DIFFERENTIAL METERS OTHER THAN ORIFICE

Kenneth Reed, III

KRK Measurement

Introduction

Cone meters differ from other differential pressure type meters, such as orifice meters and Venturi meters, basically, by design only. They are all required to meet American Petroleum Institute (API) Manual of Petroleum Measurement Standards (MPMS), Chapter 22.2 (entitled "Testing Protocol for Differential Pressure Flow Meter Devices") test criteria developed and published in 2005 and still being updated today. The cone meter is designed to measure liquid or gas. Cone meters are proprietary in design and have limited third-party testing due to patented designs and length of use in the Industry. The orifice meter is the oldest meter of the three that we will discuss and has the most third-party flow lab test data available. The Venturi meter, historically, has mostly been utilized for liquids and steam. The Venturi is also known to preform very well in harsh flows, such as sewage, wastewater, and pulp due to its free flowing design. In recent years, Venturis are more commonly being used for liquefied natural gas (LNG) and compressed natural gas (CNG) due to the ability to construct them from a wide variety of materials.

History

Differential producing meters have been in service for over 100 years. The orifice meter has been the most accepted in the oil and gas industry, since its inception for custody transfer. The Venturi meter, introduced in the 1800s, has been accepted for harsh, non-custody transfer applications, such as municipal water, sewage, or pulp. The cone meter was introduced over 30 years ago but is still considered to be in its infancy due to its patented designs and its lack of broad acceptance as an alternative to orifice meters.

How are cone meters different from other types of differential meters?

First, let us discuss the most predominant and widely-accepted differential meter, the orifice meter.

The **orifice meter** is the most predominantly utilized device for measurement of natural gas. Its dominant presence in the natural gas industry stems from many decades of acceptance as the primary means for accurate hydrocarbon measurement. The orifice meter has the most third-party flow lab test data of any differential metering device, as well as thousands of papers written about it. The newest revision of the orifice meter standard is the 2000 edition of American Gas Association (AGA) Report No. 3 (entitled "Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids"), Chapter 2 (entitled "Specification and Installation Requirements"). Simple by design, it consists of a straight upstream and downstream pipe with an orifice plate centrally located in the bore to create a pressure differential. This pressure difference will incorporate the Bernoulli equation to determine a flow rate.

The Bernoulli Equation

$$\frac{P_1}{\rho} + \frac{1}{2}V_1^2 + gZ_1 = \frac{P_2}{\rho} + \frac{1}{2}V_2^2 + gZ_2 \qquad \text{(Equation 1)}$$

where:

- P_1 = pressure upstream of the contraction
- P_2 = pressure at the throat of the contraction
- V_1 = bulk velocity of the fluid upstream of the contraction
- V_2 = bulk velocity of the fluid upstream of the contraction
- Z_1 = elevation of the upstream pipe
- Z_2 = elevation of the throat of the contraction
- g = acceleration of gravity
- ρ = fluid density

Below are some requirements of the orifice meter:

- Uses Bernoulli Equation
- Requires a flow conditioner for the shortest meter tube length, with 13 nominal pipe diameters (13D) of straight upstream pipe

- Requires a straightening vane for 17D- 29D of upstream pipe
- Requires 145D of upstream pipe with no flow conditioner
- Downstream tube requires 4.2D-5D of straight pipe
- 3:1 turndown ratio on flow rate range
- Coefficient of discharge on the order of 0.65
- Has a high permanent pressure loss (PPL) of around 70%
- Poor efficiency (high PPL = higher energy cost)
- By design, the orifice plate is susceptible to sudden impacts that cause damage as the flow must pass through the center of the pipe and continually wear at the sharp edge of the bore.
- By design, congregation of liquids or solids will form in front and behind the plate causing measurement errors.

