NEW DIFFERENTIAL PRODUCING METERS – IDEAS, IMPLEMENTATION, AND ISSUES

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Abstract: There are several relatively new differential producing meters that are available for end users. Each meter claims to have advantages over other meter types, specifically orifice meters. Meter types discussed include; cone meters, Venturi meters, multi-ported averaging pitot tubes, multi-holed orifice plates, and diagnostic differential meters. This paper is intended to be used by purchasers of these meters to help them obtain the best meter for their application. The operating principles of these meters will be explored. This paper will look at the claims that the manufacturers of these meters make in terms of accuracy, required upstream lengths, and diagnostic capabilities. Another important aspect of these meters is industry's reaction to these meters. Should these meters be included in standards documentation? What data needs to be collected to properly develop standards, and what standards exist to help develop these meters? Additionally, the implementation of these meters and metering systems is discussed with the intent of developing system uncertainties. From a calibration facility perspective, many issues have been observed with differential metering systems. Several of these issues will be discussed in detail along with their associated implications.

Keywords: Differential Pressure Producing Meter, New Meter Technology, Meter Accuracy, Meter Calibration

1. Introduction

Differential Pressure Producing (DP) meters have been used to measure the flow of natural gas for over 100 years. Currently there are more orifice meters in use than all other metering technologies combined. The popularity and simplicity of these meters has led to manufacturers developing new types of differential meters to compete with the "classic" differential meters; orifice, Venturi, and subsonic nozzles. In order to sell these new meters, they must present some improvement over the existing metering technology. These improvements may come in any one or in any combination of the following areas: cost, installation requirements, accuracy, permanent pressure loss, reliability, and/or maintenance requirements.

Any user of a DP metering system must have a solid understanding of the fundamentals of that metering system. It is extremely important to note that a DP metering system does not just consist of the primary element. Other components of that metering system can have just as large of impact of the measurement system.

Determining the accuracy of a meter is an important component of selecting the proper meter for use. Calibration of meters is the initial step to determining the accuracy of a metering system. Issues seen during the calibration of these meters will be discussed. This paper looks into how the overall accuracy of a system is affected by each of the components of the system.

Users of these meters are faced with the difficult task of determining the proper metering system for the application. This paper is designed to help the user determine what properties of a DP meter are important in their application. This paper also offers advice on pitfalls that DP meter users could fall into if not careful.

Finally, this paper will look at creating standards for DP meters. Standards exist for the “classic” DP meter types, but steps need to be taken if the industry is interested in developing standards for other DP meter types.

2. Differential Pressure Producing Metering System Principles of Operation and Components

Any differential pressure producing meter operates on the same principle, the conservation of energy. In flowing fluids, the flowing energy is contained by two variables, the pressure of the fluid, and the velocity at which the fluid moves. If the assumption is made that no energy is lost, a relationship between the pressure of the fluid and the velocity at which the fluid is moving can be derived. With the end goal of determining the velocity of the fluid in mind, if the changing pressure of the flowing fluid can be measured, the velocity of the fluid, and therefore the flowrate of the fluid can be determined. There are two main methods for controlling the velocity of the fluid.

1. Reduce the flowing area to increase the velocity of the fluid.
2. Bring the fluid to a stop.

These two methods of altering the flow present two different DP metering systems. A majority of the DP meters fall into the first category, but in some applications bringing some of the fluid to a stop provides an effective measurement technique. Examples of reducing the area to increase the velocity include:

Orifice Meters (Concentric, eccentric, multi holed, etc.)
Venturi Meters
Cone Meters

For these meter types, the fluid is accelerated by the reduced area, therefore causing the pressure of the fluid to drop. Pressure is measured upstream of the reduction and downstream either in the reduced area, or further downstream. As the fluid returns to the full flow area of the pipe, the velocity decreases again, and the pressure increases. Due to losses, the pressure will never return to the value seen before the reduction.

In all DP meters, the Bernoulli equation relates the change in pressure to the velocity of the fluid. In developing the equation, there are two main assumptions that are made to make the equation much simpler. The first assumption is that there is no friction in the flow. This assumption implies that no energy will be lost as the velocity of the fluid changes. The second assumption is that the density of the fluid does not change as the fluid changes velocity. The effects of these assumptions will be explained in further detail. The two different styles of DP meters require two different versions of the Bernoulli equation. For meters that reduce the flow area to increase the flowing velocity, the equation is expressed as follows.

$$q_{pps} = 0.09970190 \frac{CYd^2}{\sqrt{1-\beta^4}} \sqrt{h_w \rho_{f1}} \qquad (1)$$

Where:
q_{pps} = mass flowrate (pounds per second)
C = discharge coefficient (dimensionless)
Y = expansion factor (dimensionless)
d = diameter of smallest area (in)
β = diameter ratio (dimensionless)
h_w = differential pressure measured across the meter (inches of water at 68º F)
ρ_{f1} = density of the fluid at the upstream plane of the meter (pounds mass per cubic foot)

There are several terms that require further explanation.

