INCREASED APT PERFORMANCE

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ABSTRACT

For the past 35 years, people in the process industry have relied on the averaging pitot tube for differential pressure (DP) flow measurement. This paper will identify two major advancements in the averaging pitot tube (APT) technology. Together, these improvements have reduced the noise content of the DP signal, increasing the signal to noise ratio and significantly improving the performance of the device.

An integrated reading of the flow velocity profile samples across the full diameter of the pipe and produces a more accurate representation of the average velocity. This integration technology provides a more precise reading than traditional APT technology since the measurement reflects the velocity of the flow across the entire pipe diameter and is not an average of discrete samples across the flow profile.

Creating larger stagnation zones that allow pressure ports to measure a more stable pressure efficiently reduces data variation common with traditional APT's. This results in a more repeatable and reliable measurement.

By combining stagnation zones with a more efficient method of sampling the velocity flow profile, the accuracy and repeatability of the traditional APT has been substantially improved and provides a more reliable measurement.

INTRODUCTION

Recent averaging pitot tube innovations have redefined the application range for APT's and challenge the traditional paradigms associated with using this technology to measure flow. Currently, APTs are utilized in various process industries such as oil and gas production and petrochemical applications. Typically these applications require repeatable measurements that are successfully provided by APTs. A repeatable reading indicates the same measurement taken over a period of time but does not necessarily reflect the true flow velocity.

However, historically, APTs are not installed where a highly accurate measurement is essential. Although most APT's are specified to be ± 1 accurate, they are perceived to be 3 percent devices and unable to provide an accurate measurement in these flow applications.

In addition to dispelling this accuracy misconception, improvements on the APT technology and performance are essential to the continued use of the devices in light of other competing technologies such as vortex, coriolis, and ultrasonic meters. Intense research and design efforts have been dedicated to improving the performance of the DP transmitters that are attached to most primaries. Multivariable transmitters are able to compensate for temperature and pressure changes and provide real-time measurements. Smart transmitters provide information without interrupting the control signal. However, the lack of APT improvements has limited the efforts to improve overall APT flow measurement accuracy.

According to Jesse Yoder of Flow Research, "While many advances have been made in DP transmitters, no corresponding advances have been made in primary elements. It is important not to equate the accuracy of a pressure transmitter with the accuracy of a total flow measurement system…. So even if the pressure transmitter is reading the pressure at 0.1 percent accuracy, if the accuracy of the primary element is at 2 percent, the accuracy of the flow measurement reading is no greater than 2 percent." (1)

This paper will identify two technological advancements that have increased APT accuracy. Combined, these two improvements will enable APT usage to expand into previously inaccessible applications that have been barred due to APT performance issues. Improving the primary element will also complement pressure transmitter advancement and enable higher performance for every flow measurement point.

NEW INTEGRATING MEASURING METHOD IMPROVES ACCURACY

APT Design and Operation Principles

A DP signal consists of the difference of two basic measurements- the impact (high) pressure and the reference (low) pressure. (Please refer to Figure 1). On an APT, the impact pressure is sensed on the front of the device as the flow initially approaches the bluff body. The standard pitot tubes only measured the impact pressure of the velocity flow profile at a single point on the front of the sensor. However, fluid velocity is not consistent across the pipe cross-section. As reflected in the cross section of a turbulent flow profile, the velocity is higher in the middle than on the edges due to viscosity and pipe friction effects. With these changes in the flow profile, gaging the true velocity of the fluid with a single point subjected the measurement to significant errors.