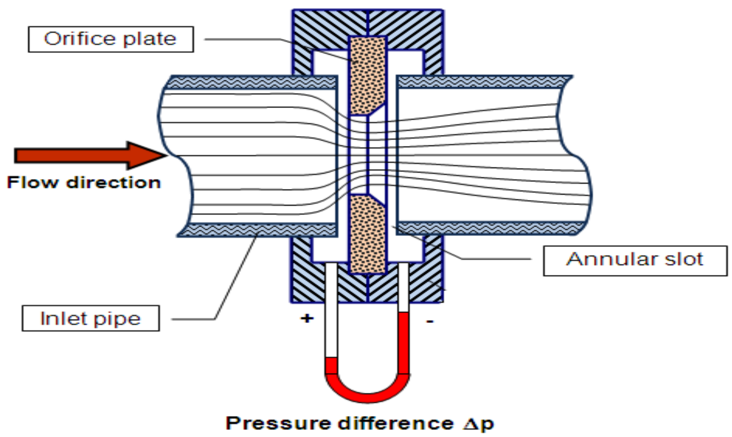

FIGURE 1. Orifice Meter Illustration

Next, we will discuss the principle of the Venturi meter.

Like the orifice meter, the **Venturi meter** has been around for over a century. Inside the Venturi meter, the fluid/gas is accelerated through a converging cone with an angle of 15-21º. The pressure difference between the upstream side of the cone and the throat is measured. This differential provides a signal for the rate of flow. This meter consists of two conical pipes connected to a throat to produce a pressure differential. This pressure difference can incorporate the Bernoulli equation to determine a flow rate. The differential producing Venturi meter has a long history of uses in many applications. Due to its simplicity and dependability, the Venturi is among the most common flow meters. With no moving parts or abrupt flow restrictions, the Venturi can measure fluid flow rates with a minimal total pressure loss.

The principle behind the operation of the Venturi flow meter is the Bernoulli effect. The Venturi meter measures a fluid's flow rate by reducing the cross-sectional flow area in the flow path and generating a pressure difference. After the pressure difference is generated, the fluid passes through a pressure-recovery exit section where up to 80% of the differential pressure generated at the throat is recovered. This makes the Venturi meter much more efficient than the orifice meter.

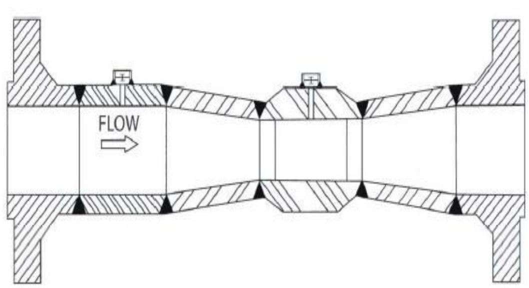

FIGURE 2. Venturi Meter Illustration

Below are some requirements of the Venturi meter:

- Uses Bernoulli Equation
- Venturi requires 5D of upstream and 2D of downstream straight pipe
- 10:1 turndown ratio on flow rate range
- Coefficient of discharge on the order of 0.95
- Has a low PPL of around 20%, i.e., higher flow efficiency than an orifice meter
- By design, the Venturi meter is not as susceptible to impact since any debris would be a deflected or have a glancing blow
- No place for congregation of liquids or solids, self-cleaning by free-flow design

Next is the cone meter.

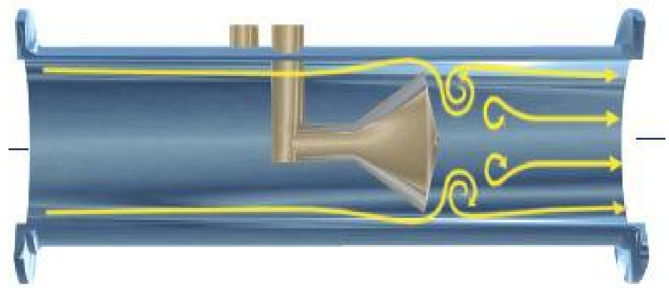

FIGURE 3. Cone Meter Illustration 1

The centrally located cone inside the meter body reshapes the profile of the flow as it enters the meter body. The cone can have many different diameters, which makes most "cone meters" a fixed beta ratio. The principle of the meter is similar to that of the orifice meter and the Venturi meter, using a beta ratio. As the flow comes into contact with the cone, it creates a low-pressure region just downstream of the cone. See illustrations below:

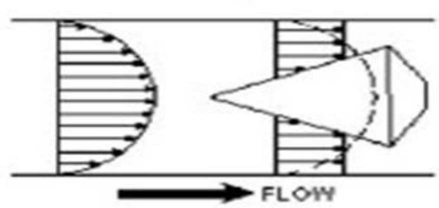

FIGURE 4. Cone Meter Illustration 2

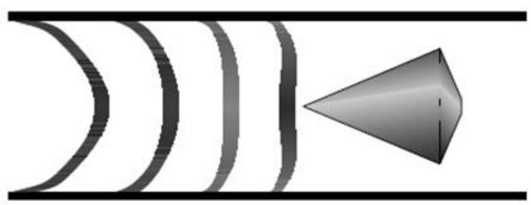

FIGURE 5. Cone Meter Illustration 3

This pressure difference can incorporate the Bernoulli equation to determine a flow rate. This unique design and how it changes the profile of the gas as it enters the meter without a flow conditioner assures accurate and repeatable measurement even with harsh upstream conditions. Little or no upstream straight piping length is required.

