Natural Gas Metering With Ultrasound – A New Dimension of Metering

Ultrasonic, Transit Time, Path, Path Angle, Multipath Meter, Flow Profile, Profile Distortion

James W. Bowen and Achim Zajc

Introductory concepts for the measurement of natural gas using the principle of pulse transit time measurement are discussed. Diagnostics typical to multipath transit time meters using ultrasonic pulses are described and guidance provided regarding their interpretation. Multipath arrangements and transducer types are also addressed. Guidance is provided on the proper application and on-going operation of ultrasonic meters to assure continued measurement integrity.

1. Introduction

Over the past 15 years, gas ultrasonic meters have transitioned from the engineering lab to wide commercial use as the primary device of choice to measure gas volume for fiscal accounting. Wide acceptance and use by gas pipeline companies has occurred during this time due to the device's

- Reliability
- Accuracy
- Repeatability
- Capacity (rangeability)
- Commercial availability that translates into product support, and
- Adoption of industry standards for fiscal measurement applications

Briefly, the historical development of fluid velocity measurement in closed conduits with sonic pulses was first considered in the 1920's with the discovery that transmission and reception of repetitive sound bursts could be used to describe the location and speed of moving objects; this principle was soon used to build sonar and radar arrays. Attempts were made over the years to apply the principle to measurement of fluid velocity in conduits, but it wasn't until the development of economical high speed electronics and digital signal processing in the late 1970's that a repeatable instrument with sufficient resolution for gas applications was devised.

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 production of a gas ultrasonic meter that utilizes:

- Robust transducers that generate 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 and reception of sonic pulses with sufficient time domain resolution.
- Combining transducer and electronics to permit high pulse transmission rates, and their transit time measurement, to allow rapid integration of fluid flow velocity so that accurate measured values can be reported once per second.

Virtually all ultrasonic meters used by pipeline companies 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 characterize 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 flow calibrated, diagnostic assessments can describe whether proof, i.e. meter factor, shifts due to fault in the meter's operating elements (i.e. 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).

2. Operating Principal

Knowledge regarding the measuring 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.

Multipath ultrasonic meters that are typically used for gas custody transfer calculate gas flow rate from velocity measurements made over a pipe's cross-section, using the following process:

- Transducer pairs are installed in a meter body and are used to make transit time measurements of ultrasonic pulses which each transducer both transmits and receives. Pulses shot in the downstream direction are accelerated, while those shot upstream are decelerated by the gas flow. (At 0 flow, transit times in the up- and down-stream directions are equal.)
- Velocities are calculated for each transducer pair, or path, from the measured transit time difference between pulses shot in the up- and down-stream directions.
- The multiple path velocities are averaged into the bulk velocity using a weighting scheme that depends on the path's location in the pipe cross-section for which velocity is "sampled".
- Bulk velocity is multiplied by the meter body's cross-sectional area to calculate uncorrected flow rate.

Velocity measurements are made along multiple paths using transducer pairs arrayed in known position in the meter body. Since the "absolute digital travel time measurement method" is employed (firing pulses in rapid succession in opposite directions across the same flight path in the pipe), fluctuations in pressure, temperature and gas composition do not affect velocity measurement due to the nearly instantaneous sonic pulse emissions by individual transducer pairs.

Below are the basic equations(1) used for transit time measurement (1,2), bulk velocity (3), speed of sound (4), flow calculation (5) and a schematic **(Figure 1)** of a transducer pair's geometry that puts the vector sums into context. Note that the only thermodynamic term in any of these equations is *c*, speed of sound. This is a fluid property, and the only term in these equations that varies with gas composition, pressure and temperature (i.e., fluid density).

$$t_U = \frac{L}{c - \nu \cdot \cos\varphi} \tag{1}$$

$$t_D = \frac{L}{c + \nu \cdot \cos\varphi} \tag{2}$$

$$\nu = \frac{L}{2 \cdot \cos\varphi}\left(\frac{1}{t_D} - \frac{1}{t_U}\right) \tag{3}$$

$$c = \frac{L}{2} \cdot \frac{(t_u + t_d)}{t_u \cdot t_d} \tag{4}$$

$$Q = A \cdot V \tag{5}$$

Where:

L = Path length (ft or m)
t_u = Transit time upstream (sec)
t_d = Transit time downstream (sec)
c = Speed of Sound (fps or m/s)
φ = Path angle (degrees)

