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Ultrasonic Meters: A Natural Choice To Measure Gas Flow

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Anyone who is familiar with natural gas flow measurement has probably heard of turbine flowmeters and orifice plate flowmeters. But the flowmeter that has been making the biggest impression on users in the past few years is the ultrasonic flowmeter. This article discusses the use of ultrasonic flowmeters to measure natural gas flow, and describes two flowmeter facilities in the United States where they are tested and calibrated.

What Are Ultrasonic Waves?
What are ultrasonic waves, and how are they used in flow measurement? Ultrasonic flowmeters use ultrasonic sound waves that are beyond the frequency of what humans can hear. Most people can hear sound waves between 20 and 20,000 cycles per second, or hertz. Ultrasonic waves are sound waves above 20,000 cycles per second. Some animals hear and emit these sounds. For example, bats hear and emit ultrasonic sound waves that they use to hunt prey and for navigating. Moths can sense ultrasonic waves, which they use to detect predators. Ultrasonic waves are used to detect flaws in industrial parts, to explore the depths of the ocean, and to diagnose and treat diseases.

How Ultrasonic Flowmeters Work
Ultrasonic flowmeters are designed to work both in closed pipes and in open channels such as rivers or streams. For closed pipes, they work on both liquid and gas applications. Ultrasonic flowmeters work by sending an ultrasonic signal in the form of a wave from one side of the pipe to the other, and measuring the time it takes the signal to cross the pipe. The flowing stream of liquid or gas affects the signal, and the velocity of the flowing stream is proportional to the time it takes an ultrasonic signal to travel from one side of the pipe to another. Ultrasonic flowmeters work by measuring the travel time of the ultrasonic wave, and computing flow velocity based on that measurement.

There are two types of ultrasonic flowmeters: transit time and Doppler. Both types depend on the fact that the flowing stream affects the travel time of the ultrasonic wave. Both ultrasonic transit time and Doppler flowmeters have sending and receiving transducers. For transit time flowmeters, a transducer sends an ultrasonic wave across the flowing stream to the receiving transducer. In many cases, the receiving transducer and the sending transducer are on the same side of the pipe, and the ultrasonic wave bounces off the opposite side of the pipe and is reflected back to the receiving transducer. Now the receiving transducer becomes the sender, and sends an ultrasonic signal back in the opposite direction. The sending transducer now becomes the receiver. When the ultrasonic pulse travels with the flowing stream, it travels more quickly than when it travels against the flowing stream. By alternating between sending and receiving ultrasonic signals, and by measuring the travel time of these signals across the pipe, the transducers constantly calculate the velocity of the flowing stream.
Ultrasonic Doppler flowmeters also make use of an ultrasonic wave, but they utilize entrained air or particles that move with the flowstream. Instead of bouncing off the opposite side of the pipe, the ultrasonic waves are deflected by the entrained air or particles. A frequency shift occurs when the ultrasonic beam bounces off the entrained air or particles. The flow rate of the gas or liquid in the flowstream is proportional to the degree of this frequency shift. Doppler ultrasonic flowmeters measure the amount of frequency shift and compute flow velocity based on this measurement.

While ultrasonic flowmeters come in both clamp-on and spoolpiece varieties, the clamp-on meters have so far been limited to use for liquid applications. The clamp-on models can be installed without disrupting the flowstream, and are simply clamped onto the outside of the pipe. Spoolpiece models are installed by cutting into the pipe, and are usually attached with flanges. One advantage of clamp-on meters is that they can be used in a variety of pipe sizes, while spoolpiece models need to be cut to fit the size of the pipe they are being installed into. Another method consists of hot-tap meters. For hot-tap meters, a hole is drilled into the pipe, and the transducer is inserted into this opening.

Ultrasonic Flowmeter Suppliers
Ultrasonic flowmeters began being used for industrial applications in the 1970s, when Panametrics (Waltham, MA) got its start in ultrasonic technology. The company initially supplied ultrasonic meters to measure natural gas flow. At the time, however, the market was not ready for this new technology, partly because pressure drop was not the issue it has since become. For this reason, Panametrics turned its attention to measuring flare gas instead of natural gas. Panametrics continued developing its flare gas products throughout the 1980s. Eventually the company introduced the GN868 for measuring natural gas. This meter comes in both hot tap and spoolpiece models. Today Panametrics sells ultrasonic flowmeters for both flare and natural gas applications.

