

AN OVERVIEW OF AGA 9 – ULTRASONIC METERS

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ABSTRACT

The American Gas Association published Report No. 9, *Measurement of Gas by Multipath Ultrasonic Meters* 2nd Edition [Ref 1] in April 2007. Report 9 details recommended practice for using multipath gas ultrasonic meters (USMs) in fiscal (custody) measurement applications. This paper reviews some of history behind the development of AGA Report No. 9 (often referred to as AGA 9), key Report contents, which includes information on meter performance requirements, design features, testing procedures, and installation criteria. This paper also discusses changes that will be incorporated in the next revision. At the time of this paper the expected publication date is the Fall of 2015.

INTRODUCTION

Members of the AGA Transmission Measurement Committee (TMC) wrote AGA 9. It started in 1994 with the development of Technical Note M-96-2-3, *Ultrasonic Flow Measurement for Natural Gas Applications* [Ref 2]. This technical note was a compilation of the technology and discussed how the USMs worked. Phil Barg of Nova Gas Transmission was the chairman when the document was published in March of 1996. During the two years it took to write the technical note, Gene Tiemstra and Bob Pogue, also of NOVA, chaired the committee.

This Technical Note has sections on the principle of operation, technical issues, evaluations of measurement performance, error analysis, calibration and recommendations, along with a list of references. It is important to note that the TMC members (end users) were primarily responsible for the development of this document. Three USM manufacturers, Daniel, Instromet and Panametrics, contributed information, but in the end the users were leading its development.

After completion of the Technical Note, the AGA TMC began the development of a report. John Stuart of Pacific Gas and Electric (PG&E), a long-standing member of the TMC, chaired the task group responsible for the report. There were more than 50 contributors that participated in its development, and included members from the USA, Canada, The Netherlands, and Norway. They represented a broad cross-section of senior measurement personnel in the natural gas industry.

AGA 9 incorporates many of the recommendations in the GERG Technical Monograph 8 [Ref 3] and certain related OIML [Ref 4 & 5] recommendations. Much of the

document was patterned around AGA 7, *Measurement of Gas by Turbine Meters* [Ref 6]. After two years of technical discussions, balloting, and revisions, the document represents the consensus of several dozen metering experts. It is important to note that in 1998 little was known about the USMs installation effects, long-term performance and reliability. Most of the performance requirements in AGA 9 were chosen based upon limited test data that was available at that time. Also, if no data was available to support a specific requirement, AGA 9 was silent, or left it up to the manufacturer to specify.

Since 1998 perhaps more than two thousand USMs have been installed, many for fiscal measurement. A conservative estimate of more than a million dollars has been spent on research by independent organizations such as GTI (formally GRI). Several papers have been published discussing issues such as installation effects [Ref 7] from upstream piping and even more on dirty vs. clean performance [Ref 8, 9, 10]. All this information will be utilized to help produce the next revision of AGA 9 which is scheduled to be published in February 2007 (at the time of this paper's submission it has not yet been released). Some of the many changes that will occur are discussed later in this paper.

REVIEW OF AGA 9

§1 INTRODUCTION (SCOPE OF REPORT)

Section 1 of AGA 9 provides information on the scope of the document. It states that it's for *multipath ultrasonic transit-time* flow meters that are used for the measurement of natural gas. A multipath meter is defined as having two or more independent acoustic paths used to measure transit time difference of sound pulses traveling upstream and downstream at an angle to the gas flow. Today most users require a minimum of 3 acoustic paths for fiscal measurement. The scope goes on to state "Typical applications include measuring the flow of large volumes of gas through production facilities, transmission pipelines, storage facilities, distribution systems and large end-use customer meter sets."

AGA 9 provides information to meter manufacturers that are more performance-based than manufacturing-based. Unlike orifice meters that basically are all designed the same, USM manufacturers have developed their products somewhat differently from one another: most notably, in path configurations. Thus, AGA 9 does not tell the manufacturers how to build their meter, but rather

provides information on the performance the product must meet.