Discharge Coefficient (C)

The discharge coefficient is the correction for the assumption that was made that no frictional forces act on the fluid. For all DP meters, this assumption is not correct. There will always be frictional forces acting on the fluid. Some DP meters have more frictional forces than others. Meters with higher frictional forces result in more permanent pressure drop for that meter type. Orifice meters have the lowest discharge coefficient because they have the highest frictional losses. The discharge coefficient may be determined from empirical data, or from actual calibration data. Discharge coefficient has been shown to be a function of a dimensionless parameter called Reynolds number. This is discussed further in section 4. The discharge coefficient is mostly a function of the geometry of the meter and pressure tap locations. Typical discharge coefficients for DP meters are:

Orifice meters: 0.60
Venturi meters: 0.99
Cone meters: 0.88

Expansion Factor (Y)

The expansion factor is the correction for the assumption that was made that the density of the fluid did not change when the velocity of the fluid changed. This assumption will be correct for fluids that are incompressible, but for compressible flow, this assumption needs to be corrected for. The expansion factor can be theoretically determined assuming adiabatic expansion of the fluid. The most accurate method to determine the expansion factor is to test for it. By holding a constant flowrate, and varying the pressure, the expansion factor can be determined. The expansion factor is largely a function of the ratio of differential pressure to the static pressure, but is also a function of the diameter ratio (β) and the isentropic exponent of the fluid. In low pressure applications, the expansion factor can induce up to a 30% change in the reported flowrate. If the expansion factor is not accounted for, the flow will over register.

Diameter Ratio (β)

The diameter ratio is different for different meter types. For devices such as orifice plates, Venturi, and nozzles, the diameter ratio is simply the diameter of the smallest area divided by the diameter of the largest area.

$$\beta = \frac{d}{D} \tag{2}$$

For other meter types such as cones and multi-hole orifice plates, the diameter ratio is more complicated. The general form for the equation is:

$$\beta = \frac{d_{eff}}{D} \tag{3}$$

Where:
d_{eff} = the effective diameter of the flowing area

Examples of determining the effective diameter for cone meters and multi-hole orifice plates are shown in section 3.

Examples of meters that bring a portion of the flow to a stop are:

Pitot Tubes
Multi-ported Averaging Pitot Tubes

These meters bring a portion of the flow to a stop. By decelerating the flow, the pressure is increased. This increased pressure is called the stagnation pressure as all of the energy from the velocity of the flow has been converted into pressure. This stagnation pressure can be used with the inlet static pressure to calculate the flow.

$$Q_m = N * K * Y * F_a * D^2 \sqrt{\rho_f} * \sqrt{h_w} \tag{4}$$

Where:

Qm = Mass Flow Rate
N = Units Conversion Factor
K = Meter Flow Coefficient
Y = Meter Gas Expansion Factor
Fa = Thermal Expansion Factor
D = Internal Pipe Diameter
ρf = Flowing Density
hw = Differential Pressure (typically "H2O)

Equation 4 is almost identical to equation 3. The biggest difference is the use of K instead of C as the flow coefficient. For these meter types, the idea is identical, but the equations appear slightly different.

A DP metering system consists of three types of components:

1. Primary Element
2. Secondary Elements
3. Tertiary Elements

These components are all equally important in accurately calculating flow through a DP meter. If any of these components are not what the other components are expecting, the flow will not be accurately recorded.

The primary element is the geometry of the meter that causes the fluid to accelerate or decelerate. It is important to note that the primary element consists of any geometry that can affect the relationship between flowrate and differential pressure. The following items are all part of the primary element:

Flow restriction (orifice, cone, wedge, etc.)
Tap hole location and geometry
Upstream pipe
Downstream pipe
Flow Conditioner
Pipe and restriction surfaces

If the user does not want to calibrate their meter, it is important to understand how each of these parameters influences the flow measurement, and determine limits on these parameters.

The secondary element consists of any devices used to read the outputs of the meter. In DP metering systems, the following devices typically qualify for secondary instrumentation:

Pressure Transducer
Differential Pressure Transducer
Temperature Transducer
Gas Chromatograph

These elements measure the outputs of the primary components, and transfer the values to the tertiary component. The tertiary component is the flow computer. The raw values are placed into the flow computer, and the flow computer calculates the flow using the equations shown above.

Each component will contribute to the overall uncertainty of a DP metering system. A user could purchase the highest quality transmitters, but have a primary element that is not calibrated, and render the high quality secondary instrumentation worthless. This is explored further in section 4.

3. Various types of Differential Pressure Producing Meters

Orifice Plates

Figure 1. Orifice Plates and Runs

Orifice plates are the most studied type of DP meter that has been produced. Several standards exist for the use of orifice plates, specifically ISO 5167 and AGA Report Number 3. These documents list the limits in which an orifice plate can be used for the custody transfer measurement of natural gas. The standards organizations have collected thousands of data points to determine the discharge coefficient and expansion factor for certain types of orifice plates so these plates do not have to be flow calibrated. This empirical equation required millions of dollars in testing and reporting. There are several orifice meters that do not fall within the standards. Manufacturers of new meters such as the multi-hole orifice (Figure 1, upper right), do not have the time or resources to develop such an equation for the meters. To determine the discharge coefficient and expansion factor for such a device, the device should be calibrated over the Reynolds number range that it will be used in the field. This is discussed further in section 5. To calculate the diameter ratio for a multi-hole orifice plate, first the total flow area must be calculated. In the case of an orifice with three identically sized holes, the total area would be:

$$A_{eff} = \frac{3 \cdot \pi \cdot d^2}{4} \qquad (5)$$

Where:
A_{eff} = The total area of all three holes
d = diameter of each hole

Now the effective diameter can be calculated:

$$d_{eff} = \sqrt{\frac{4 \cdot A_{eff}}{\pi}} \qquad (6)$$

Now equation 3 can be used to determine the diameter ratio.

Care should be taken when using these meters to ensure that there is proper alignment between the holes and the tap location. If that alignment changes, testing has shown that the performance of the meter will be impacted. This type of orifice plate generally uses an offset from the equation given in a standard. This offset is determined from a water calibration, and an informed consumer will ask for evidence that the calibration is valid over an entire Reynolds number range. According to the manufacturer's, the benefit to these types of meters is that they don't need a full calibration, and that they require fewer upstream lengths than a standard orifice. Again, an educated consumer will ask for the data to show this is the case, and a good manufacturer will have performed this testing. Testing of this type is explained further in section 6.