The two companies that dominate the natural gas flow measurement market today are Instromet (Dordrecht, The Netherlands) and Daniel Industries (Houston, TX). Instromet's main business is as a supplier for natural gas applications. In addition to ultrasonic flowmeters, the company sells turbine flowmeters. Instromet entered the market when it acquired the ultrasonic division of Stork Brabant. Instromet's primary business is as a supplier of flowmeters and related products for gas flow measurement. Besides ultrasonic meters, Instromet sells turbine flowmeters, rotary gas flowmeters, gas pressure regulators, complete metering stations, and gas chromatographs.

Daniel's main business is supplying products for analyzing and measuring natural gas and liquid petroleum products. Flow measurement products include ultrasonic flowmeters for measuring natural gas, turbine meters, and electronic flow computers. Other Daniel products include orifice measurement products, chromatographs, gate valves for controlling liquid and gas pipeline flows, and pneumatic and hydraulic actuators for the automation of valves in industrial products and energy. Emerson Electric purchased Daniel Industries in June 1999.
FMC Kongsberg is a new entry into the ultrasonic market (See Photo 1). FMC Kongsberg got its start in the ultrasonic flowmeter business when it purchased the multipath natural gas ultrasonic flowmeter market from Fluenta, in Norway. While most of its sales have been in Europe, the company is now expanding its ultrasonic natural gas business into North America. Fluenta still sells ultrasonic flowmeters for measure flare gas.

The question of accuracy is a major issue for ultrasonic flowmeters, especially since one of their chief advantages is high accuracy. The issue of accuracy arises because not all the particles in a flowstream are traveling at a uniform rate. In fact, the speed of a flowstream is slower the closer it is to the side walls of a pipe. Ultrasonic flowmeters that only use a single path to measure flow velocity cannot achieve the same degree of accuracy as those that use multiple paths. Ultrasonic flowmeters that have only a single path are often used for check metering, and are not normally used for custody transfer applications.

One major difference in the ultrasonic flowmeters offered by Instromet, Daniel, and FMC is in the number of ultrasonic flow paths used to calculate flow rate. All of these are multipath meters, meaning they use two or more ultrasonic paths to calculate flow rate. An ultrasonic wave (or beam) transmitted across a pipe and received by a transducer acting as a receiver counts as a single path. Daniel's flowmeter has four flow paths, Instromet's has five paths, and FMC's meter has six paths. By using multiple paths, these flowmeters achieve greater accuracy than single path meters. Multipath meters can achieve accuracy in the range of 0.5 percent or better, while the accuracy of single path meters is in the 1 to 2 percent range.

Advantages of Ultrasonic Flowmeters
What are the advantages of ultrasonic flowmeters, and why have they been taking the market by storm? One chief advantage of ultrasonic flowmeters, which has already been discussed, is their enhanced accuracy. Other advantages include the following:

- Little or no pressure drop
- No moving parts
- Low maintenance
- Can easily handle large pipe sizes
- Little Or No Pressure Drop

Pressure drop is a major issue in natural gas transmission plants, because if a natural gas flowstream loses pressure, it costs money to bring the pressure of the flowstream back up to where it was. Orifice plate flowmeters cause pressure drop because the orifice plate is an obstruction in the flowpath. As natural gas flows through the opening in the orifice plate, which by necessity is smaller than the pipe diameter, pressure loss occurs. Pressure loss also occurs as natural gas flows through turbine flowmeters, which rely on the speed of a turning rotor to determine flow rate. Because ultrasonic flowmeters do not place an obstruction in the flowstream, their presence results in very little or no pressure drop.

No Moving Parts
Moving parts is mainly a problem for turbine flowmeters. Turbine meters have a rotor that turns in proportion to flow velocity. This rotor, including the bearings, is subject to wear. Chemicals and dirt that affect the bearings can also affect the performance of turbine flowmeters. Ultrasonic flowmeters do not have moving parts to wear out. Instead, the ultrasonic wave is sent electronically. The lack of moving parts helps make ultrasonic flowmeters very low maintenance meters.

Low Maintenance
The lack of moving parts is a portion of the low maintenance story for ultrasonic flowmeters. Another portion has to do with the lack of wear. Orifice plates are subject to wear over time, which can degrade accuracy. This is especially true if there is dirt or any other impurities in the flowstream. As a result, orifice plate flowmeters need to be checked periodically for wear, and to determine if they are still reading accurately. Because ultrasonic flowmeters are not subject to wear, and do not have moving parts, maintenance costs are very low.

