FUNDAMENTALS OF MULTI-PORT AVERAGING PITOT TUBES IN NATURAL GAS MEASUREMENT

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INTRODUCTION

The availability and cost effectiveness of natural gas make it a major source of energy. Its distribution and transportation involves many aspects of moving natural gas from producing locations to storage locations and then to end-users. Often, a system will also include hundreds of compressor stations, which move gas through the pipelines and maintain pressure in storage fields. Delivery of gas, when and where needed, requires extensive knowledge of flow rates throughout the system. Reliability of these measurements dictates decisions to redirect flows, increase or decrease storage and add or reduce the number of compressors running.

The traditional measurement of natural gas has been the orifice plate; however, the averaging pitot tube (APT) has proven an economical preference in many applications. APTs are used at many locations along the pipeline for check metering, balancing and line packing. At storage fields, the APT helps determine flow rates, leakage rates and migration rates. Within the vicinity of the compressor station, APTs are invaluable in maintaining the efficiency of turbines and maximizing equipment uptimes.

The APTs non-restrictive, low profile design, reduces the permanent pressure loss across the device which greatly reduces operating costs. The simple insertion–type procedure makes installation less costly.

Economic factors encouraged the need for better performing APTs, with greater reliability and accuracy. These factors led to the emergence of the "multi-port averaging pitot tube." As with the orifice plate and other head-type primaries, this refined version of the basic pitot tube is based on Bernoulli's Theorem. The multi-port APT provides an extension and enhancement of proven concepts that offers many benefits. The multi-port APT is a simple design with equal or better performance than traditional DP devices for fluid flow measurement and process control applications.

BASIC OPERATING PRINCIPAL

The multi-port APT is a head-type device that calculates the flow rate from the measured differential pressure (DP). This modernized pitot tube produces a DP signal proportional to the square of the flow rate in accordance with Bernoulli's Theorem. This signal has two components, the upstream impact pressure (high pressure) and the downstream static pressure (low pressure). The sensor averages the flow profile and produces an accurate DP signal, illustrated in Figure 1.

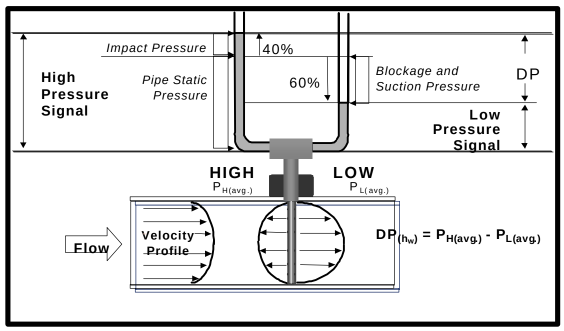

FIGURE 1 – OPERATING PRINCIPAL OF MULTI-PORT AVERAGING PITOT TUBE

The high pressure is produced by impact or stagnation of the moving fluid on the sensor. The velocity profile results in a corresponding stagnation pressure profile. The multi-port APT senses the impact pressure profile through a series of ports located on the front of the sensor that completely spans the inner diameter of the pipe. Inside the high pressure chamber, the average velocity pressure is maintained by the proportionality of the sensing port diameters to the cross-sectional area of the plenum. The resultant is a high pressure signal that is the sum of the static pressure and impact pressure.

As the fluid continues around the sensor, it generates a vortex shedding pattern and creates a low pressure profile. The low pressure is used as a pressure reference so that the velocity of the fluid can be determined independently of pipe static pressure. The low pressure is sensed by ports, located downstream and opposite the high pressure ports. Working on the same principal as the high pressure side, an average low pressure is maintained in the low pressure plenum, assuring less dependence on the magnitude of flow or Reynolds Number.

The difference between the high and low pressure signal is about twice the impact to static differential pressure. This higher DP is a benefit over the true pitot, which only measures impact and static pressure and often produces a DP that is too low to be useful.