Venturi Meters

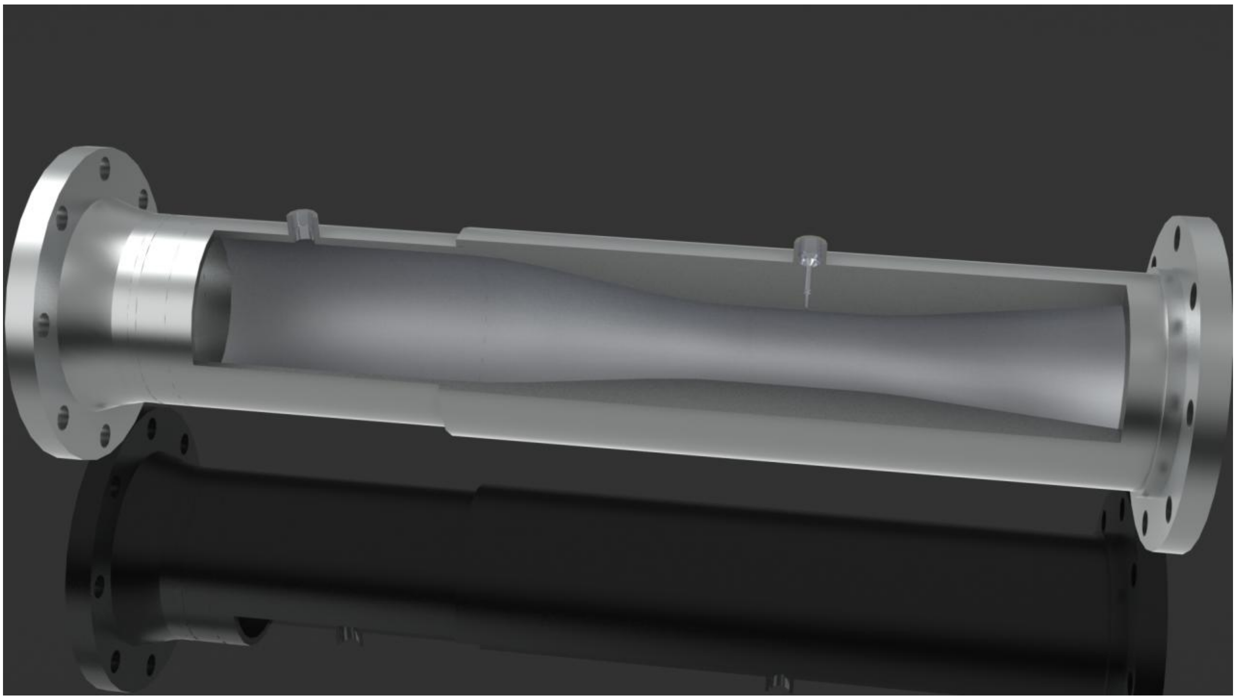

Figure 2. Venturi Meter

Like the orifice meter, the Venturi meter has had a significant amount of data taken, and a standard developed. For this reason, a properly manufactured Venturi meter does not need to be calibrated. To achieve increased uncertainty of an orifice or Venturi meter, a calibration can always be performed. The advantage of a Venturi meter over an orifice meter is that the Venturi meter will have less permanent pressure loss. These converging and diverging sections provide less loss for the fluid as it passes through the obstruction.

Cone Meters

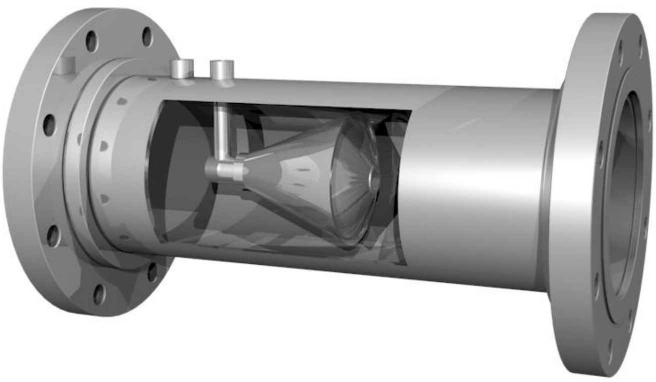

Figure 3. Cone Meter (Courtesy of McCrometer Inc.)

Cone meters, as seen above in Figure 3, force the flow to an annular area along the edge of the pipe as opposed to the orifice or the Venturi. Manufacturers of this type of meter claim that this action conditions the flow, therefore allowing the meter to be used with further upstream lengths than an orifice plate. In fact, Colorado Engineering Experiment Station Inc. (CEESI) has performed testing to API MPMS 22.2 for several manufacturers of cone meters, and in all cases, fewer upstream lengths are needed than is stated in the standards for orifice plates. Cone meters also have a lower permanent pressure loss than orifice plates.

Determining the diameter ratio for a cone meter is slightly different. To determine the annular flowing area between the pipe wall and the cone edge, the following equation can be used:

$$A_{eff} = \frac{\pi D^2}{4} - \frac{\pi d_c^2}{4} \qquad (7)$$

Where:
d_c = Cone diameter

With the effective area known, equations 6 and 3 can be used to determine the diameter ratio. If the equations are combined, the following simple equation can be used:

$$\beta = \frac{\sqrt{D^2 - d_c^2}}{D} \qquad (8)$$

As with all DP meters, the calibration data for a cone meter should cover the Reynolds Number range that the meter will see in the application.