§2 TERMINOLOGY

Section 2 discusses terminology and definitions that are used throughout the document. Terms like auditor, designer, inspector, manufacturer, etc. are defined there.

§3 OPERATING CONDITIONS

Section 3 discusses operating conditions the USM shall meet. This includes sub-sections on gas quality, pressures, temperatures (both gas and ambient), gas flow considerations, and upstream piping and flow profiles. The gas quality specifications were based upon typical pipeline quality gas and no discussion was included for sour gas applications other than to consult with the manufacturer. It is important to note that these requirements were based upon the current manufacturer's specifications in order to not exclude anyone. Based on the current state of AGA 9 revision, there are no significant user impact issues, yet on the table, regarding Section 3.

§4 METER REQUIREMENTS

Section 4 is titled and "Meter Requirements" discusses the many meter conditions manufacturers are required to meet. There are sub-sections on codes and regulations, meter body, ultrasonic transducers, electronics, computer programs, and documentation. Section 4 really provides a lot of information regarding the conditions the meter must meet to be suitable for field use.

The sub-section on codes and regulations states the following: "Unless otherwise specified by the designer, the meter shall be suitable for operation in a facility subject to the U.S. Department of Transportation's (DOT) regulations in 49 C.F.R. Part 192, *Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards*"[Ref 11].

Meter Body

The section on meter body discusses items such as operating pressure, corrosion resistance, mechanical issues relative to the meter body, and markings. Here it says manufacturers should publish the overall lengths of their ultrasonic meter bodies for the different ANSI flange ratings. It does state that the designer may specify a different length than standard, but in reality that is rarely done.

Corrosion resistance and compatibility to gases found in today's pipeline is required. Corrosion not only of wetted parts, but also for the external conditions a meter is subjected to such as rain, dust, sunlight, etc.

The inside diameter of the ultrasonic meter shall have the same inside diameter as the upstream tube's diameter and must be within 1%. The value of 1% was based mainly on early European studies and also work performed at the

Southwest Research Institute's MRF (Metering Research Facility) in San Antonio, Texas.

AGA 9 discusses the ability to remove transducers under pressure. With little knowledge about the need to periodically remove and inspect, it was thought that removal under pressure would be a common step of routine maintenance. Thus, this section also discussed the manufacturer providing some method for removal under pressure.

Today, after several years of experience, most users do not remove transducers under pressure. History has shown they are very reliable. Also, as there are often multiple runs in parallel, shutting in a run and depressurizing for transducer removal is often the preferred method. Additionally, once the meter run is depressurized, the internal condition of the meter and associated piping can be inspected. Some companies even have an annual program of internally inspecting their meters. For these reasons extracting transducers under pressure are not as common as once thought.

Proposed Changes:

- Operator responsibility for following Manufacturer recommendations in use of transducer extraction tools is stated.
- Specification of at least 2 meter body pressure taps, vs. 1 in previous publication, for static pressure measurement.

Transducers

The section on transducers discusses a variety of issues including specifications, rate of pressure change, and transducer tests. The intent was to insure the manufacturer provided sufficient information to the end user in order to insure reliable and accurate operation in the field, and also to insure accurate operation should one or more pairs need replacement in the field. Subsections include basic specifications, rate of pressure change, exchange and transducer tests.

Proposed Changes:

- Hydrostatic test of meter bodies shall not be done with transducers installed if test pressure is above ANSI rating. For higher pressures, transducers need be removed.

Electronics

Much discussion was taken on the issue of electronics and the expected improvements that come with time. The goal of the committee was to require electronics that were well tested and documented, but allow improvements without placing an undue burden on the manufacturer. This idea is evident throughout the document, but is especially relevant in the electronics and firmware sections.

The electronics section includes two suggested types of flow output communicated to flow computers: serial and

frequency. Serial communication (digital using either RS-232 or RS-485) is suggested because the ultrasonic meter is clearly a very “smart” instrument and much of its usefulness relies on the internal information contained in the meter. The frequency output is not required but standard on all USM, and is needed in applications where flow computers and Remote Terminal Units (RTUs) do not have the necessary software application to poll the USM using the serial port.

