# EFFECTS OF ABNORMAL CONDITIONS ON THE ACCURACY OF ORIFICE MEASUREMENT

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The orifice meter is one of the most widely utilized measurement devices and is one of the oldest, next to the bucket. The orifice meter is one of the most basic devices ever invented for measurement and has many advantages because of its simplicity and also has many associated problems as a result of its simplicity.

The basic make up of an orifice measurement assembly calls for a plate with a hole of *certain* dimensions, mounted in a *certain* configuration inside a flow tube with *certain* characteristics. Pressure measurements are taken at *certain* locations, and the flowing media is of a *certain* flow pattern entering a *certain* length of pipe. When adding the necessary pressure sensing devices for the determination of line pressure and differential pressure and a probe for sensing the temperature and a sample of the flowing fluid to determine exactly what is flowing as far as composition of the fluid, it is *certain* of having a measurement. What is not *certain* is the accuracy or reliability of that measurement unless the *certain* recommendations, determined by the many organizations establishing guidelines for orifice measurement have been followed. Those organizations are the American Gas Association (AGA), the American Petroleum Institute (API), and the American National Standard Institute (ANSI). The documents developed by these organizations provide all the *certainties* and if the requirements contained in ANSI/API 2530 and AGA 3 are followed, then the reliability of measurement will be somewhat assured.

Conditions that fall outside the recommended guidelines contained in the standards will result in errors in that measurement. Only good inspection methods by thoroughly trained people will determine if the installation is, in fact, within "code" and capable of quality measurement.

Abnormal conditions which will effect the accuracy of the measurement, can be one or any combination of the following:

A. Weld protrusions, gaps or excessive roughness in the inlet section of the meter tube,
B. Pressure taps out of tolerance,
C. Plate out of alignment with the centerline,
D. Orifice plate thickness, edge, finish or flatness not in code,
E. Flowing fluid conditions,
G. Flow profile problems,
H. Instrumentation deficiencies,

The first four conditions, listed above as abnormal conditions, are many times the result of using hardware that does not meet code requirements. Thorough inspection of the hardware will determine if the pressure taps are set at the proper distance, which is one inch from the center the tap hole to the face of the plate. The hole should be free of burrs, the internal surface should be finished to within 300 micro/inches for the number of diameters required. The bore of the tube should be round and within the required tolerances.

These abnormal conditions, indicated above, should never be encountered in the field. An inspection for abnormal conditions should be completed before the assembly is ever installed. The same can be said of the actual orifice plate. If the inspection of the plate shows any rounding of the edge, nicks or roughness on the face, the plate should not be used.

Conditions will be found in the "real world" that often affect the hardware which brings about "abnormal conditions. There should be concern with these abnormal conditions, as there is often no control over them. Manufacturing and inspection of the hardware can be controlled, but the "real world" has effects on the performance of orifice measurement.

The flowing of fluid in a measurement system will eventually cause conditions which will result in measurement error. The build-up of scale in the inlet section will cause a deviation from the recommended surface finish and will result in an inaccurate reading. This effect is more pronounced in higher beta ratio systems. The pitting that results from erosion is of a lesser effect than the scale build-up. Build-up of scale around the pressure taps will lead to errors as well.

The same build-up on the face of the orifice plate will also cause significant errors. Usually this build-up is heavy oil or grease. The requirement for proper measurement, as far as the plate is concerned, is a sharp edge, centered in the pipe with a smooth surface. When build-up occurs, this condition is lost and the measurement will be effected. Many suggestions have been made as to the total error caused by build-up, but due to the variables, it is very difficult to assign a percentage to any of these conditions.

The effects that abnormal conditions of the hardware, of any orifice measurement system, have on the accuracy of the measurement, can be determined in some quantitative manner and has been attempted at a number of labs and under some field conditions. The best that can be said of those tests is that the measurement is affected. For example, tests performed on bent plates show errors from 2% to 20%. This also holds true for the errors found in rounded edges and nicks in plates. The range of potential error is often very significant but very often difficult to determine.

Many times the errors that occur are due to the flow conditions, which are either pulsations, swirl, or high liquid content. The existence of pulsations can be determined and if it is found to be present, it can be assured the measurement will be in error. The same is true for swirl. It has been determined through tests that swirl can cause as much as 15% error in measurement. The removal of the swirl can cause additional errors if the straightening vanes become partially plugged as this will result in a change in flow profile. If a high liquid content is present, a two phase flow measurement is required. This cannot be accomplished with the orifice system alone.

In general, tight control over the hardware purchase, frequent hardware inspection, monitoring the gas quality and checking for the possibility of pulsation will provide some degree of confidence in the flow measurement.

