V-Cone®, An Alternative to Orifice Meter in Wet Gas Applications

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Abstract
This paper will discuss the use of the V-Cone differential pressure flowmeter to measure the flow of wet gas. Wet gas flow measurement is gaining considerable attention due to its importance in the oil and gas industry. Separator and well-head flow lines are two examples where wet gas can occur in a production system. Orifice plates have long been used for these applications. While orifice plates offer good measurement in clean gas applications, an alternative is needed that will provide better performance in the harsh environment of wet gas flow.

Introduction
Definition of wet gas
Wet gas is a term that is often used but rarely defined. A loose definition is the flow of gas (typically natural gas) with a small amount of liquids. Wet gas could be considered a subset of two-phase flow. The question is where does wet gas end and two-phase flow begin? The answer has not been determined. In 1997, a consensus was that wet gas was gas flows with liquid contents less than 5% by *mass*. In 1999, the envelope has been stretched to include liquid mass fractions even up to 50%. This can mean liquid *volume* fractions up to 5%. For this paper, wet gas will be considered present where the liquid *mass* fraction is less than 50%.

DP measurement for wet gas measurement
Differential pressure (DP) flow meters are ideally suited for the harsh environment of wet gas. Because they have no moving parts, DP meters are less likely to experience mechanical problems. Turbine meters, for example, have bearings that can easily be destoyed with the dirty liquids in wet gas flow.

DP meters do not have internal sensors in the flow stream. The nature of DP meters is only a restriction in the flow line. This restriction does not require electronics to generate the DP signal. Many newer technologies depend on sensors in the flow stream. Ultrasonic meters have transducer sockets that can fill with liquids and cause loss of signal. The signal paths of ultrasonic meters can also have trouble if the path is required to bounce off the pipe wall at a point where liquids are present.

Lastly, DP meters can be made from almost any type of metal. Duplex and Hastelloy materials can easily be used in the construction of DP wet gas meters. For these reasons and more, DP meters such are still the preferred choice for wet gas flow measurement.

V-Cone wet gas testing

Wet gas testing has been completed on the V-Cone at the Southwest Research Institute. As of May 1999, this is the only completed test data on the V-Cone in wet gas flow. Several projects are in progress or planned for the 3rd or 4th quarter 1999.

Southwest Research

Southwest Research Institute (San Antonio, Texas, USA) completed a series of testing on three 4" V-Cones with beta ratios of 0.45, 0.59, and 0.67. The flowing gas was nitrogen, the liquid was water.

A copy of the report is available from McCrometer. The Southwest report project number is 04-8369-002. The McCrometer literature number is 24513-17. This literature is in CD-ROM format and contains the SwRI full report, as well as videos of the flowing wet gas conditions in the V-Cone and an orifice plate.

Results from these tests show the V-Cone performs well under wet gas conditions with liquids up to 5% mass fraction. With beta ratios of 0.45 and 0.59, the maximum deviation from baseline conditions was 1% of rate. With beta 0.67, the maximum deviation from baseline was 1.5% of rate.

Ohio University

Ohio University has a program in progress to evaluate wet gas flows and their effect of flow measurement devices. Twenty-two oil companies involved in production support the program. They will emphasize the use of wet gas flow meters in offshore and subsea applications. The program is run by the Institute for Corrosion and Multiphase Technology, Department of Chemical Engineering. They will test two of the three meters that were also tested during the SwRI testing. The flowing gas is nitrogen and the liquid is oil with a viscosity of approximately 2 cP.

The flow regimes will include fairly slow velocities due to capacity limitations of the facility. The V-Cones will be model VW04 with betas of 0.45 and 0.59. Velocities will range up to 5 m/sec (15 ft/sec). Pressures will range from atmospheric to 27 bar (400 psig).

Wet Gas JIP

A wet gas Joint Industry Project is currently running. Initial testing has been completed on orifice plates and venturis. The next stage of the testing will include up to two V-Cones.

The JIP is funded by the contributions of the members and the Gas Research Institute (Chicago, Illinois, USA). Due to the nature of the JIP, results will not be published for a specified amount of time. Results from the V-Cone testing will likely not be available for several years.

The exact parameters of the testing have not been finalized. The V-Cones will likely be 4-inch size of several different beta ratios. The test facility will be the new wet gas loop at Colorado Engineering Experiment Station, Inc. (Nunn, Colorado, USA). The nominal line size of the loop is 4 inch with 600 class pressure rating. Flowing gas is natural gas and liquids can be varied from condensate to crude oil. Velocities can reach 30 m/sec (100 ft/sec) and liquid mass fractions up to 50%.