FLOW CALCULATION

The family of primary flow measurement devices referred to as "head" or "differential pressure" type consists of units such as the orifice, venturi, pitot tube, flow nozzle, elbow meter and multi-port APT. Each of these head type devices operates in accordance with Bernoulli's Theorem for fluid flow and the continuity equation. Bernoulli's Theorem is a means of expressing the application of The Law of Conservation of Energy to the flow of fluid in a pipe. Bernoulli's equation states that the total energy at any location in the pipe is equal to the sum of the static energy (pressure head), the kinetic energy (velocity head), and the potential energy (elevation head). In steady incompressible flow, without friction, the sum of the velocity head, pressure head and elevation head is constant along any streamline. Assuming the elevation difference between two measuring points is negligible, Bernoulli's Theorem is written as:

$$\frac{V_1}{2g} + \frac{P_1}{\rho} = \frac{V_2}{2g} + \frac{P_2}{\rho}$$

where *V* is the velocity in feet per second, *g* is the gravitational constant is feet per square second, *P* is the pressure in pound per square foot, and *r* is the density expressed in pounds per cubic foot.

Since Bernoulli's Theorem states that flow is steady, the continuity equation must apply. The continuity equation states that the mass rate of flow between two points must be constant. This equation is written as:

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

Through application of an energy balance around the sensor and the continuity equation, the hydraulic equation for incompressible flow below applies. This equation is:

$$Q = KA\,(2gh)^{1/2}$$

where *Q* is the actual volumetric flow rate, *K* is the flow coefficient, *A* is the flow area, *g* is the gravitational constant, and *h* is the differential pressure expressed as elevation of flowing fluid.

The most common unit of volumetric measurement in the United States is the cubic foot. In the above equation, the volumetric flow, Q, is calculated in ft^3/sec, which is in actual units. For gases, the cubic foot is still the unit of measurement, but a cubic foot of gas has no absolute or comparative value unless the pressure and temperature of the gas are specified. Gas measurement tells us that the amount of matter within one cubic foot space, at a pressure of 1000 psia, is greater than the amount of matter within that space if the pressure is atmospheric. Energy is the amount of heat that can be generated by that cubic foot of gas, and the amount of energy is directly proportional to the number of molecules within the cubic foot spaces. Since the natural gas industry is selling energy, pressure and temperature must be specified.

Since it is the amount of matter (mass) that is required to be measured as the gas flow along the pipeline, the actual volumetric flowrate terms do not lend themselves to this task easily. Because of the inability to compare the mass of a gas in actual volumetric terms, the standard volumetric term was developed. The most common unit of gaseous flowrate measurement is of a gas that would be contained in a one cubic foot enclosure if the pressure was 14.73 psia and the temperature was 60°F.

The approximate conversion from actual volumetric flow rate to standard volumetric flow rate is accomplished by the Boyles-Charles law. This law forms the equation:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

This only considers ideal gases, where real gases deviate from the Boyles-Charles law. The amount of deviation depends upon pressure, temperature and composition of the gas. The deviation is known as the compressibility factor of the gas. The equation for standard volumetric flow rate, which is calculated from actual volumetric flow rate where pressure and temperature are known, is:

$$Qs = \frac{P_2}{14.73} \times \frac{(460 + 60)}{T_2} \times Q_2$$

For most flow conditions, the conversion to standard volumetric flowrate using only the Boyles-Charles relationship will be accurate within a few percent. To be correct, as needed in the natural gas industry, the Boyles-Charles relationship must be modified as follows:

$$\frac{P_1V_1}{Z_1T_1} = \frac{P_2V_2}{Z_2T_2}$$

where Z is the compressibility factor at each pressure and temperature condition. This modification lead to the flowing equation:

$$Qs = \frac{P_2}{14.73} \times \frac{(460 + 60)}{T_2} \times \frac{Z_b}{Z_2} \times Q_2$$

where Z_b is the compressibility factor at base or standard conditions and is generally considered to be unity, Z_b =1.000, and Z_2 is compressibility factor at P_2 and T_2.

