A MINIATURE, LOW PROFILE PRESSURE TRANSDUCER

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INTRODUCTION

A miniature 0.76 mm (.030 inch) thick pressure transducer designed for applications requiring surface pressure measurements is discussed. The transducer incorporates a micromachined silicon diaphragm with four active arm diffused strain gages which offers maximum sensitivity and wideband frequency response. All temperature compensation and zero balance circuitry are contained within its housing. The overall diameter is 6.3 mm (.25 inch), see Figure 1, and it weighs less than 0.1 gram. Four integral 36 AWG leads are used for connection to the unit. This instrument is supplied in either 15 psia or 50 psia ranges with 300 millivolts typical full scale output with 10 volts supplied.

APPLICATIONS

The Aircraft Industry has been the driving force behind development of this low profile transducer. Requirements for pressure measurements on thin vanes and blades have pushed the development of thinner and thinner pressure transducers. Even this 0.76 mm (.030 inch) thickness can adversely affect gas flow in high speed turbines. Because of this, such transducers are installed into machined recesses (Fig. 2a). An epoxy is commonly used to fill the cable channel and then carefully machined flush with the surface.

This low profile configuration also finds use in missile and airplane skin pressure measurements, where the pressure transducer is installed in a similar manner to the more common strain gage (Fig. 2b). Since it is not necessary to drill holes through the structure, it can be used at leading edges and on thin, flexible structures such as helicopter blades.

The ease of field installation onto curved surfaces or thin metal sections makes the unit desirable for pressure profile testing of ground installations as well, e. g. jet engine test stand struts. The units are mounted (Fig. 2c) directly onto the struts using an overlay of tape to attach them. By installing a string of transducers, the pressure induced load profile can be accurately measured on any complex shaped structure.

MOUNTING CONSIDERATIONS

This is a cement mounted transducer and many types of bonding materials may be used. However, if removal of the transducer without damage is desired, the selection of adhesive is very important. The housing of the transducer is very thin and can easily be damaged from bending and prying under the edge. Also, solvents for the adhesive may damage the transducer interior if allowed into the pressure inlet area. Silicone RTV adhesives or wax can be used for mounting and can be cut away or removed with the application of heat to free the transducer without damage.

Another factor associated with mounting materials is their effect on the transducer when installed on structures which are subject to bending. Structure surface strains which are transmitted to the base of the transducer result in an error signal output. The design of this transducer provides for base strain isolation within the assembly. However, its performance can be enhanced if additional strain isolation is provided by using soft mounting materials or by reducing the mounting area. Fig. 3 shows the results of base bending tests of a 15 psia transducer mounted on a 12 mm (.47 inch) thick steel beam. When mounted with silicone rubber of about 70 shore hardness and 0.2 mm (0.008 inch) thick, the error is very small and at 250 microstrain is equivalent to only 0.001 psi output, see Curve c. The error increases as shown in Curve b when the transducer was mounted with a thin bondline of RTV. Even when rigid mounted with a thin glueline of a rigid cyanoacrylate adhesive the error is only 0.008 psi at 250 microstrain as shown in Curve a. As shown in Fig. 4, errors increase linearly as basestrain increases. Incrementally rotating a test unit through 360° has verified that the strain sensitivity error is relatively independent to orientation of bending.

MOUNTING CONSIDERATIONS (Cont.)

In addition to the effects of mounting materials on base strain sensitiviy, the thickness of the structure on which the transducer is mounted affects the strain output. Thinner beams such as blades or airplane skin typically bend with smaller radii of curvature than the 12 mm thick beam used for the test in Fig. 3. This results in increased error from strain sensitivity of the transducer approximately inversely proportional to the beam thickness. Bending beam tests have shown that on a 3 mm thick beam, the error at 250 microstrain would be approximately 0.004 equivalent psi output with the transducer mounted as in Curve c of Fig. 3 compared to 0.001 psi on the 12 mm thick beam.