Pitot Tubes and Multi-Ported Averaging Pitot Tubes

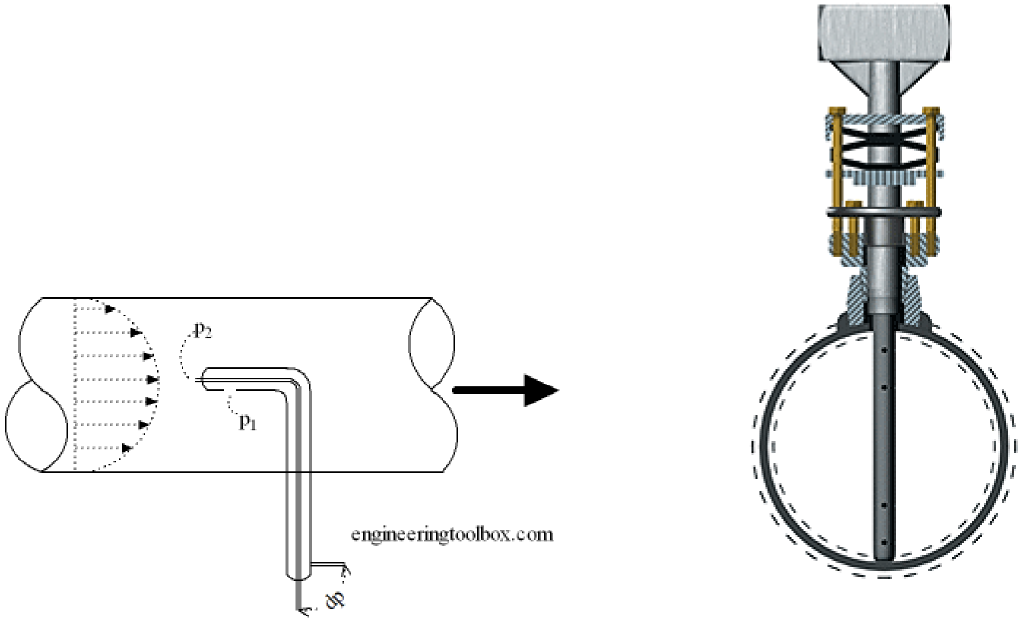

Figure 4. Pitot Tube and Multi-Ported Averaging Pitot Tube (Courtesy of Veris Inc.)

Pitot tubes are very effective for measuring the velocity at a single point. As can be seen in Figure 4 above, the flow in a pipe is not the same throughout the pipe, so the distance that the Pitot tube is inserted into the pipe will affect the velocity measured by the Pitot tube. On solution to this is to measure the stagnation pressure at several points across the diameter of the pipe, and average those values together. This is the idea behind the multi-ported averaging Pitot tube. By looking at the average stagnation pressure across the pipe, this meter will be less sensitive to installation effects. How well the meter handles installation effects must be determined experimentally. There are some variations to this meter type that by accelerating the flow, increase the measured differential pressure. This higher differential pressure can be measured more accurately by most differential transducers. When discussing the turndown of a DP meter, all meters will be limited by two things:

1. The turndown of the applicable calibration data, and
2. The ability of the differential transducer to measure low dPs

If the transducer can accurately measure down to 0.1" H_20, and the meter has been calibrated that low, any DP meter can accurately measure the flow.

Torus Wedge Meter

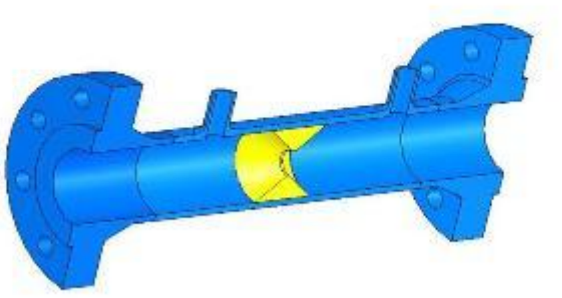

Figure 5. Torus Wedge Meter (Courtesy of Densipro Measurement Services, LLC)

The torus wedge meter is one of the newest meters on the market. The meter is designed to fit in existing orifice flange unions to replace an orifice meter or as a stand alone flanged meter. According to the manufacturer, the benefits of the meter include; increased turndown, lower overall pressure loss (similar to a Venturi), and increased wear capabilities. CEESI is working with the manufacturer in developing this technology. Testing is taking place to determine expansion factor and installation effect influences through API 22.2 testing protocols. Just like any other DP meter, if properly calibrated, this meter will provide high accuracy flow measurement.

Diagnostic Meters

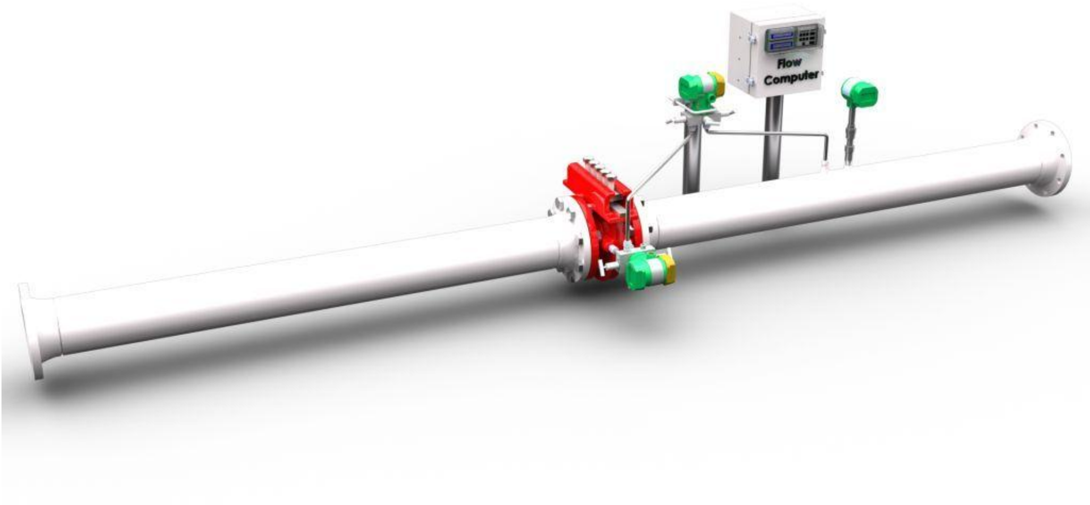

Figure 6. Diagnostic Differential Pressure Measurement System (Courtesy of dP Diagnostics)

