Test Device developed under this contract has the level of mechanical repeatability needed to assure reliable testing of MILES transducers. The standard deviation $\sigma = 8\%$ may be somewhat improved in the automatic Test Device design to be developed under Phase II.

2. Test results indicate that proper Test Device installation combined with the use of the existing cross-correlation signal processing techniques and signal averaging techniques will assure reliable operation in a high noise factory environment.

3. The hazards identified (Category II, marginal) can be either significantly minimized or eliminated altogether in the automatic Test Device to be provided under Phase III.

4. *The current design can be readily automated.*

5. Test results indicate that the electromagnetic (ARMCO iron) shield incorporated in the current design may not be required for reliable Test Device operation in the factory environment.

6. Test results indicate that the saturating coils did not function as intended and, in fact, are not required for reliable Test Device operation.

SECTION VIII

RECOMMENDATIONS

The following recommendations are made for work to be performed under the follow-on Phase III contract:

1. Additional analysis and testing should be conducted to determine whether an electromagnetic shield is required for reliable Test Device operation in a factory environment.

2. The Phase III model should incorporate a device for straightening the MILES transducer before it is fed into the Test Device.

3. The Phase III contract should implement the results of the hazard analysis conducted under Phase II. Special attention should be given to implementing a function that removes solenoid power in the event of any operator (or other) interference with proper operation of the pneumatically actuated cable clamps.

4. Automatic on-line statistical analysis of the data collected during factory test of MILES transducers should be limited to minimum, maximum, mean and standard deviations for the pressure/seismic response, magnetic response and distance between transpositions.

5. Line levelers shall be installed on the takeup and supply reels.

6. Due to the small number of devices being fabricated, a commercially available data acquisition computer system should be used to automate the tester.

APPENDIX A

DESIGN CONFIGURATION

This section contains the detailed design information for the Phase II MILES tester configuration. The tester consists of a transducer test chamber assembly connected to an electronics console. The test chamber is shown in Section III, figure 2. The electronics console (not shown) houses a Brush chart recorder, cooling fan assembly, system power supply ($\pm$ 15 Vdc), and a circuit card cage assembly. Connected to the electronics console is a remote preamplifier assembly to which the MILES transducer under test connects. The following paragraphs are operational descriptions of the significant tester elements built under Phase II.

MILES Tester System Concept

Figure A1 is a block diagram of the basic MILES transducer sensitivity measurement concept. It is basically a cross-correlation scheme used for both pressure and magnetic response measurements, however, the pressure channel only was made operational during Phase II. Magnetic measurements were made by simply recording the preamplifier output (without correlation). With a MILES transducer placed within the test chamber (as described earlier in this report) an appropriate magnetic bias is established within the test chamber by two (2) bias solenoid field coils. This magnetic bias field can be modulated at low levels for transducer magnetic sensitivity tests ($\pm$ 100 gamma peak).

Transducer pressure sensitivity tests are made by applying a sinusoidal longitudinal force to the transducer at a transposition. This modulating force (2 pounds peak-peak) is generated by a 60 rpm (1 Hz) hysteresis syncronous drive motor coupled to the transducer through a crank-arm, coil spring, force transducer (load cell), and clamp-arm assembly. The output of the force transducer (1 volt/pound) is used as the cross-correlation reference signal. A correlation reference circuit low-pass filters, phase shifts, and amplifies the force transducer output signal prior to cross-correlation with the amplified MILES transducer output. The MILES transducer preamplifier/low-pass filter has a nominal gain of 106 dB (200,000) at 1 Hz (the center frequency of the signal processing circuits).

Cross-correlation of the MILES transducer output with that of the modulating force transducer output is done by multiplying the two signals together (four quadrant multiplier) and averaging the subsequent output