This miniature transducer has been shown to have excellent strain isolation. As an example the strain error for a 15 psia unit of 0.004 equivalent psia is only 0.027 percent of full scale pressure output. However, it should be recognized that this direct strain input to the gages is a constant percentage of full scale. Therefore, this same strain error for a 50 psia unit is approximately 0.013 equivalent psia at 0.027 percent of full scale.

FREQUENCY RESPONSE

The unique sculptured piezoresistive silicon diaphrgam incorporated in the transducer not only allows dc (steady state) response, but also provides a high resonant frequency. The active area of the pressure sensing surface of this flush mounted assembly is less than one square mm. More efficient gage performance results from two features; (1) Stress concentrations at the gage locations and (2) Using a tranverse gage layout. The first, stress concentration is produced by anisotropic etching of the silicon to sculpture the surface. Thin sections can be obtained in the gage area with the remainder of the diaphragm surface at its original thickness. This configures the maximum stress to occur exactly in the location of the gages for high

FREQUENCY RESPONSE (Cont.)

efficiency in terms of high output and resonant frequency. The second, transverse gage layout in the stress area results in improved amplitude linearity. The sensitivity change in tension and compression are opposite in sign and tend to cancel in the transverse gage design. This provides better linearity to higher pressure stress levels than other parallel gage designs.

This low profile pressure transducer has been tested in a closed shock tube where a step change causes a shock pressure wave to strike the transducer diaphragm directly. Fig. 4 shows the frequency response obtained by fourier transform of the transducer's differentiated response to the pressure step. Below the 180,000 Hz resonant frequency shown for the 15 psia version, minor resonance ouput can be observed in the region of 70 KHz. This is likely related to the dead volume cavity in the housing. The magnification factor in this region is small and can be further reduced by filling the cavity with silicone grease or gel. Typical resonant frequencies of the 15 psia and 50 psia versions are 180,000 Hz and 320,000 Hz respectively.

ACCELERATION EFFECTS

The small stiff diaphragm results in a very low sensitivity to applied acceleration of 0.0002 equivalent psia output per g acceleration. This small mass also provides durability in very high acceleration environments. The transducer has survived 10,000 g's of acceleration and shock and 1,000 g's peak vibration. Following these severe levels, the transducer operated with no appreciable change in output or performance.

TRANSIENT THERMAL AND LIGHT EFFECTS

The Environmental Test Industry is already aware of the extremely low thermal transient and phase change (e.g. air to water) errors which Endevco sculptured diaphragms provide. This low profile pressure transducer is no exception. When tested per ISA S37.10 Pargraph 6.7 Procedure 1, the transient temperature sensitivity is

TRANSIENT THERMAL AND LIGHT EFFECTS (Cont.)

about 0.03 millivolt/degree F. The transducer output for phase change when quickly changed from air to water medium is typically 2 millivolts. With the addition of silicone grease or gel over the diaphragm, these errors can be reduced significantly. An additional benefit of the silicone grease or gel is to improve the resistance to moisture for the transducer.

The transient light or photoflash response is about 4 millivolts or less when tested per ISA S37.10 Paragraph 6.7 Procedure II. For many explosive tests black silicone grease or gel applied to the diaphrgam effectively eliminates the response to transient flash.

CALIBRATIONS PROVIDED

Each unit is supplied with a data sheet (Fig 5) with the specific calibration values for that transducer. The values are compared by a computer to the specification limits. The typical accuracies shown in the figure are generally much better than the maximum limits. Therefore, transducers with improved accuracy can be selected for special applications. Compensation specifications over a wide temperature range of -54°C to +121°C (-65°F to +250°F) can also be supplied for this miniature transducer.

SUMMARY

The miniature, low profile pressure transudcer has performance which is typical of larger models of pressure transducer. It is designed to make accurate pressure measurements in the midst of other environmental phenomenon of strain, acceleration and thermal transients. Its miniature size and thin, low profile satisfies the needs of many special measurement applications that require surface pressure measurements in wind tunnel or in flight testing.

