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A Primer on Primary Elements
Understanding a Key Aspect of DP Flow Measurement

By Jesse Yoder, Ph.D.

Differential-pressure (DP) flowmeters have been used in industrial environments measure flow for more than 100 years. Today, DP meters are still widely used b they are well understood, relatively inexpensive, and easy to install.

DP flowmeters use a device called a primary element to create a constriction in flowstream and arrive at a flow measurement. There are a number of types of p elements, including orifice plates, Venturi tubes, averaging Pitot tubes, and flow These primary elements have different geometric shapes and employ different r to create a pressure drop in the fluid line. Orifice plates are the most common t primary element used, although Venturi tubes and flow nozzles are gaining popi

Flow Research (www.flowresearch.com) recently completed a study of the DP fl market, including both DP transmitters and primary elements. The purpose of th was to determine market size and trends and to see how DP flow measurement up against other flow technologies. The study yielded some surprising results, ir the following:

- The value of the worldwide DP flowmeter market, including DP flow transmitters and primary elements, will exceed one billion dollars in 2007.
- The DP flowmeter market is experiencing annual growth in the 6 percent range.
- Growth in the DP flowmeter market is particularly driven by the rising worldwide demand for energy and the search for new supplies of oil and natural gas.
- Suppliers are adding new features and product enhancements to their DP flow transmitters, bringing greater accuracy and stability.
- Multivariable transmitters are continuing to show rapid growth, aided both by suppliers and by new products in this market.
- While orifice plates are still the dominant type of primary element, averaging Pitot tubes and Venturis are showing strong growth.
- Primary element suppliers are bringing out innovative and new products to enhance their primary-element product lines.

Worldwide sales of DP flowmeters account for more revenues than any other flowmeter type, when the value of DP transmitters and primary elements are taken into account. The DP flowmeter market has in the past been undervalued because the value of primary elements has not been included in the value of this market. With the value of the primary elements market included, it is clear that the DP meter segment is the largest of any flowmeter type.

Primary Elements

Even though primary elements play a fundamental role in DP flow measurement their importance is sometimes overlooked in favor of DP transmitters. Yet selecting th

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primary element is an important part of obtaining an optimal DP flow measurement. The best primary element for an application depends on fluid type, line size, fluid temperature and pressure, and many other variables. The following discussion lists the different types of primary elements available, and some of the application considerations.

Orifice Plates

Orifice plates are the most common type of primary element. An orifice plate is a flat, usually round piece of metal, often steel, with an opening or "orifice" in it. The orifice plate needs to be positioned at a correct position in the flowstream for it to function as a primary element for the purpose of making a differential-pressure flow measurement. For it to be so positioned, it must be held in place. This is typically done by an orifice assembly, an orifice flange, or a holding element.



Orifice plates. Photo courtesy ABB Inc.

In addition to an orifice plate and assembly or flange, most orifice-plate installations require the presence of a valve manifold, which serves to isolate the pressure transmitter from the process. DP flow transmitters use either a three-valve or a five-valve manifold.

Orifice plates are classified according to the shape and position of the hole or holes they contain. The following are the main types of orifice plates:

- Concentric
- Conical
- Eccentric
- Integral
- Quadrant
- Segmental

Single vs. Multiport Pitot Tubes

The Pitot tube is named for Henri Pitot, who invented it in 1732. Henry Philibert Darcy published a paper in 1858 that made improvements on Pitot's invention. A patent for the use of a Pitot tube to measure velocity in pipes was given to Henri in 1889. There are two types of Pitot tubes in use today — single-port and multiport averaging tubes.

A single-port Pitot tube includes an L-shaped tube that measures impact pressure. The tube is inserted into the flowstream, with the opening facing directly into the flow. Another tube measuring static pressure has an opening parallel to the direction of flow. Flowrate is proportional to the difference between impact pressure and static pressure.

A multiport averaging Pitot tube has multiple ports to measure impact pressure and static pressure at different points. The DP transmitter computes flowrate by taking the average of the differences in pressure readings at different points.

Some companies, such as Emerson Rosemount (www.rosemount.com) and Veris (www.veris-inc.com), have introduced proprietary versions of the averaging Pitot tube.

Emerson Rosemount's proprietary version is called the Annubar, and it was formed by Dieterich Standard, now part of Emerson Process Management. Veris's average tube is called the Verabar.

Venturi Tube

The Venturi tube was invented by an Italian physicist named Giovanni Battista Venturi in 1797. In 1887, Clemens Herschel used Venturi's work to develop the first commercial flowmeter based on it. His version of the Venturi flowmeter became known as the Herschel Standard Venturi. Herschel published his paper called "The Venturi Water Meter" in 1898. In 1970, BIF (www.bifwater.com) introduced the Universal Venturi Tube.



Venturi flow element. Photo courtesy of ABB Inc.

A Venturi tube is a flow tube that has a tapered inlet and a diverging exit. The DP transmitter measures pressure and uses this value to calculate flowrate.

Flow Nozzle

A flow nozzle is a flow tube with a smooth entry and a sharp exit. The DP transmitter computes flowrate based on the difference between upstream pressure and downstream pressure. Flow nozzles are mainly used for high-velocity, erosive, nonviscous flows. Flow nozzles are sometimes used as an alternative to orifice plates when erosion or cavitation would damage an orifice plate. They offer excellent long-term accuracy.



Flow nozzle. Photo courtesy of ABB Inc.

Wedge Elements

A wedge element is a flow tube that has a V-shaped flow restriction protruding into the flowstream from at least one side of the pipe. Wedge elements are designed to measure fluids with high solids content. They are also well-suited for air, viscous flows, and slurries.

Other Primary Elements

Other primary elements include low-loss flow tubes, Dall tubes, and the V-Cone element. Low-loss flow tubes are designed to produce a minimum amount of pressure loss. The Dall tube was invented by hydraulics engineer Horace E. Dall as an adaptation of the Venturi tube. The V-Cone is a proprietary device that is designed for flow measurement with minimal upstream piping. It is manufactured and sold by McCrometer (www.mccrometer.com).

One other category that deserves mention is laminar flow elements. They are of for air and gas flow measurement. Laminar flow elements are used with mass flow controllers to create a pressure drop and a flow measurement. They are also used to measure airflow to internal combustion engines.

While much attention has been paid to improvements in DP transmitters, including development of multivariable technology, primary-element suppliers are also displaying an innovative spirit. One example is Veris, which has introduced the Accelebar. The Accelebar combines a flow nozzle with an averaging Pitot tube into a single element. Another innovation comes from Emerson Process Management, which has integrated a multivariable transmitter with an Annubar averaging Pitot tube to form an integrated flowmeter called the ProBar.

DP flowmeters are widely used in the oil & gas industry, and in all the other process industries. Considering the size of their installed base, along with their current sales, DP flowmeters will be around for many years to come. As such, look for more innovations to come from the primary elements side of the DP flowmeter segment going forward.

Jesse Yoder, Ph.D., is president of Flow Research Inc. of Wakefield, Mass. He has 20 years of experience as an analyst and writer in process control. Dr. Yoder specializes in flowmeters and other field devices, including pressure, level, and temperature measurement. He has written over 70 market research studies in industrial automation and process control, as well as numerous journal articles. Dr. Yoder can be reached at 781-261-1111 or jesse@flowresearch.com.

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