DATE OF ISSUE: June 19, 1956

Report Number: K-973, Part II

Subject Category: INSTRUMENTATION

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# VIBRATION EFFECTS ON THE TAYLOR 206R PRESSURE TRANSMITTER, PART II


G. H. Job and J. A. Owen

Instrument Engineering Department

Plant Engineering Division



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Oak Ridge, Tennessee

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## ABSTRACT

This report presents the results of a series of tests comparing the performance of a standard Taylor 206R Pressure Transmitter with one altered to overcome the undesirable effects of mechanical vibration. The alterations consist of adding a dashpot, filled with Taylor XC-299 fluid, on the Sensing Lever; replacing the Overthrow Spring with a flexible metal strip; removing the capillary tubing and capacity cylinder in the secondary bellows assembly; and feeding the output signal directly into the secondary bellows.

The performance of the altered transmitter is compared with that of the transmitter as originally designed. While the effects of vibration are not completely eliminated, they have been reduced by a factor of three at frequencies above 60 cps., and have been almost completely elimininated below 60 cps. In addition, the dynamic performance of the transmitter has been improved.

It is recommended that all new transmitter installations be made with transmitters altered to reduce the effects of mechanical vibration.

# VIBRATION EFFECTS ON THE TAYLOR 206R PRESSURE TRANSMITTER, PART II

## BACKGROUND

The preliminary study of the response to external vibration of the Taylor 206R Pressure Transmitter has been presented in Part I of this report. In that study, it was shown that the transmitter was very sensitive to external vibration forces. This responsive characteristic was most pronounced in the region of 3600 cpm. and 2400-2700 cpm. It was further shown that the best corrective method was to install a dashpot on the Sensing Lever and to remove the resistance-capacitance element in the secondary bellows assembly. For further background details, the reader is referred to Part I of this report.

The results of the preliminary study were discussed with the Taylor Instrument Companies, makers of the transmitter, who devised and furnished for testing various designs of dashpots, dashpot fluids, and overthrow linkages. These parts were tested and evaluated and a final set of alterations was selected. This report describes the final design and presents the results of a series of performance tests on a transmitter incorporating these alterations.

## ALTERATIONS

The Taylor Type S dashpot (see Fig. 1-B), using XC-299 fluid, proved to be the best practical design. This dashpot is connected to the Primary Sensing Lever and mounted on the baffle support as shown in Figure 1-A. Taylor's XC-299 fluid was found to be the most effective damping medium for reducing vibration response without introducing static linearity and hysteresis errors. This fluid is a mixture of DC-200 (with a Viscosity of 100,000 centistokes) and DC-11 compound. The DC-200 oil is most effective for damping high frequency vibrations while the DC-11 compound is best for low frequency vibrations. The mixture is effective in damping both low and high frequencies.

A flexible metal strip was found to be a better overthrow linkage for connecting the Primary Sensing Lever to the Baffle than the original overthrow spring arrangement. This strip eliminates high frequency vibrations of the Baffle, present when the original overthrow spring was used, while still protecting the nozzle and baffle assembly from damage resulting from overranging the transmitter. Various designs of this strip were tried with the final design being a strip 1/4 in. wide, 1 - 3/16 in. long, and 0.002 in. thick with the width necked down to 9/64 in. in the middle as shown in Figure 1-B.

The Primary Sensing Lever Extension was re-designed to permit connection of the dashpot plunger and the Overthrow Strip.

## FIELD TESTS

A number of the altered transmitters were installed in the process area. Charts made from three of these installations for both non-damped and damped transmitters are shown in Figure 2. These charts were traced from actual miniature strip-chart recordings and show the output pressure ($P_o$) oscillations induced by vibration in the non-damped transmitters and the reduction realized in these oscillations when damped transmitters were installed.

Magnitudes of oscillations with non-damped transmitters and when replaced with damped transmitters are shown, tabular form, in Figure 3. The reduction in amplitude varies from 65% to 100% with an average of about 90%.

## PERFORMANCE OF DAMPED AND NON-DAMPED TRANSMITTERS

A damped transmitter and a non-damped transmitter were given performance tests under identical laboratory conditions.

Two types of performance tests were conducted. The first type of tests was concerned with the effect of external stimuli such as ambient vibration or shock. In this case, the input pressure to the transmitter was held at a constant value and the effect of external stimuli on the output pressure was measured. Any variation in the output pressure due to external causes is undesirable.

The second type of tests was concerned with the dynamic performance of the transmitter. In these tests, the input pressure was varied according to certain patterns, such as sinusoidally or step-wise, and the output pressure of the transmitter was examined to see how accurately it followed the input pressure. These tests were quite revealing since it might be expected that, with damping introduced into the transmitter, the dynamic characteristics might suffer. Test results, however, show the converse to be true.

The tests and test results were as follows:

(1) Vibration Susceptibility

The two instruments were mounted back-to-back on a beam which was connected to a vibration generator as shown in Figure 4. A constant input pressure ($P_i$) was adjusted to give an output pressure ($P_o$) of 50% of full scale. The output pressures of both instruments were recorded on a high-speed two-channel recorder (see Figure 5). The transmitters were vibrated at frequencies from 1,000 to 10,000 cpm. with a constant peak acceleration of 0.1 g.

Data taken from the resulting charts are plotted in Figure 6. The vibrations caused a maximum error (shift in output pressure, $P_o$, with a constant input pressure) in the non-damped transmitter of -34% which occurred at 5,100 cpm. The maximum error in the damped instrument was -13% and occurred at 6000 cpm. Maximum oscillation magnitude (indicated by the spacing between the lines in Fig. 6) was 27% of full scale and occurred at 9,400 cpm. in the non-damped instrument. The maximum oscillation magnitude in the damped transmitter was only 2% and occurred at a frequency of 3,700 cpm.

Other vibration tests have shown that the output pressure error is dependent upon the magnitude of acceleration of the disturbing vibration, the damped transmitter's error being proportionally smaller. For instance, when vibrated at a constant peak acceleration of 0.2 g., (twice that illustrated in Figure 6) the maximum error of the non-damped transmitter was slightly greater than -50% at a frequency of 5,100 cpm., while the maximum error of the damped transmitter was -35% at a frequency of 4,200 cpm.

(2) Shock Reaction

Using the same test circuit and apparatus as that of the vibration test (Fig. 4), the transmitter's reactions to shock were recorded (Fig. 12). Shock was produced by rapping the mounting beam with varying degrees of force. The chart indicates a much smaller shock reaction for the damped transmitter.

(3) Frequency Response

A sinusoidal input pressure signal of 1.0 ± 0.2 psi. was introduced to each transmitter. Under static conditions, this would produce an output pressure of 10.5 psig. (50%) ±1.5 psi. (10%). The input and output signals were recorded simultaneously by the two-channel recorder, as shown in Figure 7, at frequencies of from 1 to 1,000 cpm. Magnitude Ratio, Phase Shift, and Distortion were determined from the charts by a graphical method of Fourier waveform analysis and plotted as a function of frequency (see notes 1, 2, 3, and 4, appendix).

The Magnitude Ratio curve (Fig. 9) of the non-damped transmitter is flat to about 12 cpm. with a peak of 1.70 at about 50 cpm. and drops to 0.20 at 600 cpm. The Phase Shift curve (Fig. 8) has a peak of +30° at about 32 cpm. and drops to -60° at about 140 cpm.

The Magnitude Ratio curve of the damped transmitter is flat to about 30 cpm. with a peak of 1.10 at about 100 cpm. and drops to 0.31 at 600 cpm. The Phase Shift curve goes from 0 at 1 cpm. to -10° at 45 cpm., -24° at 100 cpm. and -60° at 220 cpm.

Total harmonic distortion of the output signal, as shown in Figure 10, reaches a maximum value of 69% at 130 cpm. in the non-damped transmitter and 15% at 250 cpm. in the damped transmitter. Harmonic distortion is the distortion in the output pattern of the transmitter as compared to the input pattern. A large amount of harmonic distortion, especially at low frequencies, would render an instrument unsuitable for anything except static measurements.

(4) Step Response

Step-wise changes were introduced into the input pressures of both transmitters while output pressures were recorded on the two-channel recorder as shown in Figure 11-A. Figure 11-B shows the output pressures of the transmitters, for an increasing and a decreasing step, plotted on an extended time scale.

The non-damped transmitter's output overshoots the true pressures by 5% in the increasing step and 17% in the decreasing step while the damped transmitter's output overshoots the true pressures by less than 1% in the increasing step and 2% in the decreasing step. The time constants, as measured from the chart, are 0.30 sec. (increasing step) and 0.06 sec. (decreasing step) for the non-damped transmitter and 0.14 sec. (increasing step) and 0.06 sec. (decreasing step) for the damped transmitter.

