AN OVERVIEW AND UPDATE OF AGA 9

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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 spring of 2017.

INTRODUCTION/BACKGROUND

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, and is included as Appendix C in the 2007 edition, but it is deleted from the upcoming revision since most of the principles described in it have been adapted to the Report's text.

After competition of the Technical Note, the AGA TMC began the developing a new Report for custody application of gas USM technology. More than 50 contributors participated in its development, and included participants from the USA, Canada, The Netherlands, and Norway, representing a broad cross-section of measurement personnel in the natural gas industry at the time (circa 1997).

AGA 9 incorporates many of the recommendations in the GERG Technical Monograph 8 [Ref 3] and certain related OIML [Ref 4 & 5] recommendations. Since USM's are linear meters, much of the document was patterned around AGA 7, *Measurement of Gas by Turbine Meters* [Ref 6], another linear device. Most of the performance requirements in revision 1 of AGA 9 were based on the limited test data available at the time, and absent high rate test labs. Where no data was available to support a specific requirement, AGA 9 was silent, or left it up to the manufacturer to specify.

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 range conditions over which the USM shall perform with specified accuracy. 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, titled “Meter Requirements”, addresses specific mechanical and electrical reuqirments manufacturers need meet to operate the devices in a hazardous environment. Sub-sections on codes and regulations, meter body markings, ultrasonic transducers, electronics, computer programs, and supporting documentation are included.

§4.3 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.

External and Internal Corrosion resistance and compatibility with gas mixtures commonly found in today’s pipeline is stipulated.

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. Experience shows that transducers are rarely extracted under pressure, since many meter stations employ multiple runs, making short term outages possible. This allows de-pressurization and transducer removal after blow-down. Additionally, once the meter run is de-pressurized, the internal condition of the meter and associated piping can be inspected if boroscope and inspection ports are available.

Proposed Changes:

- Reference to use of extraction tools is eliminated.

§4.4 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.
- §4.4.3, “Exchange”, in reference to transducers, is deleted and replaced with existing §4.4.4, “Transducer Tests” , which itself remains unchanged.

§4.5 Electronics

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 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.

A majority of users apply the frequency output as input to flow computers. Most USM manufacturers employ standard Modbus collection of measurement information via a serial link or Ethernet adapter. Additional serial or Ethernet ports are used for local 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, now making it an option.
- Added statement that a scaled 4-20 ma output is not to be used for custody measurement.

- Delete of the paragraph specifying "significant change" as +/- 0.2% shift in the meter's output, and new stipulation that Manufacturer's replacement of cables, electronics, transducers, etc won't shift meter output more that Manufacturer stated repeatability (0.2%).

§4.6 ~~Computer Programs~~ Meter Firmware and Software

USMs typically do not provide a local display or keyboard for communicating with the meter as is traditional with some flow computers. USM Manufacturers provide their meter specific software for meter configuration and diagnostic interrogation. There are few specific diagnostic data requirement in manufacturer's to have similar looking and functioning software, but Report 9 does cite some in §4.6.4, "Meter Diagnostics".

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.

§4.7 ~~§6 Individual Meter Testing Requirements~~ Moved to "dimensional measurements" et al

Section's 4.7 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).

No significant changes have been proposed to §4.7 at this time.

§4.8 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.

§5.0 ~~Performance Requirements~~ Installation (was §7 in second edition of Report 9)

Many of the variables the designer should take into consideration when using USMs are addressed, such as operating conditions, use of flow conditioners and meter tube configurations etc.

§5.2 ~~Piping Configuration~~ Metering Package Design Criteria

Report 9's 1st Edition was developed with only limited empirical data. The 2nd Edition, published in 2007 was not much of an improvement. For instance, Section 5.2 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 reality this is difficult given the variety of upstream pipe configurations operators use, so the so-called end-treatments (or entrance/exit piping) are often included in the calibration of the "metering package".

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]. However, high performance flow conditioners, usually specified in meter package design, help to obtain a uniform and repeatable flow profile.

