ULTRASONIC METERS FOR RESIDENTIAL AND COMMERCIAL APPLICATIONS

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INTRODUCTION

An ultrasonic meter falls into the classification of inferential meters. Unlike positive displacement meters that capture volume to totalize volume, inferential meters measure flowing gas velocity to totalize volume. Orifice meters use pressure drop to measure velocity to infer volume and turbine meters use the speed of the rotor to measure velocity to infer volume, while ultrasonic meters use sound waves to measure flowing gas velocity to infer volume. Ultrasonic meters have been around for many years in primarily liquid measurement. However, their application in the measurement of natural gas is relatively new, and has become more commercialized over the last decade. A significant contributor to the commercialization of ultrasonic meters in gas is affordable, highly accurate timing devices, that are being mass produced for computers and digital devices. Since changes in the speed of sound are much less in gas than in liquids, measurement of these timing changes needs to be measured to greater precision.

ULTRASONIC THEORY

An ultrasonic flow meter normally operates based upon the time-of-flight or the Doppler principle. A meter utilizing the Doppler principle requires “particles” in the flow stream to reflect waves. When people think of the Doppler principle, they think of weather and police radar. The rain and your car are the “particles” used to reflect the waves. This sort of meter is common in liquid measurement because bubbles can be introduced into the liquid to reflect the waves.

Ultrasonic meters used for gas measurement typically utilize the time-of-flight principle due to a lack of “particles” to reflect the sound waves. Meters that utilize the time-of-flight principle are basically a very accurate clock. The meters measure the very small difference in the time that it takes an ultrasonic pulse to travel a known distance with and against the gas stream. Transducers typically are capable of both generating and receiving ultrasonic pulses. An ultrasonic meter for distribution applications will typically use one pair of transducers to measure the speed of gas. Higher capacity meters used in transmission applications will typically use multiple pairs of transducers to measure the velocity of the gas. An ultrasonic meter that has at least two independent pairs of measuring transducers is called a multipath meter. While differences in the flow profile are generally insignificant for distribution customers due to the small flow area, they can dramatically affect measurement in transmission pipeline applications. Larger pipeline ultrasonic meters use multiple pairs of transducers to obtain a better sampling of the flow profile. The more pairs, the better definition of the flow profile, the better estimate of the true velocity measurement, while small distribution piping single path ultrasonic meters can accurately estimate the flow profile from a single pair of transducers.

A simple explanation of the theory of a single path meter (multipath meters operate the same way, except that they use multiple pairs of transducers to sample the velocity profile) starts with the gas flowing through the meter with a speed of v. The transducers take turns producing and receiving ultrasonic pulses that travel with and against the flow of the gas. While one transducer is sending a pulse, the other transducer is acting as a receiver. The difference in time it takes for the pulse to reach the transducers is used to calculate the speed of the gas. The simplified derivation of the formula is as follows:

t_1 = time it takes pulse to reach the transducer in the direction of flow
t_2 = time it takes pulse to reach the transducer against flow
L = length of measuring chamber
c = speed of sound in the gas (approx. 1,400 ft/sec)
v = velocity of the gas

$$t_1 = \frac{L}{(c + v)} \qquad (1)$$

$$t_2 = \frac{L}{(c - v)} \qquad (2)$$

By rearranging the terms, and then subtracting Equation (2) from Equation (1), one can determine the velocity of the gas from:

$$v = \left(\frac{\Delta t}{t_1 \times t_2} \right) \times \frac{L}{2}$$

Once the velocity, v, of the gas is calculated, the volume of flow is calculated by multiplying the velocity times the cross-sectional area of the flow tube.

The speed of sound of the velocity of the gas can be calculated by rearranges the terms and then adding Equations (1) and (2). The speed of sound in the gas is then determined from:

$$c = \frac{L}{2} \times \left(\frac{t_2 + t_1}{t_2 \times t_1} \right)$$

By periodically checking the speed of sound, the meter can verify that the gas has not changed dramatically, or that the measurement has not drifted. It can also be used for tamper detection if a meter is exposed to air.

The Gill designed meter utilizes three piezoelectric transducers for accuracy. All three of the transducers are out of the gas stream; therefore, they do not have gas or contaminants flowing over them which helps increase transducer life and accuracy of the meter. Two transducers are used to send and receive transmitted pulses (Figure 2.). The third transducer is used to measure the speed of the sound for verification and to correct for transducer drift. It is located just off the outlet side of the measuring tube. The transducer emits a pulse into an area of no gas flow.