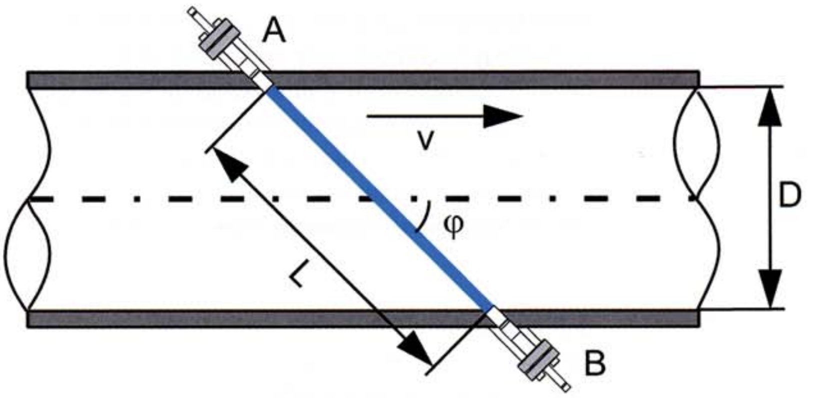

Figure 1.** Transducer pair's geometry* ***(RMG Messtechnik GmbH)*.*

ν = Path velocity (fps or m/s)
Q = Uncorrected Flow (acfs or m^3/s)
V = Bulk Velocity (fps or m/s)
A = Pipe cross sectional area (ft^2 or m^2)

Solving for velocity, ν, in equations 1 and 2, and combining their terms, results in the solution of interest: fluid velocity ν (equation 3). Note that the density dependent term, *c* (speed of sound) cancels and drops out of Eq. 3. This is possible because that fluid density (i.e., composition, P and T) is assumed to be constant at the time when the up- and down-stream pulses are fired (a .reliable assumption given that up and down-stream pulses are fired within milliseconds of one another). The mutual effect, and therefore cancellation of *c* on the up/down pulses, gives rise to the description of the meter's operating principle as the "absolute digital transit time measurement method".

Application of the absolute digital transit time method provides the technique needed to render accurate gas measurement, and its integrity is dependent on:

- Knowledge of *path length* (distance traversed by ultrasonic pulses),
- Confirmation of *clock accuracy* (accurate transit time measurement),
- Validation of pipe *cross sectional area* (accuracy in flow calculation, and transit time measurement),
- Validation of *flow profile* (accuracy of calculation of bulk velocity from individual path velocity measurements).

Diagnostic outputs monitored must verify the constancy of the bolded items in these bullets, in whole or part, to provide an assessment of the meter's operating condition.

3. Application Considerations

All gas measurement technologies have limitations, including ultrasonic meters, and it's 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 to installation. 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.

3.1 Noise

As noted in the operating principle discussion, ultrasonic flow measurement depends on accurate transit time measurement of sonic pulses. Sound is characterized by its tone (frequency) and loudness (amplitude) In the case of an *ultra*sonic meter, the tone, or frequency of the pulses is above the range of human hearing (20 kHz), hence the modifier "ultra".

Noise inside the pipe work can interfere with detection of sonic pulses if the noise is of coincident frequency with the meter's transducers and "drown out" the pulse if it is sufficiently high in amplitude. If pulses are drowned out, detection, and therefore pulse transit time measurement, becomes impossible and flow measurement stops.

Designers should always be concerned regarding the possibility of noise interfering with an ultrasonic meter's function, and should avoid installation near a noise source. That's easy (and obvious) to state, but in practice hard to accomplish since the most common noise sources are flow and pressure control valves which are nearly always co-located with meters at gas transfer stations. It is also notable that the noise offensive to an *ultra*sonic meter is inaudible to human hearing, so the valve sets that commonly cause interference are quiet or "whisper" trim style valves. These valves achieve their inaudible noise characteristic with trim designs that push the noise out of the range of human hearing, but into the ultrasonic range where UM's operate.

Therefore, designers should install ultrasonic meters where they will be least affected by the noise generated by such valves. Most UM manufacturers can provide additional guidance particular to their product. In general:

- *Meter installation:* Install ultrasonic metering upstream of regulating devices.
- *Noise reducers:* Locate noise attenuating elements between the meter and the noise source (tees, separators, etc.)
- *Consult the meter manufacturer.* They may have transducers of alternate frequency that are less susceptible to noise interference and/or the knowledge-base with respect to their meter's response so that a proposed installation can be analyzed for possible impact based on valve type, flow and pressure drop, and then make recommendation for attenuators that militate against possible interference.

