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Raising the Bar for Primary Elements

Differential flowmeters are squarely in the middle of change.

Jesse Yoder, Flow Research

New measurement technologies are flowing through the stream measurement marketplace. New flowmeters such as ultrasonic, vortex, and Coriolis are causing a fundamental shift in the market away from traditional technologies and towards the new technologies. User concerns with reliability, cost of ownership, maintenance requirements, and improved accuracy are driving these changes.

Differential pressure (dp) flowmeters are squarely in the middle of this change. Dp flowmeters use a primary element to place a constriction in the flow stream, causing a drop in pressure. The device's transmitter uses the resulting pressure drop to calculate the flow rate. Flow rate is proportional to the square root of the difference in pressure, and is calculated using Bernoulli's equation.

Something old, something new

Dp flowmeters are in the center of these technology changes because they have their feet in both camps. On the one hand, they are among the most traditional and well-understood methods of flow measurement. On the other hand, recent innovations in dp transmitters and in primary elements have put them in the group of "new technology" flowmeters. Among these innovations are the development of very high accuracy differential transmitters, the introduction of multivariable transmitters, and the advent of differential pressure transmitters that contain an integrated primary element.

While many advances have been made in dp transmitters, no corresponding advances have been made in primary elements. It is important not to equate the accuracy of a pressure transmitter with the accuracy of a total flow measurement made with that transmitter. Other factors, including the accuracy of the primary element, must be taken into account. So even if the pressure transmitter is reading the pressure at 0.1% accuracy, if the accuracy of the primary element is at 2%, the accuracy of the flow measurement reading is no greater than 2%.

Basic primary elements

The most common types of primary elements used with dp transmitters to measure flow rate include orifice plates, venturis, flow nozzles and Pitot tubes. See accompanying table. More variations exist beyond these "big four," three of which have been previously discussed in Differential Flowmeters: Simple Can Be Better, *CE*, Sept. 2000. Additionally, each additional primary element type also has many different subtypes. It also is likely that additional primary elements are yet to be developed.

As for the remaining primary element, a Pitot tube consists of two tubes that measure pressure at different locations within the pipe. One tube measures static pressure, usually at the pipe wall. The other tube measures impact pressure (static pressure plus velocity head). The faster the flow rate, the greater the impact pressure will be. Pitot tubes use the difference between impact and static pressure to calculate flow rate. While the Pitot tube is a low-cost device, the main disadvantage of a Pitot tube is that it only measures flow at a single point and should be installed at the point of maximum flow. This means that changes in velocity profile can cause significant errors. Pitot tubes are also subject to clogging.

Standard Pitot tubes only measure velocity at a single point. Averaging Pitot tubes are designed to compensate for that. These devices have multiple ports for measuring flow at multiple locations, making it possible to take changing velocity profiles into account.

Dieterich Standard’s (Boulder, Colo.) Annubar is an averaging Pitot tube device that has sensing ports on both the upstream and downstream sides of the primary element. The downstream ports provide a reference pressure, while the upstream ports provide impact pressure. The averaging effect on both is due to the multiple port configuration. This provides significantly higher accuracy than measuring flow at a single point.

Integrated dp flowmeter

One of the more significant developments in recent flowmeter history has been the emergence of the integrated dp flowmeter. In the past, end-users purchased transmitters from one company and primary elements from another. Process instrumentation now offers transmitters with an integrated primary element.

For example, Fisher-Rosemount (F-R, Eden Prairie, Minn.) offers the ProBar device which consists of a 3051 pressure transmitter together with an Annubar primary element. Similarity the Mass ProBar marries the 3095MV multivariable pressure transmitter with the Annubar device. In both cases the devices are said to provide higher accuracies and simpler installation and commissioning.

Accuracy gap

For many years, suppliers have been focusing their efforts on creating smarter and more accurate pressure transmitters. At the same time, continued technological development of computers has brought the calculating and computer power embedded in these transmitters to a new level. As a result, the accuracy level of some pressure transmitters is as high as 0.1%.

While transmitter accuracy is important, it is only one element in a complex picture. It is important not to equate dp transmitter accuracy with flow accuracy. If a primary element with an accuracy of 2% is used in computing flow rate, the accuracy of the flowrate calculation is no better than 2%, even if the pressure readings used have an accuracy of 0.1%. In this case, there is an "accuracy gap" between the primary element and its transmitter.

According to John Olin, ceo of Sierra Instruments (Monterey, Calif.),"During my 35 years in the mass flow business, I have repeatedly encountered the mantra that dp mass flow systems have an accuracy of 1%. What these ‘dp-philes’ choose to ignore is the fact that the transmitter is only one element in the system. Although the transmitter may be smart and accurate, real-world overall mass flow rate error is typically 3 to 5%."

Mr. Olin went on to explain that this is because of errors induced by the other elements in the system, such as noncollocation of the temperature sensor with the orifice, stem conduction in the temperature sensor’s thermowell, and corrosion of the orifice’s edges with resulting errors in the discharge coefficient. Variations in pipe inner diameter and the high-end conduction of the temperature sensor, which is embedded inside the probe, also cause errors in multipoint hot-tap insertion dp meters.

"The biggest problem I have with dp systems is that a total mass flow calibration is rarely provided. Instead, the system’s individual-element accuracies are blindly accepted. When their overall accuracy is audited, it usually falls in the 3-5% range," Olin continues.

The success of the integrated differential pressure flowmeter so far means that control engineers will see more integrated dp flowmeters in the future, using different primary elements. What other changes are likely to occur in dp flowmeters?

In the existing robust economy, instrumentation companies have been able to do the basic research that spawns these types of discoveries, and there is no doubt new and/or improved primary elements will result. It is possible that—even though the boundaries of research are often defined by what is already there—that the mold of existing technology can be broken and a new primary element developed that could bring accuracy and repeatability figures beyond current expectations.

DP Flowmeters Revisited				
Primary Element	**Description**	**Advantages**	**Disadvantages**	**Comment**
Orifice plate	Flat metal plate with an opening in it.	Well-understood technology; Simple construction; No cost increase with pipe size; Low initial cost; No moving parts.	Substantial pressure drop; Dirt buildup at plate; Limited turndown.	Installed between two pipe flanges.
Venturi tube	Flow tube that narrows to a throat, remains constant, and then expands.	Low pressure drop; Well suited to dirty fluids and slurries.	Can be expensive; Units are large and bulky for big pipes.	Used in big pipes for fluids containing solids, e.g., wastewater treatment plants.
Flow nozzle	A spout-like tube with a smooth entrance and sharp exit.	Good for high temperature and high pressure applications; Can handle dirty fluids better than orifice plates.	Substantial pressure drop; Can be expensive; Difficult to remove for inspection/cleaning.	Commonly used in steam applications.
Pitot tube	Two tubes with a single port each. Measures pressure at two different places in pipe.	Very low pressure drop; Low cost.	Easily clogged; Low accuracy.	Mainly used with gases.
Averaging Pitot tube	Pitot tube with multiple ports to measure flow velocity at multiple points.	More accurate than single-point Pitot tubes.	Easily clogged, not suitable for dirty fluids.	Available commercially as Annubar.