One of the biggest advantages of ultrasonic meters is the ability of the meters to perform diagnostic functions. Path lengths can be compared to determine if there is a skewed velocity profile. Changes such as a transducer going out can be detected by looking at the relationships of the paths. Until recently, differential meters were not capable of performing diagnostics. Now, any type of differential meter discussed is capable of supplying diagnostics. By analyzing not only the relationship between the standard taps on a meter, but the relationship between the total pressure loss, a differential producing meter is capable of letting the user know if something is wrong with the meter. Not only is the meter capable of telling the user something is wrong, the meter is capable of telling the user generally where the problem is located. Problems with the differential transmitter drive the relationships in one direction. Problems with the primary element drive the relationships in another direction.

When looking at the diagnostics of a DP meter, it is extremely important to establish good baseline relationships between the differential pressures. While the diagnostics of a DP meter may not state exactly what the problem is, they provide a reliable and necessary first step in locating and solving the problem.

4. Determining the Accuracy of Differential Pressure Producing Meters

When looking at the accuracy of a DP meter, it is important to evaluate the accuracy of the entire system, not just the accuracy of the primary element. If the primary element has been calibrated to 0.25%, which may not be useful if the user is implementing secondary devices that are only measuring to 1%. In general, each component of measurement will have an uncertainty and sensitivity associated with it. This paper will look in depth at the uncertainty associated the discharge coefficient for several meters.

For an orifice plate, the uncertainty is a function of diameter ratio and Reynolds Number. The equations for calculating the uncertainty in discharge coefficient are given in the applicable standard. For meter types that don't have standards, it may be difficult to determine the uncertainty in the discharge coefficient. There are several aspects that need to be looked at.

First, what is the uncertainty of the stated discharge coefficient? If the meter was individually flow calibrated, the uncertainty of the calibration facility contributes to the uncertainty in discharge coefficient. Typically, a calibration facility will give an uncertainty in mass flowrate, not in the calculated discharge coefficient. The example of API 22.2 testing in section 6 shows where additional uncertainty may come from. If the meter is using a constant discharge coefficient, the overall accuracy of the meter will not be as high as if the calibration data had been fit in some manner. How well the calibration data is fit contributes to the uncertainty. The manufacturer and the calibration facility can help the user in determining the uncertainty in discharge coefficient for a DP meter. If the meter was not flow calibrated, the manufacturer should have supporting data that states an uncertainty of using their meter. In general, flow calibrated meters will have lower uncertainty that uncalibrated meters.

Secondly, the uncertainties associated with the secondary instrumentation and fluid properties must be considered. It is acceptable in most custody transfer applications to use the stated uncertainties from the manufacturers for secondary instrumentation. There is currently an effort to develop testing protocols for secondary devices that will allow users to consistently prepare uncertainty evaluations of their systems. Fluid properties also have an uncertainty associated with them. If the fluid properties are obtained from an industry standard, that standard should list the uncertainties associated with the values. If the fluid properties are assumed or come from another source, it may be much more difficult to determine the uncertainties associated with those values.

In the following example, the uncertainties of an orifice metering system are combined and evaluated. Note how each component affects the overall uncertainty. This is a simplified example with several assumptions made. Note how the uncertainty may be different depending on whether you are calculating the uncertainty in flowrate or the uncertainty in energy delivered.

Component	**Units**	**Nominal Value**	**Standard Uncertainty (U_x)%**	**Sensitivity Coefficient (S_x)**	**(U_x*S_x)^2**
Unit Conversion Factor	NA	Constant	0.0000	0.00	0.000
Discharge Coefficient	Dimensionless	0.59925	0.5215	1.00	0.272
Expansion Factor	Dimensionless	0.99977	0.0029	1.00	0.000
Bore Diameter	Inches	1.3	0.2500	2.04	0.260
Pipe Diameter	Inches	4.026	2.5000	0.04	0.010
Base Compressibility	Dimensionless	0.9979	0.0000	1.00	0.000
Base Temperature	°Fahrenheit	60	0.0000	1.00	0.000
Flowing Pressure	psia	500	0.5000	0.50	0.063
Universal Gas Constant	ft-lbf/lbmol-°R	1545	0.0000	0.50	0.000
Differential Pressure	"H_2O	10	0.7500	0.50	0.141
Molecular Weight	lbm/lbmol	16.799	1.2500	0.50	0.391
Flowing Compressibility	Dimensionless	0.9332	0.5000	0.50	0.063
Flowing Temperature	°Fahrenheit	70	0.3775	0.50	0.036
Base Pressure	psia	14.73	0.0000	1.00	0.000
Installation Effect Factor	Dimensionless	1	3.0000	1.00	9.000
Energy Content	BTU/ft^3	1025	1.2500	1.00	1.563
Carbon Content	lbm/ft^3	0.037	1.0000	1.00	1.000

The total uncertainty is determined by summing the individual combined uncertainties (Ux*Sx)2, and taking the square root of that sum. Because this example looks at two different uncertainties (volume, and energy) the calculation is done two different ways.