3.2 Dirt

Dirt and liquids can impact the performance and accuracy of ultrasonic meters, as it does all other flow measurement technologies. The effects vary depending on the nature of the technology. For example, dirt gathering on the interior of an orifice tube or plate will have impact on the dimensional characteristics upon which orifice meters rely. In the case of turbine meters may cause the meter to run slow due to increased bearing friction. In ultrasonic meters, concern exits with respect to transducer blockage and with dimensional integrity (diametral and path length changes).

With respect to diametral changes, recall that in an ultrasonic meter velocity is measured and that uncorrected flow is calculated from the product of cross sectional area and that measured velocity. A per cent change in area equates to a per cent changed in calculated flow. Therefore there is a 1 : 1 relationship between diameter error and measurement error. Path length changes due to trash build-up on transducer faces also causes measurement errors, but these dirt induced errors caused by path length change are easily detected using speed of sound comparisons (see Diagnostics below).

Detection of dirt build-up in the meter causes larger measurement errors, but is harder to detect than for a dirt induced path length change. Subtle diagnostic indicators can be monitored, but regardless the suspicion these indicators might flag, it is usually necessary to make a visual inspection and then to clean the meter internals to eliminate the diametral reduction. Operators should:

- Make meter installations with a site assessment of the possibility for liquids/dirt contamination in mind and consider addition of inlet separators, filters and drains on the meter run to either prevent contamination from occurring or to provide a mechanism to drain liquids from the meter run.
- Consider installing the meter run with a mild slope to discourage accumulation of liquids down the length of the meter run and through the measuring section. Liquids will tend to accumulate at the lower end of the meter run which would also be the ideal location for a drain.
- Install inspection ports or even tees with uni-bolt closures to allow for visual inspection with a borescope and, in the case of inspection tees/caps, to permit for meter run cleaning.
- Adopt a regular program of diagnostic and visual inspection to detect build-up and avoid measurement errors due to diametral reduction.

3.3 Profile Distortion

As noted in the operating principle discussion, resolution of path velocities into a representative bulk, or average, fluid velocity, is essential to accurate calculation of

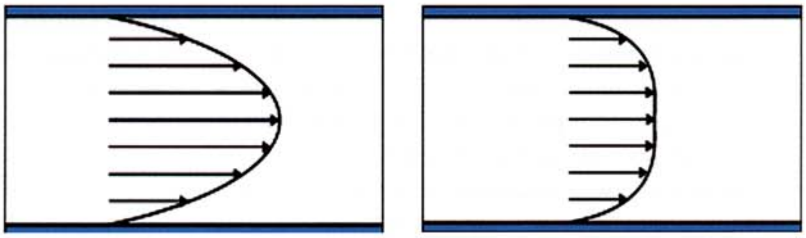

Figure 2. Laminar & Turbulent Flow Profiles (RMG Messtechnik GmbH).

uncorrected flow at line conditions. Therefore it is necessary to insure the flow profile is consistent with that found during flow calibration and additionally that the profile is symmetrical **(Figure 2)** in shape so that the individual path weighting factors applied by the meter manufacturer retain their validity.

Therefore, path velocities should be mapped during flow calibration and subsequent field inspections should compare the as-found flow profile to that documented when the meter factor was established during calibration in the flow lab.

Meter manufacturers usually employ different path configurations from one another in the quest to characterize the flow profile and accurately calculate bulk velocity: some designs are more effective in this regard than others, although arguments can be made that high performance flow conditioners, designed to generate consistent flow profiles, render this distinction moot. Regardless whether or not a flow conditioner is used it is still critical that a multipath meter provide indication when the as-found profile deviates from that expected (i.e. that from flow calibration). A good meter's path design will enable calculation and reportage of swirl and asymmetry.

