New Differential Pressure Sensor Incorporates LVDT Technology to Create More Environmentally-Resistant, Dependable and Economical Pressure Sensing Solution

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Differential pressure (dP) sensors with electronic signal processing are increasing being used to monitor flow, filter condition and level. Since these devices offer linear and accurate output, they are also replacing the differential pressure switch that only support on-off condition and useless for closed loop control system. These dPs are often configured with expensive valves and fluid filled remote seals for added protection against corrosive media, radiation and/or extreme media temperature ranges when operating in demanding environments. In cold ambient environment specially operating in temperatures below -4 deg F (-20 deg C), the sensor need to be heated either by trace heater or within a heated enclosure to maintain the operation of the dP sensor. In addition to being expensive, these valves and seals tend to be bulky and require time to install and maintain. In many critical applications such as food and pharmaceuticals, filled fluids are a serious concern due to process contamination. In gaseous systems such as hydrogen and oxygen and semiconductor applications, fluid filled sensors are being banned since the leakage of fluid into the process could lead to an explosion and serious safety issues.

A new series of LVDT (linear variable differential transformer) based oil-less dP sensor with dual channel ASIC (applications specific integrated circuit) have been developed that can operate in a wide range of corrosive materials, radiation and temperature without any oil filling and bulky sealing systems. By encapsulating LVDT proven technology with digital compensation, the pressure sensors combine the benefits of friction-free operation, environmental robustness and unlimited mechanical life. By selecting the diaphragm thickness and material properties, Table 1 show the dP ranges that can be produced using the LVDT technology.
### Table 1: Four typical popular ranges using two forms of dP sensor packages

<table>
<thead>
<tr>
<th>dP Range</th>
<th>Line pressure</th>
<th>Proof pressure (P1&gt;P2)</th>
<th>Burst pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.36 PSI</td>
<td>200 PSI</td>
<td>5 PSI</td>
<td>1,000 PSI</td>
</tr>
<tr>
<td>1 PSI</td>
<td>500 PSI</td>
<td>300 PSI</td>
<td>2,000 PSI</td>
</tr>
<tr>
<td>10 PSI</td>
<td>1500 PSI</td>
<td>1,000 PSI</td>
<td>5,000 PSI</td>
</tr>
<tr>
<td>50 PSI</td>
<td>5000 PSI</td>
<td>3,000 PSI</td>
<td>10,000 PSI</td>
</tr>
</tbody>
</table>

**Very Low range dP sensor**

In this design, a bellow is used for the measurement for very low pressure from 5” H2O (inches of water column) to 1PSID with line pressures up to 200PSI. The bellow is made from a thin, 0.002” thick (twice the thickness of an equivalent oil filled sensor), section of nickel alloy, usually Ni-span C that offers good thermal behaviour with low hysteresis and repeatability. The LVDT core, made from medium permeability material such as 52 Alloy, is attached to the bellow, as shown in Pic. 1. As the bellow moves with applied pressure, the LVDT will provide a linear signal that can be unidirectional or bidirectional, subject to the application. Pic. 2 show the sensor assembly with the LDVT and signal processing electronics.

**Pic. 1** LVDT core attachment to bellows

**Pic. 2** Sensor assembly with LVDT and electronics
The LVDT is driven from 3V, 10kHz source for the electronics board. This signal processing pc board accepts 10-32VDC unregulated supply voltage and outputs either 0-5V or 4-20mA output signal as needed. While the core is in the middle of the LVDT, the output from the electronics can be programmed to be 0V or 4mA. As the diaphragm moves, the core will transfer magnetic flux more into one of the secondary coils than the other. As a result of it, the output signal will change. Hence by applying pressure and temperature to the assembly during calibration, the zero and span values can be calibrated from 4 to 160 def F (-10 to 70 deg C). The dual channel ASIC takes data from the LVDT and temperature source before applying the polynomial correction coefficients to curve fit for error correction. Fig. 1 show the construction of this device

![Schematic of a Capsule and LVDT type transducer](image)

Fig. 1 Cross section of very low range dP sensor
Low and medium range dP sensor
The low range dP covers from 1PSID to 5PSID in 500PSI line pressures while the medium range covers 10PSID and 50PSID with line pressures up to 1500PSI and 5000PSI respectively. This concept utilizes a thick stamped corrugated diaphragm with no bellows. The LVDT and signal processing electronics are the same as used in the very low range dP sensor. In normal operation, the diaphragm is free to move up and down with applied pressure however in case of overload or high pressures, the diaphragm will bottom out and sit against the over-travel stops in both directions. The design of the over-travel stops is critical and must support the diaphragm fully. In comparison to the very low pressure dP sensor, the P1 and P2 pressure ports are reversed for this device to function properly. Fig. 2 show the cross section of this design with key components. In case of high or very cold media or radiation, the electronics can be remotely located away from the sensor head without the loss of performance. Pic. 3 show the picture for low range dP sensor with one of the ports connected to a test fixture of calibration.

Fig.2 Sketch showing key components of high line low dP range sensor
Media compatibility and wetted materials

Media compatibility of very low pressure and low to medium ranges dPs is subject to the materials being used. From 1PSID to 50PSID, the materials being offered far more exceed that of very low range dP due to the fact that most of the corrosive environments and applications reside in these ranges. Wetted materials for the diaphragm offered are;

- Inconel X-750 superalloy - excellent for oil & gas, sea water, nuclear plants
- Hastelloy C-276 superalloy - excellent for chemicals, oil & gas, sea water
- 316L stainless steel - excellent for hydrogen, oxygen, medical and food equipment
- Waspalloy superalloy - excellent for H2 + H2S service, sulfidation process
- Ni-span C - excellent for water, oils, hydraulics, exhaust gas

The body is normally machined from 316L stainless steel for low and medium range dPs while for the very low it is anodized 6024 aluminum (optional can be 316L for OEMs).

Solving ProblematicApplications

By changing the materials of the LVDT, remotely locating the electronics and/or packaging the sensor design, the following application can greatly benefit for both price and performance;
- Nuclear - since there is no oil in the sensor, the electronics can be housed separately away from high radiation and temperature. Oil filled sensors cannot perform this function unless they are isolated with costly and bulky remote seals.

- By removing the P1 port material and making it into a flush face with sanitary fitting to be
used with tri clover clamp, this can apply to food and beverage processing, autoclaves, pharmaceuticals, mud logging and many other demanding process that while experiencing cryogenic to high temperature, very high proof pressures and or contamination issues. For example, in 0-10PSID gauge operating mode where the P2 (low side of the dP) is vented to atmosphere or sealed tank, the sensor will be able to survive 500PSI over-pressure with very little zero shift (less than 0.3% of FS). Fig. 3 show how this can be achieved in a real practical way in most current applications.

Fig. 3 Flush mount on P1 while P2 is free to vent to atmosphere or connected to a reference
. High humidity - by using the device in vented gauge mode, there is no need for expensive water ingress protection devices that are needed for traditional single ended sensors.
. Cold ambient - While operating is Northern Hemisphere where temperatures can range below zero to -65 deg F (-55 deg C), there is no need for heating the device since there is no oil to freeze as required by the current products on the market