Fig. 1. MINIATURE, LOW PROFILE PRESSURE TRANSDUCER

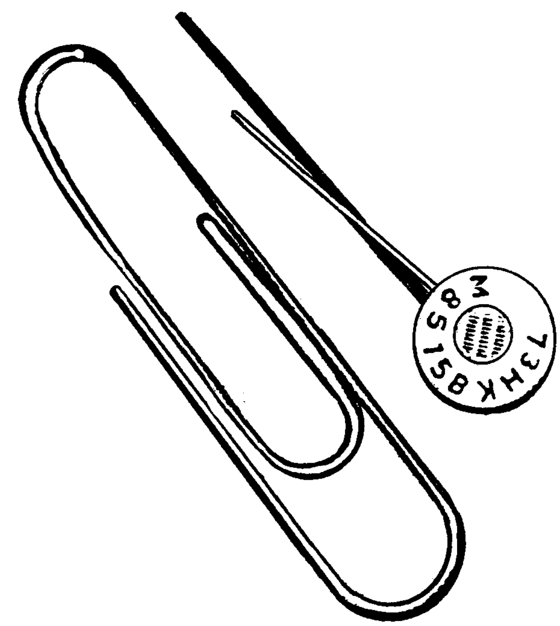


FIG. 2 MOUNTING METHODS FOR MINIATURE, LOW PROFILE PRESSURE TRANSDUCER.