Can Easily Handle Large Pipe Sizes
One of the chief advantages of ultrasonic flowmeters is that they can easily handle large pipe sizes. In fact, ultrasonic flowmeters for natural gas flow measurement are best suited to pipe sizes six inches and larger. To measure the flow of natural gas in large pipes, such as 20-, 30-, and 36-inch pipes, may require more than one orifice plate meter. In these cases, the flow is sometimes diverted into a group of smaller pipes for the purpose of measurement. This is why an ultrasonic flowmeter can replace as many as ten orifice plate flowmeters. The primary downside relating to ultrasonic flowmeters in terms of pipe size is that they have a difficult time achieving required accuracies for natural gas flow measurement in pipes that are less than six inches in diameter. The primary reason for this is the reduced length that the ultrasonic wave travels in smaller pipes.

The Impact of AGA-9
While ultrasonic flowmeters were used to measure natural gas flow in the mid-1990s, their use did not become widespread in the United States until the approval of AGA-9 by the American Gas Association (AGA). AGA-9 is a report that lays out criteria that are to be followed when using ultrasonic flowmeters to measure the flow of natural gas in custody transfer situations. AGA-9 applies only to multipath flowmeters, and is not intended to cover the use of single path meters. Approval of AGA-9 occurred in June 1998.

Why did the approval of AGA-9 have such an impact on the marketplace? To understand this, it is necessary to understand the nature of custody transfer situations. Custody transfer is so-called because one party - the seller - transfers custody of some product to another party, the buyer. In order for custody transfer of natural gas to occur, the product must be measured in a way that both parties accept as reliable. AGA-9 is a report that was formulated based on input from natural gas flowmeter suppliers and end-users.

By laying out criteria to be followed when custody transfer of natural gas occurs, the report provides an objective criterion that makes it possible for both buyer and seller to be satisfied with the method of measurement being used. This greatly simplifies the custody transfer process.

AGA-9 is not the first attempt to formulate criteria for custody transfer of natural gas. In Europe, an organization called GERG published a technical monograph in 1995 that accomplished for Europe much of what is accomplished for the United States by the approval of AGA-9. GERG is an association of nine European natural gas companies. The publication of the GERG monograph in Europe three years before the approval of AGA-9 in the United States gave a boost to sales of natural gas flowmeters in Europe. This boost in Europe is somewhat similar to the boost in sales in the United States caused by the approval of AGA-9, but it occurred between 1995 and 1998.

Calibration Of Natural Gas Flowmeters

Because of the critical nature of the measurements performed by natural gas flowmeters, they are normally calibrated before being put into service. While there are a number of calibration facilities in Europe, there are two main laboratories where natural gas flowmeters are calibrated in the United States. One is CEESI Iowa (Colorado Engineering Experimental Station, Inc.), located near Clear Lake, Iowa, and the other is Southwest Research Institute of San Antonio, TX.

CEESI Iowa

CEESI Iowa was constructed by CEESI in Nunn, Colorado. The history of CEECI in Colorado goes back to 1951, when it served as the Engineering Experiment Program of the University of Colorado at Boulder. The program served as a program for testing small rockets for the Naval Ordnance Test Station at China Lake, CA. In the 1950s, the station became the sole testing ground for turbine flowmeters used by the military. In 1966, the program spun off from the university, and was relocated to its present site—an Atlas missile site near Nunn. The facility retained its nonprofit status until 1986, when Steve Caldwell and Walt Seidl bought it, and it became an independent, commercial organization.

What is most unique about CEESI Iowa is that it is constructed on an actual custody transfer location, where a very high volume of natural gas flows 24 hours a day. Northern Border Pipeline Company owns this custody transfer facility. Natural gas flows into this custody transfer station in a huge 42-inch pipeline (See Photo 2). The natural gas is diverted from the Northern Border pipeline into the CEESI Iowa flow lab, where it is used to test and calibrate ultrasonic flowmeters. Twelve turbine flowmeters serve as the calibration standards (See Photo 3). After the natural gas is used for testing and calibration purposes, it is diverted back into the Northern Border pipeline so it can be carried to customers in Chicago and other cities. A 30-inch ultrasonic flowmeter from Instromet actually measures the transfer of the natural gas (See Photo 4).