Profile distortions can occur due to meter run obstructions, debris accumulation or surface roughness changes on the pipe wall and protrusions installed upstream of the meter (for e.g. sampling probes or thermo-wells). However, the most common source of profile disturbance is standard pipe work such as tees, elbows and headers. These elements generate swirl, asymmetry or a combination of the two **(Figure 3).**

General practices to insure consistent flow profile include:

- Design meter runs that minimize profile distortions (long runs of straight pipe u/s of the meter), or include elements, such as flow conditioners, that normalize them. *(Note: if user's elect to use flow conditioners, the meter must be calibrated with the flow conditioner installed in the same position in the meter run, relative to the meter, at both the flow lab and field installations.)*
- Select a meter design that employs a multipath design that properly characterizes the flow profile *and* can report via its diagnostics whether swirl and/or asymmetry are present.
- On initial meter start-up, map the flow profile once again to check that the translation of the flow calibrated meter system (meter run, meter and flow conditioner if used) to the field is valid: if the profile in the field is different than that measured at the lab, there is a shift in meter factor!

An area of continuing manufacturer research is to develop paths designs that permit repeatable disturbance descriptions and measure their coincident impact on meter factor shifts. With this design and information on meter factor shift, it will then be possible to correct meter output for the disturbance. This is a steep challenge since the degree and type of disturbances varies, and characterizing meter response to these many influences demands a large and statistically reliable body of accurate data.

4. Diagnostic Output: Meter Validation

All commercially viable gas ultrasonic meters offer diagnostic outputs that indicate meter operating condition, up to and including, the ability to judge whether or not volumetric output is accurate. The nature of the meter's operating principal helps define these outputs and also their interpretation.

As noted, ultrasonic meters depend on transmission and recognition of sonic pulses using precise timing measurements and known geometry (path length and angle) to accurately measure gas velocity. Manufacturers have incorporated signal (pulse) recognition and processing algorithms as well as highly accurate clocks to make timing measurements.

Therefore signal strength, signal to noise ratio and clock accuracy are fundamental to accurate and reliable meter performance. General (and rather generic) descriptions of meter diagnostics follow, but detailed descriptions are manufacturer specific and beyond the scope of this paper.

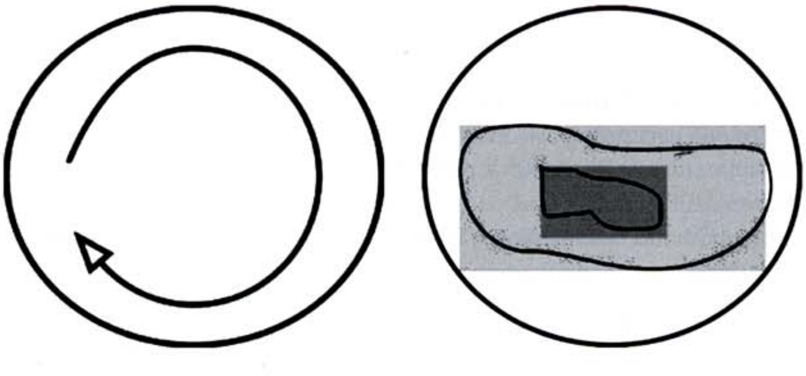

Figure 3. End view representations of Swirl and Asymmetry (RMG Messtechnik GmbH).

4.1 Transducer Gain Level

Transducer gain level is a measure of the signal strength, or amplitude, at which each transducer is excited by the meter electronics to generate ultrasonic pulses. Gains are automatically adjusted by the meter electronics so that sufficient pulse amplitude is applied to enable pulse detection. Gains vary depending on fluid density (i.e. flowing pressure, composition and temperature), and pulse reception quality.

Transducer gains should be considered as pairs (gain for the A and B side units ratioed to one another is the most common method of treatment). If a transducer pair's gain ratio breaks pattern with its previous footprint, or with the pattern of other units, it may indicate:

- Transducer fault
- Dirt accumulation on a transducer
- Other issue(s)

Transducer inspection will be required if a fault is detected in its replacement or meter cleaning might be the needed remedial actions.

4.2 Transducer Signal to Noise Ratio

Evaluation of an individual transducer's Signal to Noise ratio ("SNR") provides feedback whether noise is impacting meter function: when the SNR falls to 1 : 1, the signal is overcome by noise and measurement stops. It is important to note that variation in SNR itself is not an indication the meter's accuracy is in question, but rather that pulse recognition, (i.e. detection) is threatened. If pulses cannot be detected, measurement ceases.

