



**TAVIS Corporation**

3636 Highway 49 South  
Mariposa, California 95338  
(209) 966-2027  
Fax (209) 966-4930  
www.taviscorp.com

## TECHNICAL BULLETIN #101

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# WHEN TO USE TAVIS VARIABLE RELUCTANCE TRANSDUCERS

One question that is frequently asked by instrument engineers is, "Which type of pressure transducer is best suited to my application?". Given the number of sensing techniques available, as well as the variations in technology within each type of sensing technique, the answer requires some investigation. One fact is clear: there is no single type of pressure transducer which is suitable for all applications.

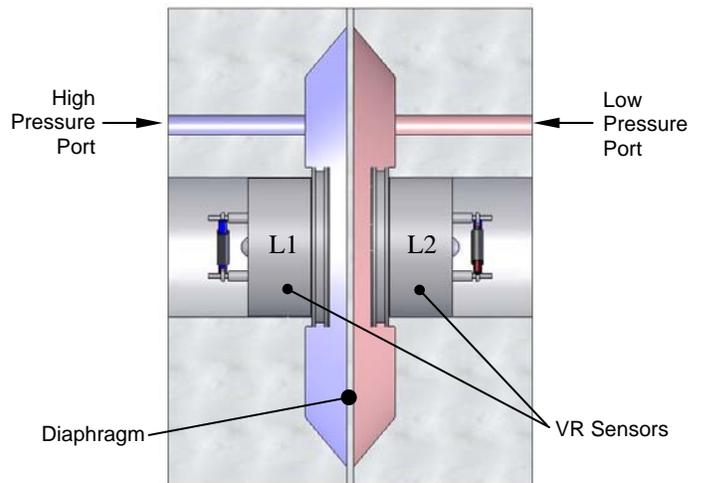
While no one type of pressure transducer is best for all applications, each does have unique advantages which make it the best choice for a given application. The purpose of this paper is to discuss the advantages of Tavis Corporation variable reluctance transducers in certain applications. We will discuss the principles of operation and advantages of variable reluctance transducers, and then briefly compare variable reluctance transducers to some alternate pressure sensing technologies. The intent of this paper is to aid the reader in deciding whether or not a variable reluctance transducer is the best instrument for a specific application.

Tavis Corporation variable reluctance transducers utilize a flat, magnetically permeable diaphragm supported between two ferric core coil sensors. When the sensors are excited by an AC signal (provided by the integral electronic package), a magnetic field is established between the diaphragm and sensors. The reluctance, or opposition to the magnetic lines of flux, is largely determined by the air gap between the diaphragm and the sensor.

When the diaphragm is relaxed, or in a "zero" state, the magnetic field between the diaphragm and sensor #1 is balanced with the magnetic field between the diaphragm and sensor #2. As the diaphragm moves away from sensor #1, the air gap between sensor #1 and the diaphragm increases while the air gap between sensor #2 and the diaphragm decreases. The output voltage ( $E_o$ ) is proportional to the diaphragm deflection (g).

One distinct advantage of this design is its simplicity. The diaphragm is the only moving part. All components within the mechanical portion of the transducer are securely welded in place. Since a change in reluctance is measured, the transducer is virtually unaffected by the measured media. The sensors themselves are completely enclosed within an Inconel housing.

The instrument depicted in Figure 1 is a differential pressure transducer, in which the pressure applied to the high port is referenced to the pressure applied to the low port. Gage, sealed and absolute pressure transducers have the same construction, but are referenced differently. Instead of having a low pressure port, the gage pressure transducer is referenced to atmospheric pressure; sealed transducers are referenced to the pressure sealed within the reference cavity; absolute transducers have the reference cavity evacuated so the pressure applied is referenced to a vacuum.