To calculate the volume uncertainty all components are included with the exception of energy content. To calculate the energy uncertainty all components are included. The values below show the calculated flowrates and the associated uncertainties in percent:

Volume Flowrate	795,664	SCFD	Volume Uncertainty	3.199
Energy Flowrate	815,555,600	BTU per Day	Energy Uncertainty	3.435

5. Selecting the Proper Differential Pressure Producing Meter for Your Application

Due to the wide variety of applications for DP measurement systems, this paper can not possibly suggest the correct meter for every application. Instead, presented here is a list of parameters for the user to consider when purchasing a DP meter.

- Accuracy of measurement – Is it necessary to have a device calibrated down to 0.25% accuracy for your application? If so, make sure you get all of the calibration records from not only the manufacturer of the primary element, but also for your secondary and tertiary measurement devices.
- Flowrate range – It is imperative to match the flowrate range of the meter to the application. Most DP meters come in a variety of line sizes, so most will be able to cover the range of the application. Properly sizing the meter to not over range transducers is extremely important. If a transducer gets over ranged, fluid will be flowing through the meter unregistered.
- Permanent pressure loss – Different DP meters have differing levels of permanent pressure loss. Manufacturers will supply this data to the users. If the user can handle more permanent pressure loss, they may opt for a cheaper meter. If the user can not handle more permanent pressure loss, they must chose a meter with converging and diverging sections to keep the pressure loss low.
- Installation effects – All DP meters will work with long straight upstream lengths in front of the meter. If that is not an option for an application, manufacturers should have information on how their meter handles installation effects. If there is a specific application, inform the manufacturer that you would like the meter calibrated in the arrangement in which it will be used. Calibration facilities often perform this type of testing.
- Secondary instrumentation – If thee application has limited accuracy in the secondary instrumentation, there is no need to purchase a highly accurate primary element.
- Durability – Some applications flow viscous or corrosive fluids. It is important in these applications to choose a meter that will stand up to the wear and tear.
- Maintenance – In general, DP meters require very little maintenance, but it is important to keep in mind that when a metering system is put together, it will periodically have to be disassembled for inspection and reassembled.
- Cost – One of the most important aspects of any purchasing decision is the cost of the meter.

6. Differential Producing Meters and Standards

As previously mentioned, standards have been developed for orifice meters, Venturi meters, and nozzles. The oil and gas industry invested significant resources to develop these meters because these were the meters being used. New meter types may certainly have advantages over these “classic” DP meters, but to get industry to accept the meters, a standard had to be developed.

If a manufacturer would like the industry to develop a standard for their meter, several requirements have to be met.

1. Standardization of meter design – this is a significant problem when trying to develop a standard for a meter type. For example, the cone meter has several manufacturers. Each manufacturer has a little bit different design, and therefore no standard can be created for that meter type.
2. Collection of data – data needs to be taken so as a database similar to the orifice database can be developed. Collection of this data could take significant time, and cost money that a manufacturer can not afford. The manufacturer typically needs to get the meters sold so they can start making money before they can properly test the design.

Given these constraints on new meter manufacturers, the prospects of developing a standard are slim. The industry wanted to do something to help facilitate the development of new meters, so they developed a testing protocol. This protocol (API MPMS 22.2 “Testing Protocol for Differential Pressure Flow Measurement Devices”) gives the manufacturers a method to test the meters to determine meter performance without undertaking the massive testing of developing a standard. The protocol also gives users a guide for comparing meters from different manufacturers.

<u>Example of Testing Performed to the Standard</u>
The following example provides an illustration as to how typical testing performed under API MPMS 22.2 is evaluated.
As per the standard, a baseline test is performed. Figure 7 below represents possible baseline results. Results are characterized in a plot of discharge coefficient versus Reynolds number.

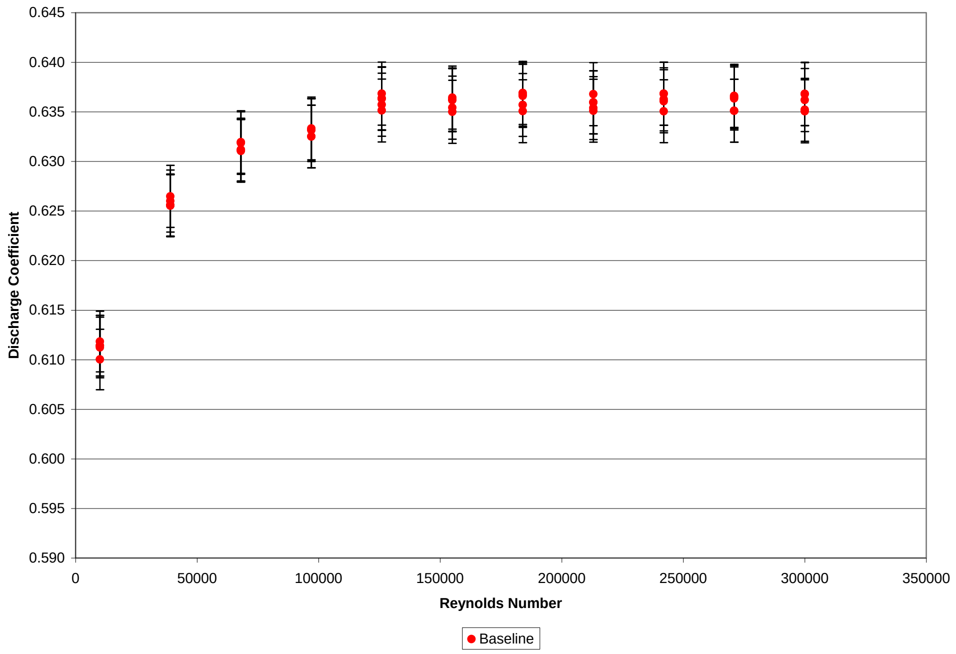

Figure 7. Baseline test results

The bands around the data represent the uncertainty in the facilities ability to determine the discharge coefficient. These values are an important component of the uncertainty that is associated with the use of the meter being tested.

