Energy Measurement Using Ultrasonic Flow Measurement & Chromatography

Introduction

Gas volume and energy metering stations using gas chromatography and ultrasonic metering are becoming a mainstream field operation and a new challenge to metering personnel. They are easy to adapt to and add a new dimension of value to the field professional. Technicians are invariably the link to the success of any changing technology that would survive and thrive in the real pipeline environment. Meter stations must be maintainable and provable. This application note examines the metering system and requirements from the technician's perspective.

The Ultrasonic Gas Flow Meter – A Brief Overview

An ultrasonic meter measures gas flow rate by sending bursts of high frequency sound upstream and downstream diagonal to the flow, measuring the transit time in each direction.

Measuring the time difference to travel upstream and downstream along a known fixed path length gives path velocity. Correcting for the angle between the path and the axial flow gives average axial velocity for the portion of the pipe's area represented by that path. Path average axial velocity multiplied by the area gives actual volume rate for the portion of the pipe's cross-sectional area represented by that path.

Sound will take longer to travel the path length against the flow than it will with the flow. The time difference is proportional to the flow velocity. The total time to travel both upstream and downstream divided into two path lengths gives speed of sound. It is important to remember that the speed of sound is measured with the same two path timings as the gas velocity. A significant error in the speed of sound measurement means you are probably making a significant error in measuring flow, while agreement means that you are probably doing an accurate job of measuring flow. The speed of sound can be calculated by use of an AGA 8-based program and by entering the gas composition percentages (from a chromatograph), line temperature, and pressure.

Installing an Ultrasonic Meter – The Technician's Perspective

Following the AGA9 recommendations, create a checklist. Example:

- ☐ Calibration data available
- ☐ Dimensional information available
- ☐ Meter is oriented correctly
- ☐ No gaskets protruding inside
- ☐ Meter bore matches the tube bire within the ± % of meter bore
- ☐ Vanes or conditioners correctly installed
- ☐ Minimum upstream and downstream pipe diameters available
- ☐ Meter supported
- ☐ Thermowell the correct number of diameters from the meter
- ☐ Factory data in the digital signal processor (head) of the USM
- ☐ All pressure bearing components in place
- ☐ No low areas are in the run (which will collect liquids and restrict the meter's area)

Understanding Flow Calibration on Ultrasonic Meters

Ultrasonic flow meters are pure-rate meters. They measure the time to travel a known distance. During production, manufacturers should precisely measure path lengths, placement, angles, bores, etc. Knowing these measurements makes an inherently calibrated or DRY-factory calibrated meter. Inferring angles and lengths by adjusting them to correctly read speed of sound should be reserved for in-situ (hot-tapped) meters where small welding variances may occur.

On a spooled custody transfer quality meter, the meter body measurements should be absolute. Applying forced lengths and angles should mean that the meter thereby requires flow calibration. Flow calibration on a properly measured DRY calibrated meter usually removes a slight zero offset. If the flow calibrated, a meter factor will be installed by the test agency if necessary and should be verified at start-up. Flow lab data should also accompany the meter for your records.

The technician will routinely check that the complete database of the meter is correct, its performance parameters are correct, and that the ultrasonic meter measured speed of sound is within a tight margin of agreement against calculated speed of sound. Maintaining the meter's accuracy usually requires very little effort. Comparing measured to calculated speed of sound allows you to know if any of your primary energy system measurements have shifted or drifted.

The sensitivity to the speed-of-sound change is a function of the change in gas composition versus temperature versus pressure, and it is shown in the following example of comparing slightly different methane versus ethane contents, temperature changes, and pressure changes. This example uses a real (and typical) production inlet gas to a gas plant.

Table 1 - Natural Gas Composition

Components	Mole percentages
Methane	81.74501
Ethane	7.56130
Propane	5.50491
Isobutane	1.42323
n-Butane	1.49864
Isopentane	0.40214
n-Pentane	0.28643
n-Hexane	0.36973
Carbon Dioxide	0.96299
Nitrogen	0.24562

Table 2 - Temperature & Pressure vs. S.O.S (in ft./sec.)