Proposed Changes:

- Process section 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 Meter Run Configurations (§5.2.3) are modified to eliminate the optional entrance to the meter run through either a tee or elbow, leaving users to their design preference so long a meter performance meets §6 requirements.

Corrected flow rate output requires USM metering packages include temperature measurement on the outlet leg of the meter run. 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 research done at SwRI sponsored by GRI in the 1990's. These studies found measurable influence onset at 2D downstream of USMs during and the committee settled on 3D as a reasonable distance.

§6.0 Performance Requirements

Since Report 9 is a performance based document, "Performance Requirements" are core to its scope, and it addresses minimum performance requirements the USM's must meet. It requires flow calibration for fiscal use.

AGA 9's second edition (2007) 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 edition preparing for release in 2017 will have 3 size ranges and new accuracy limits:

- >10" Max Error: +/-0.7% $q_t \le q_i \le q_{max;}$ +/-1.4% for $q_{min} \le q_i \le q_t$ with linearity of+/-0.2% for $q_t \le q_i \le q_{max}$
- 3"-8": Max Error: +/-1.0% $q_t \le q_i \le q_{max;}$ +/-1.4% for $q_{min} \le q_i \le q_t$ with linearity of+/-0.2% for $q_t \le q_i \le q_{max}$
- <3": Max Error: +/-2.0% $q_t \le q_i \le q_{max;}$ +/-3.0% for $q_{min} \le q_i \le q_t$ with linearity of+/-0.2% for $q_t \le q_i \le q_{max}$

Per the second edition, 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.

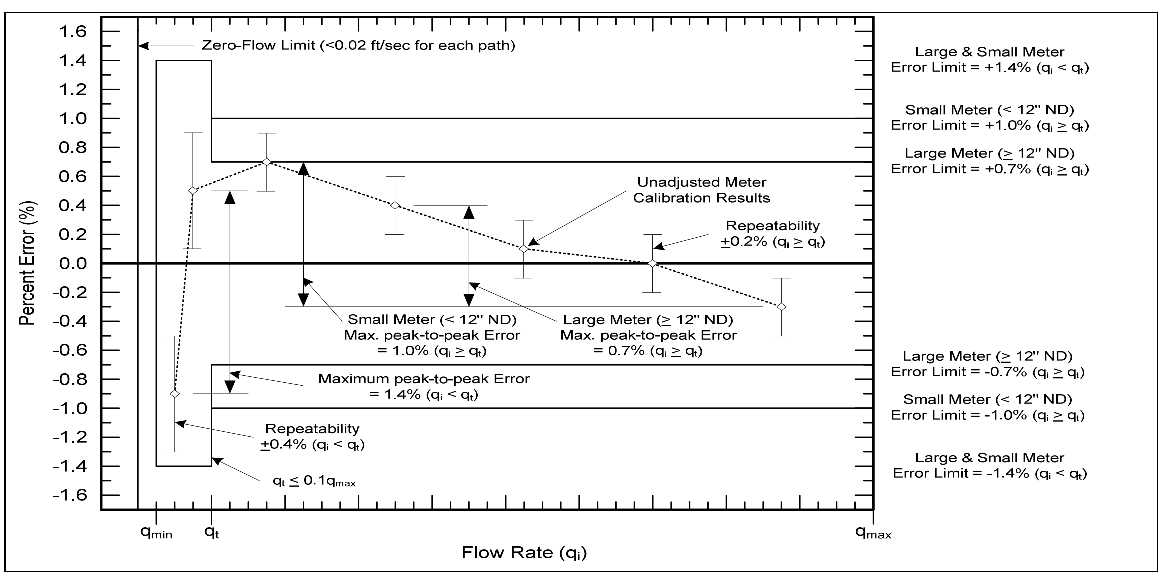

Figure 1 – Performance Specification Summary, 2nd Edition

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 believe the meter's accuracy is not significantly impacted by pressure [Ref 13] 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).

§7 COMMISSIONING & FIELD VERIFICATION

Section 7 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. 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 12].

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 13]. 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 nearly complete now and will result in an AGA 8 Equation of State document that includes AGA 10 Detailed and SGERG.

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