It may be seen that the damped transmitter is not a "slower" instrument when compared with the non-damped transmitter. Instead, its output actually approaches a new pressure level more quickly than does that of the non-damped transmitter. This faster response is predictable from the frequency response curves. The faster response is achieved principally by the removal of the capillary tubing in the secondary bellows assembly. The tubing was necessary in the standard design to obtain a steady output pressure and was a form of pneumatic damping. With the more optimum damping, obtained with the changes described herein, this pneumatic damping was no longer necessary, and its removal resulted in the better response shown by these results.

(5) Output Error vs. Input Frequency

Using the test circuit and apparatus of the Frequency Response test (Fig. 7) with a sinusoidal input signal of 50% ±2.5% of the range of the transmitter, the output error (see note 5, appendix) of the transmitters was measured at input frequencies of from 0 to 7,200 cpm. The resulting data are plotted in Figure 13.

The maximum value of the non-damped transmitter's error is -36.0% and occurs at an input frequency of 4,500 cpm., while the maximum error of the damped transmitter is -3.8% and occurs at 4,020 cpm.

If the amplitude of the input signal is increased, the magnitude of the transmitter's error also increases. An input signal of 50% ±4.0% produces a maximum output error of -48.8% in the non-damped transmitter and -22.7% in the damped transmitter.

## CONCLUSIONS AND RECOMMENDATIONS

The addition of a Taylor Type S dashpot with XC-299 fluid, a flexible overthrow strip, and the removal of the capillary tubing and capacity cylinder from the secondary bellows assembly comprise a practical and effective method of reducing the Taylor 206R Pressure Transmitter's response to mechanical vibration. These alterations do not effect the static accuracy, and the speed of response is increased by the removal of the capillary tubing.

Since the effects of vibration are not completely eliminated, the recommendations set forth in Part I of this report should still be followed; especially, in installations where severe vibrational forces exist. Briefly, these recommendations were that transmitters should be mounted on rigid steel racks with vibration isolators. All mounting bolts should be installed with lock washers and drawn up tightly. Copper tubing lines should be clamped by means of felt tubing clamps for a distance of 15 to 20 feet from the transmitter rack.

It is further recommended that all transmitters in future installations be equipped with damping since no installation is completely free of vibration or shock and a damped transmitter has better measuring characteristics. The approximate cost of equipping a transmitter with damping is $15.00 for labor and material.

The results shown in this report are based principally on the tests of one transmitter with a 2 psi range. Transmitters are known to vary slightly from unit to unit in their response to vibration. The amount of variation is slight; however, when compared to the variation between non-damped and damped transmitters.

# APPENDIX

## DEFINITIONS

(1) Magnitude Ratio

The ratio of the amplitude of the fundamental component of the output signal to the amplitude of the input signal at the same frequency.

(2) Phase Shift

The amount, expressed in degrees, by which the fundamental component of the output signal leads or lags the input signal on the time scale.

(3) Distortion

The amount by which the ordinates of the actual output pressure wave differ from the ordinates of the fundamental output component, usually expressed as a percentage of the fundamental component amplitude.

(4) Fourier Waveform Analysis (as used herein)

A graphical method of determining the amplitude and phase angle of the fundamental sine-wave component of a waveform by dividing a complete cycle into twelve equal parts and performing a series of calculations with the lengths of the twelve ordinates. See Reference Data for Radio Engineers, 3rd ed., New York, Federal Telephone and Radio Corporation, p. 291 - 6.

(5) Output Error

The difference, expressed as a percentage of the full scale range, between the measured output pressure and what the output pressure should have been, as calculated from the measured input pressure.

