AGA-9 MEASUREMENT OF GAS BY MULTIPATH ULTRASONIC METERS

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ABSTRACT

The American Gas Association published Report No. 9, *Measurement of Gas by Multipath Ultrasonic Meters* [Ref 1] in June 1998. It is a recommended practice for using 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 contents and 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 2006.

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 0f 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 competition 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 schedule 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

This section of the paper provides a brief overview of the various sections in AGA 9.

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 one with at least two independent acoustic paths used to measure transit time difference of sound 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. Thus, AGA 9 does not tell the manufacturers how to build their meter, but rather provides information on the performance the product must meet.

TERMINOLOGY

Section 2 of AGA 9 discusses terminology and definitions that are used throughout the document. Terms like auditor, designer, inspector, manufacturer, etc. are defined here.

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.

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 is 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 GRI/MRF (Gas Research Institute/ 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 de-pressurized, 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.

In 1998 ultrasonic meters were not common pipeline devices and many operators are unfamiliar with them. AGA 9 includes directions for the manufacturer in marking their product. These instructions are valuable as they will alert users as to the pertinent information that may affect the performance of the meter.

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.

Electronics

Much discussion was given 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 communication 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 a 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 each USM manufacturer of has 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. Thus, the serial link was, and for the most part still is, used primarily 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.

The 2007 version of AGA 9 does not incorporate any significant changes to this section. One statement was added that the manufacturer can provide, as an option, the ability for the electronics to go either to zero frequency, or a user-selected value, when the meter capacity has been exceeded. The purpose of this option is to help users that are using frequency for automated run switching to open the next meter run in the even the meter is over-ranged.

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 well 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.

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 ±0.7%, and ±1.0% for small meters. This error expands to ±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 with ±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.

