Venturi Meters: The Headloss Benefits of a Simplistic Design

By Bruce Briggs
Source: Primary Flow Signal, Inc.

Venturi meters are known for their accuracy, reliability and longevity, and they provide a wide variety of measurement options in piped systems for liquids, gas, steam, and mixed-media because of their dependable, long-term performance -- offering a high degree of accuracy while using very little energy.

Primary Flow Signal's Halmi Fabricated Venturi

These flow meters have no moving parts and can function reliably and accurately for decades, with some in service for more than 100 years. To this end, Venturi meters are used whenever defendable accuracy with low energy consumption is required, even on difficult applications that would render other devices, such as magnetic, ultrasonic and thermal-type meters, ineffective.

History

Venturi meters are well defined in literature with a variety of examples, such as the Classical or Herschel-type Venturi. The length of these meters was quite long because their convergent and divergent angles were small and their throat length was equal to the throat diameter. In most examples, the converging cone did not influence the meter's coefficient; however, it did have an effect on the overall energy consumption of the meter.

The Classical design also contained an averaging pressure-sensing ring (called an annulus or annular chamber) at the high- and low-pressure sensing cross sections. Depending on the manufacturer or model of the classical meter, the basic design included an annular ring at both the inlet high-pressure area and throat low-pressure locations; in some cases, the annular ring was located at only the low-pressure position. For cast and ductile iron examples, the annular chamber was cast into the body, and multiple internal taps led to the annular chamber depending on the vintage, manufacturer and model.

This "averaged" pressure was then externally led to a single tap used to connect the secondary instrumentation system. To this end, the meter was designed to be used on clean, non-corrosive fluids, eliminating the concern for plugging the chamber and thus losing the pressure signal to the secondary instrument. In addition, the annular averaging chamber was cast into the meter body and could not be easily coated or cleaned for the cast and ductile iron models. To note, if one wanted an averaging annular ring for fabricated-type meter designs where there was no cast geometry, it was located externally via a tubing ring that was connected to four, six or eight internal taps.

Updated Designs

The design and materials used in Venturi meters have remained active over the last century, and although the fundamental principles have stayed the same, some important updates have made today's technology even more accurate and reliable than past versions. Likewise, there are two versions in particular that have significantly impacted Venturi metering -- the modified short-form Venturi meter and the insert Venturi meter.

Modified Short-Form Venturi Meters

Modified short-form Venturi meters, such as Primary Flow Signal's Halmi Venturi Tube (PFS-HVT; see Fig. left), are more tolerant of upstream conditions. These meters have lower headloss; are more accurate than most other meters; have no downstream straight-pipe requirements for standard accuracy; and are less susceptible to blockages and plugging, as the annular chamber was replaced with a single- pressure tap that can be easily cleaned should any plugging occur. Typical headloss percentages for modified short-form meters range from 3 to 10 percent of differential depending on Beta ratio selected, which is better than the Classical Venturi.

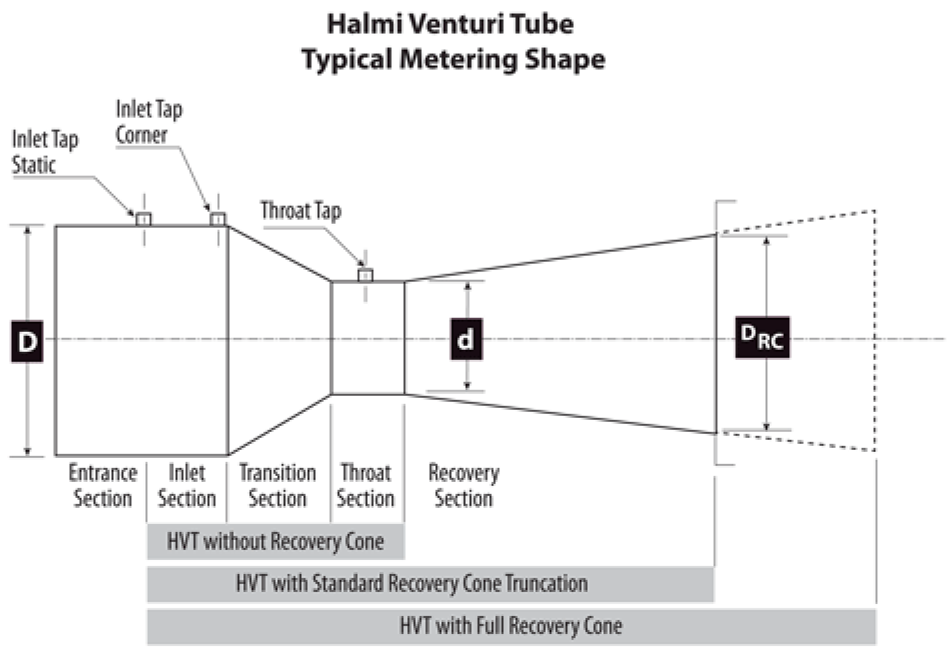
The overall length of the HVT is also considerably shorter than the Classical Venturi because the intersecting angles are much greater and the discharge end of the recovery cone does not stop in the full downstream pipe line size. Rather, it is truncated, or cut short, while the flange is designed to mate directly to the downstream pipe flange.

