Energy Measurement using Ultrasonic Flow Measurement and Chromatography
The Technician's Perspective

Charles W. Derr and Charles F. Cook
DANIEL MEASUREMENT AND CONTROL
9720 Old Katy Road
Houston, TX. 77055

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 while adding a new dimension of value to the field professional. Technicians will invariably be 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. The system and requirements will be examined from that perspective.

The Ultrasonic Gas Flow Meter – *A brief view*

An ultrasonic meter measures gas flow rate by sending bursts of high frequency sound upstream and downstream diagonal to the flow and then 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 times 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 (S.O.S.). It will become ***significantly important*** to remember that the speed of sound is measured with the <u>same</u> two "path timings" as the gas velocity. **A significant error in the S.O.S. measurement means you are probably making a significant error in measuring flow.** Excellent 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.

The Technician's Perspective

(Installing an ultrasonic meter)

*Follow the **AGA 9** recommendations*:

Construct a checklist. ***Example:***

- ___ Calibration data available
- ___ Dimensional info. available
- ___ Meter is oriented correctly
- ___ No gaskets protruding inside
- ___ Meter bore matches the tube bore within +/- 1 % 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 U.S.M.
- ___ All pressure bearing components in place
- ___ No low areas are in the run (which will collect liquids and restrict the meter's area)

Plan ahead and build a complete checklist!

Understanding "Calibration" on USM's

Ultrasonic flow meters are pure *rate* meters. They measure the time to travel a known distance. ***Geometry is everything.*** 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 "tweaking" them to correctly read S.O.S. 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 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 data base of the meter is correct, its performance parameters are correct and that the USM 's 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 S.O.S. allows you to know if any of your primary energy system measurements have shifted or drifted.

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

Natural Gas Composition

(Fig. 1a.)

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

Temp & Press – vs. - S.O.S. (in ft./sec.)

(Fig. 1b.)

	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

Example: Sensitivity of each measurement:

In the tables above; note that the mole % of Methane is 81.74501%. From 65 F. to 67 F. the S.O.S. changes 3.79 fps; or just less than 2 fps per degree F. At 65 F. a pressure change from 800 psig to 850 psig only changed the S.O.S. by 3.74 fps. Each psi of change only changes the S.O.S. by 0.074 fps. If we exchange Ethane for Methane by 1 %; or, in this example; Methane becomes 82.74501 and Ethane becomes 6.56130 at 65 F. and 800 psig the S.O.S. would change from 1142.00 fps to 1149.42. The 1 % Methane increase changed the S.O.S. by 7.42 fps!

Measurement Change		S.O.S. Change
1 % Methane	=	appr. 7.5 fps
1 psig	=	appr. 0.07 fps
1 Deg. 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 Deg F. As an observation; most measurement group's largest potential measurement obstacles will be encountered in performing proper chromatograph sampling and particularly in measuring **temperature**! More errors occur from temperature measurement practices than might be realized!

For good ultrasonic meter verification you need to have field standards which yield the equivalent of a final result of 1-2 feet per second accuracy on your S.O.S. determination. One-tenth percent Methane error plus 1 Deg 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 S.O.S. agreement to appr. 0.25%. 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 which allow hand entry of composition, temperature and pressure and calculate S.O.S., density and compressibility. This is an alternative to an automatic S.O.S. auditing system.

The technician should refer regularly to the company or contractually recommended practices for the equipment used. ***Example*** (for the ultrasonic meter):

The "Measurement of Gas by Multipath Ultrasonic Meters"; "Transmission Measurement Committee Report No. 9", "American Gas Association"; was copyrighted in 1998 and print issued in June 1998. This is a comprehensive document that serves as a "recommended practice" for properly using these meters to full advantage.

The Technician's Perspective (Ultrasonic meter)

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 key things to remember are that they are not exceedingly difficult to learn, there is no real reason for fear of the unknown as, without fail, the technicians who have specialized in operating orifice and turbine meters have had no difficulty in readily adapting to these meters.

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 not only to report the energy, but also to 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 S.O.S.