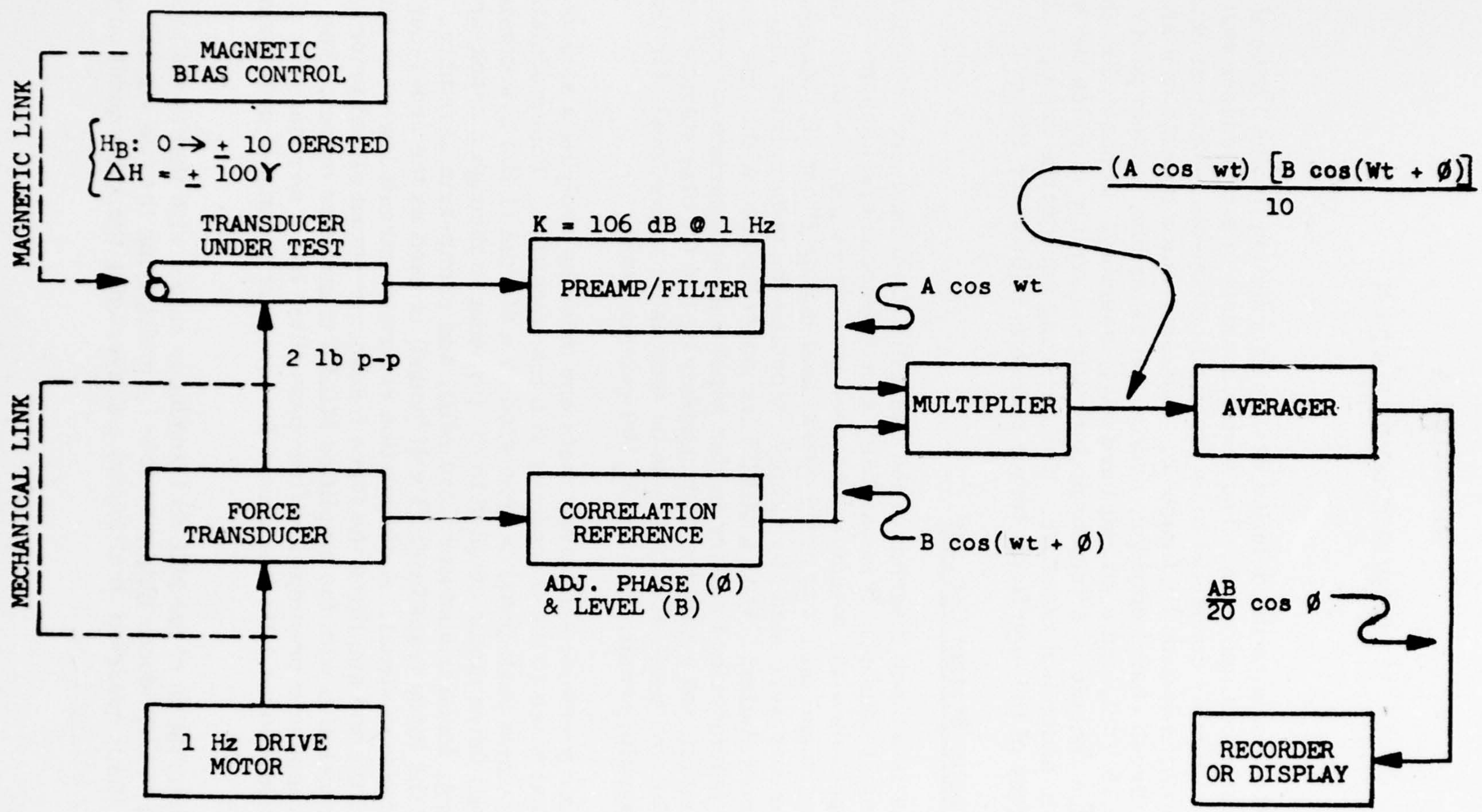


FIGURE A1 - MILES TESTER SYSTEM CONCEPT DIAGRAM per Figure A1. The resulting "DC" output is then directly proportional to the "pressure" (magnetostrictive) sensitivity of the particular MILES transducer segment under test. The averager filters any noise and the AC signal superimposed on the DC output of the mulitplier. The longer the averager time constant the better the signal to noise ratio of the measurement. As can be seen by the output equation in Figure A1, the phase difference between the two mulitplier input signals must be adjusted to zero by the correlation reference circuit for maximum positive output sensitivity. This circuit compensates for the phase shift of the transducer preamplifier and low-pass filter.

MILES Tester Pressure/Magnetic Preamplifier

Figure A2 is a schematic diagram of the tester preamplifier. It is a high gain, low noise, DC coupled low-pass preamplifier. A three (3) bit input code selects one of the five operating modes according to the address code in the lower left hand corner of Figure A2. This feature permits future automated testing of a MILES transducer once connected to its output connector. This preamplifier assembly would be physically located on the take-up reel and be connected to the electronics console through a slip-ring assembly. A direct connection was made, however, for Phase II operation. As shown, all connections to the preamplifier assembly are made through EMI filters denoted at (π).

Signals from a MILES transducer under test are first passed through a 60 Hz notch/low-pass filter/clamp network before any amplification. This ensures lowest possible intermodulation distortion at the preamplifier output. The signal is then preamplified by low-noise chopper-stabilized DC amplifier (U1). The output of U1 is then filtered by a low offset 3rd order Butterworth low-pass filter (U2) which also has low-noise properties. The signal is then postamplified by (U3) which is also a chopper-stabilized DC amplifier. The output of U3 is buffered by output follower/line driver (U4). The entire signal amplfication path is DC coupled for instantaneous overload recovery should the test apparatus be disturbed during a measurement period.

A separate "isolation" DC to DC power supply is used to power the preamplifier U2 and active filter U2. This ensures low-noise performance of these circuits and also allows in circuit transducer leakage resistance measurement. This is accomplished by relay connecting the (-15V) output of U6 to the signal processing analog ground through R23. This connection applies 15V to the MILES transducer windings and core with respect to its outer shield which remains connected to the tester analog ground and preamplifier chassis. Any transducer leakage current between windings-core