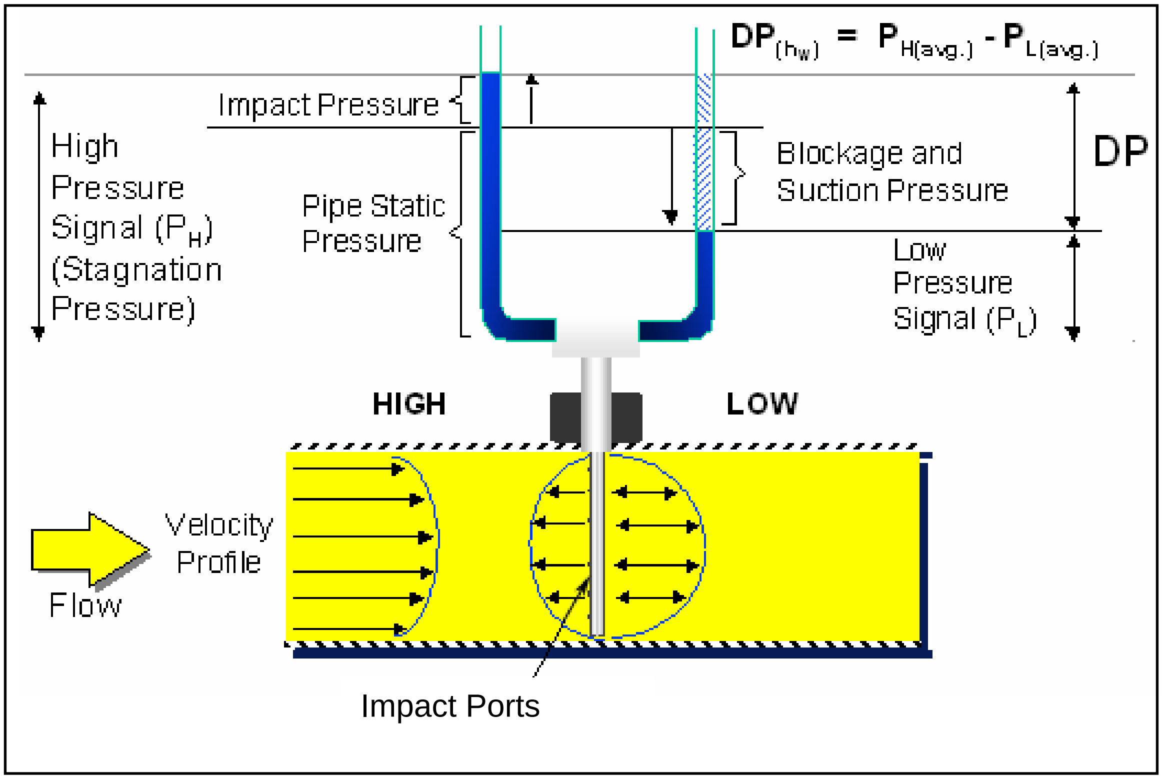


FIG. 1- DESIGN PRINCIPLES OF AN APT

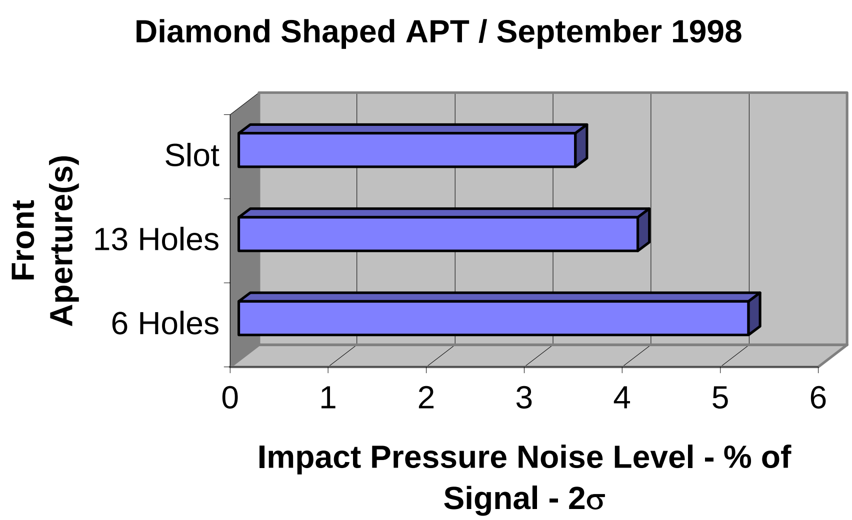
A major APT advancement was designed to take the fluctuating flow profile into consideration. Multiple sensing ports were placed, per Chebyshef's theorem, on the front of the primary to provide an average flow velocity measurement.

According to Fluid Meters (2), the Chebyshef method, "yields the smallest probable error of the mean of equally weighted observations." This multiple sensing port design was eventually incorporated onto the backside of the device as well.