FIG. 2a

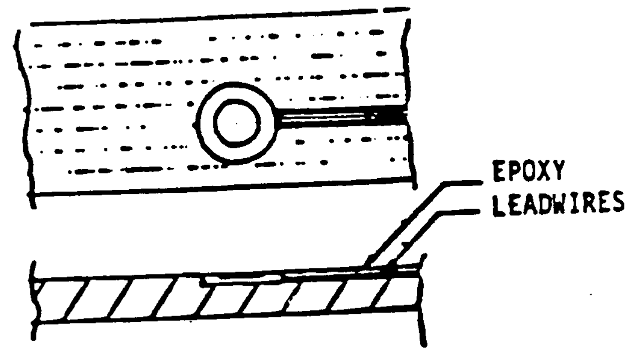


FIG. 2b

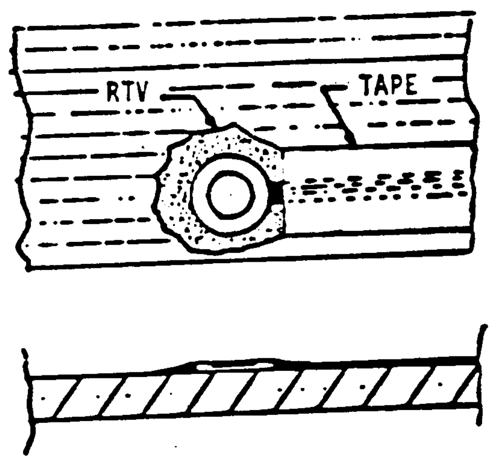


FIG. 2c

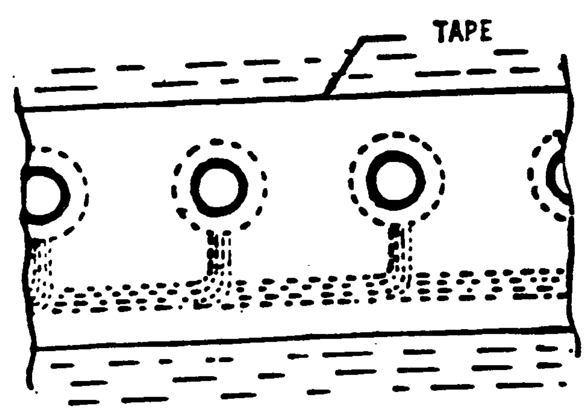
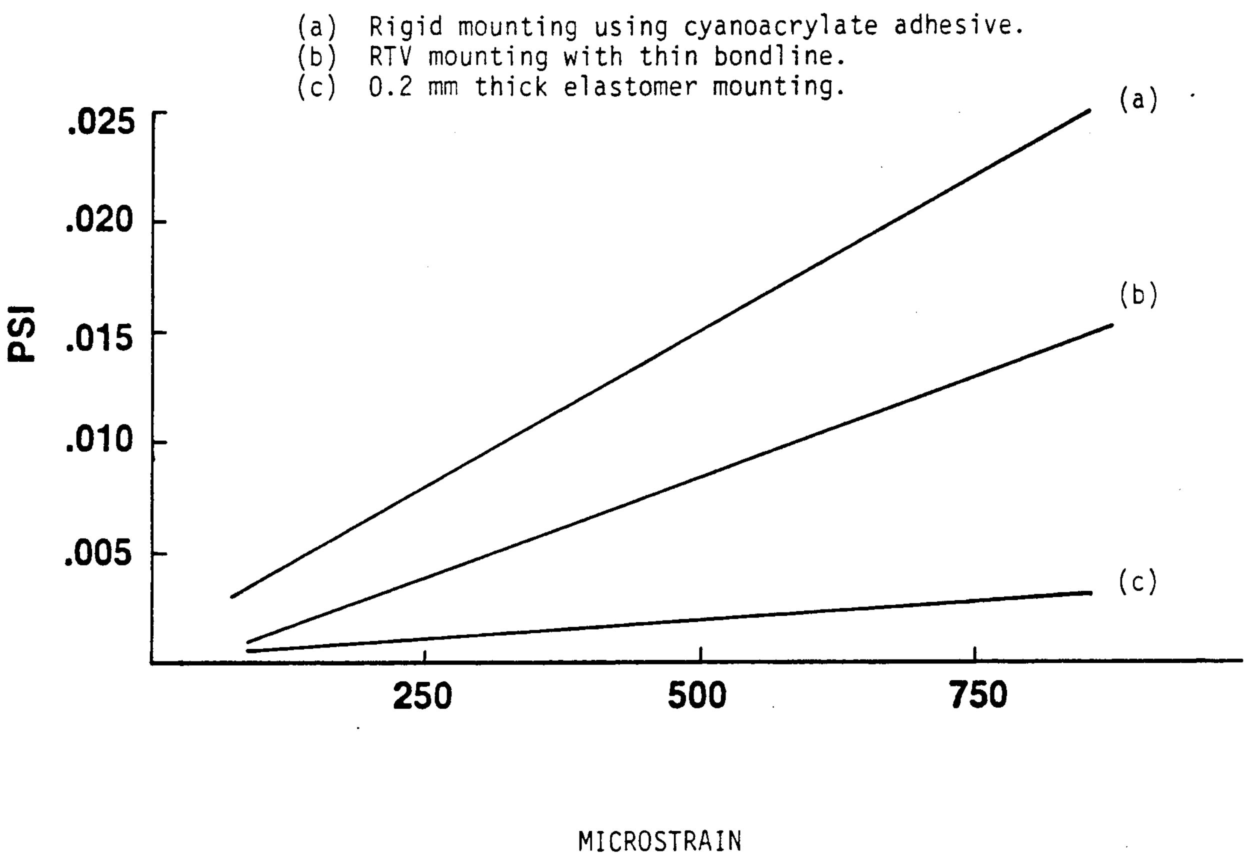


FIG. 3 BASE STRAIN SENSITIVITY OF 15PSIA
RANGE TRANSDUCER.