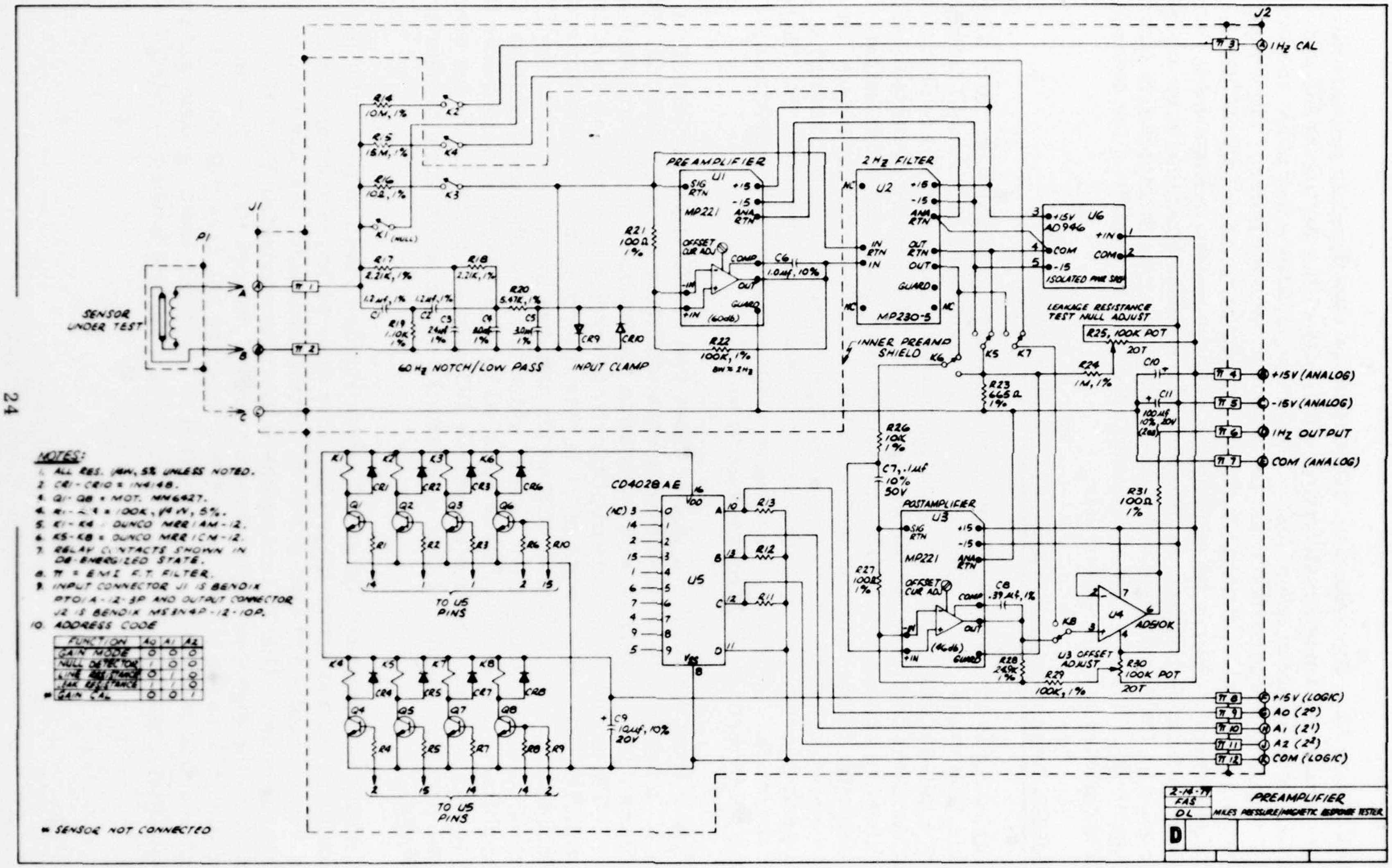


FIGURE A2 - MILES PRESSURE/MAGNETIC RESPONSE TESTER and shield are therefore converted to a voltage via R23 and amplified by U3. This output voltage is inversely proportional to the transducer leakage resistance and can be processed by the electronics console.

Transducer windings resistance measurements are made in a similar way. A constant current established by (R15) which is much greater than the transducer winding resistance is injected by appropriate relay connection into the transducer winding. The resulting voltage across the winding is amplified by (U1) whose output is directly proportional to the transducer winding resistance and can be processed by the electronics console. The various operational modes of the preamplifier assembly can be traced through with aid of the following table which gives preamplifier function and mode relay(s) state versus input address.

	FUNCTION	A0	A1	A2	K1	K2	K3	K4	K5	K6	K7	K8
0	Gain Mode	0	0	0	0	0	0	0	0	0	0	0
1	Null Detect	1	0	0	1	0	0	0	0	0	1	1
2	Line Resistance	0	1	0	0	0	0	1	0	1	0	1
3	Leakage Resistance	1	1	0	0	0	0	0	1	1	0	0
4	Gain Calibrate	0	0	1	0	1	1	0	0	0	0	0

Relay Designation: 0 De-energized
1 Energized

The input address lines are decoded by (U5) which drives appropriate relays shown in the table above via drivers (Q1 - Q8).

MILES Tester Pressure Reference

Figure A3 is a schematic diagram of the tester pressure reference. This circuit was shown in the system concept diagram, Figure A1. It conditions the force transducer output signal prior to cross-correlation with the preamplifier output.

