# Selecting Pressure Sensor for Advanced Chromatography Systems

By: Jean-Pierre Pugnaire and Richard Venable

Viatran

Chemists, biologists, and researchers in life science and industry are increasingly using high performance liquid chromatography (HPLC), gas chromatography (GC), ultra-performance liquid chromatography (UPLC), supercritical fluid chromatography (SFC) and other advanced chromatography techniques, to meet increasing demand for purity, traceability, compliance and cost control. To meet the challenges of these new applications, analytical OEMs are striving to deliver chromatography systems that have the highest accuracy, reliability, and lowest cost of ownership possible and are finding that their choice of pressure sensor for the system can have significant cost and performance consequences.

While chromatography methods vary considerably in complexity and by application, all basically involve moving one compound through another to extract valuable components, based on the principle that all molecules will flow through a given material at unique, predictable rates.

**Sensors which support advanced chromatography techniques should be evaluated for the following functionality:**

- Ability to measure high and ultra high pressure
- Ability to maintain minimal or zero internal dead volume
- Ability to operate at lower internal volumes with high throughput
- Ability to maintain zero balance during flow
- Ability to compensate for effects due to variation in ambient temperature
- Ability to provide fast frequency response
- Ability to maintain high linearity, minimal hysteresis and high repeatability

A pump moves the solute, the mobile material containing the target substance, through a chromatographic column filled with a specific packing material, called the stationary phase, which separates various components by a process known as elution. Once the moving solute elutes and leaves the column, it enters a detector, which manages the separation by comparing the known retention times of the molecules. Retention times will vary depending on the molecules being analyzed, the solvent(s) used as the eluent, and the interaction between the stationary phase.

A detector at the end of the process identifies the target substance by reading the spectrum of the separated molecules as they emerge from the tube. The detector is programmed to know when the eluent is fully aspirated into the solute and precisely how long it should take to pass through. At the precise moment of its exit, the process diverts the target components into another vessel for further analysis.

Factors that can affect the separation or timing of the retention time are the internal diameter of the tubing used, particle size within the sample, pore size of the solute media and the pump pressure. The choice of flow sensor is important because the entire process rests on accurate measurement of retention time, which requires accurate information on the flow rate. HPLC, for example, relies on pumps to manage mixtures and flow rates, normally under high pressures and deliver material, accurately and without pulsation, to the column for separation and analysis. Delivery of non-pulsed, accurate chemistry mixtures (up to 15K PSIG) requires a positive loop feedback to pump control system circuits. Achieving this for HPLC and most other advanced chromatography applications is largely dependent on the reliability and performance of pressure sensors, which are used to detect changes in the flow rate and send signals to a controller, which in turn assures the consistent, unpulsed flow of fluid to the column.

Depending upon their particular mix of requirements, OEMs typically deploy either flushmounted sensors, which thread into system channels, or flow-through sensors, in which the sensor is actually part of the piping itself. Flush-mounted sensors are characterized by a single pressure connection port, whereas flow-through sensors have two ports, one for the in-flow and one for the out-flow. Below we will compare performance of flushmount and flow-through sensors across the various criteria.

## High and ultra high pressure operation

Where traditional chromatography operates at about 5000 pounds per square inch of gage pressure (psig), high pressure applications such as ultra performance liquid chromatography can reach 20,000 psi. These pressures virtually eliminate pulsing, and improve the accuracy of the reading. Both flush mount and flow-through pressure sensors work well to 20,000 psi and above.

## Minimal or Zero Internal Dead Volume

High pressure applications such as HPLC benefit from the absence of internal crevices along the sensor flow path, because such crevices can entrap sample substances and retain them despite repeated flushing, with the result that subsequent samples become contaminated. This ability of a sensor to obtain readings without affecting the process volume is known as zero dead volume.

The single pressure port connection of flush-mount may incorporate small pockets at the diaphragm body interface in which fluid may be trapped, and thus doesn't have zero dead volume.

Figure 1- thru FLO™ transducer

Some flow-through sensor designs, on the other hand, achieve true zero internal dead volume. Viatran, for example, achieves this in its thru FLO™ transducer (Figure 1) by machining a small hole with uniform, smooth surface through a single piece of material with suitable pressure connection configurations on each end. They then machine a flat section across the outside of that piece at a tightly controlled distance from the inside diameter of the hole, insert strain gages into that section very carefully and bond them securely. Pressure applied to the hole interior causes the hole cross-section to grow larger (micro scale). The hole material transmits the mechanical strain across the diaphragm and into the strain gages. Since the gage conductors vary in electrical resistance with any strain applied to them, an electrical potential applied through them will vary in magnitude. A system can thus be developed to enable a precise pressure measurement. The standard pressure connection is 10-32 thread and cone (a standard HPLC connection) at each end, but other port configurations are available as well, including 6-40 thread and cone, and ¼-28 flat bottom. Such a one-piece sensor with a uniform smooth bore across the entire flow path thus eliminates the possibility of entrapment and provides efficient cleaning or flushing.

## Low internal volume/high throughput

Very low internal volumes are highly desirable in high pressure applications for several reasons. The scientific specimen under analysis may be small; diluting it to the requirements of a high-volume system may be impractical. Solvents needed to perform analysis may be expensive; the smaller the amount required, the better.