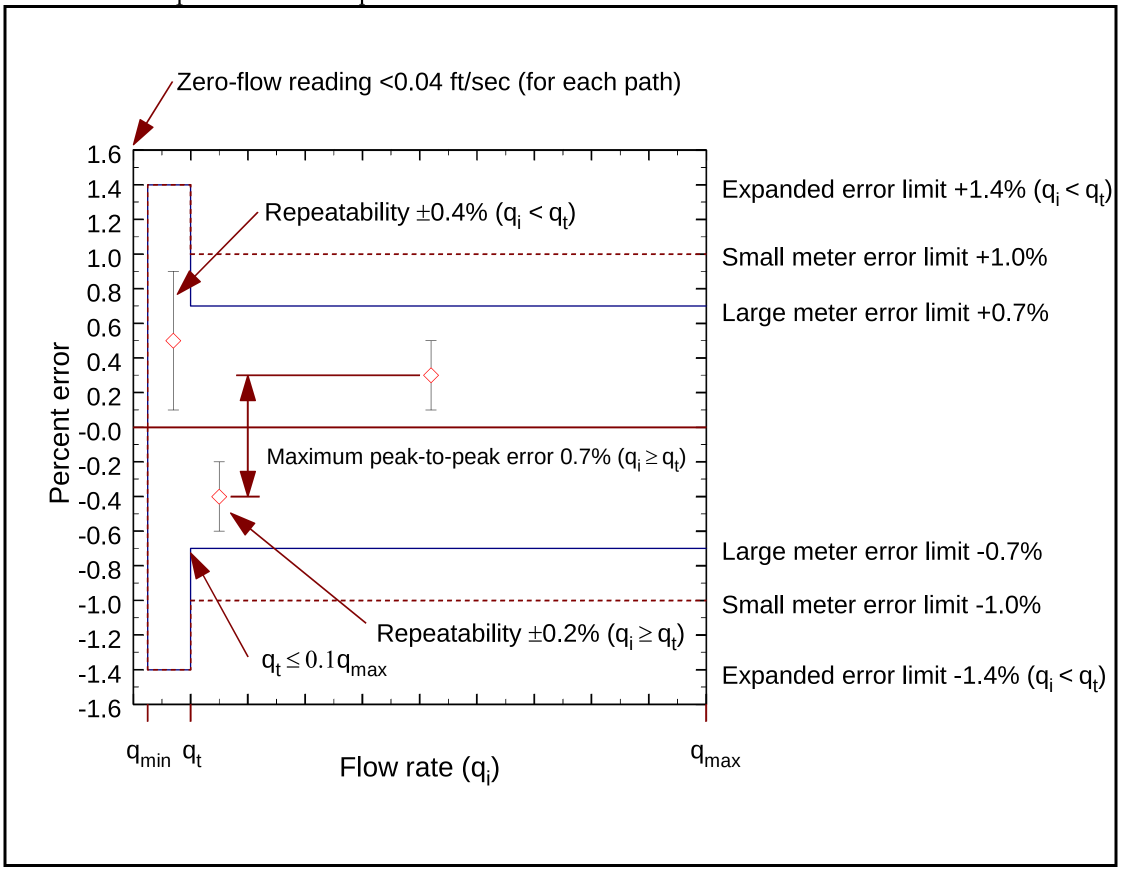

Figure 1 – Performance Specification Summary

Section 5 also discusses the potential effects of pressure, temperature and gas composition on the USM. Here is 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 feel the meter's accuracy is not significantly impacted by pressure [Ref 15].

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 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: Qmin, $0.1Q_{max}$, $0.25Q_{max}$, $0.4Q_{max}$, 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.

INSTALLATION REQUIREMENTS

Section 7 discusses many of the variables the designer should take into consideration when using USMs. 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.

The piping configuration section is probably one of the more important sections, and yet it was developed with only limited empirical data. This is due in part to the lack of test data that was available in 1998. 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. Much has been published since that date, 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 has been silent on this issue. Many customers prefer the finish to be less than 300 μ inch (micro-inch) because they feel it is easier to clean should the piping become dirty. However, AGA 9 has no such requirement.

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.

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].

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 computer 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.

AGA 9 – SECOND REVISION CHANGES

A significant amount of testing has been performed since 1998. More than two thousand USMs have been installed, with the majority in fiscal measurement applications. For more than 5 years the TMC committee has been working on the second revision. At the time of this paper Paul LaNasa of CPL & Associates and Warren Peterson of TransCanada Pipeline are co-chairing this revision. Revision 2 was sent out for ballot late in 2005. Comments were collected and resolved through a series of meetings at the AGA TMC meetings. Two separate meetings were held to resolve mostly editorial comments.

The final version will incorporate more requirements on the USM. These include changes and/or added discussion on meter accuracy, flow calibration, audit trail, meter and flow conditioner qualification, pressure effects, transducer and electronics change out, piping lengths, ultrasonic noise from control valves, and a discussion on uncertainty analysis.

Section 2, Terminology, Units, and Definitions

This version expands from Terminology to provide to also include Units and Definitions. Many new definitions were added to be more consistent with other AGA documents. Significant additions include Accuracy, Confidence Level, Discrete Error Values, Error, Maximum SOS Path Spread, Repeatability and Reproducibility just to name a few. The intent is to provide the reader with a clearer understanding of the various terms used throughout the document.

Section 3, Operating Conditions

Section 3 remains similar to the original version but has one significant addition to discuss acoustic noise. During the past several years, designers, users and manufacturers have all learned more about the impact of control valves on the USM. This release of AGA 9 provides more information to caution the user about the potential interference with the USM should a control valve be located too close, or the differential pressure to excessive. Ultrasonic noise from a control valve can render the USM inoperative [Ref 21]. As all manufacturers use different transducer designs and path layouts, there can be significant differences in recommendations for addressing the noise from control valves.

Section 4, Meter Requirements

Section 4 also remains similar to the original version but with a couple of additions. The original version required the meter to have a uniform bore throughout the meter. This version will permit the measurement section to have a different bore than the upstream and downstream piping through the use of a taper on the inlet and outlet. Additionally this version will require the meter's measurement section to have a constant bore with 0.5%, effectively eliminating the use of out-of-round pipe.

A section on Quality Assurance has been added to require the manufacturer to have a comprehensive quality assurance program in place.

An option has been added to the Output Signal Specifications Section that would permit selecting what the frequency output should do in the event the meter is over-ranged. That is, should the frequency go to zero or to some user-selected value. This is important in the event the meter is over-ranged (traditionally the frequency would go to zero) and the output is used for automatic run switching. If the meter's output simply went to zero, the automatic run switching would not activate an additional run since the frequency would normally be zero.

A section on component replacement was also included to discuss the requirements of the manufacturer to meet certain accuracy requirements in the event of component replacement. This includes transducers, cables, electronic parts and software.

Section 5, Meter Performance Requirements

Section 5, Meter Performance Requirements, has undergone some changes as well. First, the definitions that were once part of this section have been move to Section 2. New accuracy requirements of Speed of Sound Deviation have been incorporated (±0.2%). Additionally the Zero Flow Reading has been reduced from 0.04 ft/s to 0.02 ft/s for each acoustic path. This should help improve the low velocity performance of the USM. Basic meter accuracy remains the same.