SNR for transducers facing a noise source are typically lower than those facing away from the source. There is no remedial action that can be taken as regards the meter if SNR falls to the point that measurement ceases. The only remedies available are to eliminate the noise source, change that source's frequency or to change the meter's operating frequency by changing transducers. Alternatively, attenuating elements can be installed between the meter and noise source, but this is time, labor and cost intensive, unless these elements are planned for and install during the construction phase.

4.3 Speed of Sound

Speed of Sound (SoS) is a critical and powerful diagnostic tool available in ultrasonic meters from which users can determine if a meter's operating performance has shifted. Two tests can be made using meter "measured" values for SoS: 1) an absolute comparison of meter corrected SoS versus that calculated from the gas' thermodynamic properties and 2) a per path comparison to determine if an outlier on a particular path suggests it's path length has changed (path length changes are due either to meter configuration input errors or debris build-up on transducer faces).

1) SoS Comparison to Calculated Value

Recall equations 3 and 4$^{(1)}$ from the operating principle discussion:

$$v = \frac{L}{2 \cdot \cos\varphi} \left(\frac{1}{t_D} - \frac{1}{t_U} \right) \tag{3}$$

$$c = \frac{L}{2} \cdot \frac{(t_u + t_d)}{t_u \cdot t_d} \tag{4}$$

Simple inspection of these equations reveals that the fluid velocity, *v*, and speed of sound, *c*, are both directly dependent on the meter's path length and transit time measurements. Repeating in alternate language, meter pulse transit time measurements, and path length data permit calculation of <u>*both*</u> v and *c*.

The SoS in natural gas can also be calculated from its fluid properties of composition, pressure and temperature, with calculation Standards adopted by the AGA or GERG as applicable. Therefore it is possible to compare the "meter measured" value of SoS to that calculated with the AGA/GERG equations. The *measured* versus *calculated* values should agree closely (a limit of ± 0.25 % is typically used, but may need relaxing depending on the quality of compositional data).

Should a significant offset between the measured and calculated values be found, it indicates one or more of the following:

- The meter's path length(s) are in error
- The meter's clock has shifted causing transit time errors (or there is pulse mis-detection which is also an SPU problem).
- The data used to make the SoS calculation per AGA/GERG is incorrect (i.e., compositional data is in error suggesting a GC issue, or one or both of the pressure and temperature transducers is incorrect).

These conclusions can be made because meter clock/pulse detection (or SPU function), path length and fluid data are *the only variables* that can cause disagreement between measured and calculated value of SoS. Further, it can be stated that good correlation of measured and calculated SoS "prove" that clock/SPU function and path length are valid and it can be concluded, therefore, that the meter factor has not changed!

2) Path Speed of Sound Comparison.

Per path SoS footprints can be used to evaluate individual path issues related to path length, and possibly transducer function. Should an individual path's as-found SoS deviate from the established foot print (once again, the foot-print established during flow calibration and/or meter start-up should be used for reference), it can be concluded that this path's function (either path length or pulse detection on one of its transducers) is at issue. While it's true that a disparity could also be caused by a clock issue, the same clock is used for timing measurement on all paths, and were there a clock problem, all paths would probably shift in like fashion. Nonetheless, if clock were at fault, the SoS comparison between meter corrected and AGA/GERG calculated values would indicate the fault.

4.4 Profile Distortion

Profile distortions can be detected with comparison of a given manufacturer's diagnostic output for Swirl Angle and/or Asymmetry using a footprint technique similar to that suggested for Transducer Gains and per path SoS evaluation.

Users should review the available diagnostics for each of these quantities for a particular manufacturer's product, and consider the basis of calculation that each provides, since the variation in path geometries between manufacturers means that differences in the quality and sensitivity of these outputs also exists. Due to these sensitivity differences, it is not possible to provide a generic description here for alarm treatment of swirl and asymmetry outputs.

However, any multi-path meter affords users the opportunity to also foot-print the per path velocity patterns for its given geometry which can then be used to compare with the as-found velocity pattern. As a cautionary note, flow profile varies with fluid velocity so any as-found to foot-print comparison needs to be made at roughly equivalent velocity/Reynolds Number. This complication speaks to the advantage of selecting a meter manufacturer that provides ready outputs for swirl and asymmetry. It is recommended that user's request manufacturers specify the measurements and calculations made to generate swirl and asymmetry values to insure they're understood, since the various path designs/geometries offered by manufacturers necessarily means the treatment, and therefore sensitivity, of these outputs also varies.