This allows the device to be shorter, hence the name, and more energy- efficient since the frictional loss through the long Classical Venturi meter recovery cone consumes a great amount of energy. In addition, the HVT throat section is about one-half the length of the Classical Venturi meter throat section, which also contributes to lower frictional loss. It is interesting to note that most major independent laboratory flow calibration facilities around the world use Venturi meters as their primary standard. In addition, pump and blower manufacturers also use Venturi meters and other differential-type devices as efficiency testing standards.

Insert Venturi Meters

A useful addition to the world of Venturi metering is the insert Venturi meter. This design has the same geometry as the full-flanged design, but the profile is entirely inside the pipeline and is held in place with a center holder that is sandwiched between two existing pipe flanges, much like an orifice plate. The "laying length" of the meter is the thickness of the center flange, so there is a considerable saving of space.

The benefit of this design, however, is that it utilizes a static low-pressure throat tap. Unlike a "true" Venturi meter, its high-pressure sensation comes from a corner location on the inlet side of the center flange. As previously explained, the Classical Venturi senses true static pressure at both the high- and the low-pressure tap cross sections, as does the short-form Venturi design.



In order to claim that a tap senses true static pressure, the tap must sense pressure perpendicular to the axis of the flowing line fluid. The Classical and short-form Venturi meters do this very successfully in the flanged design but, without an upstream section available to locate the high-pressure tap, the insert-type Venturi meters develop their high pressure at the tap that is effectively "looking" at the oncoming flow. This makes these meters somewhat more sensitive to the effects of upstream non-straight piping.

The basic accuracy of these meters is identical to the flanged design at +/- 0.50% of the actual rate of flow. However, the PFS static high-pressure tapped insert Venturi meter design moved the high-pressure tap off of the center flange and into the upstream spool piece. With this adjustment, the meter enjoys the same installation insensitivity as the traditional flanged, full-body Venturi design at the proper static pressure-sensing location.

Conclusion

Venturi meters are useful devices to measure liquids, gas, steam, slurries, cryogenic fluids, and mixed-media flows. They are versatile in that their laying length can be changed to fit a defined space; they can be modified to provide rate of flow control or measure sewage; they can be used reliably for billing or custody transfer; and they can be used for rectangular or circular metering. In addition, Venturi meters can be oriented in any plane and can measure accurately whether the line fluid is flowing upwards or downwards. Further, Venturi meters are not subjected to downstream piping effects, only upstream piping -- the effects of which are well known and predictable.

However, it is important to note that as accurate and reliable as these meters are, there are still some limitations. Typically, the energy loss through a Venturi meter is between 0.10 and 0.25 psig. Thus, Venturi meters do consume energy, but unlike other devices, the recovery cone reduces the energy consumption to an insignificant level in most cases.

There are no intrinsic design limitations on either temperature or pressure of a proposed application or line size, which allows these meters to be effective in a variety of applications without the susceptibility of excess headloss when providing measurements. In addition, wide-range flow measurement can be accurately accomplished by using multiple DP transmitters, each calibrated for a certain flow-rate range. A range of 50 or 100 to 1 can be easily and accurately handled with the proper secondary instrument system.

About the Author: Bruce Briggs is the president and principal of Primary Flow Signal Inc., a global manufacturing, engineering and technology resource focusing on highly accurate, repeatable and reliable differential flow meters. In his more than 30 years in the industry, Mr. Briggs has built, arguably, the largest team of expert flow metering, hydraulic and applications engineers, along with technicians and specialists of diverse critical expertise. The companies are comprised of a number of enterprise-owned, fully integrated manufacturing facilities offering a world-class platform for solutions and support for the oil and gas, power, municipal water, wastewater and automotive markets.