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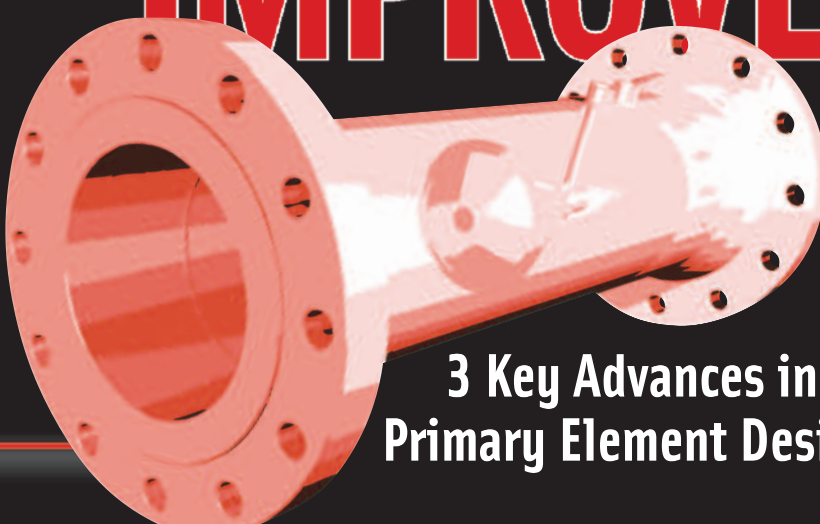


3 Key Advances in Primary Element Design

GRAND VIEW MEDIA GROUP

by Jesse Yoder, Ph.D.

Not So Element-ary

New Primary Elements Expand the Reach of DP Flow Measurement

Differential-pressure (DP) flowmeters rely on what is commonly called a "primary element" to foster the conditions for flow measurement. Primary elements place a constriction in the flowstream that causes a drop in line pressure. A DP flowmeter uses the pressure differential created between the upstream and downstream pressure to compute the flowrate.

DP flowmeters have been around for more than 100 years, and they are one of the most studied and best understood methods of measuring flow. Orifice plates are the most widely used type of primary element for measuring DP flow. Max Gehre received one of the first patents on orifice flowmeters in 1896. In 1909, the first commercial orifice flowmeter appeared and was used to measure steam flow. Soon after this, the oil and gas industry began using orifice-plate flowmeters due to low maintenance and standardization.

As orifice-plate flowmeters became more widely used, several engineering organizations began studying their use. These included the American Gas Association (AGA, *www.aga.org*), the American Petroleum Institute (API, *www.api.org*), the American Society of Mechanical Engineers (ASME, *www.asme.org*), and the National Bureau of Standards (now known as the National Institute of Standards & Technology, *www.nist.gov*). In 1930, a joint AGA/ASME/NBS test program generated a coefficient-prediction equation. Tests performed at Ohio State University (*www.osu.edu*) in 1935 in association with the NBS resulted in flow equations for DP flow that have been used by the AGA and ASME since that time.

Primary Elements

A number of different types of primary elements are used with DP flow transmitters to measure flow. The main types of primary elements are as follows:

- Orifice plates
- Venturi tubes
- Averaging Pitot tubes
- Flow nozzles
- Wedge elements

Orifice Plates

An orifice plate is usually a round, flat piece of metal with an opening (or "orifice") in it. Often orifice plates are made of steel. The orifice plate is typically held in place in the flowstream by an orifice assembly, an orifice flange, or a holding element. The orifice plate must be positioned at the correct place in the flowstream so that it can function as a primary element for the purpose of making a DP flow measurement.

Venturi Tubes

A Venturi tube is a flow tube with a tapered inlet and a diverging exit. The Venturi tube was named for an Italian physicist named Giovanni Battista Venturi, who invented it in 1797. The first commercial Venturi flowmeter was created 90 years later by Clemens Herschel in 1887. Herschel's version of the Venturi flowmeter has become known as the Herschel Standard Venturi. BIF (*www.bifwater.com*) introduced the Universal Venturi Tube in 1970.

Pitot Tubes

A Pitot tube is an L-shaped tube that is inserted directly into the flowstream. The tube contains one or more openings that measure impact pressure. Another tube that has an opening parallel to the direction of flow measures static pressure. Multipoint averaging Pitot tubes have multiple ports to measure impact pressure and static pressure at different points. Flowrate is proportional to the difference between impact pressure and static pressure measurements.

Flow Nozzles

Like a Venturi tube, a flow nozzle is a flow tube. However, a flow nozzle is not tapered like a Venturi; instead, it is relatively straight, with a smooth entry and a sharp exit. Flow nozzles are mainly used for high-velocity, nonviscous, erosive flows. They handle fluids with suspended particles better than orifice plates, due to their streamlined design. Flow nozzles offer excellent long-term accuracy.