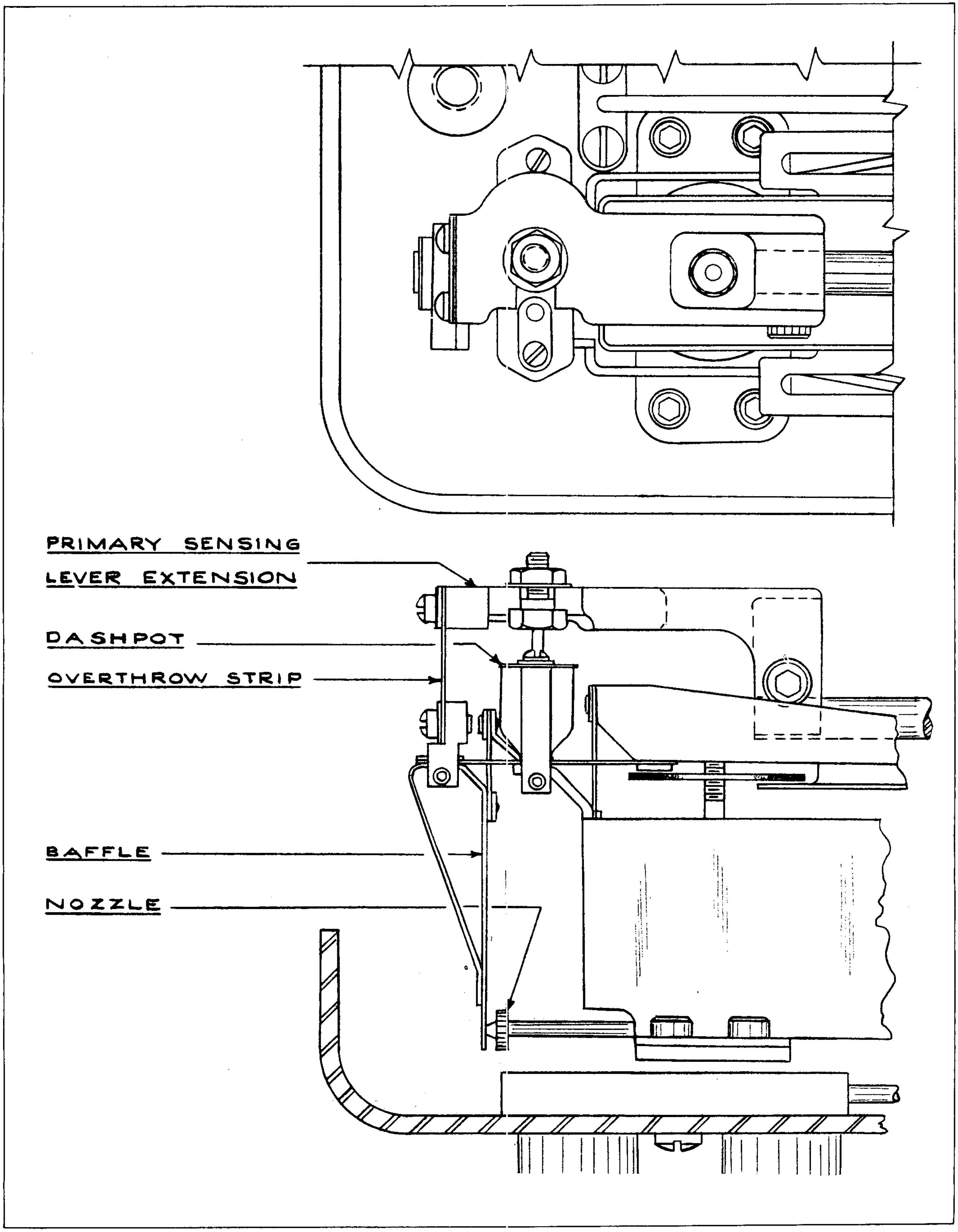


**Figure 1A**

**TAYLOR PRESSURE TRANSMITTER - DAMPED**

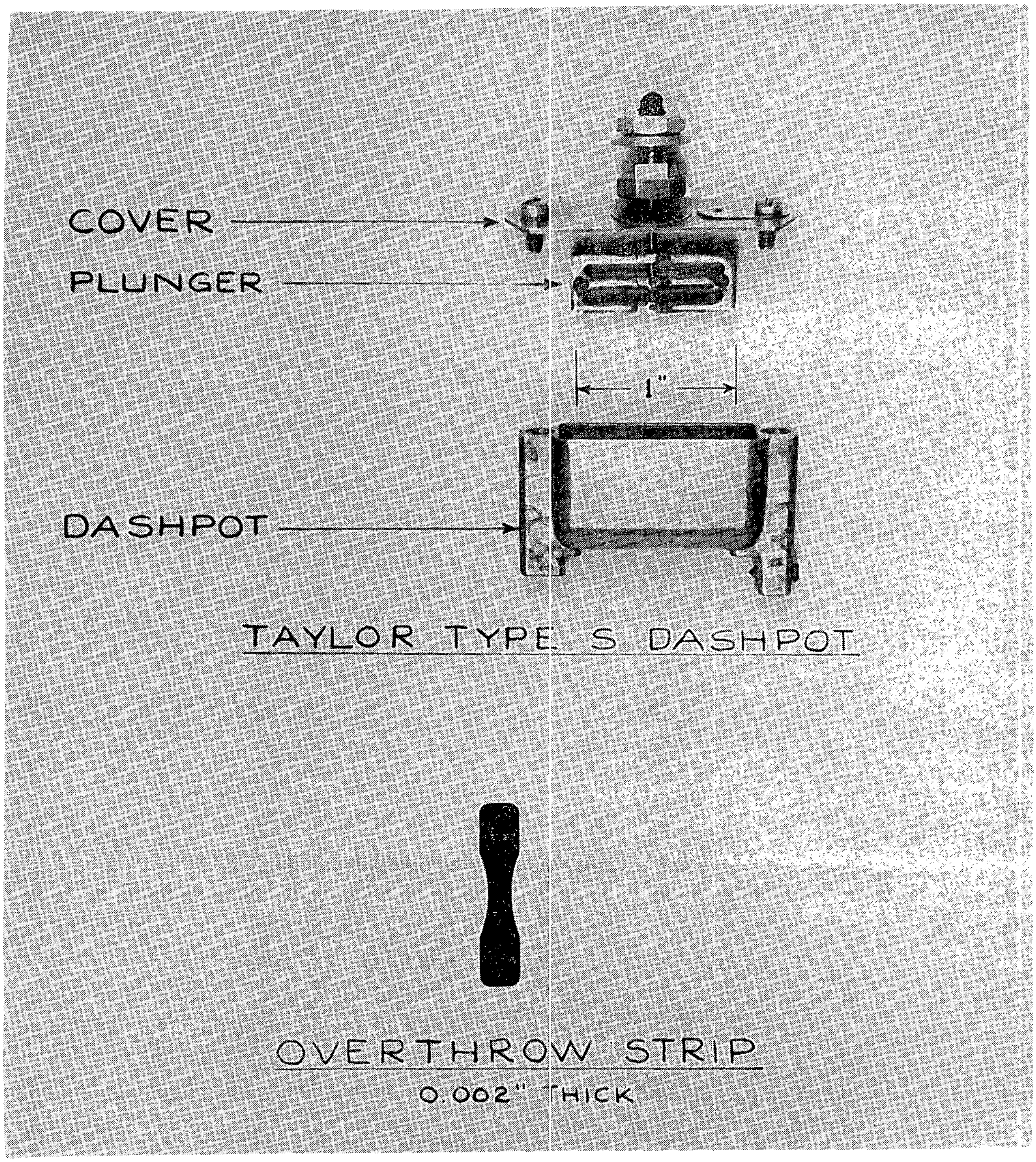


**Figure 1-B**

**DAMPING PARTS**

**FOR TAYLOR 206R PRESSURE TRANSMITTER**

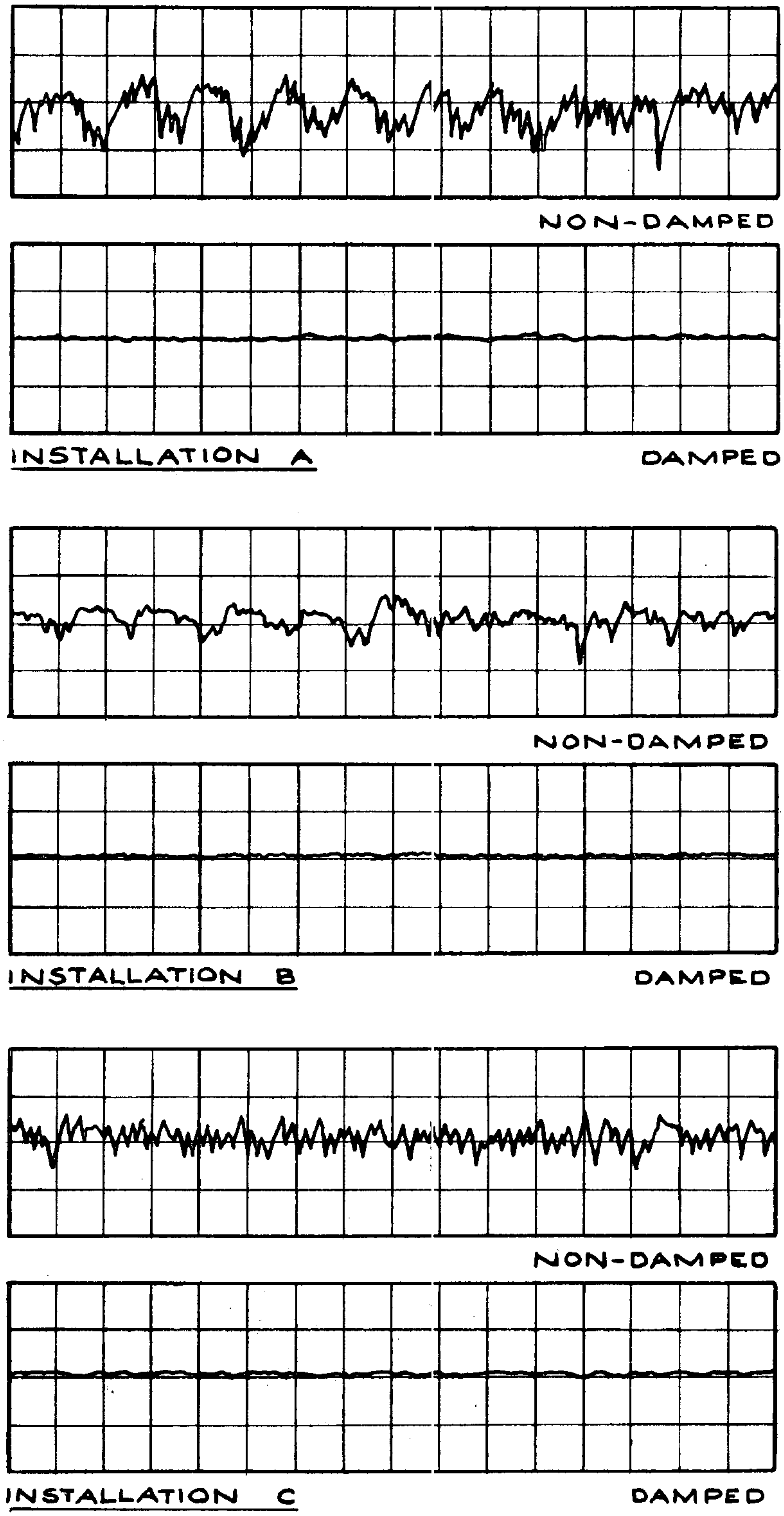


**Figure 2**
**TAYLOR PRESSURE TRANSMITTER**
**FIELD TEST CHARTS**

| INSTALLATION | OSCILLATION MAGNITUDE - PERCENT OF FULL SCALE | | REDUCTION IN OSCILLATIONS - PERCENT |
|---|---|---|---|
| | NON-DAMPED TRANSMITTER | DAMPED TRANSMITTER | |
| A | 18.8 | 2.0 | 90 |
| B | 13.5 | 1.0 | 95 |
| C | 11.6 | 1.0 | 90 |
| D | 6.6 | 0.6 | 90 |
| E | 10.3 | 1.6 | 85 |
| F | 9.8 | 1.3 | 90 |
| G | 1.4 | 0 | 100 |
| H | 6.6 | 2.4 | 65 |
| J | 5.2 | 0 | 100 |
| K | 13.0 | 0 | 100 |
| L | 2.2 | 0.8 | 65 |