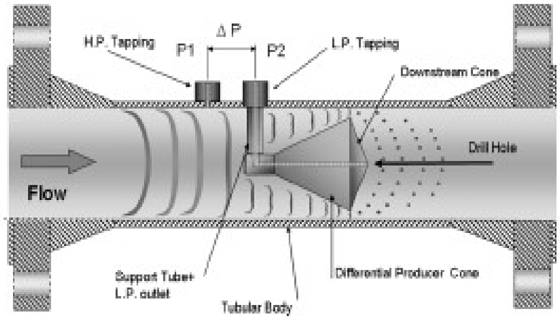

FIGURE 6. Flanged Cone Meter Illustration

Some cone meters have inter-changeable beta ratios. See the illustration below:

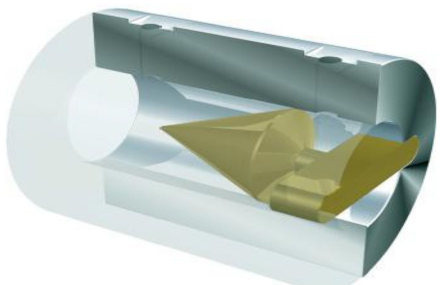

FIGURE 7. Flanged Cone Meter Illustration 1

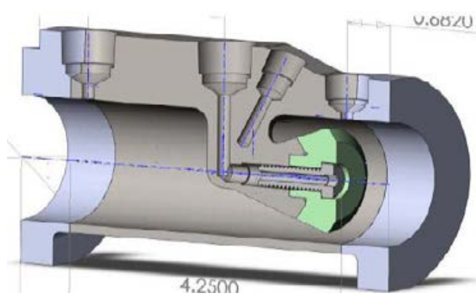

FIGURE 8. Flanged Cone Meter Illustration 2

Cone meter advantages over other differential type meters:

Advantages:

- Does not require a minimum upstream length of straight pipe, unlike an orifice meter
- Can be located closer to upstream disturbances
- Lower permanent pressure loss, better efficiency
- Self-cleaning design
- Design causes static mixing downstream for liquids
- Central location of the cone "conditions" a disrupted flow
- Turndown ratio is greater than for a single orifice plate (i.e., 10:1 or better)
- Operation and maintenance costs are lower
- Smaller foot print
- Weighs less than an orifice meter
- Easier to install due to its reduced size

- Does not require a flow conditioner
- Cone design directs flow without abrupt surface impact
- No rubber seal rings to replace, unlike an orifice meter
- High accuracy
- No areas of flow stagnation
- Typically, the meter cross section is smaller than the pipeline cross section
- Lower signal noise
- Predictable flow profile

Disadvantages:

- New technology, not easily accepted in industry
- Most designs have fixed beta ratios
- Low flow / low Reynolds Number limitation
- Orifice meter has much wider acceptance in the gas industry

Conclusion:

Cone meters will struggle to be accepted because they are a relatively new design, even at 30+ years of age. Recent advances in cone meter construction allow beta ratios to be changed, resulting in broader flow rangeability. Most companies still believe that meters that worked 30 years ago will still be what we use today. Due to the design and construction of the cone meter using CNC machining equipment, the geometry of the meter inside diameter and the eccentricity of the cone produces a much more accurate and repeatable differential meter. It will continue to take time and resources with future testing in order for most companies to accept this new metering technology for liquid and gas measurement.

Glossary:

Efficiency

Efficiency is the ratio of output to input. No machine gives out as much energy or power as is put into it. There are some losses, even in a perfectly constructed machine. Efficiency is usually expressed as a percentage.

References:

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5. "Venturi Tubes" from www.fluidictechniques.com, retrieved 1/2012.