Comparisons will prove that this equation is identical to the standard orifice equation with the same factor identification and definition in the same sequence. The standard base orifice factor (F_b) is composed of three terms: units conversion factor (F_{NA}), flow coefficient (K), and the square of the internal pipe diameter (D^2). This is shown below.

$$F_b = F_{NA} * K * D^2$$

The flow equation for the multi-port APT replaces the Fb factor with its three component parts to allow a much greater flexibility for calculations with various units.

Since the flow calculations are identical for head-type devices and many of the same factors can be obtained from common orifice calculation tables, it becomes very easy to use the multi-port APT for gas flow measurement.

DESIGN FEATURES

Like many other primary flow elements, the multi-port APT can be constructed with a number of different characteristics, but it still operates on the basic averaging pitot principal. Like the orifice plate, the multi-port APT is a simple design with no moving parts. This provides a reliable service with essentially no maintenance. The secondary instrumentation required for the APT is the same as that for orifice plates.

The physical features of the multi-port APT have a large affect on the performance of the primary, with the largest feature being the actual shape of the sensor. Round or cylindrical probe presents the largest limitation. The round sensor probe allows a variable fluid separation point from the surface of the probe. The low pressure component of the differential pressure sensor is caused by the flow separating around the sensor and the resulting boundary affect. The point at which the fluid separates from the sensor must be controlled if the performance is to be unaffected by Reynolds Number. Shaped sensors control that separation point continuously, but averaging pitots with round cross-sections are subject to a variable separation point (Figure 2). This causes a difficult to define shift in flow coefficient curve for the primary as the flow rate or Reynolds Number changes. This shift can easily amount

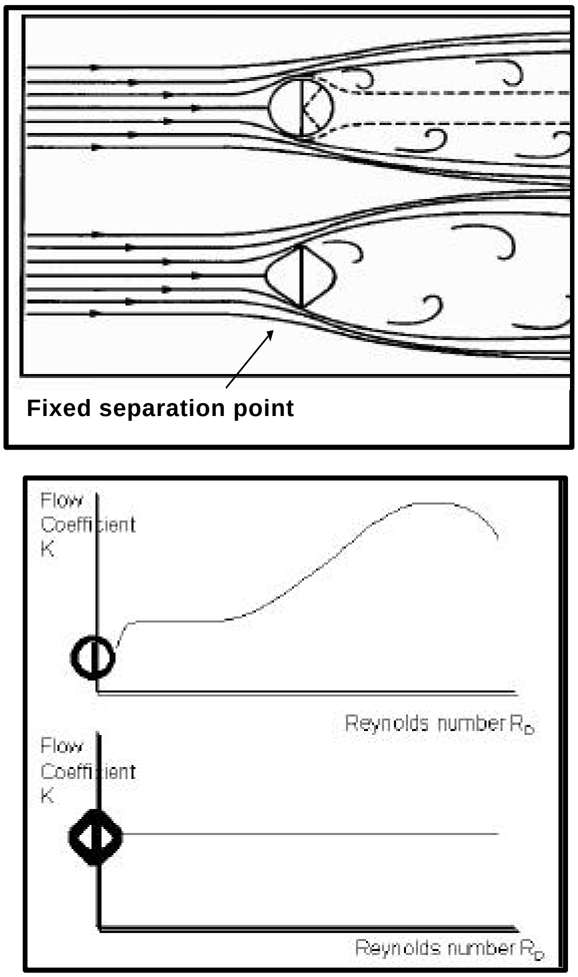

Figure 2 – Flow Around an Multi-Port Averaging Pitot Tube

to a 10 to 20 percent error in the indicated flow measurement. This separation point will vary with Reynolds Number, probe roughness and pipe turbulence. If shaped sensors are utilized the averaging pitot can be assured of a steady signal varying only with flow rate.