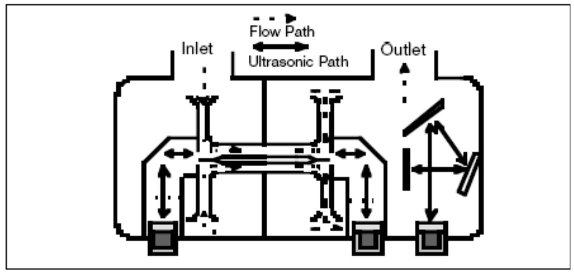

FIGURE 2

Because the E6 meter is electronic, the design lends itself to the addition of value-added features such as AMR and pre-payment systems. These options can be added via software changes and through board changes versus having “add-ons” attached to the case and index of the meter.

There are four competitors in the UK that have a license to sell the British Gas ultrasonic meter designed by Gill Electric R&D. British Gas owns the patents and rights to the design because they funded the meter development performed by Gill Electric R&D. The competitors are: Eurometers Limited (started by Gill Electric R&D, now a BTR company), Schlumberger, George Wilsons (most recently a diaphragm meter repair company), and UGI (a large manufacturer of diaphragm and rotary meters). All of the other British gas licensees are working from the Eurometers 1993/1994 production design. There is only one licensee of the British Gas technology in North America at the present time, Equimeter.

OTHER RESIDENTIAL METER PROJECTS

Siemens is the “other” major ultrasonic meter competitor. Siemens was one of the four companies offered funding by British Gas during the development of the meter. The Siemens design was derived from a heat meter manufactured by Siemens in Germany. This design utilizes two transducers. The ultrasonic waves are sent along a “W” shaped path (Figure 3.). The path design was selected to minimize the effect of changes in the flow profile. Siemens has developed the second generation of their meter. It is called the Adaptive meter. It is designed to adapt to the customer’s requirements for value-added features.

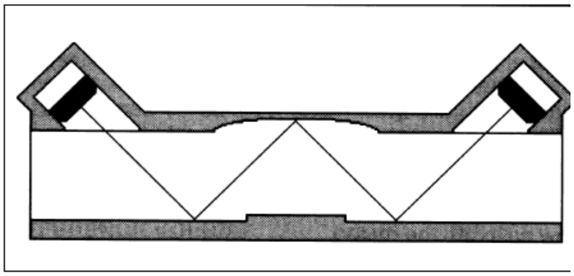

FIGURE 3

CSIRO/AGL is an Australian consortium that is also working on a domestic ultrasonic meter. It was originally scheduled to be in production in 1993. This meter is also a “dog bone” type. It has potential gas composition and contaminant problems because the transducers are in the gas stream. Figure 4 shows a “dog bone” type design.

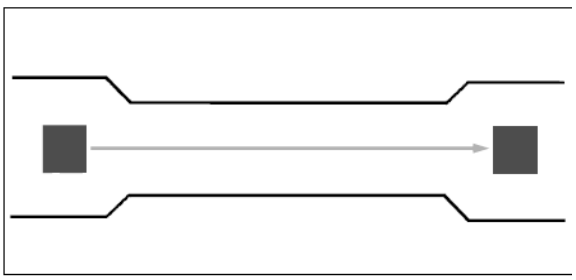

FIGURE 4

Kromschroder (part of the Elster Group) is also working on a domestic ultrasonic project. The meter is a “dog bone” type meter (two transducers in the gas stream). The meter is metal cased and powered by two “AA” size batteries.

Turin University in Italy is working on a meter project sponsored by Italgas. Their meter is also a “dog bone” type meter. This project is in the early stages of development. It was started in 1990.

LARGE ULTRASONIC METERS

As mentioned previously, large ultrasonic meters can be single path or multipath. Singlepath meters are generally not as accurate as multipath meters. Singlepath meters are also generally considerably less expensive than multipath meters. Some of the benefits of large ultrasonic meters are their ability to measure flow in both directions, potentially lower station costs (when multiple meter runs are required), a reduction in the pressure drop across the meter, and the ability to pig a pipeline (if the transducers do not extend into the flow stream).