The manufacturer of the meter may want to determine if the meter is affected by an installation effect upstream of the meter, so they perform they same test with a half-moon orifice plate upstream of the meter. Initially they may try to perform the test with a half-moon orifice plate four diameters upstream of the meter. Figure 8 shows the result of the installation effect test along with the baseline test results.

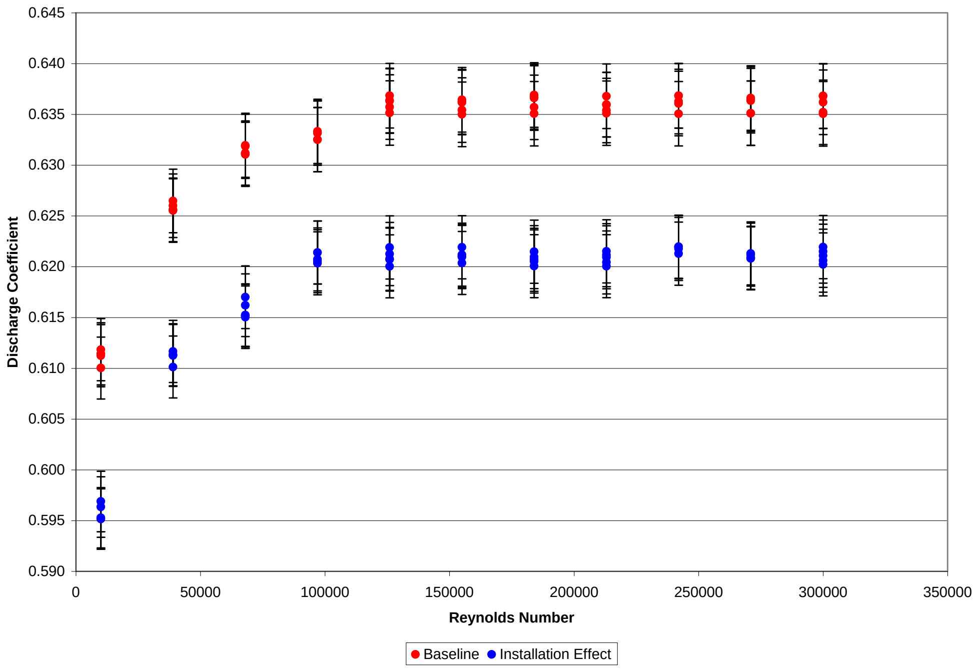

Figure 8. Installation Effect Results (Half-moon Orifice at 4 Diameters Upstream)

In this situation, the installation caused the discharge coefficient to shift down approximately 2.5%. This implies that if the meter were to be used in the field with a disturbance four diameters upstream and a discharge coefficient based on the baseline testing, the meter would over-register flow by as much as 2.5%. If that was an acceptable bias, then the testing for that upstream installation would be done. However, if a higher degree of accuracy is needed, the testing may be repeated with the half-moon orifice plate further upstream. Figure 9 represents the data from a test where the half-moon orifice plate was moved to 8 diameters upstream of the meter.

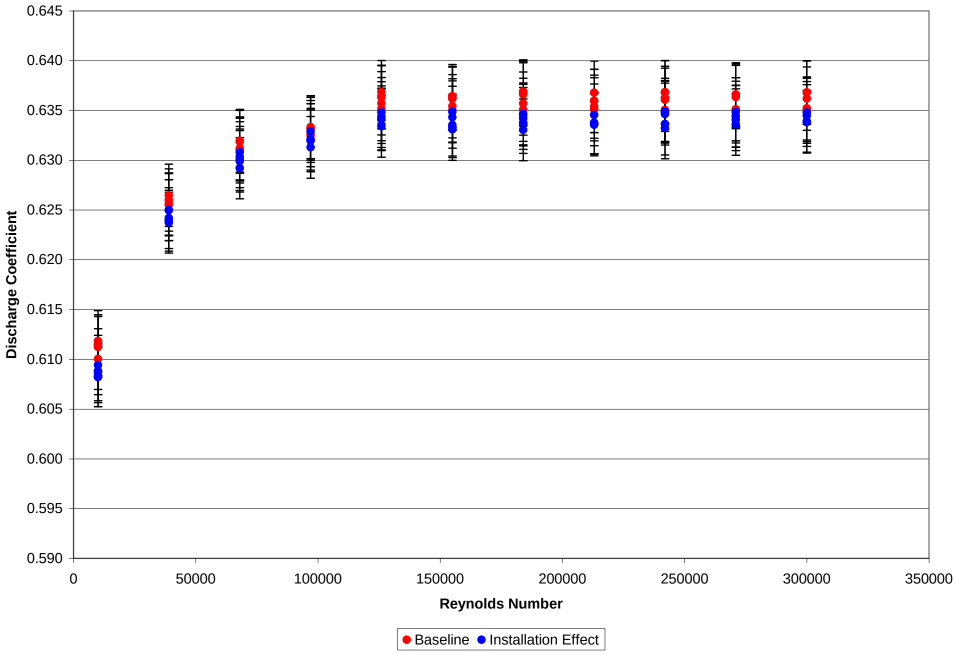

Figure 9. Installation Effect Results (Half-moon Orifice at 8 Diameters Upstream)

With the half-moon orifice located eight diameters upstream of the meter, the effect on the meter performance is much less. There still seems to be a slight bias that would cause the meter to over-register, but that bias is within the uncertainty of the facility performing the testing. Under this standard, the meter shows no additional uncertainty with an upstream disturbance at eight diameters. The testing must be repeated with a downstream installation effect, a combination of the upstream and the downstream, two elbows out of plane upstream, a swirl generator, and any special installations.

