

# The pressure to conform

## ~ Pressure measurement and differential pressure measurement in the process sectors ~

The early 1960s was a period that featured some significant engineering advancement. In the UK, the Forth Road Bridge was opened to link Fife and Edinburgh, the British Motor Corporation launched the Austin 1800, which went on to become European Car of the Year, and Dorothy Crowfoot Hodgkin became the first and only British woman to win a Nobel Prize in Chemistry for her work using X-rays to determine structure in biochemical substances.



Meanwhile, in Japan, global automation business Yokogawa was developing its first pressure transmitters, which represented a significant step forward in pressure and differential pressure measurement. Here, Andrew Fenn, the company's UK product specialist for transmitters and flow, explains how the technology should be specified by a process engineer.

Accurate pressure and level readings are essential to the safe, reliable and profitable operation of your plant. Both are key process variables, alongside considerations such as flow, temperature and liquid interface. The pressure under which a material is held can severely impact ultimate product quality by increasing variance and reducing efficiency.

Crucially, accurate pressure measurement is also a key component of an effective health and safety strategy. For example, maintaining proper boiler pressure by controlling the inflow of air used in combustion and the outflow of exhaust gases is crucial in preventing boiler implosions that can clearly threaten the safety of workers.

In my experience, accurate pressure measurement is critical in batch chemical and oil and gas applications in particular, as well as the pharmaceutical sector. However, it's fair to say that it's hugely relevant across the process industries, from food to plastics and from metals to cosmetics.

Differential pressure transmitters compare two pressures and transmit the difference to a control unit, performing multiple functions. For instance, by applying Bernoulli's equation, differential pressure transmitters can be used to infer the flow of fluid through a pipe.

In fluid dynamics, Bernoulli's principle states that for an inviscid flow, an increase in the speed of the fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy.

Differential pressure monitoring applications include filter monitoring and feed pressure monitoring in liquid or gaseous media, density and flow measurement, measurement of aggressive or viscous media, flow measurement of gases and vapours, level measurement of aggressive or adhesive media, measuring liquid in pressurised vessels and interface measurement.

### Defining our terms

Because of the pressures we all face as engineers, it isn't uncommon for a non-specialist to come across problems in specifying pressure transmitters as the result of loosely defined technical terms. We all know our own sectors backwards, but who can honestly say they understand the engineering and design requirements of every product further up or down the chain?

Transducer accuracy refers to the degree of conformity of the measured value to an accepted standard. It is usually expressed as a percentage of either the full scale or of the actual reading of the instrument. In case of percent-full-scale devices, error increases as the absolute value of the measurement drops.

Repeatability refers to the closeness of agreement among a number of consecutive measurements of the same variable.

Linearity is a measure of how well the transducer output increases linearly with expanding pressure. Finally, hysteresis error describes the phenomenon whereby the same process pressure results in different output signals, depending on whether the pressure is approached from a lower or higher point.

### Choosing a pressure transmitter

In choosing a pressure transmitter, it's important to take into account the key benefits it can provide. The market for this kind of product is extensive and includes many grey market devices that can negatively impact on product quality or health and safety.

Digital precision is an essential element in this choice, something which goes hand in hand with a high level of repeatability. This also removes the possibility of errors in the analogue to digital conversion process.

In choosing a differential pressure transmitter, one should ensure that it provides the ability to measure differential pressure and static pressure in a single instrument. This kind of versatility is essential in the modern, highly adaptive process environment. In such a product, over pressure protection is also essential to obviate the possibility of damage to the device.

In all pressure transmitters, a high level of accuracy, repeatability and stability is essential, as is a robust and reliable design, particularly in hazardous environments.

Weight may also be a consideration, depending on the application, and easy maintenance almost certainly is. This is particularly true in batch chemicals, oil and gas, where factors such as validation and traceability, lack of access to remote applications and the hazardous nature of the environment mean that maintenance opportunities have to be carefully scheduled.