In reality a majority of users use only the frequency output to connect with flow computers. Since USM manufacturers employ different features, and even different protocols, most flow computers at that time (and to some degree even today) did not provide any method for collecting measurement information via a serial link. Today more flow computers and RTUs have the ability to communicate serially to the various brands of USMs. The serial link is still primarily used for interrogation using the manufacturer’s software.

AGA 9 requires the manufacturer to also provide digital outputs (DOs) for flow direction and data valid. A digital out is used for monitoring by the flow computer to determine direction of flow (when a single frequency is used for both forward and reverse flow). Data valid is an indicator that the meter has an alarm condition that may impact its accuracy.

AGA 9 requires the meter be electrically rated for a hazardous environment as defined by the National Electrical Code [Ref 12]. The minimum rating for a USM is for Class 1, Division 2, Group D environments. Some users specify a rating of Division 1, and, for the most part, all manufacturers design for the more stringent Division 1 requirement.

Proposed Changes:

- Elimination of the requirement for a scaled 4-20 ma output.
- Statement that a scaled 4-20 ma output is not to be used for custody measurement.
- Delete the phrase “significant change” from the sentence: “The ability to replace or relocate transducers cables, electronic parts and software without a significant change in the meter’s performance...” and replace with +/- 0.2% shift in the meter’s output.

Computer Programs

Since ultrasonic meters are electronic, the information contained in the electronics needs to be accessed by the technician. AGA 9 requires the manufacturer to store all meter information in non-volatile memory to prevent loss of data if power is removed. It also requires the meter’s configuration be securable so that accidental changes can be prevented. This is usually done by inserting a jumper or via a switch located on the electronics inside the enclosure that can then be seal-wired.

USMs typically do not provide a local display or keyboard for communicating with the meter as is traditional with flow computers. Manufacturers provide their own software for this purpose. Thus, each software package does look and operate differently. To date there have been no requirements on manufacturer’s to have similar looking and functioning software.

One of the key features software must do is make it easy for the technician to understand the meter. Technicians today have a variety of equipment they are responsible for. Thus, one of the challenges for the manufacturer is to make software that is easy to learn and use. Perhaps in the future there will be certain requirements for interface software, but that will not be a requirement in the next revision of AGA 9.

Alarms and diagnostic functions are also addressed under the computer programs heading. These sections were probably more difficult to compose because of the differences associated with various meter path designs, and the corresponding differences in available data. Diagnostic data that is required might be categorized into one of three main groups; gas velocity, gas speed-of-sound and meter health.

The velocity data is used to indicate flow profile irregularities and to calculate volume rate from average velocity. The flow rate is determined from by multiplying velocity times the meter’s cross-sectional area of the meter. The speed-of-sound data is used as a diagnostic tool to check for erroneous transit time measurement errors. Other information is required to judge the quality of the data such as percent of accepted ultrasonic pulses, signal to noise ratio and transducer gains. A discussion on these is documented in several papers [Ref 13 & 14].

Other meter requirements in this section include anti-roll devices (feet), pressure tap design and location on the meter, and standard meter markings. Many of these requirements are based on field experience and the lessons learned from other metering technologies.

Documentation

Section 4.7 of Report 9’s 2nd edition discusses the manufacturing and certification documents required to be delivered by USM builders. The section has been significantly reworked to add description of required dimensional measurements, leakage tests, etc.

Performance Requirements

One of the most important parts of AGA 9 is Section 5, Performance Requirements. This section discusses minimum performance requirements the USM must meet. It does not require flow calibration, but rather relies upon the accuracy of manufacturing and assembly to infer accuracy.

This section also defines a variety of terms including three new flow rate terms. They are Q_{max} , Q_t , and Q_{min} . Q_{max} is the maximum gas flow rate through the USM as

specified by the manufacturer. Q_t is the flow rate, as defined by the manufacturer, that's the lowest before accuracy specifications are relaxed (greater error is permitted below this flow rate). Q_{min} is the lowest flow rate the user might operate where below this value the error is outside that as specified by AGA 9.