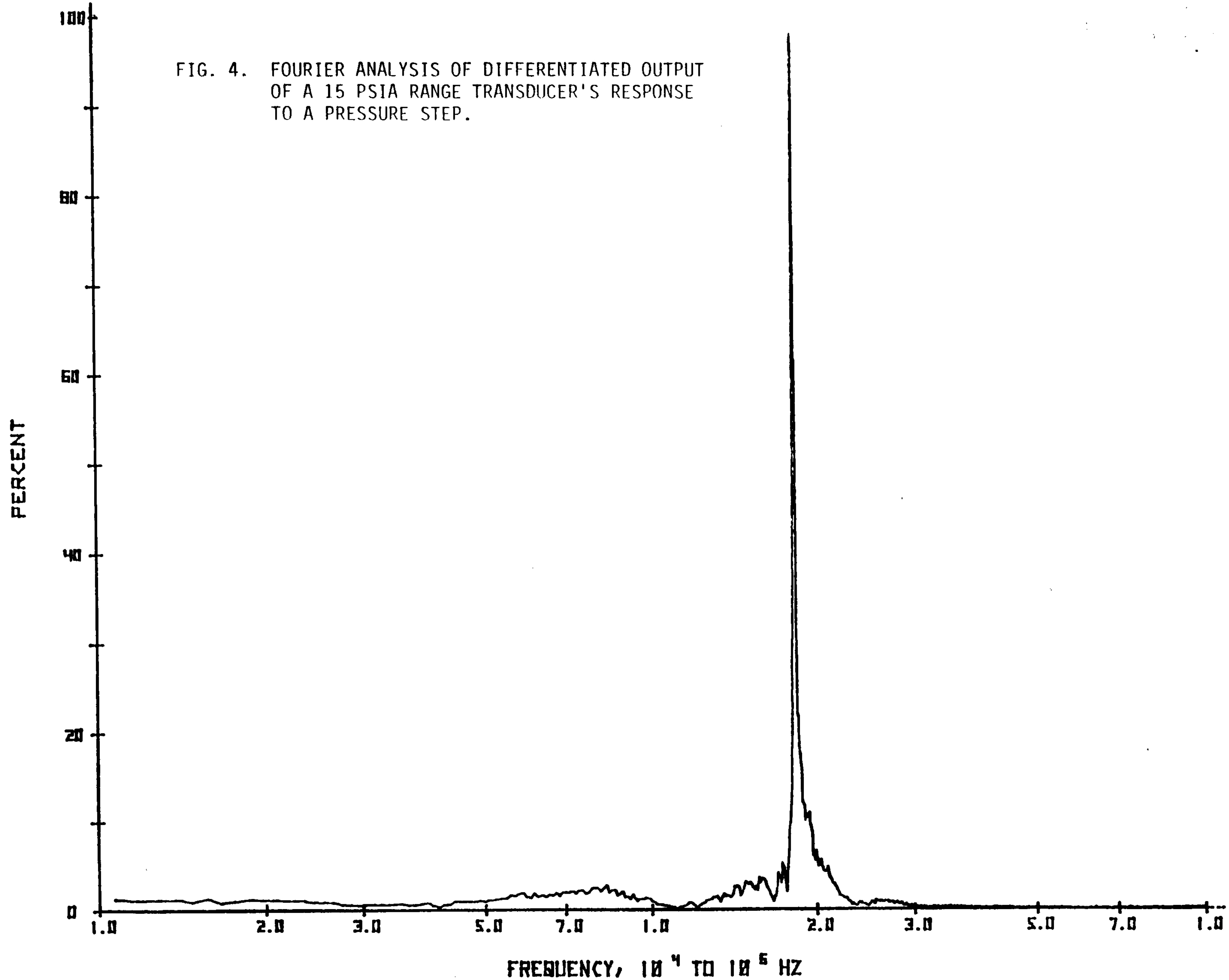


FIG. 4. FOURIER ANALYSIS OF DIFFERENTIATED OUTPUT OF A 15 PSIA RANGE TRANSDUCER'S RESPONSE TO A PRESSURE STEP.

