Transition in Natural Gas Metering

Introductory concepts for the measurement of natural gas using the principle of pulse transit time measurement are discussed in this white paper. Diagnostics typical to multipath transit time meters using ultrasonic pulses are also described, along with multipath arrangements and transducer types. Guidance is provided for the proper application, installation and condition-based monitoring of ultrasonic meters to assure continued measurement integrity.

Over the past 20 years, gas ultrasonic meters have transitioned from the engineering lab to wide commercial usage as the primary device-of-choice to measure gas volume for fiscal accounting. Acceptance by gas pipeline companies has occurred during this time due to the several devices including Reliability, Accuracy, Repeatability, Capacity, Rangeability, Low maintenance, and adoption of industry standards for fiscal measurement applications.

Over the following decade and a half, the practical challenges of making the technology commercially viable as a flow measurement device were described and addressed through innovation and development that resulted in the production of a gas ultrasonic meter that utilises:

- Robust transducers generating repeatable pulses (amplitude and frequency)
- Multiple paths to average axial velocity components over the cross-section of a closed conduit (i.e., pipe)
- High-speed electronics complete with an accurate clock to detect, resolve and time transmission/reception of sonic pulses with sufficient time domain resolution
- Integrated transducer and electronics to permit high pulse transmission rates. Their transit time measurement allows rapid integration of fluid flow velocity so accurately measured values can be reported once per second.

Virtually all ultrasonic meters used for fiscal measurement are flow calibrated at meteorologically traceable test labs. Flow tests are conducted at multiple points over the meter's operating range to characterise its proof curve. Meter factor(s) are then calculated and applied to correct the meter's output to the lab's reference standards.

An advantage of modern ultrasonic meters is that once a meter is flow calibrated, diagnostic assessments can describe proof (i.e., meter factor shifts due to a fault in the meter's operating elements, such as transducers and/or processing electronics) so that re-calibration generally isn't required (although some regulatory authorities mandate re-certification at set intervals, these mandates vary by jurisdiction).

OPERATING PRINCIPLE

Knowledge regarding the measurement principle of ultrasonic meters lays a foundation for optimal field application as well as providing the basis for understanding whether the meter continues to accurately and reliably measure gas volume. Multi-path ultrasonic meters are typically used for gas custody transfer to calculate gas flow rate from velocity measurements made over a pipe's cross-section.

APPLICATION CONSIDERATIONS

All gas measurement technologies, including ultrasonic meters, have limitations. It is important for engineers and technicians that use any flow measurement technology to consider the limitations of the primary device proposed for use at a particular meter station prior toinstallation. Careful consideration before construction and installation can avoid costly re-work should the chosen technology prove less than optimal for the particular measuring station's operating scenario.

MAKING A DIFFERENCE

With all these performance trade-off's in mind, RMG by Honeywell selected the following to optimise its meter design.

Number and Orientation Paths

Six paths arrayed in an "X" pattern in three horizontal planes: a central plane, and two geometrically similar planes. This orientation permits measurement of swirl, cross-flow and asymmetry, as well as transparent path velocity weighting per the Gauss-Chebyshev profile model for compressible fluids.

This path design was introduced by RMG by Honeywell at the end of 1998. So this is already more than 14 years ago and there is no reason up to now to change this path arrangement because of a couple of hundred successfully installed ultrasonic meters in the field, and with this design, it is possible to detect or measure the asymmetry, swirl, and cross-flow.

There is no compensation needed because the flow profile distortion is actually measured. Measurements with crossed paths ensure an optimal analysis of the velocity components v1 to v6 even in the case of asymmetries, swirl, and cross flow. The flow rate Q results from multiplying the weighted mean flow velocity by the pipe diameter.