**Figure 1**  
Differential Pressure Transducer

$$\frac{E_o}{E_i} = \frac{\Delta g_o}{2 \cdot g_o}$$

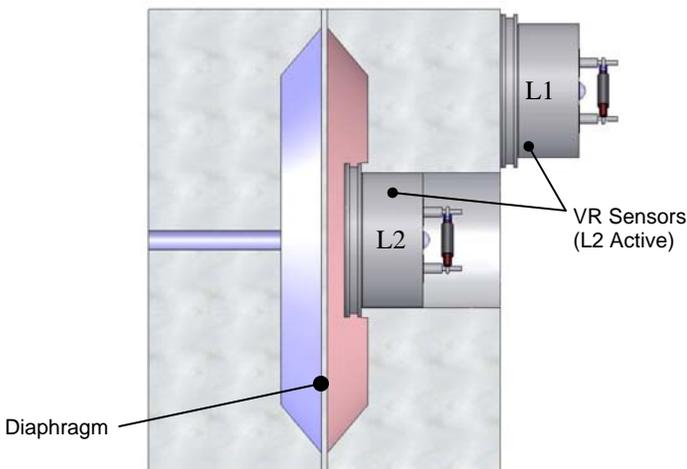
$E_o$  = Output Voltage

$E_i$  = Input Voltage

$g_o$  = Initial air gap of both the sensors

$\Delta g_o$  = Incremental change of position of the diaphragm

In higher (above 10,000 PSI) gage and absolute pressure applications, the sensors must be protected from the media pressure. To accomplish this, both sensors are mounted on the same side of the diaphragm (See Figure 2). In this case, L2 is the active sensor with L1 establishing a fixed reference. In a single active sensor instrument the output is not proportional to diaphragm displacement. Tavis Corporation employs a unique circuit in single active sensors to linearize the output. Typical linearities attained in these transducers are less than  $\pm 0.2\%$  Full Scale.



**Figure 2**  
 Absolute Pressure Transducer

$$\frac{E_o}{E_i} = \frac{\Delta g}{4 \cdot g - 2 \cdot \Delta g}$$

$E_o$  = Output Voltage

$E_i$  = Input Voltage

$g$  = Diaphragm Deflection

### *Advantages Inherent to Tavis Corporation Variable Reluctance Transducers*

- ◆ **All-Welded Construction:** Tavis transducers do not use screws, o-ring seals or mechanical linkages. All-welded construction enhances the performance of the instruments.
- ◆ **Wide Range of Construction Materials Available:** Tavis transducers can be manufactured from many materials, selected for media compatibility.
- ◆ **Long Term Stability:** Stabilities of 0.1% Full Scale (F.S.) per year can be achieved.
- ◆ **Low Response to Shock and Vibration:** Tavis transducers have been successfully qualified at 99 g RMS random vibration.
- ◆ **High Overpressure Capabilities:** As much as 1,000 times full pressure range is acceptable on some low pressure designs.
- ◆ **Very Low Pressure Measurement:** Full Scale ranges as low as 0.01 psia and psig; and 0.1 inches water column differential available.
- ◆ **Wet/Wet Differential Capabilities:** Tavis transducers can measure wet/wet differential pressure with no harm to the sensors.
- ◆ **True Infinite Resolution:** The diaphragm has no restrictions to deflection with applied pressure, allowing infinite resolution.
- ◆ **Low Power Consumption:** Power requirement is typically 5 mA at 28 VDC. Special units operate at 0.6 mA and 5 VDC excitation.

A frank discussion of variable reluctance transducers would not be complete without listing shortcomings as well as advantages. Categories in which Tavis Corporation variable reluctance transducers are at a disadvantage are:

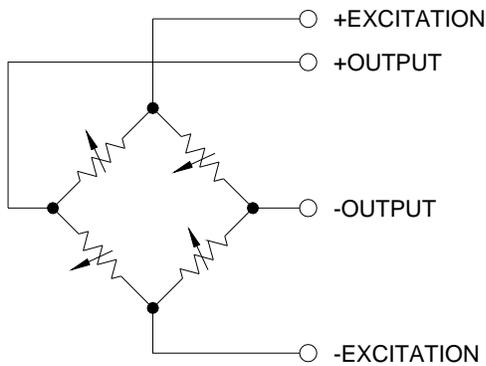
- ◆ **Size:** The smallest instrument is 1 inch in diameter with a length of 3 inches.
- ◆ **Weight:** The lightest instrument weighs approximately 5 ounces.
- ◆ **Cost:** The high reliability, accuracy and stability of Tavis variable reluctance transducers require extensive testing and quality control.
- ◆ **Magnetic Effects:** All variable reluctance transducers are affected by strong magnetic fields.

