EFFECTS OF ABNORMAL CONDITIONS ON THE ACCURACY OF ORIFICE MEASUREMENT

Taft Snowdon
Colorado Engineering Experiment Station, Inc.
P. O Box 41
Nunn, Colorado 80648

The orifice meter remains the foremost measurement device used in the industry for hydrocarbon flow. The primary element of the orifice meter is the orifice plate and orifice meter tube consisting of the orifice fitting, or flanged pressure taps, adjacent piping and the flow conditioner or straightening vanes. The complete system also includes the temperature and pressure measuring devices used often called the secondary element and the pressure lines from the taps to the pressure instruments. The American National Standard Institute/American Petroleum Institute Standard 2530 (ANSI/API 2530) also called the AGA-3, provides specific recommendations for the manufacture, inspection and installation of an orifice meter. In order to insure accuracy, with minimum uncertainty, these guidelines and inspection procedures should be adhered to. Most of these specifications can be established by taking relatively fundamental measurements of the primary element components.

Abnormal conditions existing in an orifice meter that could effect the accuracy of the system may include any of the following:

1. Orifice plate deformation
2. Plate out of alignment with pipe centerline
3. Protrusions, gaps or roughness of the meter tube
4. Pressure taps out of specification
5. Plate thickness and edge sharpness out of specification
6. Improperly formed flow profile
7. Instrumentation deficiencies

1. Deformation of the orifice plate

Adverse flowing conditions (sudden and extreme pressure changes, liquids, ice etc.) can deform orifice plates resulting in measurement error. Orifice plates should be inspected periodically to assure they remain in tolerance. Figure 1 graphically depicts the type of error which can result from bent orifice plates. (3)

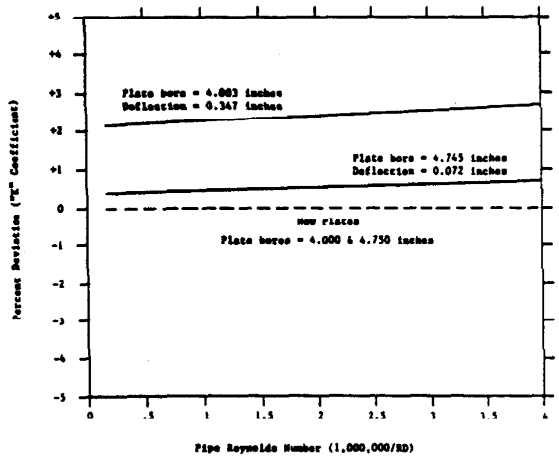

FIGURE 1
Approximate percent error - bent plate

2. Plates out of Alignment with Pipe Centerline

AGA-3 recommends that plates should not be off center by more than 3% of the inside diameter of the meter tube. The most recent studies suggest that eccentricity toward the pressure taps tend to give greater measurement error than eccentricity away from the taps or perpendicular to the taps. In general, as with most other abnormal conditions of orifice meters, the effects of eccentricity are more pronounced at higher beta ratios.

3. Protrusion gaps and smoothness of the meter tube

Protrusion into the flow stream of a meter tube is usually caused by misalignment of orifice flanges, gaskets protruding into the flow stream or weld beads not ground down. The determining factor in the magnitude of the measurement error caused by protrusions is the relationship of the protrusion to the orifice plate. The closer the protrusion to the plate, the more effect it will have and the existence of the protrusion upstream of the plate has a much more pronounced effect than if it were downstream of the plate. Also, the higher the beta ratio, the more pronounced the error.

Gaps or recesses along the pipe wall have a much smaller effect on the accuracy than does a protrusion since a gap will not normally significantly alter the main flow.

Care should also be taken to insure that the meter tube has been properly finished to a uniform smoothness. AGA-3 calls for pipe roughness not to exceed 300 microinches.

4. Pressure tap problems

Pressure tap location is extremely critical for proper differential measurement. The most widely used pressure taps in the industry are flange taps. Flange taps should be centered one inch either side of the face of the orifice plate. Tap holes should be flush and rounded with the pipe and remain clean of any blockage or buildup.

In the use of Junior and Senior orifice fittings, the problem of "tap communication" can occur due to the failure of the casting or damage to the meter fitting. If the pressure in the upstream tap is allowed to "mix" into the pressure in the downstream tap there will, of course, be erroneous differential readings. Leakage past seal ring of the orifice plate also result in incorrect differential readings. The installation of a blank plate is a good way to check for the existence of either of these two problems although this type of test can be difficult to perform under field conditions.

5. Plate thickness and edge sharpness

The sharpness and squareness of the upstream orifice edge is of extreme importance, especially with the smaller bore orifices and smaller line sizes. Unfortunately, the degree of sharpness and squareness of the orifice edge is difficult to establish with physical measurements. However, since orifice plates are so important, they warrant extreme care in their manufacturing, handling, and installation. Orifice plates should also be given careful periodic examination to make sure they remain in satisfactory condition. When checked with an orifice edge gauge, the upstream edge should not show a beam of light or should not reflect a beam of light when viewed without magnification.