Wedge Elements

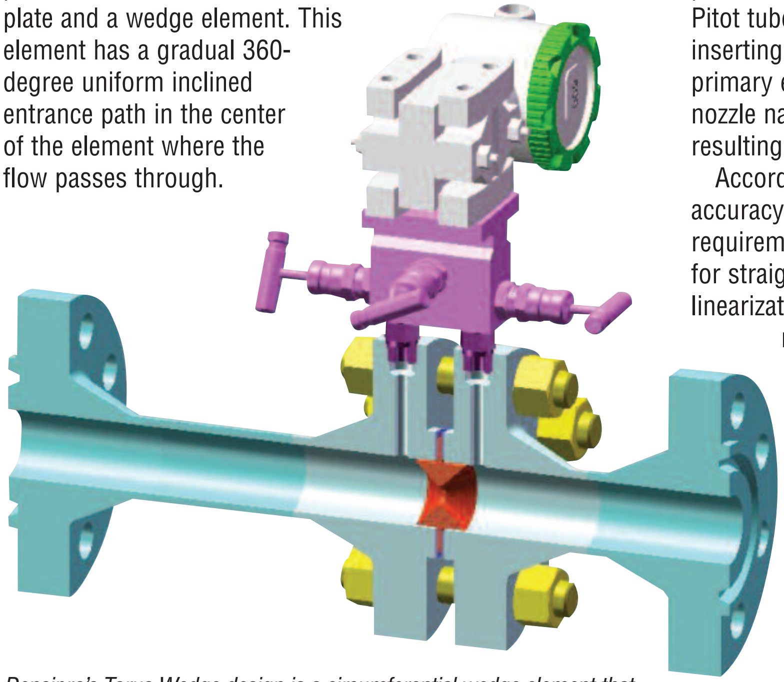
A wedge element is a flow tube with a V-shaped restriction on at least one side of the pipe. This restriction protrudes into the flowstream. Wedge elements are especially good at measuring the flow of fluids with high solids content. They also can be used to measure the flow of slurries, air and viscous flows.

Innovations in Primary Elements

While the aforementioned devices cover the main types of primary elements, some companies have released products in recent years that extend the boundaries of the typical primary element design. The following highlights three specific innovations in the area of primary element design. While these are not the only innovations in the area of primary element design, they represent some of the new thinking in the area of primary elements that is extending the relevance of differential pressure flow measurement.

The Torus Wedge

One of the more recent innovations in the area of primary element design is a product of Densipro Measurement Services (*www.densipro.net*). The company's Torus Wedge offering is a circumferential wedge element that incorporates features of both an orifice plate and a wedge element. This element has a gradual 360-degree uniform inclined entrance path in the center of the element where the flow passes through.



Densipro's Torus Wedge design is a circumferential wedge element that incorporates features of both an orifice plate and a wedge element.

This contrasts with an orifice plate, which simply has an opening in the center of the plate.

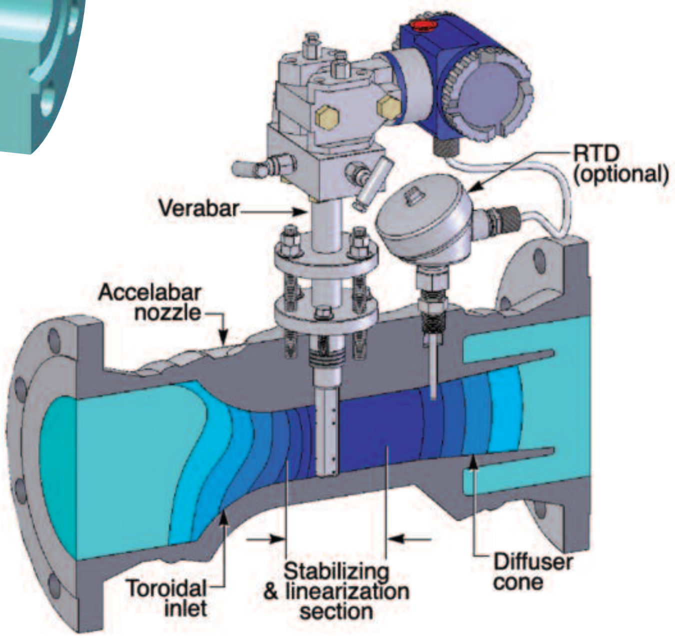
The design of the Torus Wedge gives it certain advantages over an orifice plate. The gradual entrance path eliminates the sudden restriction to flow that occurs with an orifice plate. This design also eliminates the issue of particle buildup that can occur with an orifice plate. Particles can build up at the outside edge of an orifice plate because its flat design prevents particles from being swept through. The gradual design of the device also protects against erosion that can occur to the inside edge of an orifice plate.