One important change will be the requirement for flow calibration if the USM is to be used for fiscal measurement. In the first release of AGA 9, since there were no calibration facilities in North America that could perform full-scale calibrations for 8-inch and larger meters, the committee decided that flow calibration was optional. However, today there are two facilities in North America that can perform full-scale calibrations on 30-inch meters. The many benefits of flow calibrating the USM has been well documented [Ref 21]. Thus, with the interest in reducing uncertainty, calibration will be required.

Today, the issue of calibrating a meter at a different pressure than it is operated at is not discussed as much as before. Most users recognize that meters that are designed to be installed in ANSI 600 applications have very little shift over the typical operating pressure range that they will be installed. Ss the technology expands to into lower pressures applications such as Distribution, calibration pressure may be more important. However, for the traditional Transmission applications in North America, specifying a calibration pressure is typically not required or done.

Section 6, Individual Meter and Metering Package Testing Requirements

The original AGA 9 section title was Individual Meter Testing Requirements but this version it has been expanded to include the metering package (flow conditioner and associated piping). Since most designers include piping and a flow conditioner when calibrating the UM, the section was change to accommodate this.

Much of this section remains the same but there are some additions including the Speed of Sound (SOS) being within ±0.2% compared to the theoretical speed of sound from AGA 10 [Ref. 10].

For applications that are fiscal measurement, flow calibration is required. The new recommended flow rates are 2.5, 5, 10, 25, 50, 75 and 100 percent of Q_{max}. This essentially equates to calibrating from something like 2.5 fps (0.75 m/s) to 100 fps (30 m/s). Today most users limit their meter design to operate the meter at no greater than 80 fps. Thus it is common for many to calibrate from 1-80 fps (0.3-25 m/s). Again, these are only recommendations and the user is still permitted to include more than the recommendation.

The subject of meter accuracy relative to different flow conditioners and the uncertainty of the various calibration facilities has been addressed in this section. The issue is some flow conditioners may cause a shift in meter accuracy compared to the same meter calibrated without a flow conditioner. Since virtually all designers specify using a flow conditioner, some additional tolerance was suggested to allow for small changes in the meter factor when the UM is used with a flow conditioner (accuracy specifications in this section apply only to the meter).

In the past when meters were calibrated the question about what to do with a meter that did not meet the dry calibration requirements as spelled out in Section 5. In order to address this, the 2007 version of AGA 9 now permits an additional 0.3% increase in the meter accuracy tolerance to take into consideration the potential influence the piping and flow conditioner(s) may have. This a new paragraph has been added that states the following: "If the meter calibration adjustment factor exceeds the error limit of 1.0% for large meters and 1.3% for small meters between q_t and q_{max}, against the calibration facility reference, then further investigation is recommended." This now permits the user to accept a meter that is outside the dry calibration accuracy requirements if they feel the other performance requirements of the meter have been met (linearity, repeatability, etc.).

In the sub section on Calibration Reports some additional documentation if now required by the test facility. This includes the serial number of the flow conditioner and piping (if available), identification of the type of meter adjustment method (single FWME, piece-wise linearization, etc), and numbering of the pages.

Section 7, Installation Requirements

In Section 7, Installation Requirements includes two recommended default piping designs, one for uni-directional and one for bi-directional applications. For the uni-directional design there is a recommendation of two 10D upstream spools with a flow conditioner in the middle (10D from the meter). For the bi-directional design, both upstream and downstream recommendation would be two 10D spools with flow conditioners again located 10D from the meter. See Figure 2 for an example of the piping design recommendations. These are only recommendations and the use of the optional Tee or Elbow is strictly optional.

Surface finish of the piping used with a USM has now been discussed. Section 7.2.4 states "Experience has shown that a meter tube internal surface of 250 µinch Ra or better smoothness can be advantageous in minimizing contamination build up." However, this version of AGA 9 stops short of requiring that the surface finish be 250 µinch Ra or better. Thus it is only a recommendation and there is no requirement for using honed pipe.

The first release of AGA 9 indicated the thermowell should be at least 3D from the meter for bi-directional applications. Some have interpreted this to mean that 13D from the meter is satisfactory. This version will is no more specific and requires the location to be between 3 and 5D downstream of the meter.