Figure 3
DAMPED TAYLOR PRESSURE TRANSMITTER
FIELD TEST RESULTS

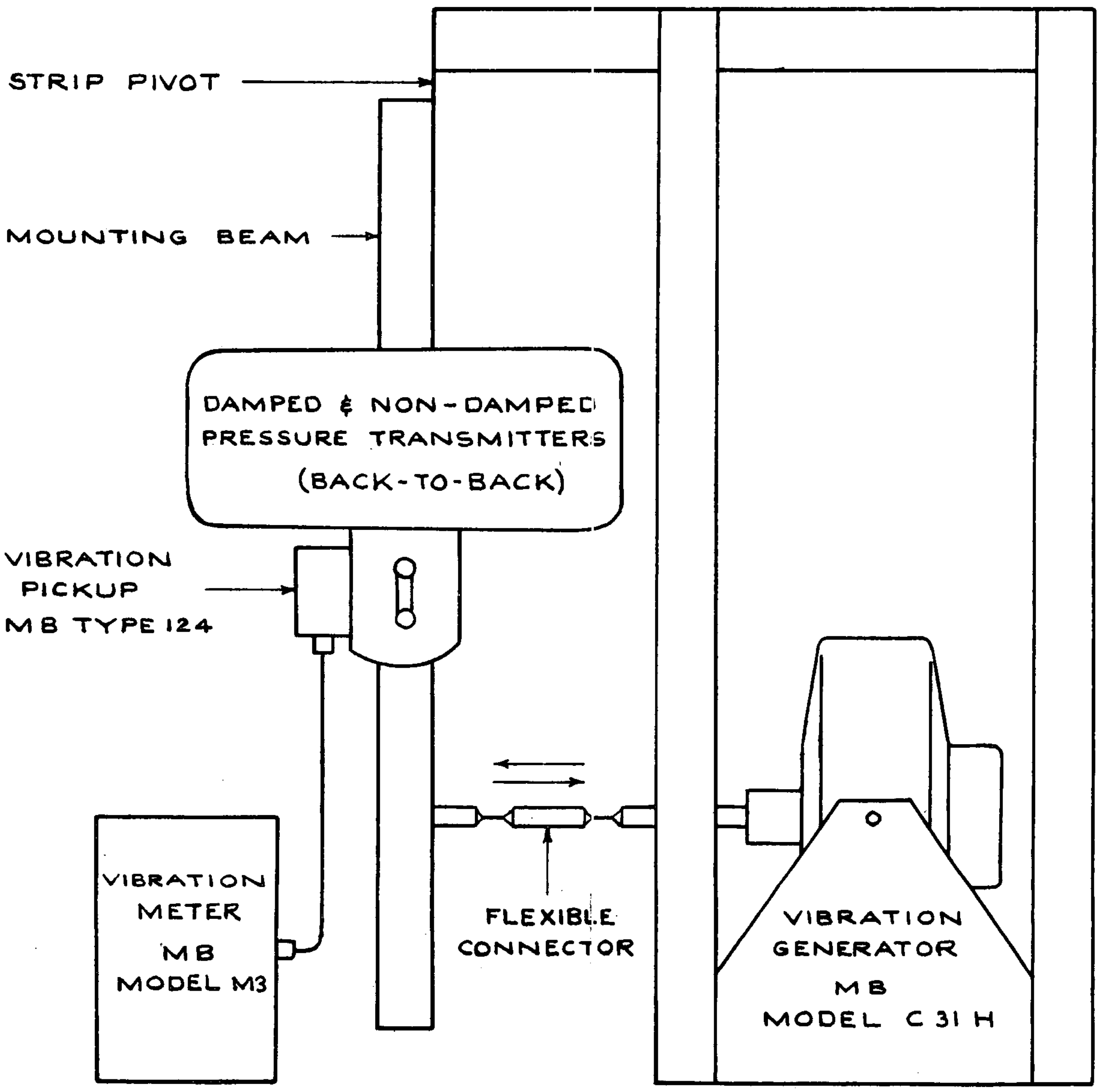


**Figure 4**

**TAYLOR PRESSURE TRANSMITTER**

VIBRATION TESTING APPARATUS

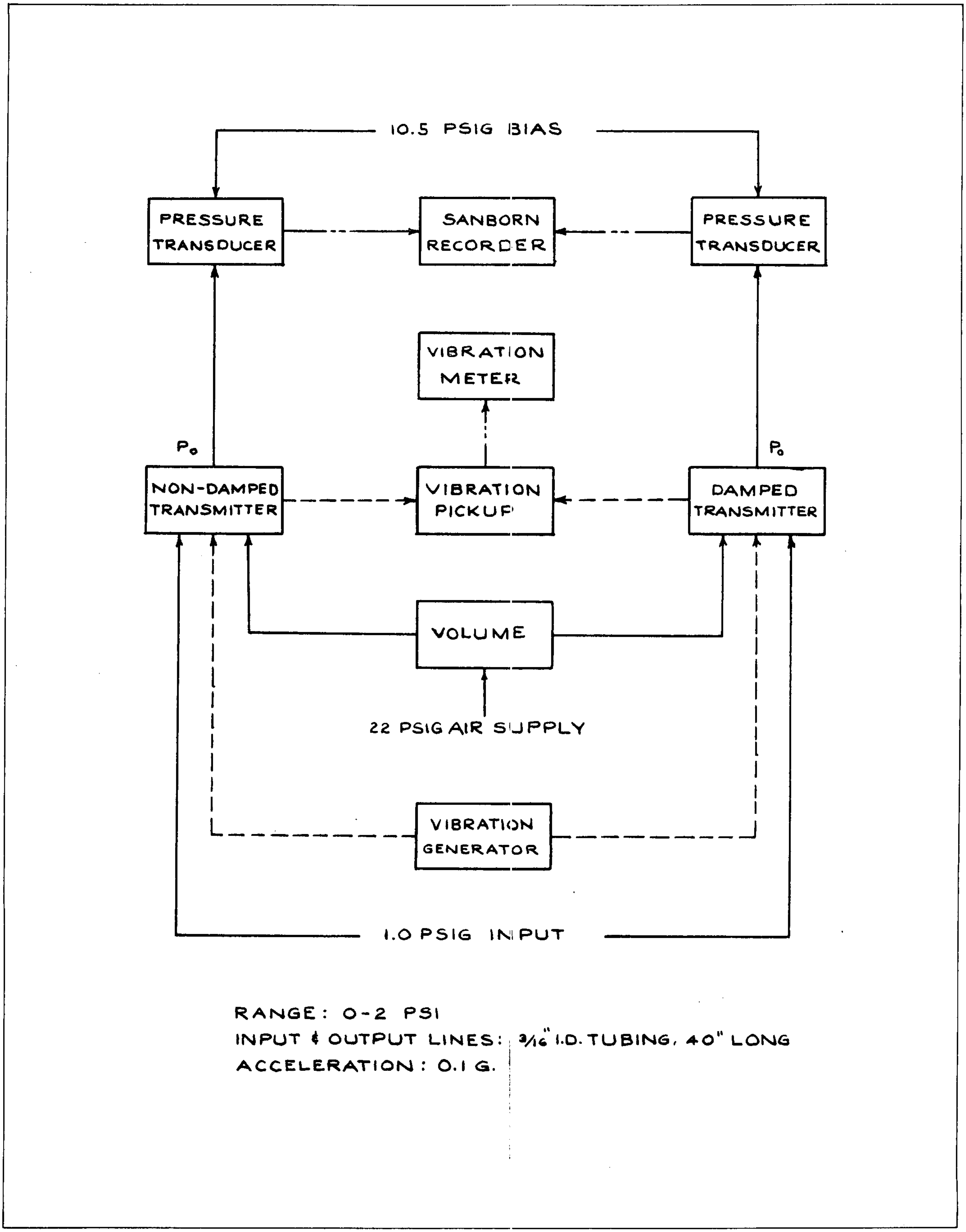


Figure 5
**TAYLOR PRESSURE TRANSMITTER**
VIBRATION RESPONSE TEST CIRCUIT

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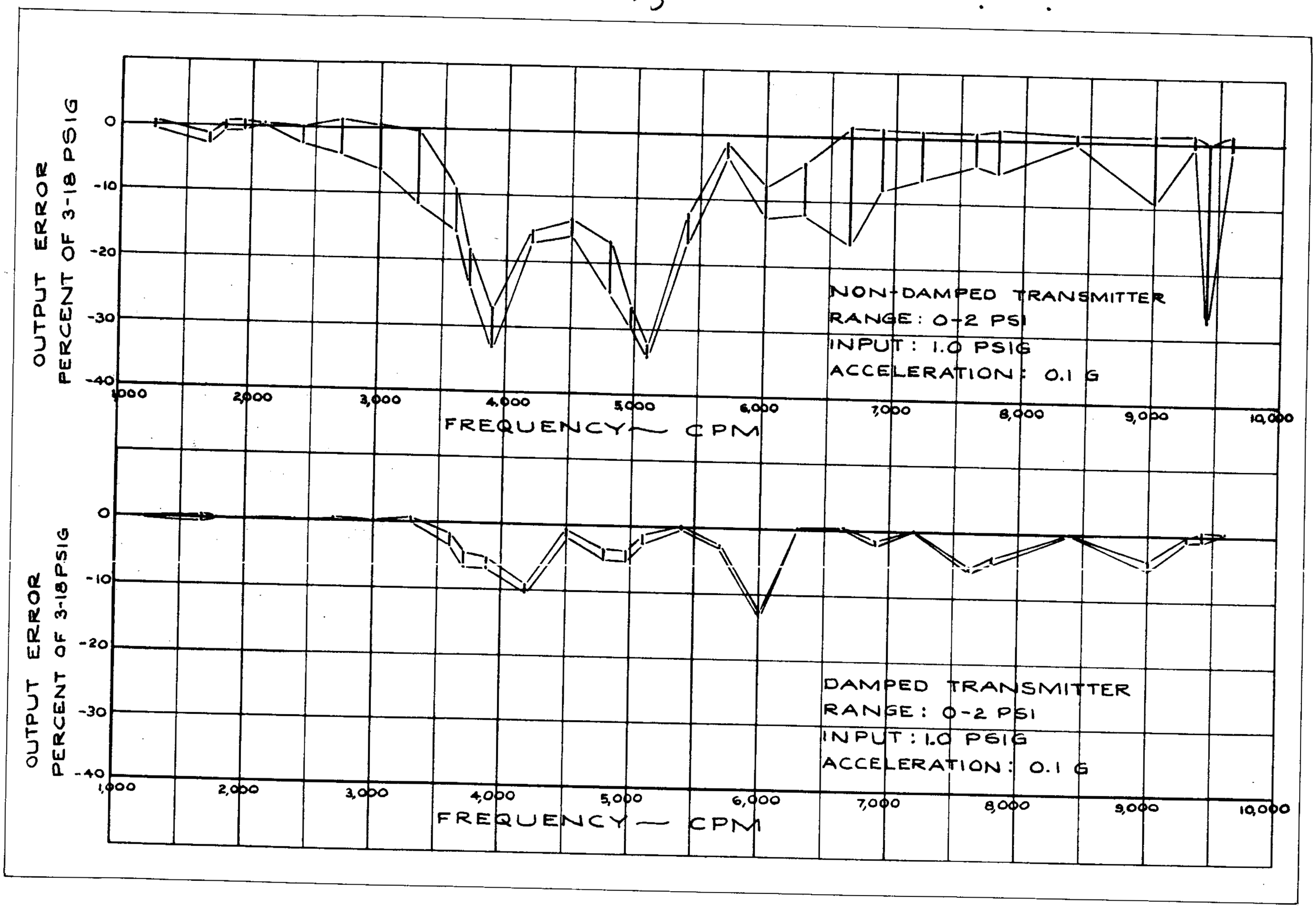