Signal from the force transducer is passed through a 3rd order Butterworth 2 Hz low-pass active filter (U1) and buffer (U2). This filter is the same as that used in the preamplifier. The signal is then phase shifted by an all-pass network (U3). This network introduces phase shift without changing the

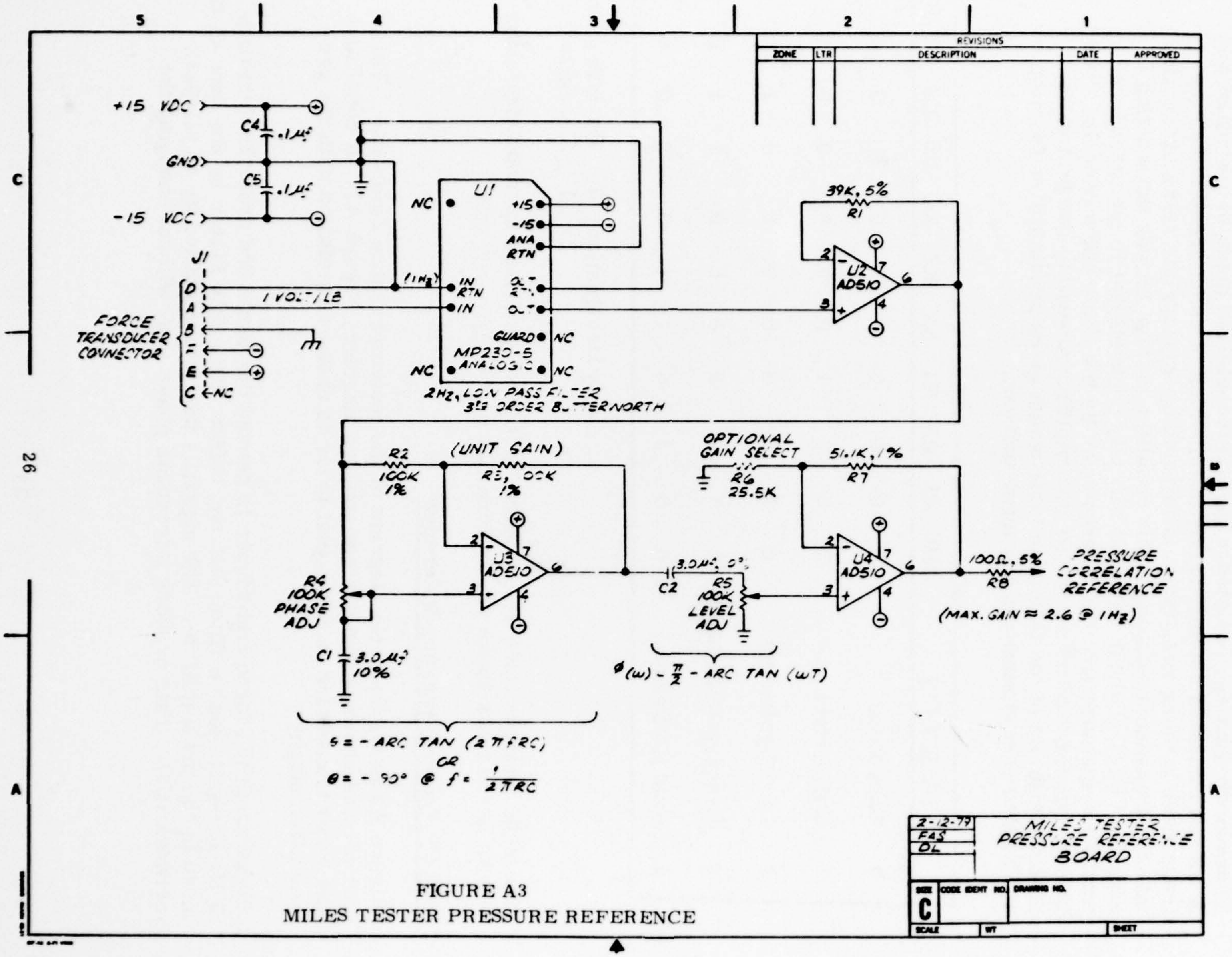


FIGURE A3
MILES TESTER PRESSURE REFERENCE

signal amplitude. The phase adjustment shown equalizes the phase shift of the pressure correlation reference channel with that of the preamplifier channel. A high pass network removes any DC terms and provides an output level adjustment for output amplifier (U4) as shown.

MILES Tester Output Correlator

Figure A4 is a schematic diagram of the tester output correlator. This circuit was shown in the system concept diagram, Figure A1. It performs a cross-correlation function between the pressure "reference" channel described above and the MILES transducer preamplifier channel.

The signals (adjusted for zero phase difference) are multiplied by a four quadrant multiplier module (U1). The output which contains DC plus AC terms is then averaged (passive RC network) to remove the AC signal (and noise). The resulting DC voltage is then directly proportional to the sensitivity of the transducer under test times a constant which is determined by system gain. The output of the averaging network is buffered by output "scaling" amplifier (U2).

MILES Tester Pneumatic Connection

Figure A5 is a block diagram and layout of the tester pneumatics. The various functions shown are discussed in sections III and IV of this report Line air at 100 psi is passed through an input filter (A) and lubricator (B) as shown). A two stage regulator scheme then provides conditioned air for the various functions shown

The high-pressure regulator (c) provides air at 80 psi for the transducer clamping cylinders (L, M, N) and pre-regulates the input of low-pressure regulator (D). The low-pressure regulator is used to provide a stable tension (bias force) to the MILES transducer under test via cylinder (J) as shown. This bias force must be stable so as to not introduce extraneous signals into the transducers during test. The calibration of the tension control regulator (D) is shown in Figure A6.