AGA 9 separates ultrasonic meters into two categories; *smaller than 12" and meters that are 12" and larger*. This division was created to allow relaxed accuracy requirements for smaller meters where tolerances are more difficult to maintain. All other requirements, including repeatability, resolution, velocity sampling

interval, peak-to-peak error and zero-flow readings are the same, regardless of meter size.

The maximum error allowable for a 12-inch and larger ultrasonic flow meter is $\pm 0.7\%$, and $\pm 1.0\%$ for small meters. This error expands to $\pm 1.4\%$ below Q_t , the transition flowrate. Within the error bands, the error peak-to-peak error (also thought of as linearity) must be less than 0.7% . The repeatability of the meters must be within $\pm 0.2\%$ for the higher velocity range, and is permitted to be ± 0.4 below Q_t . Figure 1 is a graphical representation of these performance requirements as shown in AGA 9.

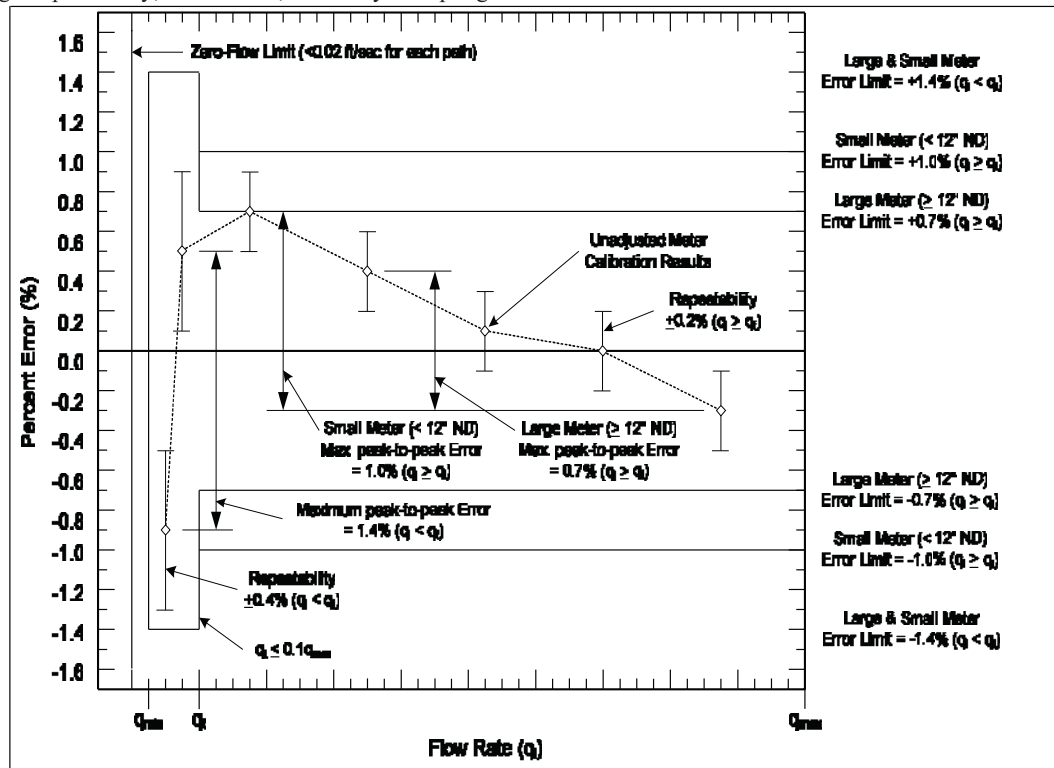


Figure 1 – Performance Specification Summary, 2nd Edition

Section 5 also discusses the potential effects of pressure, temperature and gas composition on the USM. Here it states “The UM shall meet the above flow-measurement accuracy requirements over the full operating pressure, temperature and gas composition ranges without the need for manual adjustment, unless otherwise stated by the manufacturer.” There has been some concern about calibrating a USM at one pressure and then operating at a different pressure. Although there are a variety of opinions on this, most believe the meter’s accuracy is not significantly impacted by pressure [Ref 15] since there has not been correlation with significant per pat Speed of Sound measurements (one would expect if the meter were changing dimensions due to pressure change that a path

length change would result and turn up in a path SoS deviation).