Figure 6

**VIBRATION RESPONSE**

TAYLOR 206R PRESSURE TRANSMITTERS

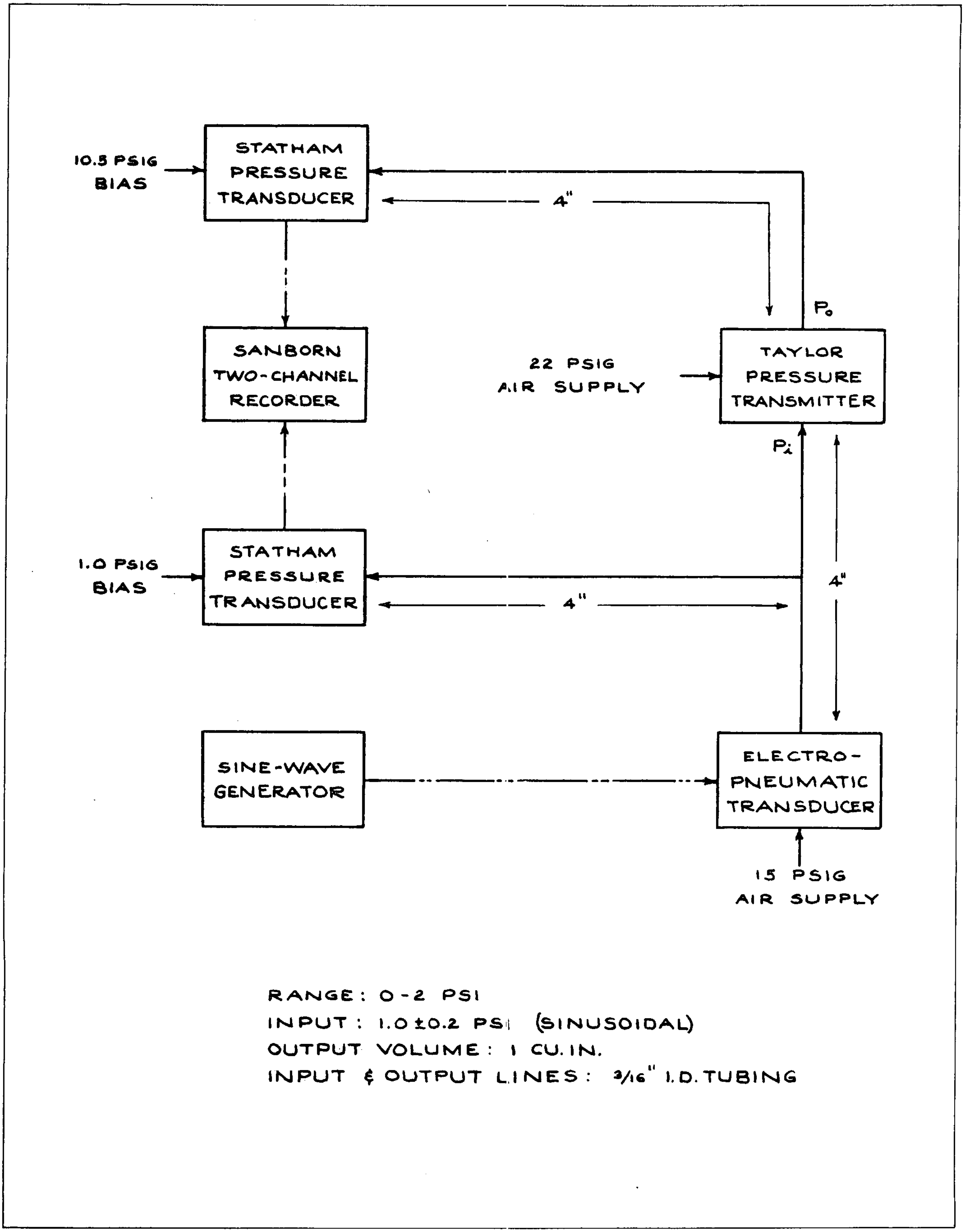



Figure 7

TAYLOR PRESSURE TRANSMITTER

FREQUENCY RESPONSE TEST CIRCUIT

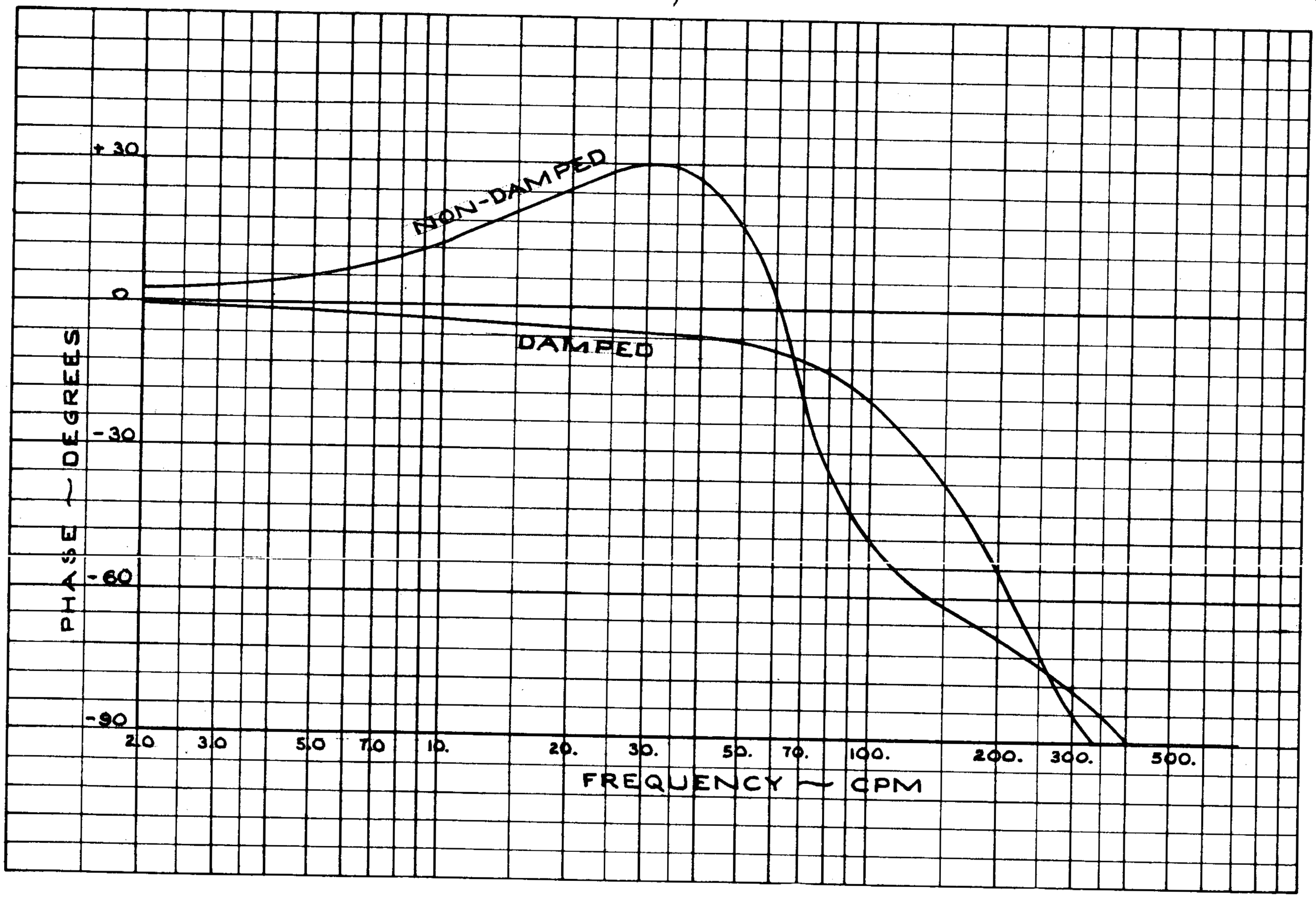



Figure 8
**PHASE SHIFT**
TAYLOR 206R PRESSURE TRANSMITTER
RANGE: 0-2 PSI
INPUT: 1.0 ± 0.2 PSI (SINUSOIDAL)

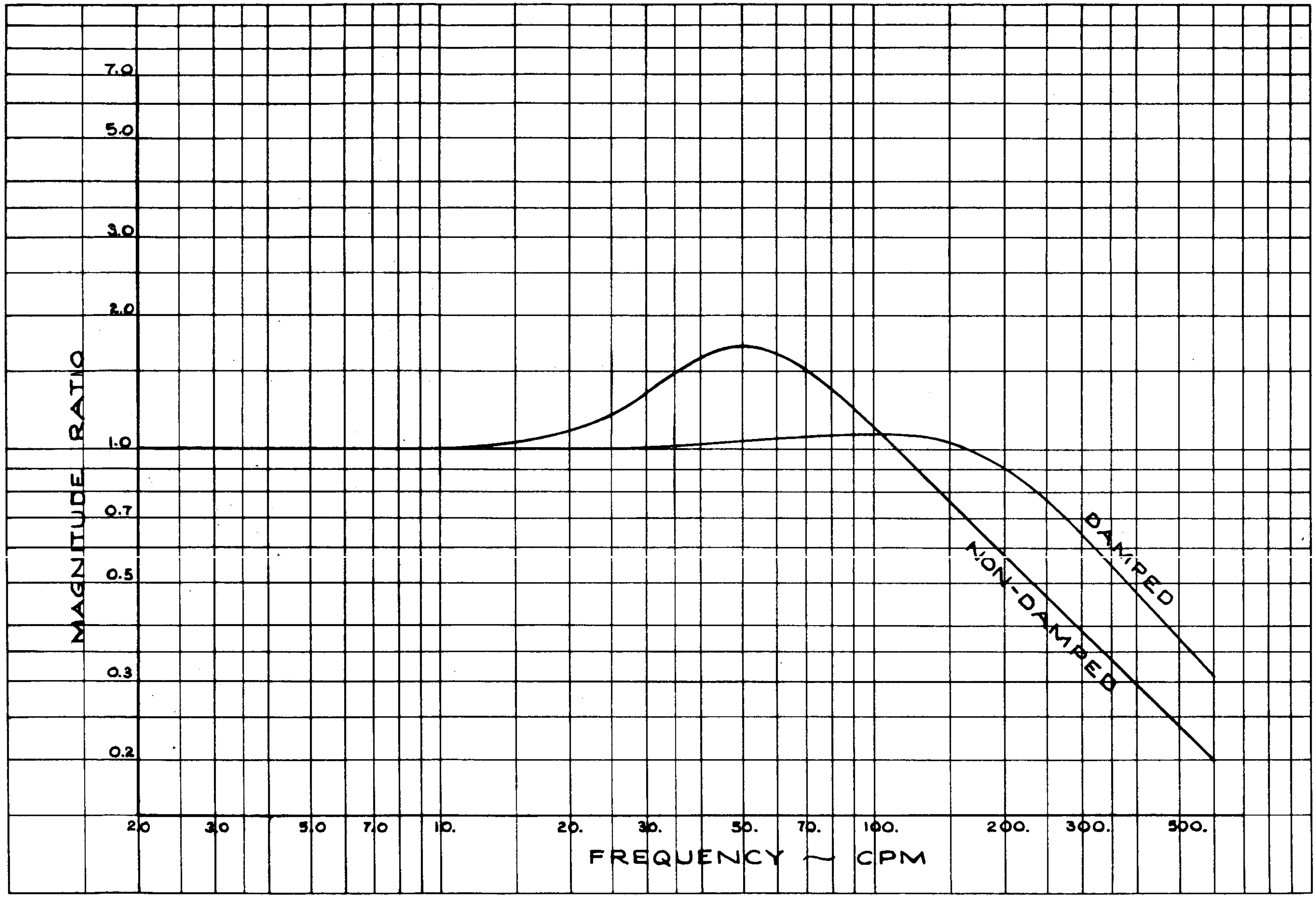



**Figure 9**
**MAGNITUDE RATIO**
**TAYLOR 206R PRESSURE TRANSMITTER**
**RANGE: 0-2 PSI**
**INPUT: 1.0 ± 0.2 PSI (SINUSOIDAL)**