MILES Tester Magnetics Wiring

Figure A7 is a schematic diagram of the Phase II magnetics circuit. This relatively high current circuit is powered by two 6 volt storage batteries. It provides a DC magnetic bias field of +10, +.25, -.25, or -10 Oersteds within the test chamber as selected by switches S1 and S2. The bias field can also be low level modulated ($\pm$ 100 gamma peak) with an external oscillator as shown. The low level 1 Hz field is used for magnetic sensitivity tests whereas the DC bias field is used for both pressure and

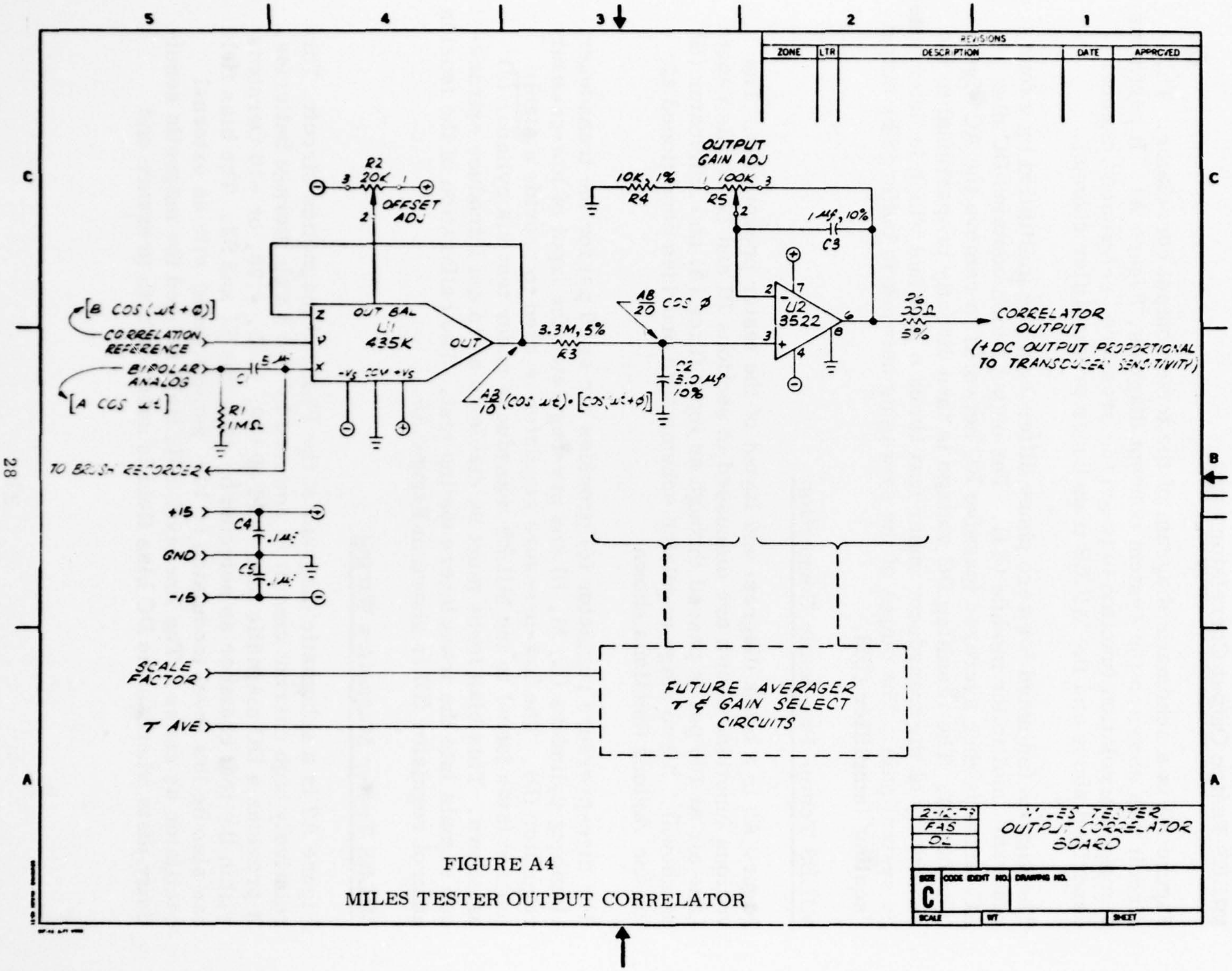


FIGURE A4

MILES TESTER OUTPUT CORRELATOR

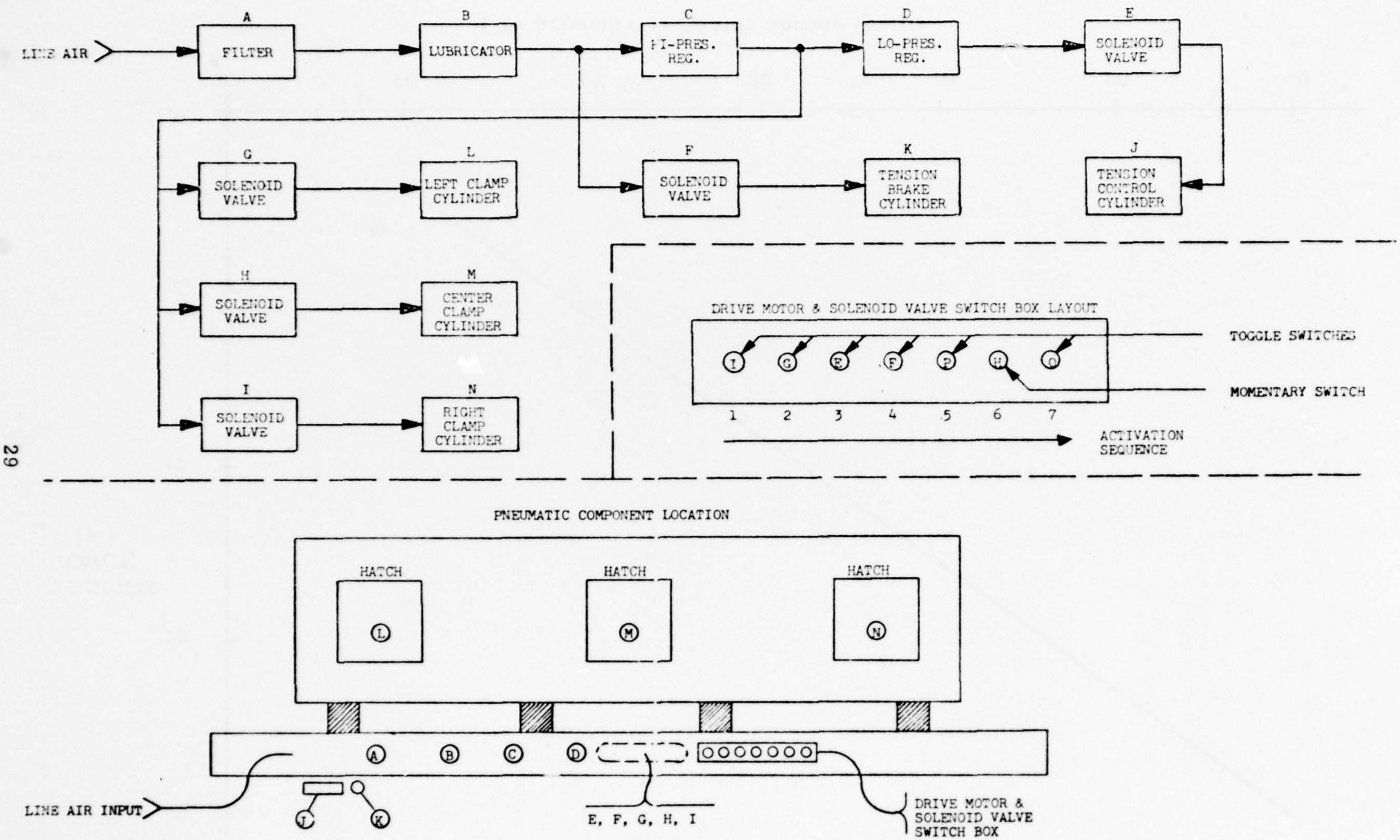