§6 INDIVIDUAL METER TESTING REQUIREMENTS

Section 6 discusses how the manufacturer will perform tests on the USM prior to shipment. Many also call this testing dry calibration. In reality dry calibration is simply an assembly process to help verify proper meter operation prior to being installed in the field. Since there were no calibration facilities in North America until the late 1990’s, it was felt that if a manufacturer could precisely control the assembly process, flow calibration would not be required. Hence the term dry calibration has often been used to describe this section.

AGA 9 requires the manufacturer to document the internal diameter of the meter to the nearest 0.0001 inches. This is to be determined from 12 separate inside diameter measurements. This dimension is to be adjusted back to 68 °F and reported on the documents. Measurements should be traceable to a national standard such as NIST, the National Institute for Standards and Technology.

Individual meters are to be tested to strict tolerances for leaks and imperfections. AGA 9 also specifies a Zero-Flow Verification Test and a Flow-Calibration Test procedure (although a flow-calibration is not required).

If a flow calibration is performed, AGA 9 recommends the following flow rates: Q_{min} , $0.1Q_{max}$, $0.25Q_{max}$, $0.4Q_{max}$, $0.7 Q_{max}$ and Q_{max} . These are simply suggested data points, and the designer can specify different, and more, if they feel it is needed. Generally speaking virtually all meters used for fiscal measurement are flow calibrated.

After flow calibration, the user is given any number of options for adjustment. A flow-weight mean error (FWME) correction scheme is suggested for determining a single meter factor. However, more sophisticated techniques are also permitted such as polynomial and multi-point linearization.

If a USM is calibrated, AGA 9 discusses requirements the calibration facility must adhere to. These include documenting the name and address of the manufacturer and test facility, model and serial number of the meter, firmware revision and date, date of test, upstream and downstream piping conditions, and a variety of other data that is to be included in the test report. The test facility must maintain these records for a minimum of 10 years.

No significant changes have been proposed to §6 at this time.

§7 INSTALLATION REQUIREMENTS

A proposal has been made to move most of this material into an expanded Section 5 (Performance Requirements), but to avoid confusion in this paper, changes will be discussed as if the material is retained in Section 7. Many of the variables the designer should take into consideration when using USMs are addressed, such as operating conditions and meter tubes. Some of the information that went into this section was based upon actual testing, but much was based upon a comfort level that was achieved with other electronic measurement products such as turbine and orifice meters.

In the environmental section basic information that the designer should be mindful of is discussed. This includes ambient temperature, vibration and electrical noise considerations.

Proposed Changes:

- Mfg's shall specify ambient temperature limits

- Process section to be added to indicate guidance for operating conditions such as pulsating flow and a more detailed discussion of potential noise impacts on USM operation.
- Recommended Default Configuration may be modified to eliminate the optional entrance to the meter run through either a tee or elbow, and replaced with... crickets. Seriously, this issue is being hotly debated and an outcome cannot be predicted at this time.

Piping Configuration

The piping configuration section is probably one of the more important and controversial sections in Report 9 due to USM sensitivity to profile distortions, and the influence tees, elbows, flow conditioners and other piping element have on flow profile. Since custody USM's are routinely flow calibrated, usually with meter runs, and then installed in field piping, there can be differences between the flow lab piping and the field installation which cause differences between flow profile as-tested and as-installed. Should this occur, it is possible that meter indicated volume output can shift!