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 possibility, but some physical inspections could become a matter of lost measurements and raise 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 formulae
- 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 Ultra-sonic flow meter with conventional pressure and temperature transmitters, (typically used in concert with a flow computer)
- BTU gas chromatograph to poll and report the Ultra-sonic metered rates and diagnostic points
- Resident program in 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

The Technician's Perspective (Chromatograph)

While the role of the chromatograph has increased, the same standards for chromatography that have been employed for energy measurement during the last two decades are still effective and sufficient to calculate the S.O.S of an ultrasonic meter. In addition, the field technician can expect to find the system S.O.S. check to be better able to provide 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 S.O.S. check provides a better check of the GC than was once known.

An Example of the Value of Equivalent Proof

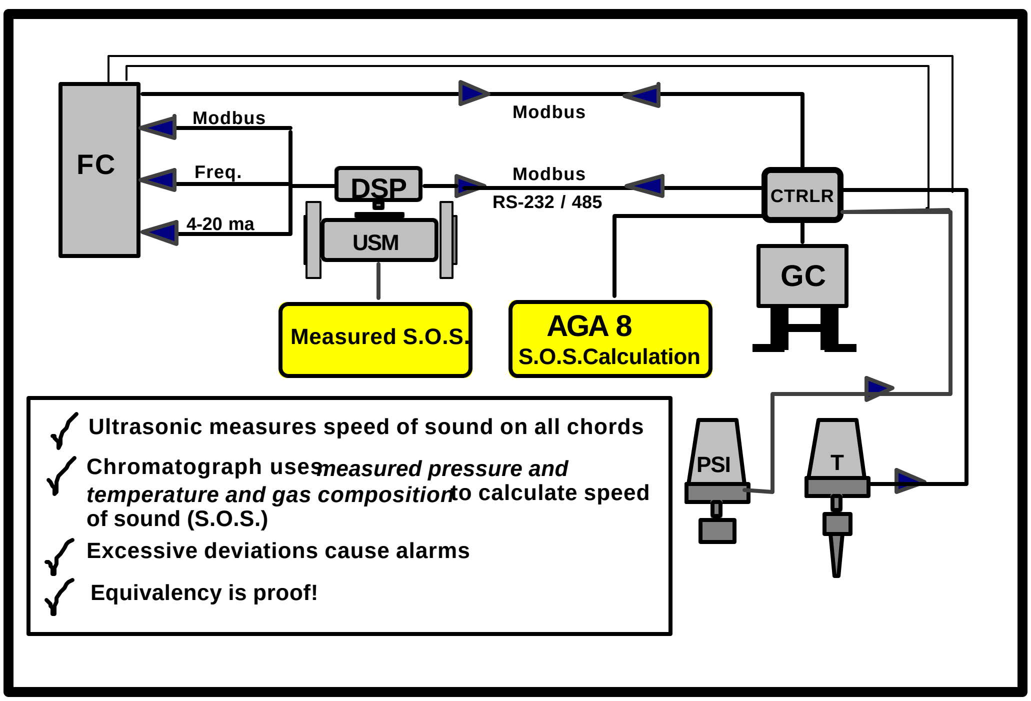
During a start up of an energy measurement system on a residue stream, comparisons of the measured speed of sound to the calculated speed of sound revealed an excessive deviation. To resolve the problem, technicians checked the following items:

- The BTU Gas Chromatograph – the unit was checked against the certified calibration gas for repeatability and the response factors were verified.
- The GC sample system – The GC service is on three streams which are a residue, bypass and a plant inlet. The sample lines were visually checked to make sure that no liquid had migrated into the GC.
- Since the GC sample system points were clean and dry the assumption was made that the ultrasonic transducers and the GC 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 GC 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 S.O.S. came into range.

Conclusion

Integrating the chromatograph into an ultrasonic metering system provides energy measurement, AGA 8 detailed compressibility values and, moreover, verifies meter performance. S.O.S. 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.



(Fig. 2A) Chromatograph and Ultrasonic Meter with S.O.S. cross-check