FIGURE A5 - MILES-TESTER PNEUMATIC CONNECTION

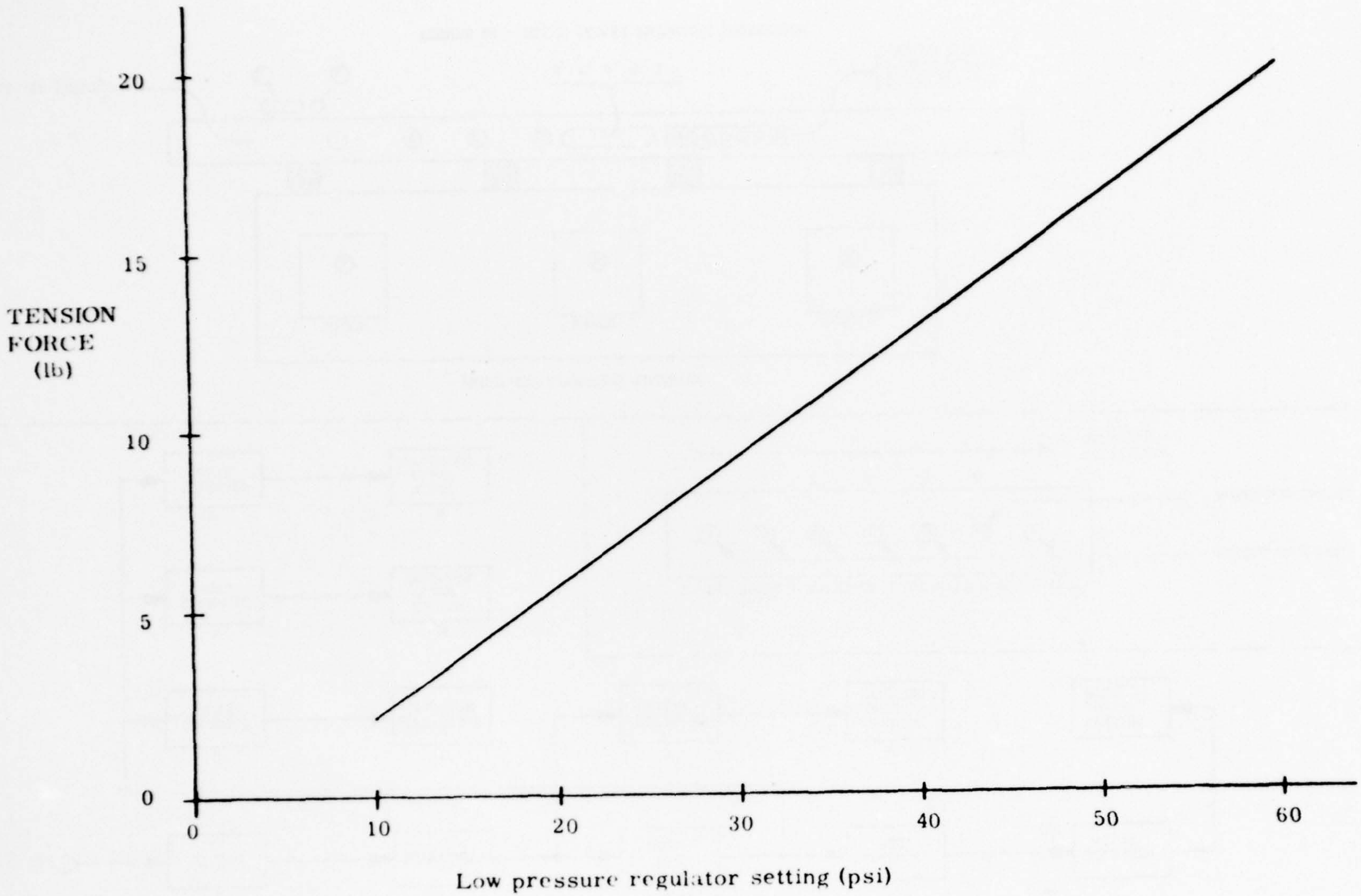
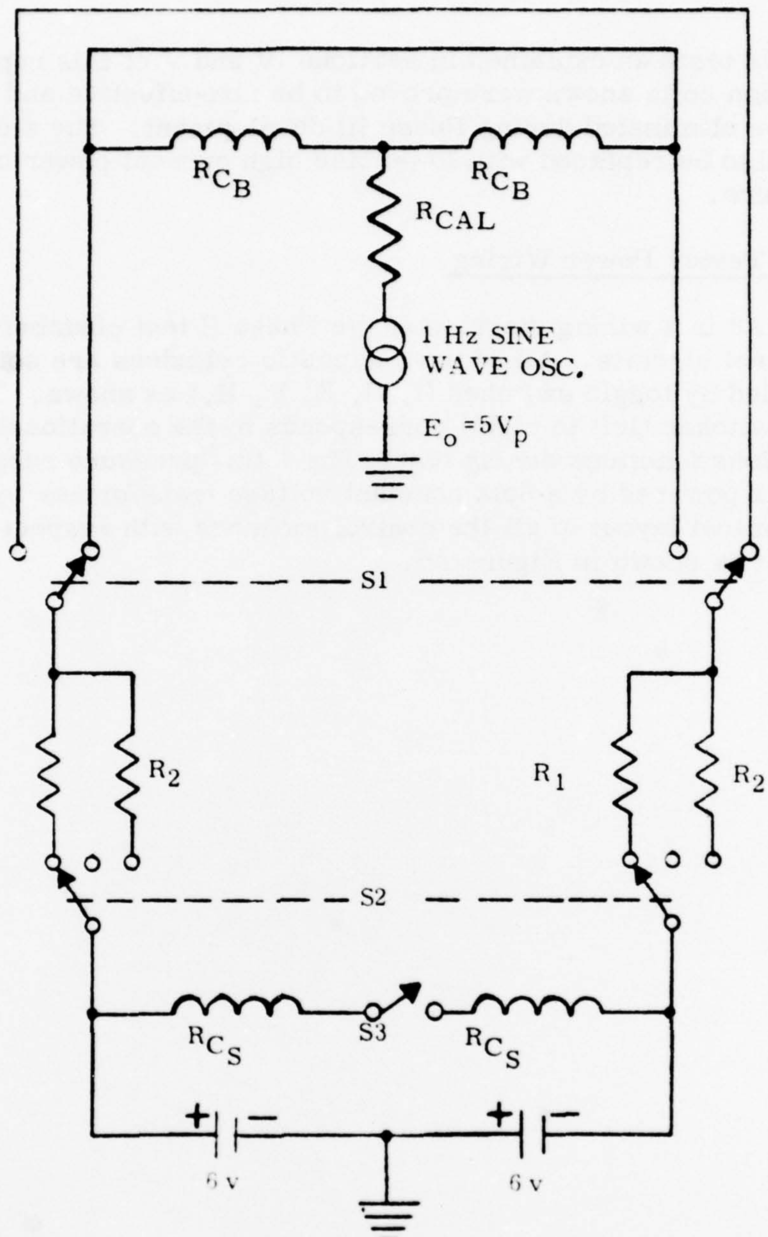


Figure A6 - Transducer Tension Control Calibration



R_{C_B} = 3.8 Ω (Field bias coils), 6.922 0e/A

R_{C_S} = 6.5 Ω (Saturation coils), 8 0e/A

R_{CAL} = 17.3 Ω (Field modulation), 100 γ PEAK

R_1 = 1.2 Ω (10 0e. CAL.)