Report 9's 1st Edition was developed with only limited empirical data. This is due in part to the lack of test data that was available in 1998, and unfortunately that dearth still existed at the time the 2nd Edition was published in 2007. For instance, Section 7.2.2 of AGA 9 discusses upstream piping issues. The intent here is to provide the designer with some basic designs that will provide accurate measurement. It states "Recommend upstream and downstream piping configuration in minimum length — one without a flow conditioner and one with a flow conditioner — that will not create an additional flow-rate measurement error of more than $\pm 0.3\%$ due to the installation configuration. This error limit should apply for any gas flow rate between q_{min} and q_{max} . The recommendation should be supported by test data." In other words, the manufacturer is required to let the designer know what type of piping is permitted upstream so that the impact on accuracy will not be greater than 0.3%.

In 1998 most manufacturers felt their product was relatively insensitive to upstream piping issues, and that was true in applying a performance standard commensurate with Turbine meters of $\pm 1\%$ (at that time). However, discovery that USM's could perform to better than $\pm 0.5\%$, and industry's desire to make that improvement have demonstrated that these effects cannot be ignored. Much data has been taken and published since 1998, and, as a consequence of this data, and the desire to provide the highest level of accuracy, most users have elected to use a high-performance flow conditioner with their USM. Testing has shown that the use of a 19-tube bundle, typical with turbine and orifice metering, will not improve the USM performance, and in most cases actually will degrade accuracy [Ref 7].

Some testing had been completed on step changes between the USM and the upstream and downstream piping [Ref 16]. The data basically showed the meter to be relatively insensitive to these changes. Based upon typical tolerances of pipe manufacturers, it was agreed to use a tolerance of 1%. In reality the step change is much less, especially if the designer specifies machine-honed pipe.

Regarding the surface finish and upstream lengths of piping require, AGA 9 was silent on this issue in 1998, but indicated that finishes of 250 μ in or smoother could discourage fouling; no change is expected to this guideline threshold.

Just like a turbine meter, a USM requires temperature measurement. AGA 9 recommends the thermowell be installed between 2D and 5D downstream of the USM on a uni-directional installation. It states the thermowell should be at least 3D from the meter on a bi-directional installation. This was based on some work done at SwRI under the direction of GRI in the 1990's. They found a slight influence at 2D upstream of USMs during some testing and thus the committee settled on 3D as a reasonable distance.

A discussion on USMs must include flow conditioners. The promise of the USM was they could handle a variety of upstream piping conditions, and that there was no pressure drop. However, today the users are looking to reduce measurement uncertainty to a minimum value. Thus, most designers today do specify a high-performance flow conditioner.

No discussion on USMs would be complete without talking about how one gets from the meter's uncorrected output to a corrected value for billing. Since the USM is a linear meter, like a turbine, rotary and diaphragm (flow rate is linear with velocity), the same equations used for these devices apply to the USM. That is, to convert uncorrected flow from a USM to corrected flow, the equations detailed in AGA 7 are used.

REFERENCES

1. AGA Report No. 9, *Measurement of Gas by Multipath Ultrasonic Meters*, 2nd Edition, April 2007, American Gas Association, 1515 Wilson Boulevard, Arlington, VA 22209
2. AGA Engineering Technical Note M-96-2-3, *Ultrasonic Flow Measurement for Natural Gas Applications*, American Gas Association, 1515 Wilson Boulevard, Arlington, VA 22209
3. GERG Technical Monograph 8 (1995), *Present Status and Future Research on Multi-path Ultrasonic Gas Flow Meters*, Christian Michelsen Research AS, the GERG Project Group and Programme Committee

§8 FIELD VERIFICATION

Section 8 briefly discusses field verification requirements. Since each USM provides somewhat different software to interface with the meter, AGA 9 was not too specific about how to verify field performance. Rather they left it up to the manufacturer to provide a written field verification procedure that the operator could follow. Many papers have been given on this subject and to some degree the field verification procedures are meter-manufacturer dependent [Ref 17 & 18].

The 2nd edition made limited progress on Field Verification, but it is intended the 3rd edition will be much more expansive regarding Field Verification practice. Much debate is occurring on these topics now to insure recommended practice matches Operator requirements, current Field practice and Manufacturer capability, and since this discussion is on-going, it is difficult to state proposed changes due to their number and variety.