A new section on meter tube ports has been added. There have been some instances where large ports were included in the upstream and downstream piping. These openings have caused unusual calibrations characteristics. As a result AGA 9 now states the port diameter should not exceed 6% of the pipe diameter. Inspection ports can be included up to 0.75" in diameter, where physically practical. From AGA 9, it states "Meter tube inspection ports, if utilized, should be located a minimum of 3D downstream and/or 3D upstream of the ultrasonic transducers and/or upstream of the flow conditioner inlet position." This is to minimize any potential interference with the flow profile.

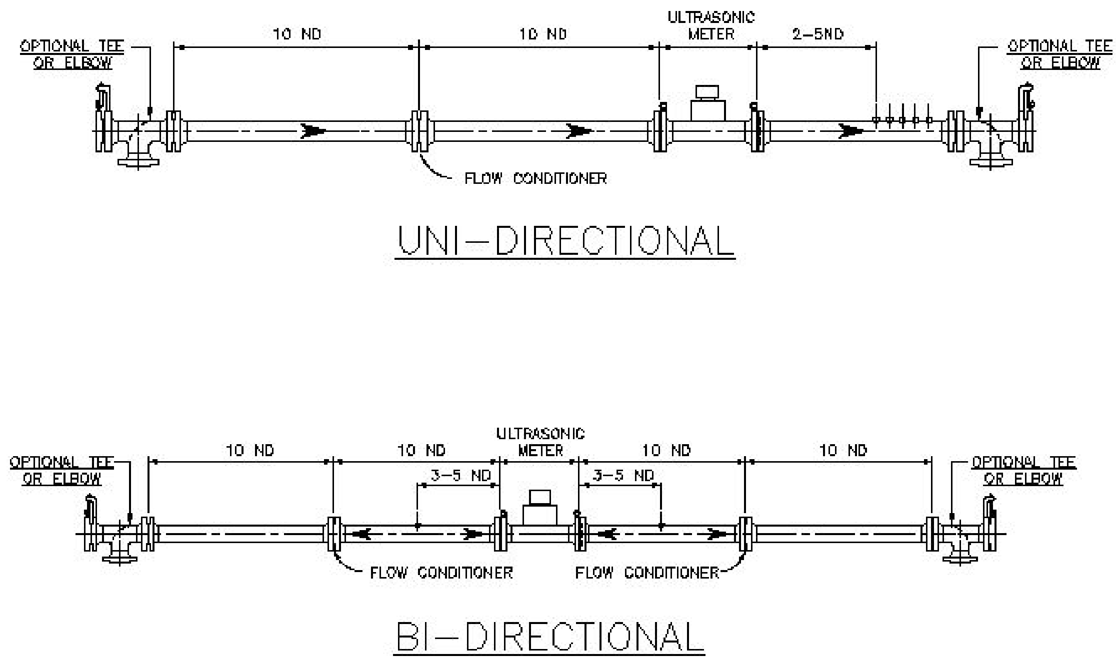

Figure 2 – Recommended Default Unidirectional and Bi-directional Installations

The subsection on Maintenance has been expanded to discuss issues that may occur in the field such as contamination. This section also discusses borescope inspection and the benefits of identifying potential internal deposits that can impact accuracy.

Section 8, Field Verification Tests

This section basically remains unchanged. It simply indicates the user should check their meter periodically to insure proper operation.

Section 9, Ultrasonic Meter Measurement Uncertainty Determination

This is a new section that discusses the uncertainty of the USM. The types of uncertainties included are meter calibration, field, secondary instrumentation and a reference to an analysis procedure that is included in an Appendix. This will help the designer understand all the various components that contribute to the total installed uncertainty of using a USM.

CONCLUSIONS

During the past several years much has been learned about the use of ultrasonic meters. Testing has been conducted not only by a variety of agencies such as GTI (formally GRI), but by end users and calibration facilities. This information is be used to provide more guidance to the designer and user of USMs.

In the 1990's metering accuracy was important, but today it is even more critical now that the price of natural gas is consistently above \$5 per thousand cubic feet, and at times approaching \$15 per thousand cubic feet. As a consequence designers are challenged to further reduce uncertainty. Requiring flow calibration, providing recommendations on piping, and adding accuracy requirements for SOS are all intended to reduce uncertainty in the field.

Today, in North America, most transmission and many distribution companies are using USMs for fiscal measurement. Even though ultrasonic meters have been used for more than a decade, the industry is still learning. During the coming years certainly improvements by all manufacturers will continue. The second release of AGA 9, which is expected to be available by March 2007, will provide a substantial improvement in the document. However, just like all AGA documents, there were features that did not make this release. Most certainly there will be a future revision to address these and incorporate additional lessons learned about this technology.

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