## *Comparative Technologies*

As previously stated, no single type of pressure transducer is best suited for all applications. This portion of the paper discusses the applicability of Tavis Corporation variable reluctance transducers as compared with alternate technologies.

### Strain Gage Transducers

Strain gage pressure transducers convert a pressure into a change in resistance due to strain. The strain elements are deformed by the movement of a pressure sensing element. In a typical strain gage, the strain elements are active arms in a Wheatstone bridge (See Figure 3). As pressure is applied, deformation of the strain elements causes the bridge to become electrically unbalanced, which provides a voltage output.



**Figure 3**

Different types of strain gages include:

- ◆ **Unbonded Strain Gage:** Unbonded metal elements are stretched and supported between a fixed and a moving end.
- ◆ **Bonded Strain Gage:** The strain element is permanently attached, or bonded, to the moving element. The bonding takes place through the use of an adhesive; or through sputtering or vacuum deposition of insulation and strain gage elements directly to the sensing element.
- ◆ **Semiconductor Strain Gage:** The strain element is semiconductor material which is bonded to, or deposited on, the pressure sensing element.

Strain gages with low level output, such as 3mV/volt to 100mV/volt, are available in very small packages, making their use advantageous in applications where size is a major

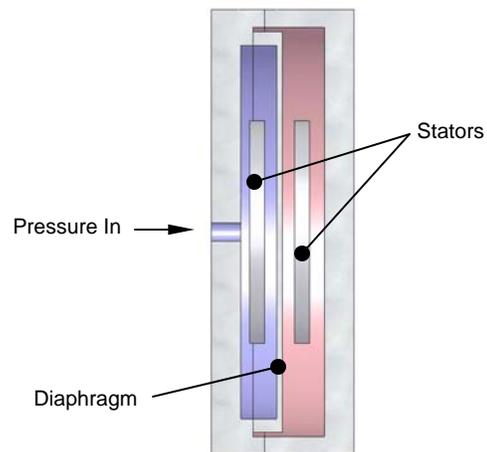
consideration. Strain gages are available with high accuracy and very good frequency response characteristics.

Some examples of applications where Tavis Corporation variable reluctance transducers could be preferred over strain gages are:

- ◆ **Low pressure measurements:** It is difficult to obtain good strain outputs at very low pressures.
- ◆ **Wet/wet delta P measurements:** Tavis variable reluctance transducers do not need to isolate the reference side. The strain element in a strain gage must be protected against moisture.
- ◆ **Applications with high levels of vibration and shock** are more suited to variable reluctance instruments.
- ◆ **Applications with extreme overpressure requirements** are suited to variable reluctance instruments.
- ◆ **Applications where stability is important over an extended period of time.**
- ◆ **Applications requiring very little hysteresis.**

### Variable Capacitance Transducers

Capacitive pressure transducers are similar to variable reluctance transducers, sensing a change in capacitance with pressure applied instead of a change in reluctance. In a typical configuration, a flat diaphragm is positioned between stationary capacitive plates (See Figure 4). Diaphragm deflection changes the circuit capacitance. This change in capacitance is detected and signal conditioned to the desired output.



**Figure 4**

Capacitive pressure transducers can make very low pressure measurements with high accuracy. However, when making the differential measurements, if the media is admitted to the gap between the stators and the diaphragm, large errors can occur. The dielectric constant of the media is significant, especially if the media is liquid. Changing the dielectric constant between the stator and the diaphragm alters the output of the capacitive transducer. For this reason, isolating membranes and oil fills are used to make differential measurements in those cases where the media is not clean, dry gas.