Although multiple sensing ports increased the number of data points and the accuracy of the reading, the design was still unable to capture a true reflection of the inconsistencies inherent in the velocity flow profile. The multiple, individual sensing ports, although a function of pipe size, were still unable to completely measure the flow profile because they sample the flow velocity at a few discrete points.

The next major APT development was a new slot design on the front of the primary. This enables an integrated reading of the flow profile to be measured across the span of the pipe. The increased number of samples improves the accuracy and reduces noise in the reading by a minimum of 35 percent. Noise, with respect to measuring DP, is the variation between one data point and another. Inconsistency among data points yields an unstable, and therefore less accurate, measurement. By decreasing the amount of noise in the reading, a slotted design effectively improves the accuracy of the device.

TABLE 1- EFFECT OF FRONT APERTURE ON NOISE LEVEL



The pressure distribution on the backside of the sensor is not influenced as greatly by the flow velocity profile since the area is out of the direct flow region. The pressure differentiation does not vary in this region so the traditional individual sensing ports remain an effective form of measurement on the backside of the sensor. These holes are located on the device per Chebyshef's equation as described above.

INCREASED STAGNATION ZONES IMPROVE ACCURACY

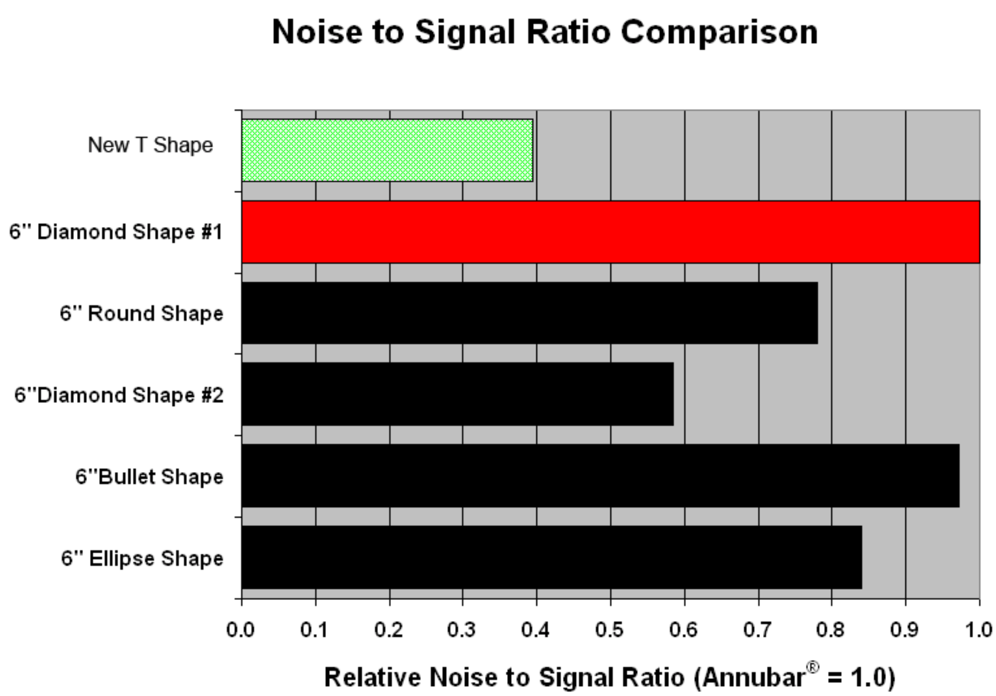
The second major variable in measuring DP is the reference pressure. This pressure is sensed on the backside of the APT sensor. Depending on the shape of the sensor, this measurement comprises up to 60 percent of the overall DP reading. To obtain consistent and repeatable measurements, APTs must generate fixed stagnation zones where this pressure can be quantified. A stagnation zone is a less turbulent area created when the flow separates at fixed points.

The reference pressure is dependent on many factors, including the shape of the bluff body that is inserted into the flow stream and the flow characteristics it creates on the downstream side. For this reason, the shape of the APT inserted into the flow stream is an important consideration.