Components	800 psig	850 psig
65 °F	1142.00	1138.26
67 °F	1145.79	1142.11
69 °F	1149.54	1145.93
71 °F	1153.27	1149.72
73 °F	1156.97	1153.48
75 °F	1160.64	1157.21

In the tables above, note that the mole % of methane is 81.74501%. From 65 °F (18 °C) to 67 °F (19 °C), the speed of sound changes 3.79 feet (1.15 meter) per second (fps), or just less than 2 fps per degree F. At 65 °F (18 °C), a pressure change from 800 psig to 850 psig only changed the speed of sound by 3.74 fps. Each psi of change only changes the speed of sound by 0.074 fps. If we exchange ethane for methane by one percent, or, in this example, methane becomes 82.74501 and ethane becomes 6.56130 at 65 °F (18 °C) and 800 psig the speed of sound would change from 1142.00 fps to 1149.42. The one percent methane increase changed the speed of sound by 7.42 fps.

Measurement Change	Speed of Sound Change
1% Methane	= appr. 7.5 fps
1 psig	= appr. 0.07 fps
1 °F	= appr. 1.90 fps

The technician should ensure that the calibration techniques and online equipment used are accurate enough to measure light hydrocarbon percentages to better than 0.1 mole percent, and to measure temperature to better than 0.5 °F. The most critical measurement challenge typically encountered in performing proper chromatograph sampling is temperature measurement.

For good ultrasonic meter verification, you need to have field standards that yield the equivalent of a final result of one to two feet-per second accuracy on your speed-of-sound determination. One-tenth percent methane error plus one degree F error is not good enough. When you can meet the field accuracy called for in this example, you can determine whether the meter is performing its measurement tasks properly or if some condition has changed it. The field result expected is speed-of-sound agreement to approximately 0.25 percent. This rounds to typically about ±3.0 fps. This audit is not extremely difficult and will become routine to the field measurement professionals. Commercial programs exist that allow manual entry of composition, temperature, and pressure and calculate speed of sound, density, and compressibility. This is an alternative to an automatic speed-of-sound auditing system. The technician should refer regularly to the company or contractually recommended practices for the equipment used.

Ultrasonic Meter — The Technician's Perspective

Ultrasonic meters are spooled meter bodies with 2–10 transducers and an onboard electronic transmitter which has serial data, frequency, and analog outputs. They require very similar piping considerations to other meters. There are minimum meter run requirements for upstream unobstructed pipe diameters, downstream unobstructed pipe diameters, specific locations for pressure taps and thermowells, liquid drainage considerations, and slightly different test and auditing procedures.

The Role of the Gas Chromatograph in Modern Energy Measurement

Gas energy flow rate is determined by multiplying the measured volumetric flow rate by the measured calorific value (AGA 5). Volumetric flow is measured in accordance with AGA 3, 7, or 9 as required by the choice of primary flow elements. When used with AGA 3 and AGA 7 flow rates, the gas chromatograph serves to report the energy and refine the volumetric flow measurement. With AGA 9, the chromatograph takes on a new role. In addition to providing measured calorific values, it serves as a partner in the process of ensuring quality flow measurement by providing compositional data necessary to calculate the speed of sound.

The Ultrasonic Meter

An initial concern of many users when evaluating ultrasonic measurement is the prospect of continuing confidence in the factory calibration or in the initial flow calibration. The calibration is not usually reset at the metering station. Physical inspections are an alternative, but some physical inspections could become a matter of lost measurements and safety issues. An installation of a gas chromatograph in an ultrasonic meter station gives the technician a method to quickly evaluate the meter station's performance and pinpoint metering problems.