5. Design Choices

In the development of gas ultrasonic meters, manufacturers necessarily make design choices that balance the desire to build the "perfect" meter with the need to provide an affordable solution that meet's customer needs and existing measurement standards (in the instant cases, AGA TMC Report No. 9 and ISO 17089).

Although the absolute digital pulse transit time method is a measuring principle common to all ultrasonic meter manufacturers, the design choices they've made for their products set each apart:

- Transducer design
- Path orientation/geometry
- Number of paths
- Pulse detection algorithms

Number of Paths: From the previous discussion of profile distortion and the need for profile repeatability, it is evident that more samples of the velocity stream, that is, more paths in a meter, the better the measurement. However it's also obvious that more paths means higher cost and the need for the SPU to digest more data which might slow down volume output reporting because of higher calculation overhead. Additionally, in smaller meter sizes, it is not possible to install a large number of transducers due to physical limits on available space

Path Orientation: Limits on the number of paths and a desire to maximize sampling/characterizing of the flow profile can be stretched (if not overcome) with careful positioning, or orienting, of the transducer paths. Once again, there are trade-offs between getting more slices of the measuring section's cross section versus axial orientation that can measure swirl, cross-flow and asymmetry. Some manufacturers use a path orientation that bounces ultrasonic signals off pipe walls to increase axial sampling, while others use point-to-point transmission to avoid pulse attenuation and warping that can compromise signal detection.

Transducer Design: Ultrasonic transducers, the consistency of which is at the heart of any robust meter design, are engineered to deliver maximum amplitude at given frequencies while maintaining transmission of a uniform pulse shape that is repeatable so the pulse can be reliably detected. This is a challenge that's been answered in various ways, once again involving trade-offs between benefits, cost and reliability. Some manufacturers therefore offer transducers with exposed elements so the signal isn't attenuated by a cap that would protect the transducer from foreign object damage and also inhibit dirt build-up. Others cap the elements but pressure balance to achieve better signal integrity.

Pulse Detection Algorithms: An SPU (signal processing unit) that can consistently detect pulses in a challenging operating environment (i.e. noisy, dirty, etc.) is also key element in devising a reliable meter. Ultrasonic pulses are affected by noise interference, and sometimes noise other than pulses may be detected by an SPU and erroneously interpreted as an ultrasonic pulses: large measurement errors can result.

Pulse mis-detection, also known as a "cycle jump" of "peak skip" might also occur that results in systemic transit time measurement errors. (Refer to **Figure 4** below for a depiction of a typical ultrasonic wave packet). Individual peaks in the pulse envelope are often used in manufacturer pulse detection algorithms as start/stop points for transit time measurements to achieve the resolution needed for accurate flow measurement. A peak skip is manifest when the SPU selects the wrong peak on which to start or stop transit time measurement, which fault can be found using the path speed of sound correlation suggested in §4.3 above.

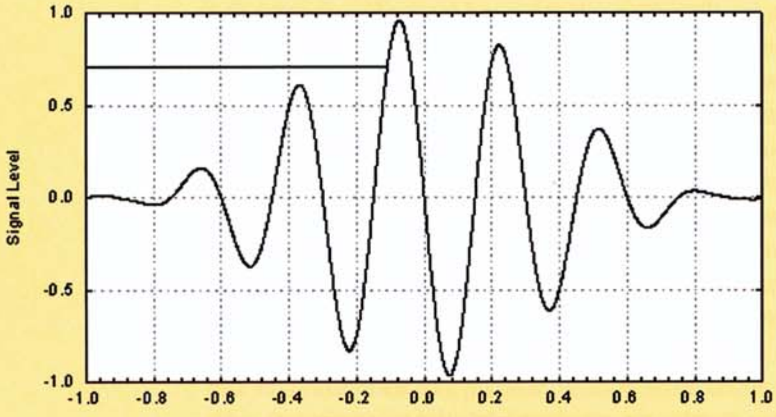

Figure 4. Typical ultrasonic pulse (American Gas Association).