Relatively thick orifice plates which are not beveled can also cause significant measurement errors. Discharge coefficients tend to decrease with decreasing plate thickness. However, correctly beveled plates tend to negate thickness problems.[3]

6. Flow Profile

Orifice meter measurement errors caused by swirling have been shown to be very significant and unpredictable. The two most common methods used to attempt to remove swirl are to install lengthy runs of straight upstream piping or to install an upstream flow conditioner.

While the use of lengthy upstream piping can be helpful this does not always remove a significant amount of swirl. It also might not be a practical solution in many meter installations. For example, to remove swirl caused by two elbows in perpendicular planes might require 100-150 pipe diameters of pipe upstream. Installing flow conditioners, such as tube bundles or Sprinkle plates, has been shown to effectively remove swirl. However, caution should be used in the placement of flow conditioners. Significant errors in measurement can be caused by flow conditioners located within 10 diameters of the orifice plate.

7. Instrumentation

Much care must also be taken when selecting, connecting and reading the measurement instruments associated with an orifice meter. The flowing temperature, static pressure and differential pressure must be recorded correctly for optimum results.

The need to install a temperature probe in a temperature well is, in itself, cause for a potential measurement error. The effects of stem conduction, probe self-heating and even direct sunshine on the meter run or on instrumentation can all have effects on accuracy. For example, a temperature error of only two degrees at a nominal temperature of 60 degrees Fahrenheit will produce an error of almost 0.2%. Temperature wells are sometimes filled with a suitable heat transfer fluid to aid in temperature conductivity especially when the temperature probe fits loosely in the temperature well.

An often overlooked source of potential error is the effect of the barometric pressure on static pressure measurement. Quite often the static pressure (psig) measurement is in gauge pressure and a nominal barometric pressure is added to the static gauge pressure for calculations. Since a barometric pressure swing of 0.1 PSIA is not uncommon, significant errors could occur in low pressure systems if accurate barometric pressures are not used. For example, if an assumed barometric pressure of 14.6 PSIA is used for a 30 PSIG system and the actual barometric pressure is 14.5, the error in the static pressure would amount to 0.22% which would translate to volume error of approximately 0.11%.

Probably the most critical measurement taken for an orifice meter is the differential pressure. As with the static pressure most of the instruments used for the differential pressure measurement are rated as a percent of full scale value. Therefore, if we use an instrument that is rated 0.25% at full scale and is operated at 10% of full scale, the accuracy is 2.5% of the reading. The "stacking" of differential transmitters can significantly improve the accuracy of the measurements.

It must be kept in mind that instrument lines are also part of the measurement system. The build-up of liquids in the instrument tap lines or the plugging of tap holes can have very significant effects. Instrument lines should also be of similar volume otherwise it distorts the true signal, particularly when there is a nonstable flow.

Summary

AGA-3 precisely defines the minimum standards for upstream and downstream sections of the orifice meter run as to length, internal surface finish, the location of the pressure taps, and flow conditioners. It also specifies orifice plate tolerances. Since orifice meter calculations are based on carefully controlled experiments performed while following specifications outlined in this standard it must be faithfully adhered to if reliable results are expected.

A well defined quality assurance procedure for orifice meters must be developed and followed. Particular care must be given to the installation of the orifice meter and the selection and calibration of the appropriate instrumentation. Reliable measurements can not be expected from an orifice meter built and installed to specification while using instrumentation that is out of its range or out of calibration.

As can be seen, given all the variables involved, quality measurement using an orifice meter requires great care and can, in some instances, be difficult to attain. Sometime there are going to be system situations that are just unavoidable. Often, to obtain the true (or "more correct") answer requires that an independent means of measurement be used. This can be accomplished either through a calibration performed on-site through the installation of a reference meter or by having the system calibrated in a recognized flow facility.

References

1. ANSI/API 2530, (AGA Report No. 3, GPA 8185-85) "Orifice metering of Natural Gas and Other Related Hydrocarbon Fluids", Second Edition, 1985.

2. A.S.M.E. Research Committee on Fluid Meters, "Fluid Meters, Their Theory and Application", Sixth Edition, ASME, New York, 1971.

3. Teyssandier, R.G. "Effects of Abnormal Conditions on Accuracy of Orifice Measurement", 1985 Proceedings, International School of Hydrocarbon Measurement.

4. McConaghy, B. J. Bell, D. G., Studzinshi, W. "How Orifice-plate Condition Affects Measurement Accuracy", Pipe Line Industry, December 1989.

5. McManus, S.E., Brennon, J. A., Sindt, C. G., "Effects of Abnormal Conditions on Accuracy of Orifice Measurement", 1987 Proceedings, International School of Hydrocarbon Measurement.

6. Stark, S.T.; Williams Natural Gas Company, private discussions.

7. Caldwell, Steve; Colorado Engineering Experiment Station, Inc., private discussions.