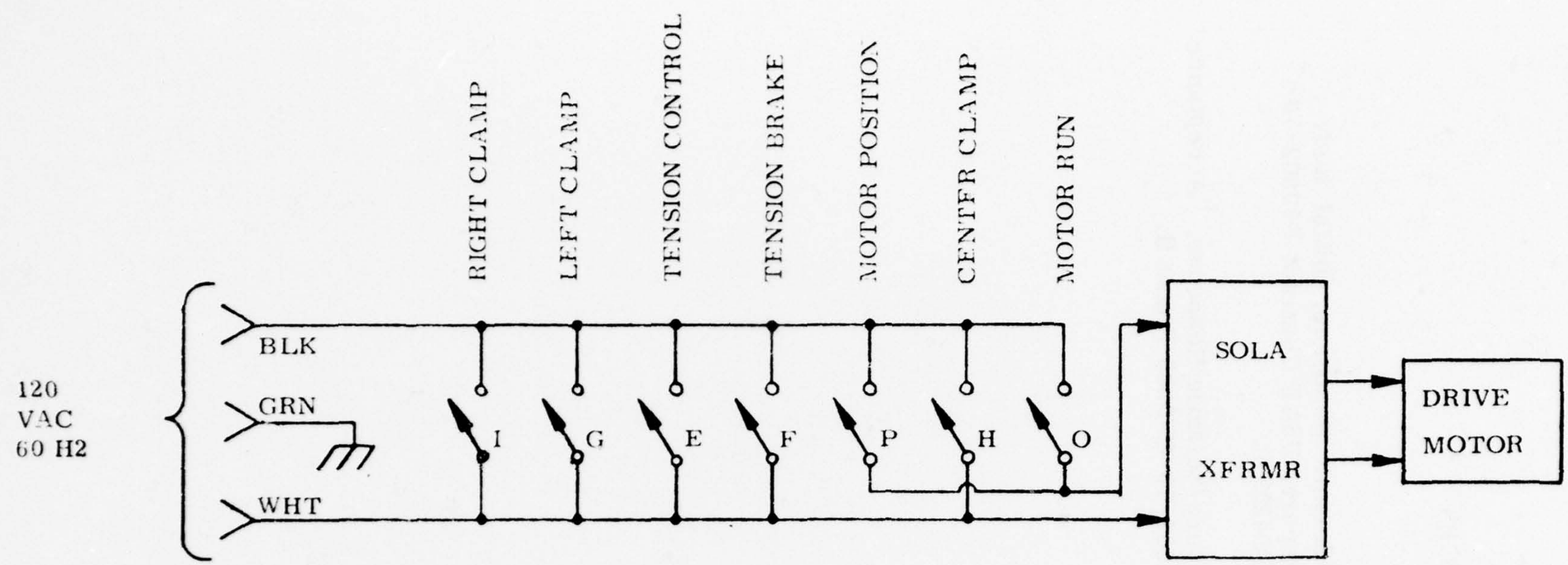
R_2 = 193 Ω (.25 0e. CAL.)

S_1 = Field Polarity DPDT
S_2 = Field Strength DPDT - center off
S_3 = Saturation coils SPST

Figure A7 - MILES Tester Magnetics Wiring magnetic tests as explained in sections IV and V of this report. The saturation coils shown were proved to be non-effective and therefore would be eliminated during Phase III development. The storage batteries would also be replaced with low-noise high current power operational amplifiers.

MILES Tester Power Wiring

Figure A8 is a wiring diagram of the Phase II test chamber 120 V AC, 60 Hz control circuits. All of the pneumatic cylinders are solenoid value controlled by toggle switches (I, G, E, F, H,) as shown. The layout of these switches (left to right) corresponds to the operational sequence of the various functions during test. The 1 Hz "pressure response" drive motor is powered by a Sola constant voltage transformer by switch (0). The physical layout of all the control switches with respect to the test chamber is shown in Figure A5.



Notes:

1. All switches shown "off"
2. "I, G, E, F, H, O" are SPST toggle switches
3. "P" is a S.P., N.O. momentary push button switch
4. Refer to data sheets for complete SOLA & MOTOR wiring
5. Mount all switches in bud "mini-box"

Figure A8 - MILES Tester Power Wiring

REFERENCES

1. Starr, J. B., "MILES Pressure/Seismic Response, Initial Study and Analysis," Final Technical Report, USAF Contract F30602-76-C-0385 Phase I, RADC-TR-77-222 (A042095).

2. Sutherland, K. J., "MILES Pressure/Seismic Response, "Acceptance Test Report, USAF Contract F30602-76-C-0385 Phase II.

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