Studies of the multi-port APT have proved that a shaped sensing probe will provide stable accurate flow measurement. A cutting surface, corner or edge at the side of the primary sensor probe provides enhanced performance. This is similar to the function of the edge of an orifice plate. One major advantage the multi-port APT has over the orifice plate is its superior resistance to wear. These units will maintain accuracy for a longer period than the orifice plate. The 90 degree knife-like edge of the orifice plate is sensitive to wear, nicks, dirt and grease build-up, which can result in measurement errors as high a 20 percent from the actual. Frequent inspection is often necessary to maintain confidence in orifice measurement.

SENSOR DESIGN

Diamond shapes sensors have successfully been used in multi-port APTs. Theses truncated shapes provide the flow coefficient stability for dependable measurement over desired flow ranges. This stable accuracy is accomplished by forcing a fluid separation at a fixed point at the side of the sensor probe at all flow conditions. This establishes a constant flow coefficient over the entire flow range.

Elliptical and bullet shaped sensors have also been used in multi-port APT design. These sensors generate significantly less DP the diamond shape. They are also sensitive to the alignment in the flow stream due the side ports upstream of the variable separation. This can result in measurement errors up to 20%.

All averaging pitot primaries must reduce the multiple sensed pressures, to one, that represents the average flow in the pipe. This means that all ports must be equally weighted, otherwise, one port's contribution could have a larger affect on the measured average pressure. The best manner to accomplish this is to control the ratio of port size to plenum cross-sectional area. Extremely small port holes can cause problems, but to ensure equal weighting, the holes must be small relative to plenum area.

The ports need to be located in such a manner that an average of their pressure contributions represents the average fluid velocity. The ports must be of sufficient quantity to properly sense variations in the velocity profile. This requires more ports in large pipe sizes, just as more points would be sampled in a pitot traverse. A properly designed APT will have more holes in larger pipe sizes. The location and number of sensing ports applies to both upstream and downstream sides of the sensor.

The design features discussed above are necessary to produce accurate multi-port APTs. The establishment of the accuracy of the APT is dependent on the determination of the flow coefficient K. K is the term for the correction in the theoretical flow due to the influence of velocity in the pipe, the assumption of zero energy loss in derivation of flow equations, and the location of pressure taps. K is the same term as Cd, which is used orifice plate calculations. The flow coefficient of any flow measurement device is the actual flow rate divided by the theoretical flow rate. Flow coefficient must be developed in the flow laboratory where the true flow rates are known.

As most head-type devices are used in the uncalibrated state, it is important that the flow coefficients be predictable in different pipe sizes. With tradition head-type devices, the flow coefficients have been established by testing dating back over fifty years and they are confirmed by relating the coefficient to beta ratios. This combination of empirical testing and theory has resulted in the confidence that is now felt in orifice plate coefficients. Multi-port APTs have also been thoroughly tested by numerous independent flow laboratories and customers. With more than a million multi-port APTs in service, there is a high confidence factor in their accuracy is growing.

Since the sensor forms an obstruction in the pipe that changes the velocity of the flow as it passes around the sensor, research into flow coefficient for different shaped APTs is prevalent. Using this research, flow coefficients can be linked to the blockage caused in the pipe by the sensor. Blockage is defined as the area of the sensor divided by the area of the pipe.

The change in velocity due to blockage will affect the downstream pressure sensed by the APT. Therefore, a correlation between the flow coefficient and blockage is not only possible, but also necessary. Poorly engineered multi-port APTs may still determine flow coefficients for a few pipe sizes and a fit curve to the data to determine all other K-factors. This should not be deemed sufficient.

By constructing a multi-port averaging pitot tube correctly, and determining the flow coefficient rigorously, it is now possible to produce a flow primary that can accurately be applied to a variety of pipe sizes in the uncalibrated state.