In addition, smaller system sizes handle higher pressures more easily. The walls of tubes, pumps and other pressure-containing chambers do not need to be as thick for higher pressures when their internal cross sections are reduced, thus saving cost and space.

While both flow-through and flush-mount transducers can be produced with low internal volume, flow-through transducers have a technological advantage. Viatran produces a very low internal volume flow-through transducer, Model LV2, having 1.6 microliters maximum internal volume (appearance, mounting configuration and ports same as shown in Figure 1).

## Low pressure operation

Some advanced chromatography applications, such as those used in new pharmaceutical markets, require extreme low pressures. Flush-mounted pressure sensors can perform well in these applications. Flush diaphragm pressure can be extended to pressures as low as ~3 psig (0.2 bar). The drawback, however, is that such sensors have significant internal dead volume, and, as discussed above, have internal corners and crevices that can trap sample substances despite repeated flushing; potentially contaminating subsequent HPLC samples.

The lower performance limit for zero dead volume flow-through sensors is limited to between about 100 and 2,000 psi, depending on internal volume, material compatibility and performance requirements. This is because the thin diaphragm thicknesses necessary to sense those pressure levels adequately are not technologically attainable.

Achieving the lowest pressure ranges in a flow-through sensor requires a combinationof modifications, including enlarging the bore, using a low-modulus material such as analuminum alloy and increasing the amplification. However, not each of these options is desirable or possible in every application. Increasing the bore size also increases internal volume; aluminum is highly reactive to common HPLC media; and increasing the gain also increases electronic noise and thermal errors. The use of aluminum may be acceptable, however, if an inert coating such as Teflon or Parylene C on the wetted surfaces is permissible. Accurate measurement of low pressures in HPLC applications with true zero internal dead volume remains a challenge for design engineers.

## Effect on zero balance due to flow

Maintaining zero balance is important because it has a direct effect on accuracy. Flowthrough sensors have some distinct advantages in this area. The flow-through strain gage patch is very compact and is matched to the temperature coefficient of expansion of the structure. Power dissipated by the strain gage is low (<10mA with the 350 Ω gage), therefore minimizing thermal error due to fluid flow. In flush-mount designs, however, the error due to flow depends on the size of the diaphragm, its thermal conductivity, and the matching of coefficient of thermal expansion with the mounting structure.

## Temperature compensation

Changes in ambient temperature affect the output, and can produce significant errors in pressure readings if not compensated for. Both flow-through and flush-mount sensors use adjusted compensation to correct for the effects of temperature to within a specified tolerance.

## Frequency response

Also due to its compact size, mechanical frequency response of the flow-through sensor is high-- at least 10K Hz. Electronic frequency response also affects total frequency response; but in this regard, flow-through and flush-mount sensors are no different. High frequency response is a necessary prerequisite for detecting and measuring rapid changes in pressure.

## Linearity, hysteresis and repeatability

Linearity, hysteresis and repeatability are among the most important measures of accuracy and reliability. These are a function of physical properties of the sensor more so than whether it is flow-through or flush-mount.

Linearity is the maximum deviation from a straight line from zero pressure to full scale outputs. Hysteresis is the output difference between increasing and decreasing pressure application. Repeatability is the variation in output signal between consecutive pressure cycles under identical conditions. Each parameter is expressed as a percentage of full scale. A design which achieves the highly desirable high linearity, low hysteresis and high repeatability begins with selection of the sensor body material from among certain materials such as certain grades of 316 stainless steel, titanium alloy or aluminum alloy. Other requirements are integral to the design of the sensor and its surrounding system, and involve ensuring that certain geometries and materials with unsuitable mechanical properties do not significantly influence the sensing function.

## Conclusion

If ability to measure pressure is the sole performance measure, then both flush-mount and flow-through sensors perform equally at high and ultra high pressures, while flushmount sensors have an advantage at low pressures. With modifications in bore and material, flow-through sensors can provide readings at low pressures. However, accuracy becomes reduced to the extent that amplification must be increased in order to make up for the decrease in signal due to lower pressure. Use of flow-through sensors at low pressures, therefore, is limited to specific applications.

After ability to measure pressure, ability to maintain purity through zero dead volume is among the most important criteria for advanced chromatography applications. Flowthrough sensors designed for zero dead volume are far superior here because they can take readings without interfering with the process flow. They can be cleaned and flushed completely, eliminating the danger of contaminating subsequent flows with residual material that may have been trapped in a pocket or crevice.

Flow-through sensors also have faster warm up time, faster frequency response, and are better able to maintain zero balance due to flow. On all other criteria -- temperature compensation, linearity, hysteresis and repeatability and frequency response-- flush-mount and flow-through are on par.

Unless your application requires low pressure operation, flow-through sensors with zero dead volume are the best choice for advanced chromatography systems.

Viatran

**Viatran**
199 Fire Tower Drive
Tonawanda, New York 14150
Phone:+1-716-629- 3800
Toll Free: +1-800-688-0030
Fax: 716-693-9162
Email: VTcustomerservice@viatran.com
Web: www.viatran.com

CERTIFIED ISO 9001:2015 COMPANY