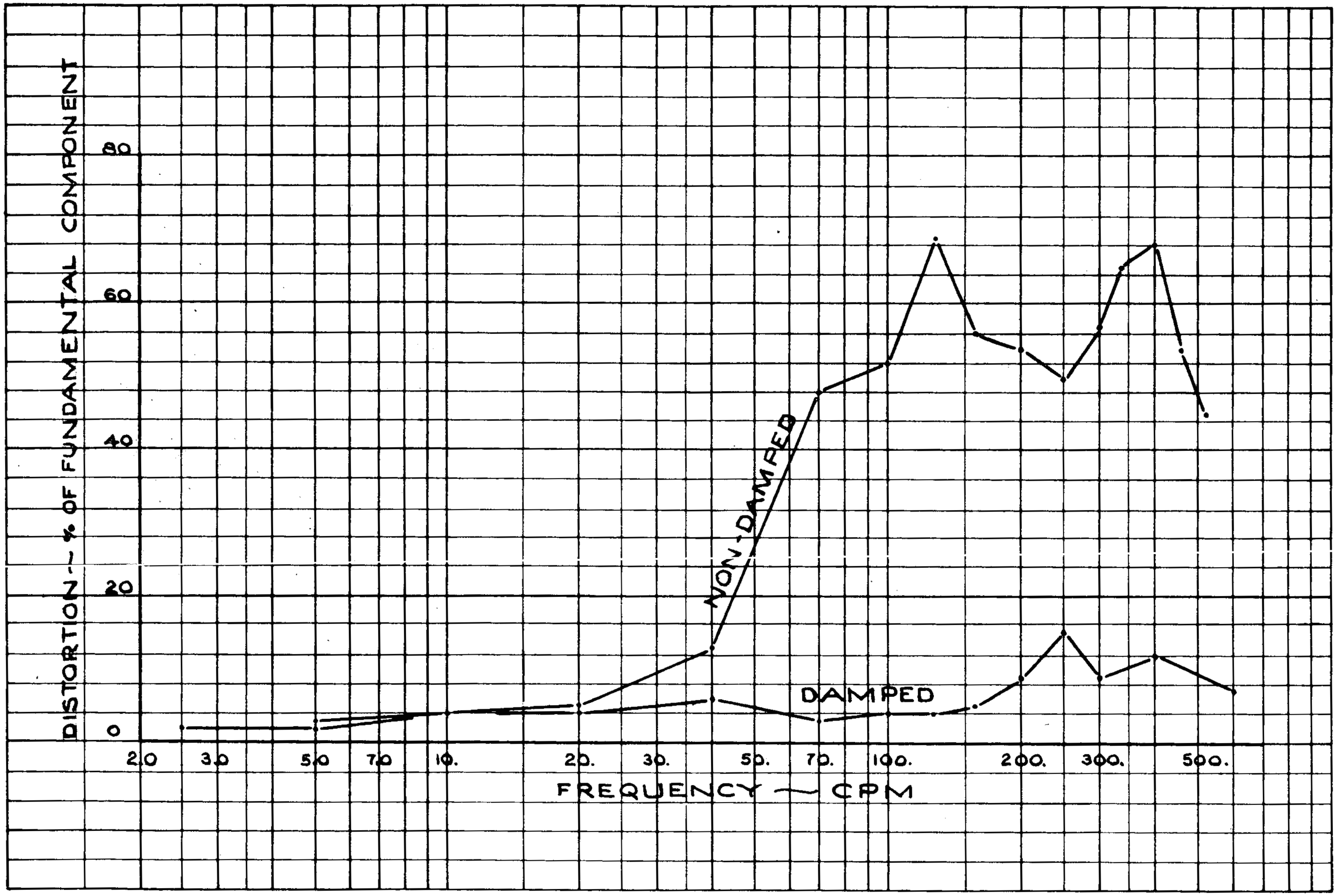



**Figure 10**
**MAXIMUM DISTORTION**
**TAYLOR 206R PRESSURE TRANSMITTER**
**RANGE: 0-2 PSI**
**INPUT: 1.0 ± 0.2 PSI (SINUSOIDAL)**