Typically today the operator would check the basic diagnostic features including velocity profile, speed-of-sound by path, transducer performance, signal to noise ratios and gain. One additional test is to compare the meter's reported SOS with that computed by a program based upon AGA 8 [Ref 19].

At the time of the first release there was no universally excepted document that discussed how to compute SOS. However, in 2003 AGA published AGA Report No. 10, *Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases* [Ref 20]. This document, based upon AGA 8, provides the foundation for computing SOS that most software uses today, and is incorporated by reference into the 2nd Edition. It will pass that AGA 10 collapses into AGA 8 and that the SoS calculation will be harmonized, to some extent with SGERG, the European consortium's method to calculate SoS in hydrocarbon mixtures. This effort is underway now.

- No. 2 - Transmission and Storage, Groupe Européen De Recherches Gazières
4. OIML R 6 *General provisions for gas volume meters*, 1989 (E), International Recommendation, Organization Internationale de Métrologie Légale, Bureau International de Métrologie Légale, 11, rue Turgot - 75009 Paris - France
5. OIML D 11 *General requirements for electronic measuring instruments*, 1994 (E), International Document, Organization Internationale de Métrologie Légale, Bureau International de Métrologie Légale, 11, rue Turgot - 75009 Paris - France
6. AGA Transmission Measurement Committee Report No. 7, *Measurement of Gas by Turbine Meters*,

- American Gas Association, 1515 Wilson Boulevard,
Arlington, VA 22209
7. T. A. Grimley, *Ultrasonic Meter Installation Configuration Testing*, AGA Operations Conference, 2000, Denver, CO
 8. John Lansing, *Dirty vs. Clean Ultrasonic Flow Meter Performance*, AGA Operations Conference, 2002, Chicago, IL
 9. John Stuart, Rick Wilsack, *Re-Calibration of a 3-Year Old, Dirty, Ultrasonic Meter*, AGA Operations Conference, 2001, Dallas, TX
 10. James N. Witte, *Ultrasonic Gas Meters from Flow Lab to Field: A Case Study*, AGA Operations Conference, 2002, Chicago, IL
 11. Code of Federal Regulations, Title 49 — Transportation, Part 192, (49 CFR 192), *Transportation of Natural Gas and Other Gas by Pipeline: Minimum Federal Safety Standards*, U.S. Government Printing Office, Washington, DC 20402
 12. NFPA 70, *National Electrical Code*, 1996 Edition, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269
 13. John Lansing, *Basics of Ultrasonic Flow Meters*, ASGMT 2000, Houston, TX
 14. Klaus Zanker, *Diagnostic Ability of the Daniel Four-Path Ultrasonic Flow Meter*, Southeast Asia Flow Measurement Workshop, 2003, Kuala Lumpur, Malaysia
 15. Dr. Jim Hall, William Freund, Klaus Zanker & Dale Goodson, *Operation of Ultrasonic Flow Meters at Conditions Different Than Their Calibration*, NSF MW 2002, Scotland
 16. Umesh Karnik & John Geerlings, *Effect of Steps and Roughness on Multi-Path Ultrasonic Meters*, ISFFM 2002, Washington, DC
 17. John Lansing, *Smart Monitoring and Diagnostics for Ultrasonic Meters*, NSF MW 2000, Scotland
 18. John Lansing, *Using Software to Simplify USM Maintenance*, AGA Operations Conference, 2003, Kissimmee, FL
 19. AGA Transmission Measurement Committee Report No. 8, *Compressibility Factors of Natural Gas and Other Related Hydrocarbon Gases*, American Gas Association, 1515 Wilson Boulevard, Arlington, VA 22209
 20. AGA Report No 10, *Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases*, July 2002, American Gas Association, 1515 Wilson Boulevard, Arlington, VA 22209
 21. John Lansing, *Ultrasonic Meter Station Design Considerations*, Western Gas Measurement Short Course, 2003, Victoria, BC, Canada
 22. John Lansing, *Benefits of Flow Calibrating Ultrasonic Meters*, AGA Operations Conference, 2002, Chicago, IL