Chromatograph Requirements for Energy Measurement and Verification

- Compositional measurement of all hydrocarbons from methane through C6+ and the measurement of the inert components such as nitrogen and carbon dioxide
- Certified calibration standards maintained at safe temperatures
- Adequate means to remove, transport, and maintain a representative sample to the sample loop in the chromatograph
- Practical reporting of measured data to a computer or system that resolves AGA 8 formula
- Cycle time - sufficiently fast to provide compositional updates and energy updates to reduce uncertainty

The Instrumentation in the Modern Energy Measurement System

The instrumentation for the modern energy measurement system is listed as follows:

- Multi-path ultrasonic flow meter with conventional pressure and temperature transmitters (typically used in concert with a flow computer)
- BTU gas chromatograph to poll and report the Ultrasonic metered rates and diagnostic points
- Resident program in the GC to calculate the speed of sound for mathematical comparison to the speeds for chords measured by the ultrasonic meter
- Program which includes a reporting system to view, print, and report the data to a master host and provides deviation alarm closures

Gas Chromatographs

While the importance of the gas chromatograph's role has increased, the same standards for chromatography that have been employed for energy measurement during the last two decades remain effective and sufficient to calculate the speed of sound of an ultrasonic meter. In addition, the field technician can expect to find the system's speed of sound check to be more reliable in providing assurance of quality energy measurement than the previous typical energy calibration check of the chromatograph alone. The sum of all the parts of the systematic speed-of-sound check provides a better check of the gas chromatograph than was once known.

An Example of the Value of Equivalent Proof

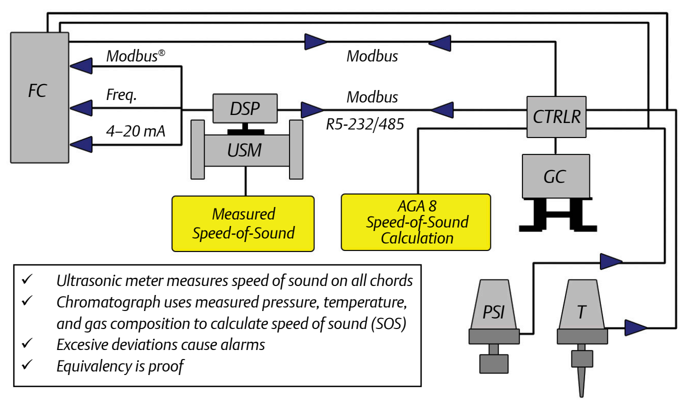
During a start-up of an energy measurement system on a residue stream, comparisons of the measured speed of sound to the calculated speed of sound revealed an excessive deviation.

To resolve the problem, technicians checked the following items:

- The BTU gas chromatograph: The unit was checked against the certified calibration gas for repeatability and the response factors were verified
- The gas chromatograph sample system: The gas chromatograph service is on three streams with a residue bypass and a plant inlet. The sample lines were visually checked to make sure that no liquid had migrated into the gas chromatograph
- Since the gas chromatograph sample system points were clean and dry, the assumption was made that the ultrasonic transducers and the gas chromatograph were not contaminated
- The pressure and temperature transmitters were re-checked

After eliminating the possibilities of problems on the ultrasonic meter and its pressure and temperature transducers, the technicians checked the gas chromatograph sample system purging and found that an inlet stream was not sufficiently purged, thereby altering the methane measurement. Once the proper sample flow rates were established for all streams, the measured and calculated speed of sound came into range.

Figure 1 - Chromatograph and Ultrasonic Meter with Speed-of-Sound Cross-Check



Conclusion

Integrating the chromatograph into an ultrasonic metering system provides energy measurement, AGA 8 detailed compressibility values, and verifies meter performance. Speed-of-sound comparisons assure the field technician that the entire system is within specifications and that the system meets custody transfer specifications. As illustrated in the previous example, the sum of the parts working together provides better information than checks on individual components will provide on their own.

Global Headquarters
Emerson Automation Solutions
10241 West Little York, Suite 200
Houston, Texas 77040
USA
Toll Free + 866 422 3683
+ 713 396 8880
+ 713 466 8175
gc.csc@emerson.com
www.Emerson.com/RosemountGasAnalysis

Linkedin.com/company/Emerson-Automation-Solutions
Twitter.com/Rosemount_News
Facebook.com/Rosemount
YouTube.com/user/Rosemount

00800-0300-3700_RevAA

ROSEMOUNT™

EMERSON™