According to Densipro, the Torus Wedge is a good fit for measuring the flow of gas, liquids, steam, multi-phase liquids, and wet gases. The Torus Wedge has large rangeability (turndown) over a standard orifice plate. It is also easily configured to support the measurement of highly viscous fluids, slurries, drilling fluids, saturated and superheated steam, and corrosive fluids; and it provides flexibility in sizes and installations. It is available in both spoolpiece and insert element versions. The Torus Wedge, like other primary elements, relies on a DP flow transmitter to compute flow based on the difference in upstream and downstream pressures.

The Accelabar

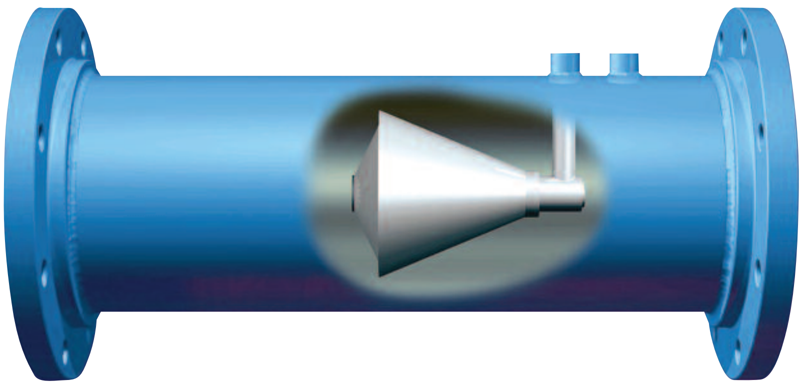
Veris (*www.veris-inc.com*) is another company that manufactures a unique primary element. Veris is perhaps best known for its Verabar, an averaging Pitot tube. The Verabar has a single-piece construction and is designed to minimize the possibility of clogging, which can be a problem for averaging Pitot tubes. Veris has built on its success with the Verabar by inserting the Verabar into a flow nozzle and creating a new primary element, called the Accelabar. In this design, the flow nozzle narrows the flowstream and accelerates the flow, resulting in a stronger differential-pressure output.

According to Veris, the design of the Accelabar increases accuracy and reduces the need for a straight-run piping requirement before the meter. This reduced need for straight run is made possible by the stabilization and linearization of the flow profile that occurs inside the flow nozzle. The strong differential output also increases the Accelabar's operating range (turndown). In addition, the design of the Accelabar results in lower permanent pressure loss than traditional orifice plate designs.



Veris's Accellabar is a primary element that places an averaging Pitot tube inside a flow nozzle.

The Accelabar can be used to measure the flow of gas, liquid, and steam. Gas applications include natural gas, methane, nitrogen, air, and mixed gases. For liquids, the Accelabar measures the flow of chilled water, hydrocarbon liquids, condensate, and feedwater. Steam applications include saturated and superheated steam, along with university steam metering.



McCrometer's V-Cone primary element consists of a contoured cone suspended inside a straight pipe. As the flow passes the cone, short vortices are formed with a low amplitude and high frequency signal.

The V-Cone

Like the Accelabar, McCrometer's (*www.mccrometer.com*) V-Cone is designed to reduce the need for straight piping run before the element. McCrometer developed the V-Cone in the mid-1980s as a byproduct of an attempt to create a flowmeter with a bypass line to measure water flow. In such a flowmeter, a proportional amount of the flow is diverted to a smaller bypass line, and this smaller line is used to measure flow in the large line. This is the technology used in mass flow controllers. The first commercial version of the V-Cone was patented in 1987. The "V" in V-Cone comes from its similarity to a Venturi tube.

The V-Cone consists of a contoured cone suspended inside a straight pipe. As the flow passes the cone, short vortices are formed with a low amplitude and high frequency signal. According to McCrometer, the V-Cone's design provides high accuracy and repeatability, with minimal need for recalibration.

The V-Cone is designed to measure flow under harsh operating conditions. Applications include measurement of clean and dirty liquids, wet gases, slurries, and steam. The shape and position of the cone enables the V-Cone to act as its own flow conditioner, which minimizes the need for upstream or downstream straight piping run. It comes as a spoolpiece or as an insertion weld-on saddle flowmeter.

The Future of Primary Elements

The primary elements described above are designed to address certain shortcomings or issues with traditional primary elements, as well as other types of flowmeters. The Torus Wedge substitutes a gradual restriction for the sudden restriction of an orifice plate, resulting in a more stable measurement and a design that eliminates particle buildup. All three primary elements claim to reduce or eliminate the need for upstream straight piping run. This can be especially important today in contexts where space is at a premium, e.g., on oil platforms and in some process plants.

Both the Torus Wedge and the Accelabar combine features of two different types of primary elements. This may be one path to future innovation in primary elements. Whatever the case, given the large installed-base of DP flowmeters worldwide, expect to see more unique primary element designs coming to market going forward. FC

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