Shape Geometry Determines Size of Stagnation Zones

Primary elements with geometries that facilitate stagnation zones are beneficial in creating signals with lower noise signals. The amount of noise generated by APTs vary with shape geometry. The size and shape of the stagnation zones and the placement of the pressure ports relative to those zones plays a major role in determining the noise content of the DP signal.

TABLE 2- PERCENTAGE OF NOISE ACCORDING TO APT SHAPE



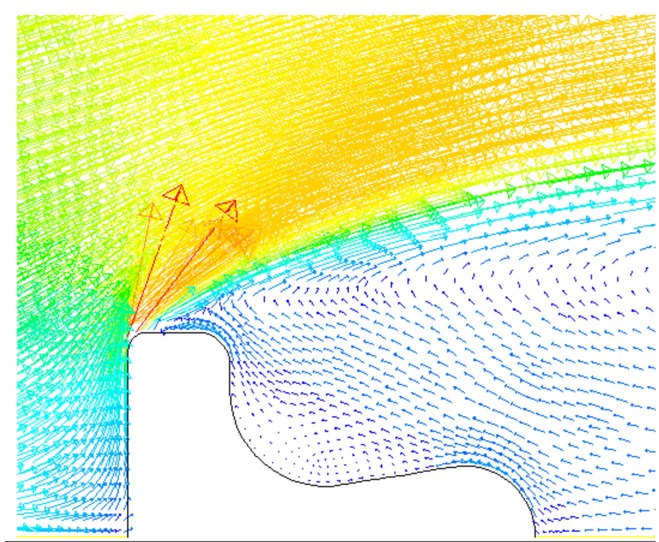
The first APT introduced was a round sensor. Round sensors do not produce extensive stagnation zones due to uncontrolled separation points. As a result, the changing velocity at the backside of the primary created an inaccurate pressure measurement. The flow coefficient required to compensate for this change expanded and degraded the accuracy of the device.

Dieterich Standard conducted extensive research on the round sensor several years ago and found that, "The inconsistency resulted in decreased accuracy, repeatability and low flow turndown… this lower performance would require limiting the device to applications in the lower or predictable operating range…" (3)

Another popular sensor shape is the diamond. This shape traditionally created the strongest signal strength of any currently available APT, but also produces the noisiest signal. In a design effort to reduce the noise content of the DP signal from the diamond-shaped APT, testing was conducted on a T-shaped sensor and revealed that this shape promotes consistent separation points and fairly large stagnation zones. As the fluid continues past either side of the sensor and creates separation points, the velocity increases. The velocity of the fluid that accumulates in the area directly behind the front of the sensor is decreased, creating a quiet, or less turbulent, zone (Please refer to Figure 2).

The predictability of flow at the separation points enables the signal output to be duplicated over an extended period of time, which minimizes noise in the reading, reducing the deviation of one data measurement to another. This creates a strong and repeatable DP signal over a wide flow range.

FIGURE 2- VELOCITY VECTOR DIAGRAM FOR T-SHAPED APT SENSOR



CONCLUSION

Measuring flow by calculating the DP is a trusted technology that has existed for centuries. It is well understood and has a large installed base. While much technological advancement has been made to improve the transmitter portion of the system, the accuracy of APTs has largely remained around 1 percent. Since primary element errors are calculated in to determine the total system accuracy, transmitter efficiency is only as good as the primary. Improving the performance of APTs is essential to creating a high performance flowmeter.

Impact and reference pressure readings that reflect the true characteristics of the flow profile are necessary for APTs to provide accurate measurements. Conducting an integrated reading across the entire pipe diameter is the best method of ensuring that the inconsistencies of the velocity flow profile are reflected in the measurement. The slot design records an infinite number of data points that allow the average calculated to reflect the velocity of the fluid as accurately as possible.

Consistent separation points create stagnation zones. A large stagnation zone located on the backside of the APT sensor decrease the velocity of flow in that area and enables the reference pressure to be measured more accurately.

Over time, continuous advancements have been made to the APT technology. Bernoulli's Theorem, the continuity equation, and hydraulic equation continue to provide the foundation and remain constant throughout these changes. Overall, the unique characteristics of each design and how they measure impact and reference pressure improve APT performance. For the most accurate measurement possible, it is essential to accurately measure the changing characteristics of the velocity flow profile and create stagnation zones.

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