FLOW MEASUREMENT ACCURACY

When considering accuracy of any head-type primary it is important to differentiate between the accuracy of the primary flow element and the overall system accuracy. The accuracy of any head-type primary is based on a number of “ifs,” some are which are:

- If there is adequate straight run piping before and after the primary.
- If there is a fully developed, uniform, repeatable, turbulent velocity profile.
- If the piping meets certain maximum internal roughness tolerance.
- If the piping meets certain maximum concentricity tolerances.
- If the alignment is within accepted tolerance for the particular primary.
- If, in the case of the orifice, the orifice plate has a sharp 90E knife edge on the bore.
- If the orifice is concentric.
- If the orifice plate is flat (not bowed or dished).
- If there are no foreign materials or debris on the orifice plate.
- If the orifice surface finish meets specifications.
- If the fluid is a single phase and not a two-phase fluid.

Each head-type primary device, based on its particular design, would demonstrate its particular flow characteristics when establishing its flow coefficient K. Using data from the flow lab, the K values can be established, and the error tolerance based on one and two standard deviations can be established for a given head-type primary device. The error tolerance for typical head-type devices such as the orifice or the multi-port averaging pitot is ±1% of value.

FLOW TURNDOWN RELATED TO ACCURACY

The term "flow turndown" is simply the maximum flow divided by the minimum flow. This term, used in conjunction with pipe Reynolds Number for a given application and primary, also relates to flow accuracy for the application. It is important to consider that the measurement accuracy can exceed the stated tolerance when using too great a flow turndown at some point a new K value must be selected for the application.

A thorough understanding of the real meaning of the error tolerance for the secondary is necessary. The accuracy of most secondaries or DP transmitters is referred to as percent of full scale (or full span), not percent of value. A percent of value accuracy is the error at a specific value, but in secondaries it typically implies that the device has a consistent error statement over the entire operating range. This simply means that the error experienced at any flow rate is compared only to the meter full scale or full span value. In terms of error tolerance, this produces the smallest magnitude of numbers and, when referring to errors, small numbers are what people like to hear.

A percent of full scale accuracy relates the error of the device when it is measuring a quantity that represents 100% of the output signal. The real numbers emerge when you convert the stated percent of full scale over the equivalent percent of value numbers. This produces a plot that shows that the best accuracy occurs at the full scale point and the true error increases for flow rates less than full scale. For instance, a typical DP transmitter with 0.1% of full scale allowable error tolerance can produce less than 2% error in flow at about 25% of full scale flow rate. This equates to about 4 to 1 flow turndown. Transmitters with better accuracy statements can produce smaller true errors in flow, but will have the same pattern.

Most measurement people, once they establish these possible error values, determine that they do not want a measurement system to produce errors of greater than 2%. Therefore, the industry derived the statement that the head-type primary measurement device has a flow turndown range of approximately 4 to 1. Thus, the acceptable accuracy range of the DP transmitter become the limiting factor for the measurement application even though the primary has a stable flow coefficient over a wider flow turndown range. The APT can easily produce 10:1 flow turndown with 1% actual value accuracy.

There are several methods by which this flow range can be extended without an increase in the possible flow errors stated above. One technique is referred to as stacking transmitter ranges and uses the most accurate portion of the range of each transmitter. Another metering method for wide range flow measurement is automatically increasing or decreasing the number of parallel metering assemblies, thus increasing the total flow of the system while maintaining a proper flow range for each metering assembly. In addition, there is now a new technology that wet calibrates a primary and Smart secondary, which incorporates a special linearization curve. This allows a 10:1 flow turndown with 0.5% actual value accuracy.

ENERGY SAVINGS

The importance of the cost of energy, especially in natural gas application, has become a large economic factor. The measurement of flow, just like all other processes, does consume some amount of energy. The amount depends on the flow measurement primary used.

The assumption that the energy consumed by the primary is considered negligible is no longer true. Comparison of the permanent pressure loss for a multi-port APTs to a widely used primary such as the orifice will usually show savings of thousands of dollars per year. This can be achieved for each flow measurement point. This is especially true for the natural gas industry where cost savings in compression costs can lead to thousands of dollars per year. Figure 3 shows the relative DP values and associated permanent pressure loss for an orifice plate and multi-port averaging pitot for the same flow measurement application.