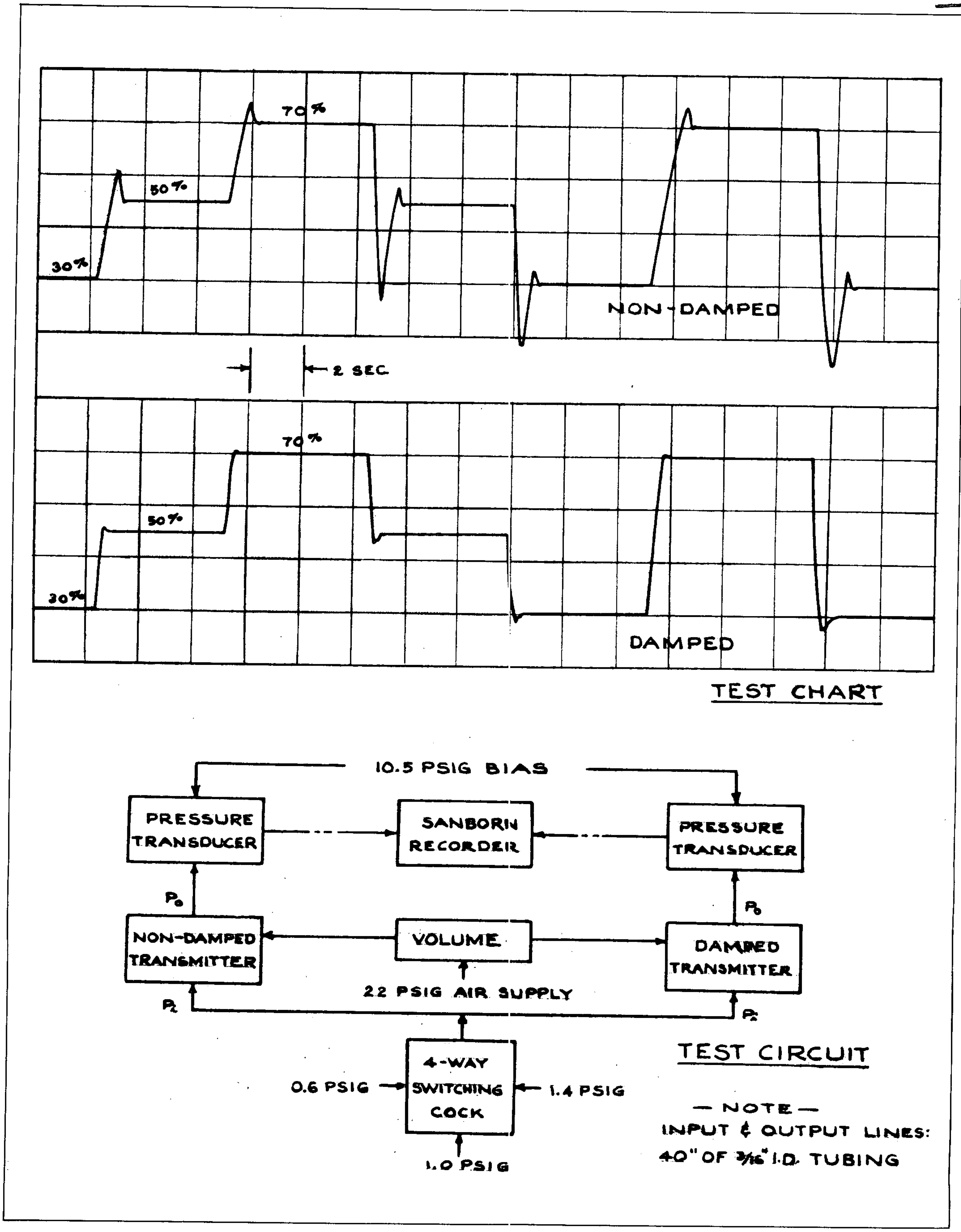



Figure 11-A

STEP RESPONSE

TAYLOR 206R PRESSURE TRANSMITTER

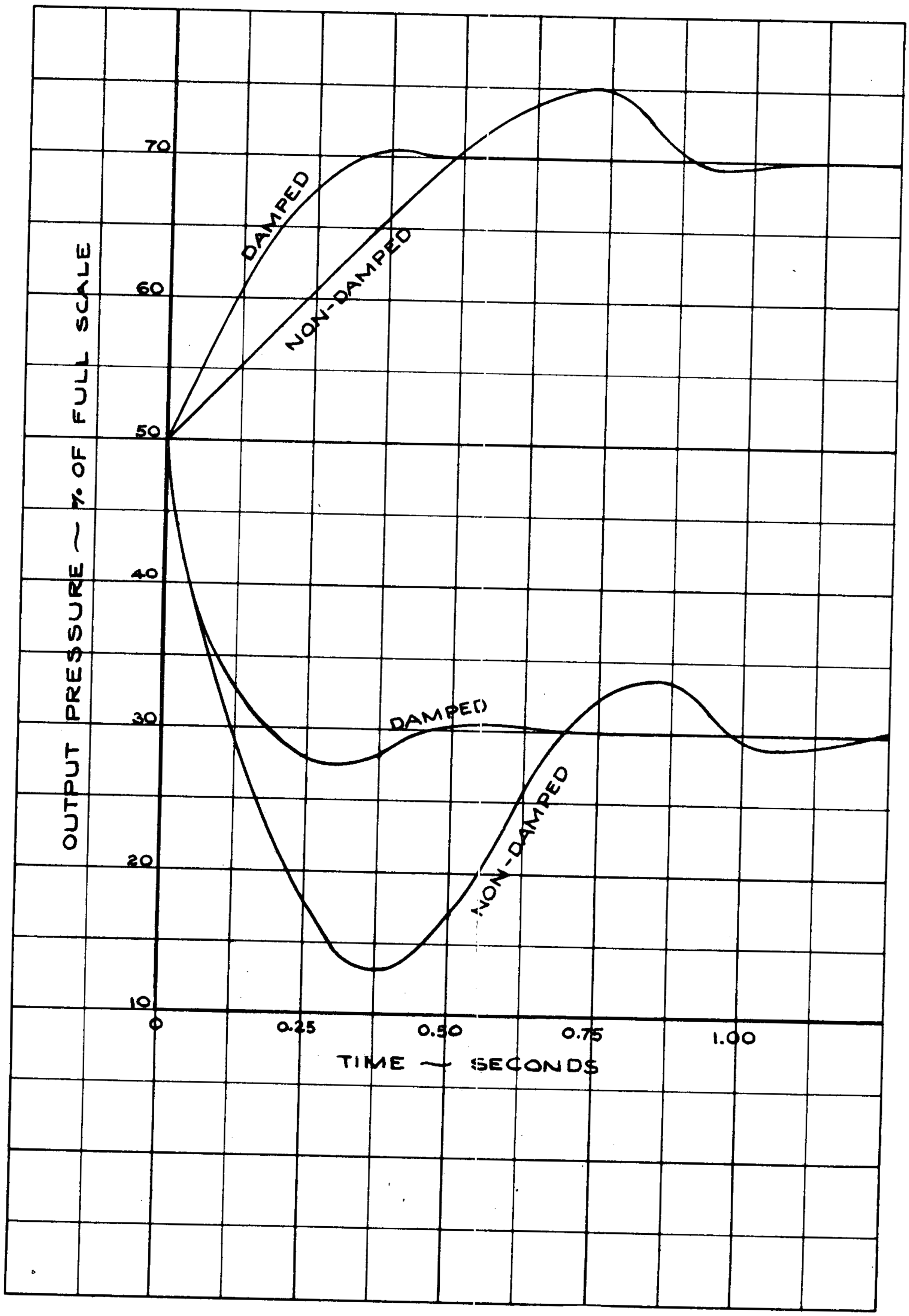
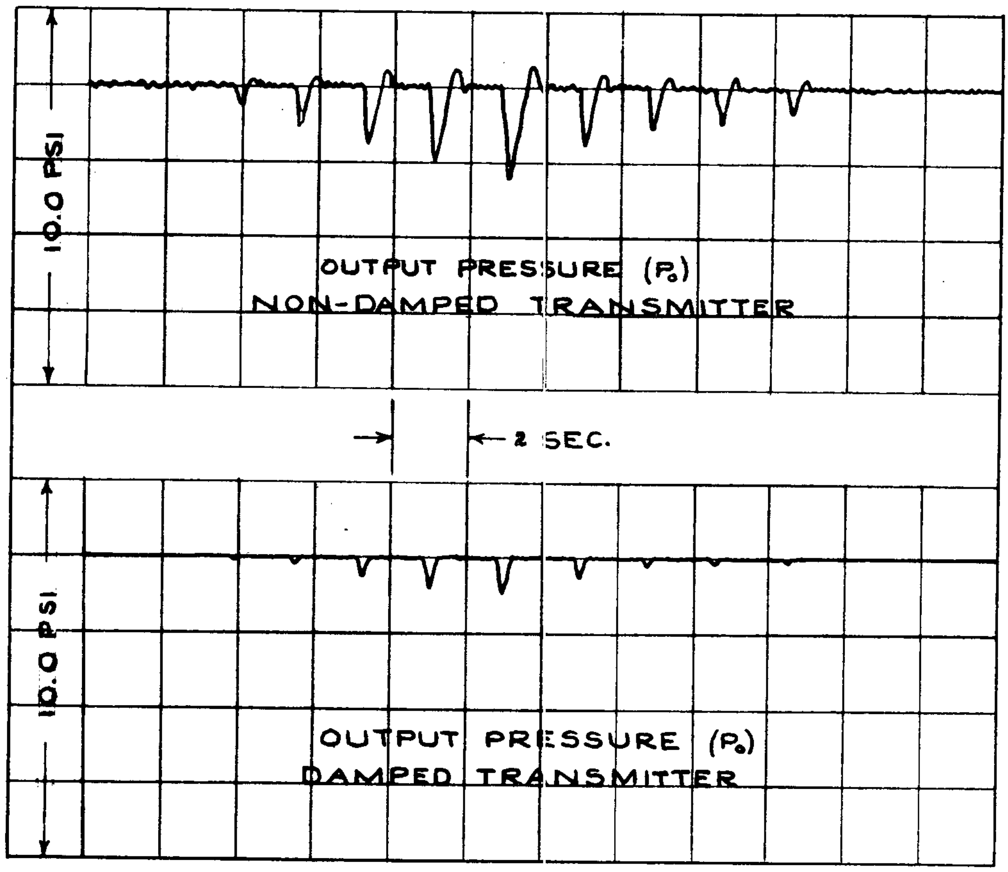



**Figure 11-B**

**STEP RESPONSE**

TAYLOR 206R PRESSURE TRANSMITTER




THIS CHART INDICATES THE OUTPUT PRESSURE REACTION TO SHOCK PRODUCED BY RAPPING