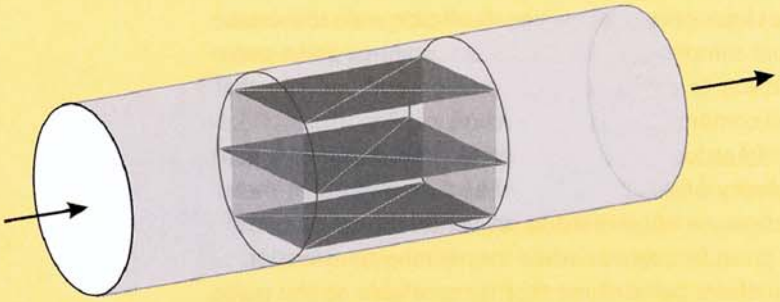

Figure 5. RMG path arrangement (RMG Messtechnik GmbH).

Therefore, manufacturers have applied various criteria to pulse validation (counting peaks or measuring individual peak amplitude, for e.g. and selecting a specific peak to use for transit time measurements). Another technique is to sample repetitive pulses and compare them to one another, which technique is often called "stacking". Again trade-offs drive design choices: Stacking, for example can be an excellent way to validate pulses, however it slows processing down, reduces the number of validated pulses and may therefore provide statistically small time samples that reduce sensitivity and reliability in these measurements: sometimes processing may be slow enough to cause data refresh rates that exceed 1 second.

Figure 6. *RMG USZ 08 (RMG Messtechnik GmbH).*

Meter Bore: Some manufacturers have found that a reduced or tapered meter bore can improve the velocity profile so fewer paths are needed. A reduced bore also "jets" the flow so the velocity field pulls away from the pipe wall in the measuring section and therefore doesn't generate near-wall turbulence that may impact signal detection with lower amplitude (i.e. lower energy) pulses. A reduced bore may also skirt the need to offer meter bodies in various pipe schedules. Once again trade-offs are involved, in this case some rangeability is sacrificed, and the opportunity for liquid and debris exists to collect at the low points at the entrance and exit of the meter bores.

With all these choices in mind, RMG has selected the following to optimize it's meter design:

Number and orientation paths: 6 paths arrayed in an "X" pattern in three horizontal planes: A central plane, and 2 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 **(Figure 5).**

RMG has also opted to utilize 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 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 designs have utilized bounce paths with reflectors, but development of smaller transducers has allowed to array 12 on a meter body to 4" diameter so that use of a point to point path construct is possible.

Transducer Design: RMG has developed compact, Titanium encapsulated, high energy transducers in 100 and 200 kHz models, so that the unit is resistant to dirt and we can offer customers alternate frequency designs to cope with noisy environments. The high amplitude capacity of the piezo-ceramic sensor permits use of the dirt-resistant cap (which must still be thin shell Titanium to avoid attenuation) without the need to pressure balance the unit.

Detection Algorithms: RMG utilizes numerous criteria to validate pulses without compromising high firing rates (10 pulses per second). One of the criteria common to many manufacturer's including RMG is peak identification and quantitation as regards position and amplitude in the pulse envelope. However use of comparative analysis of pulses, or "stacking" has been avoided since it was found the burden of signal processing in challenging environments (noisy, turbulent, etc.) causes either data refresh rates to exceed 1 second, or a reduction of evaluated samples that falls below statistical acceptability. So the company has implemented additional qualitative analysis to evaluating the pulse envelope and identify ultrasonic pulses, while still maintaining high firing rates.

Figure 6 shows an example of an USZ 08 ultrasonic meter installed in a gas station.

6. Conclusion

Ultrasonic meters are the overwhelming technology of choice for large capacity gas measurement stations because of their reliability and rangeability.

Speed of Sound Diagnostics inherent in these transit time meters, coupled with Industry established Speed of Sound calculations based on gas properties, yield the additional advantage of providing a simple technique to validate meter integrity in the field.

RMG has evaluated design options and adopted technologies that provide customers a reliable and economical solution to their flow measurement challenges.

Literature

[1] AGA TMC Report No. 9, "Measurement of Gas by Multipath Ultrasonic Meters", copyright 2007, American Gas Association.

[2] RMG, "USZ-08 Operating Manual", Copyright 2008, RMG GmbH.

Authors

James W. Bowen
Director Transmission Measurement |
Mercury Instruments LLC | Houston | TX USA
E-Mail: jbowen@mercuryinstruments.com

Dr. **Achim Zajc**
Product Manager Gas Measurement Technology |
RMG Messtechnik GmbH | Butzbach | Germany |
Tel. +49 6033 897-138 |
E-Mail: achim.zajc@rmg.com