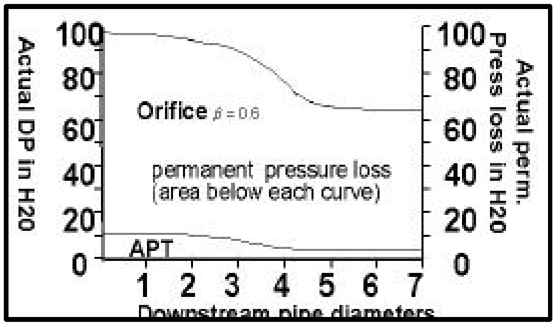

Figure 3 – Comparison of Permanent Pressure Loss

The resultant lower permanent pressure loss can be converted directly to dollars per year operating cost savings or energy savings.

Using the following energy cost savings equations, an operating cost can be identified for each type primary under consideration. The energy cost savings that can be achieved by the multi-port APT is then apparent in real numbers that are meaningful to the user.

$$HP = \frac{(SCFH)(PPL)(T_F + 460)}{(P_F)(10.78X10^6)}$$

$$\$ / yr = (HP)(0.746)(hrs / yr)(\$ / KWH)$$

where *HP* is pump or compressor horsepower required to restore the pressure loss for the primary, *PPL* is permanent pressure loss for the primary expressed in inches of water column, T_F is flowing temperature of the gas in Fahrenheit, P_F is flowing pressure of the gas in pounds per square inch, *$/yr*. is hours per year of unit operation, and *$/kWh* is dollars per kilowatt hour.

A complete Energy Savings Planner and worksheet of these type of flow measurement calculations with detailed instructions for natural gas is available upon request from the author.

When the quantity of flow measurement points throughout a process plant, pipeline, or distribution system are considered, then the dollar savings can become very large. A pressure loss savings at the flow measurement primary could also lead to related equipment sizing reductions and attendant cost savings. An energy cost savings of this nature can move to the bottom line of the accounting books and, thus, becomes an added company profit.

INSTALLATION

The multi-port APT is very simple to install since it is inserted through a small connection on the pipe wall. The size of the mounting connection on the pipe wall for the sensor probe is typically ½", 1", or 2". These connections can be any of the standard construction types commonly used such as threaded, flanged, compression fitting, or welded, depending on application specifications. Multi-port APTs with hot-tap capabilities can be inserted and retracted under line pressure without interruption of the flow. This allows minimal down time and allows pigging.

Since the mounting connection size for the primary is relatively small when compared with the pipe size, it can dramatically affect the job economics. The primary is simply inserted across the full pipe diameter through the small opening of the mounting connection.

Fluid flow measurement, as accomplished by any flow measurement device, is a precision art requiring precision of manufacturing, installation, operation, and maintenance. The multi-port APT requires the same degree of precision. The resultant will be long term reliable and accurate flow measurement. The multi-port APT is designed for the sensing ports to be at a specific location in the pipe in order to provide a proper and correct flow signal. When installed incorrectly, errors in the flow measurement can occur. This is true for all flow measurement primaries relative to their basic operating principle.

Therefore, good flow measurement results for any flow measurement device require close attention to and care for proper installation of the primary done in accordance with the manufacturer's recommendations. This point cannot be over emphasized because many good flow measurement devices or designs have been neglected by poor or improper installation of the primary in the field.

INSTRUMENTATION FOR MULTI-PORT AVERAGING PITOT TUBES

Since the multi-port APT is a head-type primary that generates a DP signal in the same fashion as the orifice, flow nozzle, and venturi, the same secondary instrumentation is fully applicable. The DP signals from the multi-port APT are generally in the range of approximately 5 inches water column to about 50 inched water column, where the typical orifice DP might be 100 inches water column or higher. Improved DP technology has allowed transmitters to measure in lower ranges. Thus, the choice of the DP transmitter is simply a matter of choosing the proper range. DP transmitters with appropriate ranges are available from many different manufacturers in the industry.