THE MOUNTING BEAM WITH VARYING DEGREES OF FORCE. VIBRATION TEST CIRCUIT AND APPARATUS WERE USED.

**Figure 12**

**SHOCK REACTION**

**TAYLOR 206R PRESSURE TRANSMITTERS**

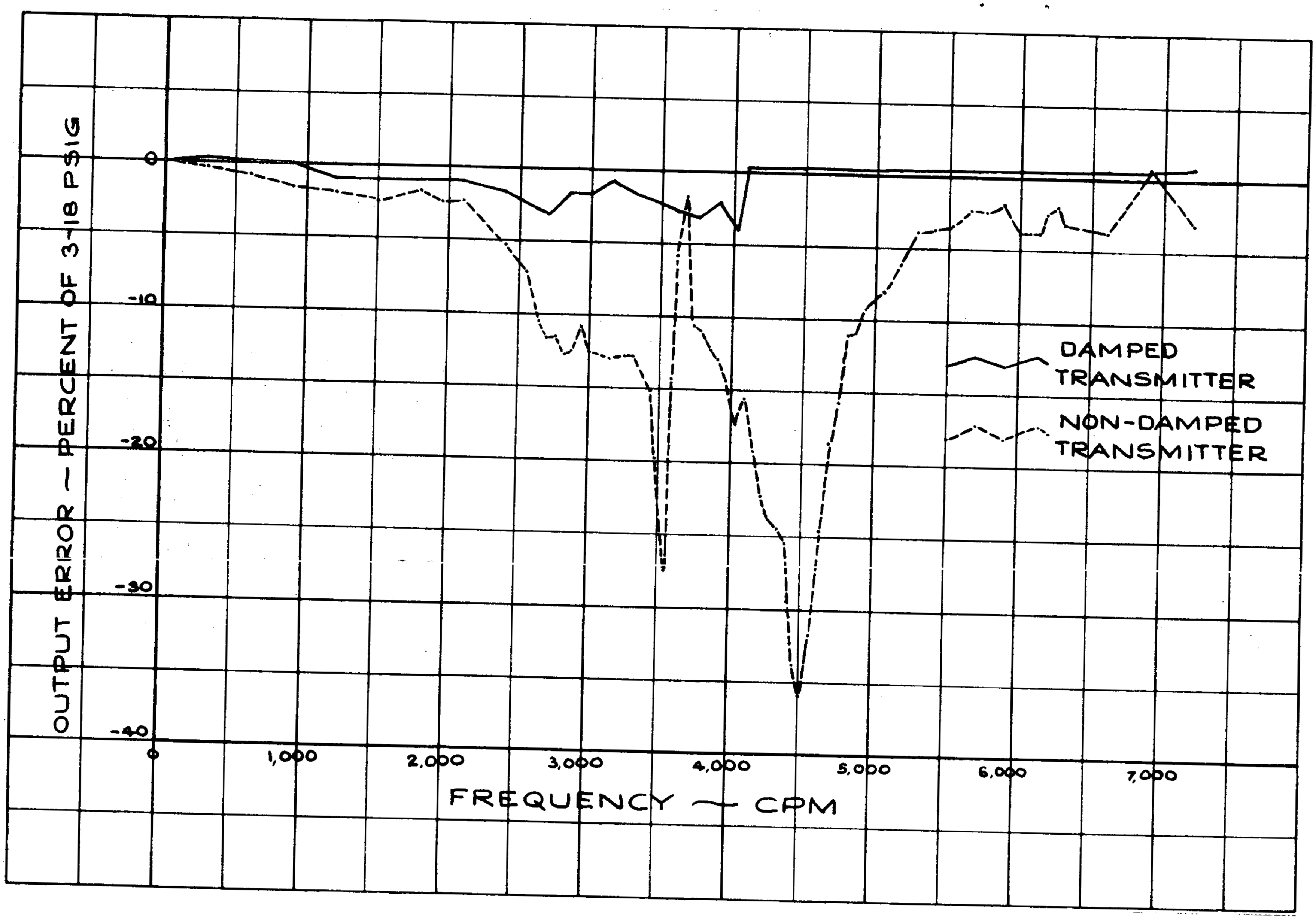



Figure 13
**OUTPUT ERROR VS. INPUT FREQUENCY**
TAYLOR 206R PRESSURE TRANSMITTER
RANGE: 0-2 PSI
INPUT: 1.00 ± 0.05 PSI (SINUSOIDAL)