Large ultrasonic meters can be dry calibrated or flow calibrated. In a dry calibration, the meter geometry is measured and the transducers (temperature and pressure) are verified against standards. This provides a theoretical calibration. Recent testing by NOVA indicates that dry calibration is generally not an acceptable means of calibrating meters. Three people from NOVA presented a paper (Karnik, et al.) at the AGA Operations Conference in May 1997. The paper presented test data that showed that a dry calibrated meter might be as accurate as ±1.0%; however, they also had meters ±6.0%. The meter that was ±6.0% had problems with its electronics. The only way to detect the problem was to switch electronics and compare the meter against a standard (basically flow calibrate the meter).

The meters can also be flow calibrated against a reference standard. Flow calibration will provide a more accurate calibration. The calibration pressure should be as close to operating conditions as possible to provide the best information on in-service meter performance. The proposed Canadian standard states that meters must be flow calibrated at a minimum of 40% of rated capacity.

There are basically two suppliers of large capacity ultrasonic meters to the North American natural gas industry: (1) Daniel; and, (2) Instromet (formerly Stork). Both offer single and multipath meters.

The Daniel multipath meters have four acoustic paths. Their transducers send and receive pulses across four planes using an “X” pattern. A simple schematic of the Daniel design can be seen in Figure 5. Their original design was developed from British Gas technology.

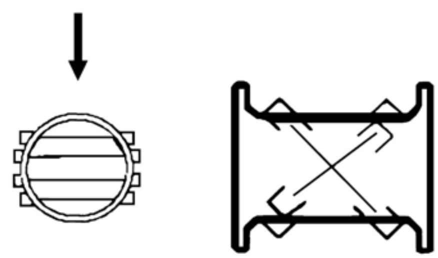

FIGURE 5

The Instromet multipath meters have three or five acoustic paths (i.e., pairs of transducers). The five path meters use a combination of single and double reflection paths. The three path meters use at least one single reflection path.

INDUSTRIAL AND COMMERCIAL APPLICATIONS

Since the development of the residential E6 meter for Europe, and the residential SONIX215 for North America, Sensus metering Systems has been expanding the single path ultrasonic meter into industrial and commercial sizes. The

SONIX600 and SONIX880 were introduced in North America in 2003 and a SONIX2000 introduced in 2008. The SONIX600 and SONIX880 still contain the three transducers design, with two transducers doing the measurement, and the third transducer providing health checks, tamper detection, and more accurate measurement. The SONIX600 has a capacity of 600 cfh at ½" water column pressure differential and 1,130 cfh at 2" differential with a 20 psig maximum operating pressure. The SONIX880 has a capacity of 880 cfh at ½" differential and 1,625 cfh at 2" differential with a 20 psig maximum operating pressure. The newest addition to single path ultrasonic measurement in North America is a SONIX2000. This meter actually uses two flow tubes, with two pairs of transducers to do the measurement, and a fifth transducer providing health checks, tamper detection, and more accurate measurement.

The SONIX2000 is currently rated at 2,000 cfh at ½" differential and further development is exploring the possibility of a higher rating. It has a 60 psig maximum operating pressure with the option to add a live pressure transducer for volume correction.

CONCLUSIONS

While ultrasonic meters have been used for many years in liquid measurement, they are relatively new to the natural gas industry. Multipath meters appear to be more applicable to larger pipe sizes where flow profiles may vary, and more velocity samples are required to provide accurate results. This does make multipath meters more expensive, but they are measuring greater volumes at higher pressures. The single-path ultrasonic meters appear to be settling into distribution applications where the volumes and pressures are considerably less than for their multipath counterparts. This permits smaller flow areas and single path measurement to be very applicable. There are nearly 1.3 million Residential ultrasonic meters being used in the UK now. However, due to costs, residential single-path ultrasonic meters are fitting into niche applications in North America. Coming on stronger are the single-path ultrasonic meters for industrial and commercial applications. I&C single path ultrasonic meters appear to be very cost competitive, much smaller and lighter weight, more accurate initially and over time, and have lower flow capabilities. Doubling up on the flow tubes and transducers has permitted the expansion of the single path ultrasonic technology to increase the capacity to 2,000 cfh, and opening the possibilities of going even higher. The electronic platform of ultrasonic meters not only makes the meters very reliable over their operating range and life, it also readily adapts to value-added features, diagnostics, data logs, and configuration changes better than other technologies. Because ultrasonic meter are flow rate based devices, calibration on flow rate based provers such as sonic nozzle provers is ideal. The worldwide natural gas industry appears to be embracing single path ultrasonic technology rapidly due to the benefits these meters offer.

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