FIG. 5

PRESSURE TRANSDUCER TEST REPORT

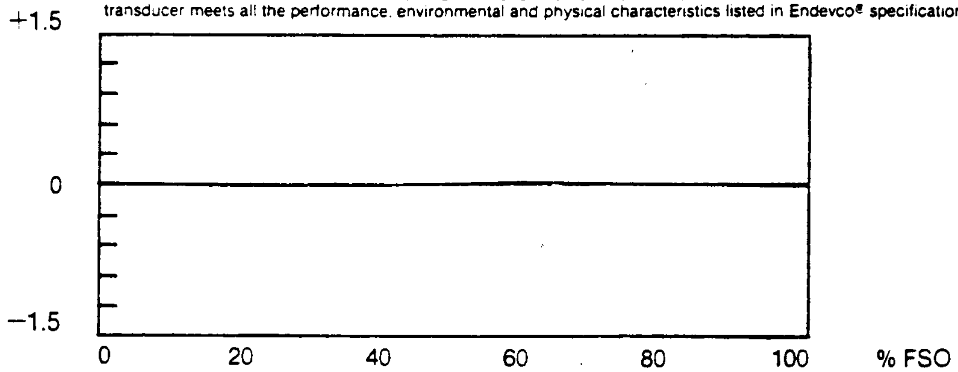
MODEL 8515B-15 **SERIAL #** 55HW

Range	15	psia
Sensitivity	20.93	mV/psi
Excitation	10.00	Vdc
Zero Pressure Output	3	mV
Full Scale Output	314	mV
Non-Linearity	.03	%FSO
Hysteresis	0	%FSO
Non-Repeatability	0	%FSO
Combined Lin., Hyst., & Rep.*	.03	%FSO
Thermal Zero Shift	.45	%FSO
Zero Shift After 3 × FSO	-.01	% 3 ×FSO
Thermal Sensitivity Shift	.44	%
Input Resistance	2118	Ω
Output Resistance	1820	Ω
Isolation Resistance	>100	MΩ

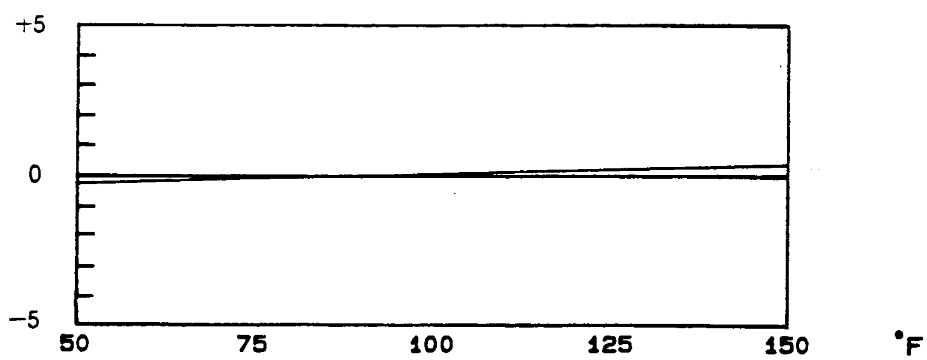
*RSS

All calibrations are traceable to the National Bureau of Standards and in accordance with MIL-STD-45662. This certifies that this transducer meets all the performance, environmental and physical characteristics listed in Endevco® specifications.

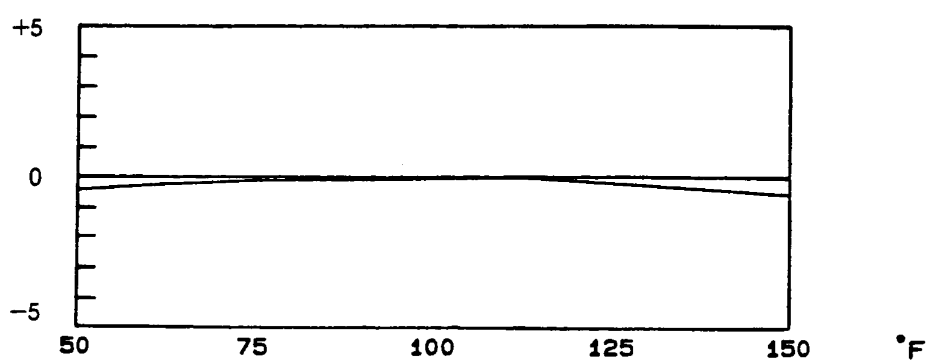
NON-LINEARITY (% FSO)



THERMAL ZERO SHIFT (% FSO)



THERMAL SENSITIVITY SHIFT (%)



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