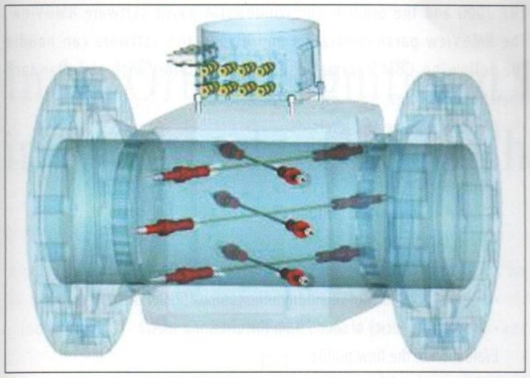

Figure 1: RMG by Honeywell path orientation

$$Q = A \cdot \bar{v} = A \cdot (w_1 v_1 + \cdots + w_6 v_6)$$

Where:
Q = Uncorrected flow (acfs or m^3/s)
A = Pipe diameter (ft or m)
w_1 = Weighting factor
v_1 = Path velocity (fps or m/s)

RMG by Honeywell has also opted to utilise a point-to-point pulse path to avoid problems with signal attenuation or warping that can occur with bounce path technology.

Pulse warping can be reduced by the use of reflectors (flats attached to the interior of the measuring section where pulses are bounced), however, reflectors compromise a full bore design and themselves generate turbulence.

Note: previous RMG by Honeywell designs have utilised bounce paths with reflectors for DN 100 (4 inch) and DN 150 (6 inch), but development of smaller transducers has allowed RMG by Honeywell to array 12 on a meter body to DN 100 (4 inch) and DN 150 (6 inch) diameters so that use of a point-to-point path construct is possible. As such, this path arrangement of six paths is now available from the smallest DN 100 (4 inch) to the largest DN 1000 (40 inch) ultrasonic meter available.

The six paths arrayed in an "X" pattern in three horizontal planes allow direct measuring of the asymmetry of the flow profile. Figure 2 shows this technique. The figure is separated into three sections:

- Section 1: Axial flow velocity
- Section 2: Tangential flow velocity
- Section 3: Total flow velocity

The velocity in general is a vector. The axial flow velocity is the main flow direction of the gas in the ultrasonic meter (Z direction). The results of the ultrasonic meter measurement are the two blue vectors. The addition of the two blue vectors in avector parallelogram results in the black vector (Vz) which is the gas velocity at that level in the direction of Z.

The same consideration is valid for the tangential flow velocity. Here, the addition the two smaller blue vectors results in the green vector, the gas velocity in the direction of X (Vx), or in other words, the asymmetry of the flow profile.

Now we have two resulting vectors: one is Vz for axial flow and another is Vx for tangential flow. By adding both vectors, we get the total flow velocity vector (the red vector in Figure 2 in the total velocity section). The angle between the total flow velocity vector and the Vz – vector is the so called swirl angle. In ideal conditions, the angle between both equals zero.

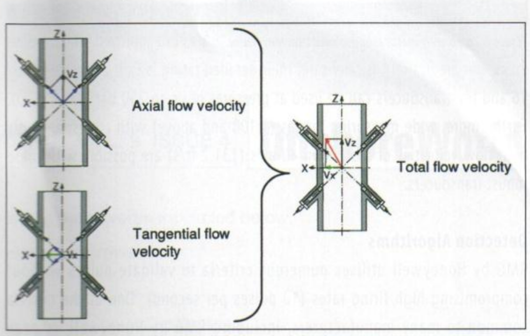

Figure 2: Vector analysis of the gas velocity in a single level

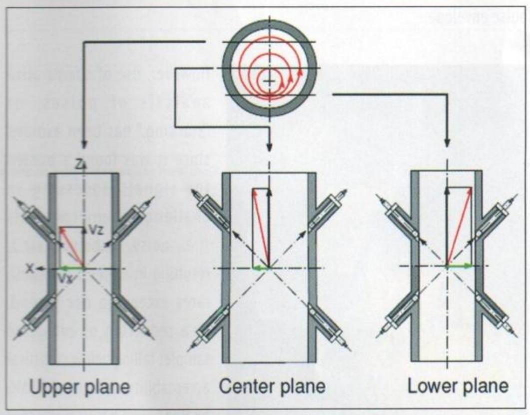

Figure 3: Vector analysis of the gas velocity in all three levels to cover the complete flow profile

The USZ 08 ultrasonic meter from RMG by Honeywell is designed with three levels of measurement (two paths on each of three horizontal planes), and the straight-forward vector analysis can be done in all three levels (upper plane, centre plane and lower plane) as indicated in Figure 3. This path arrangement makes possible the best coverage of the flow profile with a minimum number of paths. Therefore, an additional Reynolds Number correction is not required because the USZ 09 is measuring the flow profile.