The CEESI Iowa facility flows from 1-2 Bcf/d. Because the natural gas is flowing all the time, the facility is manned around the clock. Users who wish to have their flowmeters calibrated ship the meter to CEESI Iowa, where it is calibrated and then shipped back to them. The presence of this facility in the United States is an important step forward for the ultrasonic industry, because users no longer have to pay to ship their flowmeters to Europe and back. Often the shipping is arranged through the company that the meters are purchased from, and the meters are calibrated before being put into service.

What is involved in calibrating an ultrasonic flowmeter? The natural gas flow is measured using highly accurate turbine meters that have themselves been calibrated according to NIST (National Institute of Standards and Testing) standards. A record is made of the ultrasonic flowmeter in terms of its performance at different flow levels, and any deviation from the actual flow rate is determined. This record is made available to the end-user, along with a suggested formula for adjusting the reading so it is within a specified degree of accuracy. The end-users who own the ultrasonic flowmeter often attend the tests and serve to witness the results. CEESI Iowa does not normally make hardware adjustments to the ultrasonic flowmeter to make it read more accurately. Instead, a software adjustment is made to the reading so that it is within a specified degree of accuracy.

Even the creation of a formula to make the flowmeter read more accurately is not always straightforward, because there is often more than one formula that will do this job, give the data points. In some cases, each reading is shifted by the same numeric amount. In other cases, a more complex formula is created to bring the reading as close to total accuracy as possible. “We let the end-user of the flowmeter be the guide when it comes to making this software adjustment,” says Joel Clancy, Operations Manager. “Some users prefer to make this adjustment themselves, while others prefer one method of adjustment over another.”

Southwest Research Institute

Another facility where ultrasonic natural gas flowmeters are calibrated is Southwest Research Institute (SwRI). SwRI was founded in 1947 in a former ranch headquarters building on a 750-acre tract donated by the founder, Tom Slick. Since that time, SwRI has grown to occupy 1,200 acres with 2,700 employees. Today, SwRI is involved in a wide range of different research areas, including engine fuels, materials research, space sciences, nuclear waste analysis, nondestructive testing, and fluid dynamics. The natural gas calibration and testing group is one of many divisions of this very large research organization. The Gas Research Institute (GRI) established this group for the purpose of having a facility devoted to studying natural gas flow and calibrating flowmeters. Besides the natural gas group, there is a separate group that studies liquid flow.

SwRI takes a different approach to calibration of natural gas flowmeters than CEESI Iowa. Instead of using “live” natural gas flow from a pipeline, SwRI buys natural gas from a local natural gas supplier. The natural gas is delivered to SwRI in a 12-inch pipe (See Photo 5). Since this gas is flowing at a relatively low rate, SwRI uses a natural gas compressor to condition the gas and bring it to the proper flow rate and temperature for calibration purposes. The capital cost of the equipment to do this job is several million dollars. Despite the cost of this equipment, SwRI cannot achieve flow rates even close to those achieved by CEESI Iowa. As a result, SwRI’s facility is best suited to calibrating ultrasonic flowmeters from six to 12 inches in size, although the facility has calibrated meters as large as 20 inches.

Another important difference between SwRI and CEESI Iowa is that CEESI Iowa, along with CEESI in Nunn, Colorado, is a private, commercial organization that is primarily funded by fees charged for calibrating flowmeters. SwRI, by contrast, is a not-for-profit research organization that is more devoted to doing research than to doing day-to-day calibrations. As a result, testing and calibrating are more of a priority at CEESI Iowa, while pure research is less of a priority. At SwRI, research is more of a priority, and testing and calibrating flowmeters is less of a priority. Both facilities play a highly important role in enabling end-users to put ultrasonic flowmeters into operation for the purpose of measuring natural gas.

A Look Ahead

The next several years promise to be a time of substantial growth for natural gas ultrasonic flowmeters. Though growth in Europe has leveled off to some extent from what it was several years ago, substantial growth can still be expected in the United States and Canada. A new flow calibration facility is being built in Winnipeg, Canada, and this can be expected to help sales of ultrasonic flowmeters in Canada. Suppliers also report a substantial amount of interest in ultrasonic flowmeters to measure natural gas flow in Asia. While there is currently no Asian supplier for these meters, Asia is a new frontier that will be a significant source of growth for this industry over the next five years. *P&GJ*

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