One of the main sources of error in any orifice installation is in the instrumentation. The differential pressure measurement is, at best, difficult to make with absolute accuracy. Most instruments used for this measurement are rated a percent of full scale value. Therefore, if an instrument is used that is rated 0.25% of full scale and is operating at 10% full scale, the accuracy is 2.5%. Stacking transmitters will greatly improve the measurement accuracy. Shifts in the zero and span caused by high line pressures will affect the accuracy. The environmental temperature also greatly affects operational performance.

The build-up of liquid in the signal lines will distort the pressure signal from the orifice fitting and cause errors that can range from negative flow indications to full flow at "no" flow. The mismatching of volumes in the sensing lines will also affect the measurement, especially if there is pulsations or rapid changes.

Static pressure measurement is also affected by environmental temperature conditions just as the differential pressure measurement is. The assuming of barometric pressure is a common practice in gas measurement. This assumption can lead to errors of as much as 0.25%, given the normal change present in atmospheric pressure on low pressure systems.

The use of temperature wells in piping systems can also lead to measurement error. Consideration should be given to insure the probe is out of the direct sunshine and a conducting fluid is used to assure heat transfer.

As is evident from the preceding discussion, good quality measurement is often difficult to attain and requires quality hardware, diligent installation practices and quality calibration procedures, if reliable results are expected. Many times, however, this alone is not enough. The actual installation may be affected by other situations in the system such as compressors, control valves or other equipment. Often, to obtain the true answer requires that an independent means of measurement be used. This is either in the form of a calibration performed on the system through the installation of a reference meter or by having the system calibrated by a flow measurement facility. Field proving of liquid meters is more common place than field proving of gas meters but, in either case, a reference meter is usually installed in the system and the flow diverted through the reference meter for comparison to the working meter. The choice of reference meters is dependent upon the system conditions, gas composition, flow rate, available pressure and available pressure drop.

A calibrated flow system consisting of an orifice or turbine flowmeter could be installed as a *reference meter* but, its performance must be well known. This may be achieved by performing a calibration simulating the operating conditions, including proper Reynolds number range and equivalent density performance as in the case of a turbine transfer calibration. The most reliable method of calibration is to use a critical flow venturi as a transfer standard. This device has been used extensively as a transfer standard for the development of the basic orifice factors.

The use of the critical flow venturi has a number of limitations such as requiring pressure drops of 5 to 15 percent of the inlet pressure, streams with a low hydrocarbon and water dew point and the requirement of having a detailed gas analysis of the stream.

Orifice flowmeters are usually calibrated because of user concerns over the results. Calibrations may be necessary when orifice installations are not to code specifications (higher or lower beta requirements, short inlets or scale build-up). Occasionally, calibrations will be performed on a specific installation in which an orifice plate was installed backward. The calibration data is used to determine the actual flow to recalculate billing for a given period.

The methods of calibrating an orifice system, are very basic when the critical flow venturi is used as a *reference meter*. The orifice system (meter runs, plate and the inlet conditioning and, if possible, the associated instruments) is installed in series with a venturi. Laboratory quality instruments are also installed to obtain the best possible results. Test results are then calculated by the basic hydraulic equation and then compared to the value of the standards.

The comparing of the theoretical discharge coefficient to the actual discharge coefficient is an excellent method of determining the effects of abnormal conditions on the performance of a meter. Comparisons of laboratory quality instruments to the user's instruments via the calculations of flow from both systems can separate the probable cause of a discrepancy, i.e. (instrumentation or installation)

Laboratory instruments are now available which allow orifice research to reach a much higher degree of confidence than the field measurement can be expected to attain. For example, diameter measurements of 0.0002" on the bore of the meter tube and half of that for the orifice bore differential pressures to 0.01% of reading, static pressures to 0.01% of reading, temperatures to 0.1 degrees and the performing of calibrations on air which reduce the uncertainty in gas properties. Primary mass air flow measurements to 0.1% are obtainable. Because of these accuracies, the value of laboratory calibration, have become very valuable in the accuracy testing of flow computers and orifice measurement systems.

In conclusion, the "real world" offers many different challenges for accurate reliable measurement. Many of the items discussed are the normal conditions found in the field, which in other places would be considered abnormal. The fact is, with diligent inspections and adherence to established codes and the use of quality hardware, accurate and reliable measurement can be obtained in spite of all the potential problems.

References:

(1) ANSI/API 2530 "Orifice Metering of Natural Gas"
(2) Non published test data CEESI
(3) "The Effects of Recesses and Protrusions On the Discharge Coefficient of A Flange Tapped Orifice Plate" Zedan, M.F., Teysandier, R.G. Daniel Industries.
(4) "Sonic Nozzles" Britton, C.L.
(5) "Fluid Meters, Their Theory and Application" ASME 6th Edition