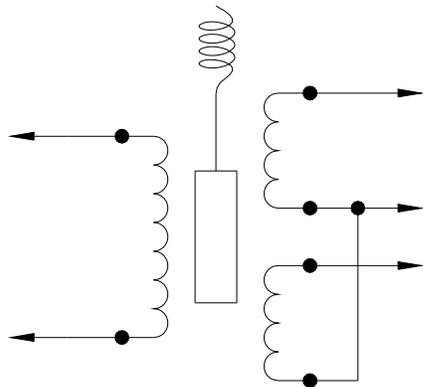
Typical applications in which Tavis Corporation variable reluctance transducers might be chosen over capacitive transducers are:

- ◆ Wet/wet delta P: Tavis variable reluctance transducers have no need to isolate the reference cavity from the measured media.
- ◆ Special applications: Tavis variable reluctance instruments are ideal for applications requiring specialization.

### **Linear Variable Differential Transformer (LVDT)**

Like Tavis variable reluctance transducers, LVDT transducers are variable reluctance devices. The change in reluctance is accomplished through the movement of a core within a differential transformer.

The applied pressure causes motion of a sensing element, typically a capsule or bourdon tube. This motion moves the core within the transformer, usually through a mechanical linkage (See Figure 5).



**Figure 5**

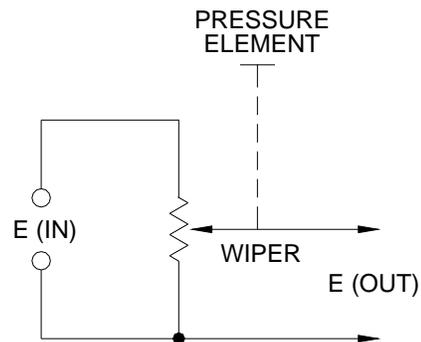
Displacement of the core requires greater motion of the pressure sensing element than that usually associated with a flat diaphragm. This makes more complicated elements necessary, sometimes in conjunction with amplifying mechanical linkages. Use of linkages increases vibration response.

Applications in which Tavis Corporation variable reluctance transducers could be better suited than an LVDT transducer include:

- ◆ Very low pressure measurements.
- ◆ High pressure measurements.
- ◆ Wet/wet differential measurements.
- ◆ Applications with high levels of vibration.
- ◆ High overpressure applications.
- ◆ Applications requiring ease of cleaning the pressure cavity. Bellows and capsules are more difficult to clean than flat diaphragm devices.
- ◆ Applications requiring greater frequency response than provided by an LVDT.

### **Potentiometric Pressure Transducers**

Potentiometric pressure transducers are relatively simple. Pressure applied to the sensing element causes the wiper of a potentiometer to move, giving a change in resistance with the application of pressure. In order to obtain adequate displacement of the wiper, a sensing element such as a bellows or bourdon tube is usually used, often with an amplifying mechanical linkage as illustrated (See Figure 6).



**Figure 6**

Applications in which Tavis Corporation variable reluctance transducers could be better suited than potentiometric transducers include:

- ◆ High resolution requirements: Wire wound potentiometers have finite resolution.
- ◆ Very low pressure measurements.
- ◆ Wet/wet differential measurements.
- ◆ Requirements with high levels of vibration.
- ◆ High overpressure applications.
- ◆ Applications requiring long term stability.

### *Summary*

In comparing alternate sensing technologies, Tavis Corporation variable reluctance transducers have some features which are advantageous over other technologies. Tavis transducers are ideally suited in the following applications:

- ◆ Very low pressure.
- ◆ Wet/wet differential pressure.
- ◆ High vibration environments.
- ◆ High overpressure environments.
- ◆ Long term stability and long life requirements.

Tavis Corporation variable reluctance transducers have a long history of providing reliable and accurate instruments in rough environments. Our application Engineering staff is available to help you work out difficult measurement applications.

### Notes