The other readout and calculating instrumentation such as static pressure and temperature transmitters, field level flow computers, local indicators, recorders, central computer systems, and supervisory gear are the same for the multi-port APT as for any other head-type primary.

The multi-port APT can be used for flow measurement only or as the primary measurement source for a flow control loop with operating performance equal to any other flow measurement device.

The application of the multi-port APT and related instrumentation for gas flow measurement custody transfer is often considered. A gas custody transfer application usually specifies that the flow measurement must be in accordance with AGA Report #3 (ANSI/API 2530). Since AGA Report #3 addresses only the orifice, it becomes necessary for the user to broaden the scope of his gas contract to allow other primaries equivalent to the orifice to be used. It has been proven that the multi-port APT flow measurement accuracy is equal to or better than the orifice. Therefore, another advantage of the multi-port APT is the long-term accuracy stability that will result in a savings to parties in custody transfer .

It is important that the users recognize that AGA only writes Flow Measurement Manuals and does not give approvals for flow measurement devices. Therefore, AGA Report #3 is only offering an acceptable gas flow measurement technique that is not mandatory. Thus, the multi-port averaging pitot is also capable of and appropriate for gas custody transfer applications, provided the user will allow it in the gas contract. In this way, the advantages of the multi-port APT can be extended to gas custody transfer applications.

Moreover, the multi-port APT is widely used in check-meter applications. It is also used for compressor surge control, station balance, compressor throughput, and fuel gas measurement. Its hot tap installation capability, elbow mount installation, and bi-directional flow measurement capability are well suited for this purpose.

NEW DEVELOPMENTS

High Accuracy/High Turndown Flowmeter

A new product has been developed that combines the multi-port averaging pitot technology with Smart electronics. This integrated circuitry is state-of-the-art, temperature characterized, and contains multi-port linearization capabilities over a 10:1 calibrated flow turndown. The simultaneous calibration of the multi-port pitot and electronics is done in a NIST traceable lab. These points form a characterization curve that is programmed into the electronics. The result is a linearized flow meter that matches the actual flow rate to within ±0.5% of reading over a ten to one flow turndown. A 4-20mA output linear to flow and digital HART® communications are available. The electronics are built integral to the primary, eliminating the need for instrument lines and valves, making installation much easier than traditional DP devices. Figure 4 shows a comparison of an orifice accuracy versus turndown and this new, improved “ProBar™” technology.

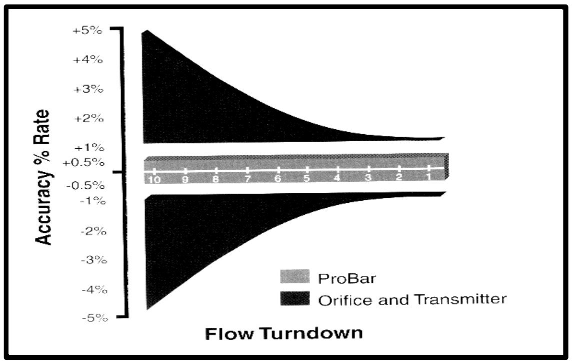

Figure 4 – Turndown of Orifice versus ProBar

<u>Pressure/Temperature Compensated Multi-Port Averaging Pitot Tube</u>

Multivariable mass flow transmitters provide cost-effective mass flow measurements for natural gas. These compact devices accurately measure differential pressure, static pressure and process temperature. Where traditional meters measure a single process variable, multivariable transmitters simultaneously measure all process variables necessary for calculating either pressure and temperature compensated gas flow. The transmitter then provides a 4-20 mA signal proportional to mass flow usable for control or metering.

Traditionally, DP flow has been calculated in a DCS or flow computer using a simplified mass flow equation. In simplified DP mass flow measurements, a constant is used to represent many of the terms in the flow calculation.