Using API MPMS 22.2

API MPMS 22.2 provides the user of differential producing with a mechanism to compare the performance of different types of meters. Care should be taken when analyzing the results of the testing. Meters can be used in many ways. The standard tests the meters ability to mitigate installation effects. Users of meters must be wary of several issues that could arise when using differential meters.

Firstly, if the manufacturer does not want to flow calibrate every meter, they must perform testing to determine the affect of all of the parameters that have a known effect. If this testing is not done, and properly analyzed to determine proper tolerances, each meter must be individually flow calibrated.

Another issue that must be addressed is the flow calibration of each meter. It is a well known fact that the discharge coefficient of differential producing meters is a function of Reynolds number. If the meter is not calibrated over the Reynolds number range that it is being used, significant errors may be incurred.

A final issue that the user must be aware of is how the discharge coefficient is determined. Figure 10 shows two methods for determining discharge coefficient from calibration data. Curve fitting the data can be very effective. It is important however to pick the proper curve fit. If a curve fit is used, an iteration process must be calculated to determine the flowrate. Alternatively, a constant Reynolds number can be used. In the example in Figure 10, the error associated with the curve fit of the data could be as much as 0.5%. If the constant discharge coefficient is used, an error of up 4% may be seen. The amount of error that may be seen depends on how much the discharge coefficient varies over the range. If the variance over the range is very small, a constant discharge coefficient is effective. Another alternative is to use a theoretical determined discharge coefficient. The problem with this method is that unless the theoretical value has been developed and verified with data, it can be almost impossible to determine the uncertainty associated with the discharge coefficient.

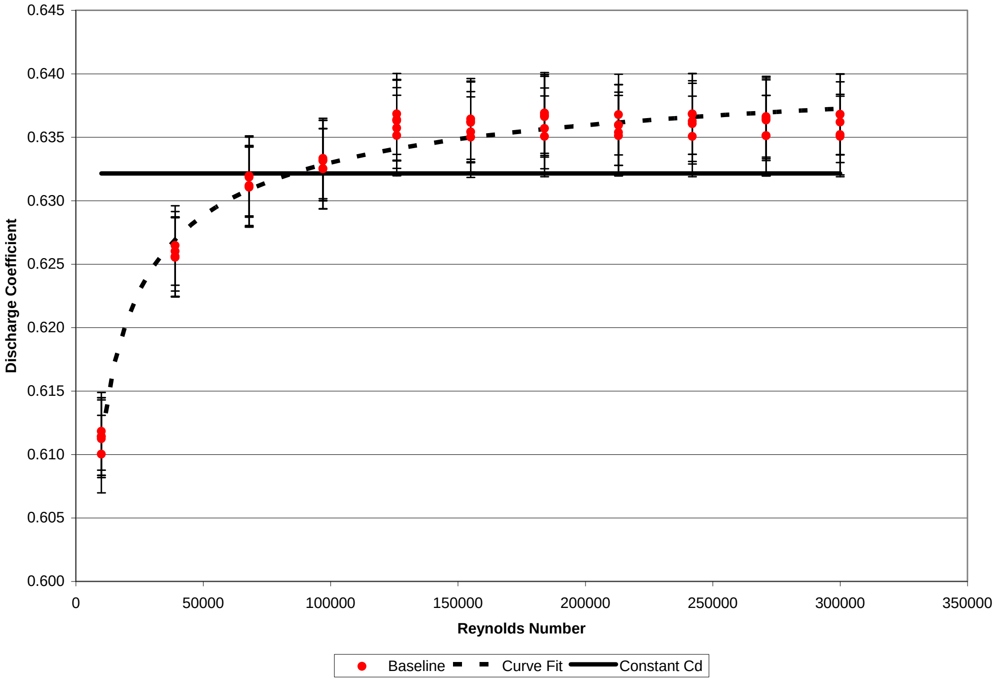

Figure 10. Discharge Coefficient Determination

7. Conclusions

New technologies can make it difficult for a user to determine what the best meter for their application is. The best thing a user can do is to educate themselves on the basics of the meters and understand the needs of the application.

Differential meters operate on the conservation of energy. The Bernoulli equation allows the flowrate through the meter to be determined by measuring the differential pressure caused by the primary element. The meter parameters are measured by secondary instruments, and then tertiary devices calculate the flowrate. Each of these components contributes to the overall uncertainty of the system, and therefore must be accounted for when determining the accuracy of the system.

Each meter type will have advantages and disadvantages when compared to the other types. To properly analyze which meter is best for the application, the user should look at the following parameters:

- Accuracy of measurement
- Flowrate range
- Permanent pressure loss
- Installation

- Secondary instrumentation
- Durability
- Maintenance
- Cost

API 22.2 provides a mechanism for ushering new technology to the users. It is imperative that users of meters tested to API 22.2 understand how the testing protocol is performed and how to properly interpret the reports.

New Differential Pressure Producing meters can provide exciting advantages over existing technology. As the importance of measurement continues to increase, the ability to properly measure flowrates becomes more important. Through proper development, calibration and use, new DP metering technology can provide the accurate measurement the world needs.

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