Transducer Design

RMG by Honeywell has developed compact, Titanium-encapsulated, high-energy transducers in 120 and 200 kHz models, making the unit resistant to dirt. Alternate frequency designs are available to help customers cope with noisy environments.

Figure 4: Completely metal-encapsulated titanium sensor

The high amplitude capacity of the piezo-ceramic sensor permits the use of a dirt-resistant cap (which must still be thin shell Titanium to avoid attenuation) without the need to pressure balance the unit. Figure 4 shows the 120 kHz transducer used in the USZ 08. RMG by Honeywell transducers are EExd approved for hazardous areas, but are not intrinsically safe. Their detailed rating is Ex II 2G Ex de IIC T5/T6 and the transducers can be used at pressures of up to 250 bar (ANSI 1500). Furthermore, wide measuring ranges (1:100 and above) with correspondingly high flow velocities of more than 40 m/s (131.2 ft/s) are possible with these robust transducers.

Detection Algorithms

RMG by Honeywell utilises numerous criteria to validate pulses without compromising high firing rates (10 pulses per second). One of the criteria common to many manufacturers, including RMG by Honeywell, is peak identification and quantisation in regards to position and amplitude in the pulse envelope.

Figure 5: USZ 08 of RMG by Honeywell installed in a tandem arrangement in a gas metering station for an underground storage facility in Germany

However, use of comparative analysis of pulses, or "stacking," has been avoided since it was found a burden for signal processing in challenging environments (i.e., noisy, turbulent, etc.), resulting in either data refresh rates exceeding one second, or a reduction of evaluated samples falling below statistical acceptability. As a result, RMG by Honeywell has implemented additional qualitative analysis to evaluate the pulse envelope and identify ultrasonic pulses, while still maintaining high firing rates. Figure 5 shows an example of an USZ 08 ultrasonic meter installed in a gas station.

CONDITIONING BASED MONITORING (CBM)

One of the advantages of ultrasonic meters, in comparision with all other flow measurement technologies, is the availability of a lot of additional information diagnostics beyond just delivering pulses or signals proportional to the gas volume. All this additional information and diagnostics is mostly handled through separate Windows™-based software. RMG by Honeywell has two ways of using additional diagnostics; one is the flow computer ERZ 2000 and the other is the WindowsTM-based software RMGView. The RMGView parameterisation and diagnostics software can handle the following CBM parametres "live" in parallel with the standard operational features:

- Monitoring of the AGC levels
- Comparison of the Speed of Sound (SoS) of each path
- Signal quality:
  - Signal-to-noise ratio (SNR) in dB
  - Valid samples in %
- Comparison of the Speed of Sound (SoS) due to AGA 10:
  - Estimated velocity of sound from the composition of the natural gas
  - Measured velocity of sound from the ultrasonic meter
- Evaluation of the flow profile:
  - Comparison of flow profile factors
- Monitoring the swirl angle φ
- "Live" - RMG Precision Adjustment

CONCLUSION AND OUTLOOK

Today, ultrasonic meters are widely accepted for custody transfer and allocation metering because of their technical advantages over other flow metering technologies like turbine meters and vortex meters. This situation is also due, in part, to advancements in ultrasonic meter technology and establishment of the ISO standard in 2010.

Ultrasonic meters are now the overwhelming technology-of-choice for large capacity gas measurement stations because of their reliability and rangeability. Every year, more and more ultrasonic meters are sold (with greater pressure on pricing), resulting in the development of smaller size meters (< DN 100 [4 inch]) for distribution networks and downstream applications. For these applications, the installation requirements for ultrasonic meters have to be simplified — a challenge to be met in the near future by improvements to the technology.

Another reason for the on-going success of ultrasonic meters is the potential to provide operators with simple diagnostic techniques to validate meter integrity in the field, such as RMG by Honeywell's precision adjustment measurement and the comparison of Speed of Sound diagnostics. The coming years will bring additional diagnostic advancements within ultrasonic meters, which will simplify installation, operation, and meter validation.

There is also a clear trend towards ultrasonic meters in larger sizes. Unfortunately, there are no test rigs capable of serving these applications in a proper way. This situation is coupled with the challenge of obtaining a time slot on a test rig for high-pressure calibrations.

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