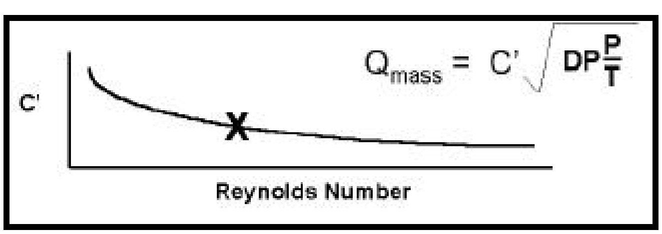

Figure 5 – Traditional DP Flow

The constant C, combines the units conversion factor, velocity of approach factor, gas expansion factor, and the discharge coefficient. In fact, only the units conversion factor is constant. The other terms are functions of the process variables. The simplified flow equation cannot compensate for changes in these terms, resulting in unrecorded errors in the calculated flow rate.

Compensating flow is the process of combining the dynamic fluid condition with the flow signal to calculate true flow. The Rosemount 3095MV transmitter uses a fully compensated equation for mass flow through any differential producer.

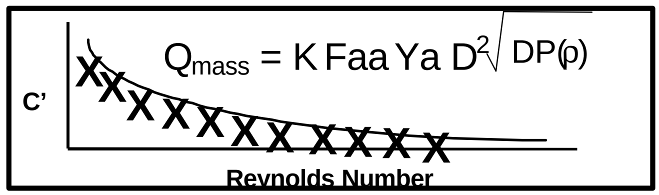

Figure 6 – Fully Compensated DP Flow

The Rosemount Model 3095MV transmitter provides the greatest DP flow accuracy over the widest operating range by dynamically compensating flow equation variables real time, including discharge coefficients, velocity of approach factor, thermal expansion effect, and density and compressibility in accordance with AGA 8. This fully compensated flow equation reduces the source of traditional DP flow uncertainty, thereby providing a more accurate flow calculation.

In addition to the new high accuracy/high turndown ProBar, another new flow meter product has been developed that can calculate mass flows for gas with just one penetration into the pipe, the Mass ProBar™.

The Mass ProBar is a highly accurate insertion flow meter that measures flow rate for natural gas. The Mass ProBar measures pressure, temperature and DP with only one tap into the process line, offering significant installed cost savings. The multivariable electronics are capable of measuring all three process variables and calculation mass flow. The dynamic compensation provides a system accuracy of ±1.3% of mass flow over an 8 to 1 flow turndown. This is better performance than traditionally compensated DP flow measurement.

A RTD is mounted into the pitot sensor, using one of the non-sensing chambers as a thermowell. Differential pressure is sensed across the diamond-shaped multi-port averaging pitot. Static pressure is sensed from the high side of the averaging pitot tube. An integrally mounted multivariable transmitter that calculates the mass flow and outputs it as a 4-20mA signal takes in all these three process variables. The individual process variables are also available via digital HART communications or the Tri-Loop splitter, which outputs all three process variables in the 4-20mA signal. This product cuts installation and hardware costs in half and provides a higher accuracy mass flow system.

CONCLUSION

Traditional flow measurement devices have their place in the natural gas industry, and will continue to offer good service into the foreseeable future. However, with over one million flow measurement application, the enhanced multi-port averaging pitot tube has proven its ability to perform and deliver stable, accurate repeatable and dependable flow measurement. Where they can be applied, insertion multi-port averaging pitot primaries can offer significant advantages over the traditionally used orifice plate. These advantages include ease of installation, hot-tapping capabilities, lower installation costs and lower permanent pressure loss.

Insertion meters offer strong economical and convenience-related benefits when compared to the orifice plate and other differential pressure producing devices. Each insertion meter type has its own advantages, but the natural features and advances in the design of the primary make it a attractive choice for measurement in the natural gas industry.

The flow measurement industry has the opportunity to improve company profits and the technology of process flow measurement and control by recognizing and utilizing the multi-port averaging pitot, ProBar, or Mass ProBar in today's flow measurement applications.

Figure 7 – Mass ProBar