Problems with wet gas

Depending on gas velocities, wet gas flow is usually in annular or stratified regimes, as shown in Figure 1.

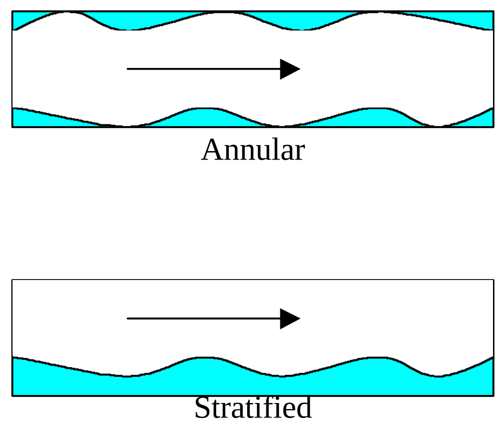

Figure 1

In both of these regimes, the majority of the liquids, and the particles conveyed by the liquid, are moving along the walls of the pipe. With a device such as an orifice plate, the primary element opening is located in the center of the pipe. All the liquids and particles must come into contact with the plate and then pass over the sharp edge. With the V-Cone, the primary element opening is located along the pipe walls. The cone, which creates the restriction, is positioned in the center of the pipe leaving an annular opening. See Figure 2.

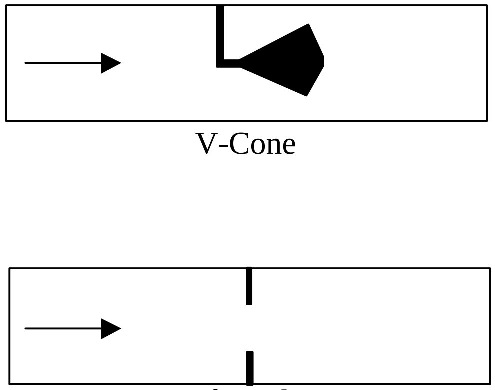

Figure 1

Wear

With a centrally located cone, the V-Cone is protected from the abrasion of wet gasses. The majority of liquids and particles in the flow pass by the V-Cone primary element without contacting its sharp edge. Erosion is thus avoided in the V-Cone and long-term performance is guaranteed to be stable.

Liquid hold up

Two more problems are associated with the orifice plate blocking the flow of liquids in wet gas flow. First is liquid hold up and the second is slugging. Liquids hold up can happen either before or after the plate. In general terms, liquids are more likely to hold up before the plate in slower velocities and after the plate in higher velocities. In the slower velocities, the liquids will gather before the plate until a sufficient amount is present to force some over the sharp edge.

Hold up during high velocities will happen after the plate not before. As the liquid impacts the plate, the gas moving through the orifice will force the liquid over the sharp edge. The liquid will then be dispersed be the high velocity of the vena contracta. As the liquid decelerates, it will move towards the pipe wall and some will be caught in the recirculating zone of the orifice. This recirculating will bring the liquid back upstream, where it will gather at the back face of the plate. This is clearly demonstrated on the wet gas CD-ROM from McCrometer.

Liquid hold up can a problem for orifice plates, since this will change the physical dimensions of the primary element. The upstream and/or downstream dimensions can be effected by the presence of liquid.

Liquid hold up is also the cause of slugging. Slugging is pipelines can cause both structural and measurement problems. The orifice acts as a collection place for liquids, which can aid in the creation of slugging flow. The V-Cone has no possibility for liquid hold up and cannot be the cause of slugging downstream.

Other benefits of using V-Cones

Besides the above benefits, the V-Cone offers the following additional benefits:

1. Short installation requirements. The V-Cone can be retrofitted into existing locations without repiping. New installations can be planned without designing for unnecessary meter runs upstream or downstream.
2. Low signal noise. The noise to signal ratio is lower in the V-Cone than orifice plates.
3. Low headloss. With lower signal noise, the V-Cone DP level can be much lower, thereby offering lower headloss than orifice plates.

See references listed below for more information.

Conclusion

While the V-Cone is relatively new and the testing performed thus far is inconclusive, all indicators show the V-Cone could be an acceptable alternative to the orifice plate for wet gas flow measurement. The geometry lends itself to better and longer performance than orifice plates. The upcoming tests at Ohio University and the wet gas JIP will answer some of gas industry's remaining questions.

References

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CEESI Wet gas flow loop, Nunn, Colorado USA