Similarly, in these sectors it's essential that the manufacturer you choose to partner with can provide a range of materials for wetted parts to cater for aggressive process media.

The most advanced pressure transmitters on the market use silicon resonant sensors, fabricated from a single crystal, using proven 3D semi-conductor micromachining techniques.

In these cases, two "H" shaped resonators are patterned on the sensor, each operating at a high frequency output. As pressure is applied, the bridges are simultaneously stressed, one in compression and one in tension. The resulting change in resonant frequency produces a high differential output (kHz) directly proportional to the applied pressure. This simple time-based function is managed by a microprocessor.

The net effect of silicon resonant technology is that temperature effects are reduced to less than 1/10th of other silicon technologies (10 ppm/deg C), making these sensors extremely stable in the most demanding process applications.

The output produces a much higher signal to noise ratio than traditional analogue sensors and, compared to piezoresistive silicon sensors (the silicon resonant sensor's immediate predecessor) the output is at least four times greater. Errors resulting from temperature and static pressure are thus insignificant in relation to total output.

Finally, one should ideally consider advanced digital diagnostics to help avoid unpleasant surprises and minimise downtime. Other essentials are mass flow output direct from the transmitter, without the need for a flow computer, thus minimising cost, as well as technology to reduce process leak paths.

### Common application problems

One frequent application issue is impulse line blockage. Common differential pressure sensor configuration includes impulse lines that couple the sensor to the process fluid or gas to be measured. The impulse lines are typically small bore lines filled with a fluid. This fluid provides pressure coupling between the sensor and the process.

Dirt in the process can settle in these lines causing blockages to form. Typical blockages include solid depositions, wax depositions, hydrate formation, sand plugging, gelling, frozen process fluid plugs and air or foam pockets. All of these blockages can cause errors in measurement.

The impulse line condition can be detected by extracting the fluctuation component from the differential pressure and static pressure signals. The extracted component of the process fluctuation is used to determine the amount of impulse line blocking. The ability to detect the early signs of instrument impulse line blockage problems is a key requirement of an advanced differential pressure transmitter. While this isn't by any means a common function of even the most advanced products currently on the market, it is very useful.

### Standards and accreditations

As with most equipment used in the process sectors, it's essential for the pressure transducer you choose to provide the appropriate accreditation to the most relevant industry regulations and standards.

Typically, these would include hazardous area accreditation such as ATEX (Appareils destinés à être utilisés en ATmosphères EXplosibles) and testing-house approvals from accreditation agencies like FM Approvals and CSA, as well as the IEC (International Electrotechnical Commission). One might also expect marine certificates, CE marking, GOST for transportation into the Soviet Union, PED (Pressure Equipment Directive) compliance and SIL2/3 capability (Safety Integrity Levels determined by TUV Nord and certified to IEC61508) as standard.

### What does the future hold?

Generally in industry, pressure exceeding 1,000 psig (pounds per square inch gage) is considered to be high pressure. However, due to advancements across the sector, there are now devices that can measure high pressure up to an incredible 200,000 psig or more.



To give you a clue of scale, extremely high power water jet cutters might operate at 100,000 psi, the pressure on the hydraulic system of an Airbus A380 is around 5000 psi and the blood pumping through your veins while you read this is probably somewhere between 1.55 psi and 2.35 psi.

The demand we face as manufacturers of pressure transmitters is the continually developing requirement for even higher pressure measurement than is currently offered to the market place. While we provide this, we have to also maintain our high standards of accuracy, stability and repeatability along with robust construction, low maintenance and suitability for the application.

Pressure measurement has certainly come a long way since Yokogawa introduced its first products in this sector in the early 1960s. However, just like the Forth Road Bridge, many of our oldest technologies are still relevant today and, in the spirit of Dorothy Crowfoot Hodgkin, we are still committed to continuous innovation and product development.

Whether we will need to work on a 200,000 psig application in the near future is very much in doubt, but what is certain is that we are relied upon in thousands of process industry applications across the world.

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