North Sea

FLOW

Measurement Workshop

1998

PAPER 9 - 3.1

NEW A.G.A REPORT NO9. MEASUREMENT OF GAS BY ULTRASONIC GAS METERS.

J Stuart, Pacific Gas and Electric Co.
K Warner, Daniel Europe Ltd

With regard to the second paper within submitted by Mr John W Stuart, the following re-print has been accepted in good faith by the organisers with responsibility for all permissions being accepted by the authors.

The Essence of A.G.A. Report No. 9, Measurement of Gas by Multipath Ultrasonic Meters

KEVIN L. WARNER, Ultrasonic Product Manager, Daniel Industries.

ABSTRACT

The American Gas Association has recently published (June, 1998) a new recommended practice; *Report No. 9, Measurement of Gas by Multipath Ultrasonic Meters*. This paper reviews some of the contents of A.G.A.-9 including recommended meter performance requirements, design features, testing procedures, and installation criteria. This paper is a companion to John Stuart's paper which was presented at the 1997 A.G.A. Operations Conference in Nashville, Tennessee entitled, *New AGA Report No. 9, Measurement of Gas by Multipath Ultrasonic Gas Meters*. It is also included here for easy reference. The topic selected in this paper were chosen based on the author's opinion of the audience's interests.

A.G.A-9 was drafted by the A.G.A. Transmission Measurement Committee which incorporated many of the recommendations in the GERG Technical Monograph 8 (1995) and certain related OIML recommendations. After over a year of technical discussions, balloting, and revisions, the document represents the consensus of several dozen metering experts in the US and Canada. It is hoped that A.G.A.-9 will soon be considered by ISO/TC 30 as the basis for a new ISO standard.

SELECTIVE REVIEW OF A.G.A. REPORT

Scope of Report

A.G.A.-9 was developed for multipath ultrasonic transit-time flow meters, typically 6" or larger and used for the measurement of natural gas. A multipath meter is defined as one with at least two independent measurement paths.

Meter Requirements : Codes and Regulations

A.G.A.-9 makes many statements which are essentially design instructions for manufacturers of meters. One reason this approach was taken was to insure the end user that an ultrasonic product would be safe and consistently manufactured. Unless otherwise stated, the meters are to be suitable for use in an area which is subject to the requirements of the U.S. Department of Transportation's regulations in 49 C.F.R. Part, 192, Transportation of Natural and Other Gas by Pipeline : Minimum Federal Safety Standards.

Meter Requirements : Meter Body

Manufacturers are urged to publish the overall lengths of their ultrasonic meter bodies. This is to help skid and other designers who may not be familiar with ultrasonic metering to define metering section dimensions.

The inside diameter of the ultrasonic meter should be within 1% of the upstream tube's diameter. The value of 1% was based mainly on early European studies and also work performed at Southwest Research Institute in San Antonio, Texas. Other meter requirements in this include anti-roll devices (feet), pressure tap location on the meter, and standard meter markings. These requirements were based on field experience and the lessons learned from other metering technologies.

Meter Requirements : Ultrasonic Transducers

Ultrasonic transducers are not common pipeline devices and many operators are unfamiliar with their properties. A.G.A.-9 includes clear directions to the manufacturer for the specification, marking, and testing of transducer pairs. These instructions are valuable because they will alert users as to the pertinent information which may affect the performance of the meter. A.G.A.-9 also requires that transducers be manufactured so that they may be exchanged and requires instructions for the exchange process.

Meter Requirements : Electronics

Much discussion was given to the issue of electronics and its evolution with time. The goal of the committee was to require electronics which were well tested and documented, but to allow improvements without placing a larger than necessary burden on the manufacturer. This idea is evident throughout the document but is especially relevant in the electronics and firmware sections.

The electronics output section includes two suggested types, serial and frequency, along with a list of others. Serial communication 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 convenient option, especially in locations which are configured for turbine meter inputs. A.G.A.-9 also mentions analog outputs, direction indicator, a low-flow cutoff, and volume accumulators.

Meter Requirements : Computer Programs

Since ultrasonic meters are electronic, the computer programs and information contained in the electronics of the meter are extremely important. A.G.A.-9 requires that it be possible to interrogate the meter and determine its calibration parameters. It also requires that the meter be securable, so that accidental or undetectable changes can be prevented.

Alarms and diagnostic functions are clearly addressed under the computer programs heading. These sections were difficult to compose because of the subtle differences associated with every different path configuration imaginable. The data which is required is of three main types, gas velocity, speed-of-sound, and electronic failure. The velocity data is to indicate flow profile irregularities or velocity range exceptions. The speed-of-sound data is to be used as a diagnostic tool to check for erroneous transit time measurement errors. Other data is required to judge the quality of the data such as "% of accepted pulses."

Performance Requirements

The heart of A.G.A.-9 is contained in the Performance Requirements section. A.G.A.-9 separates ultrasonic meters into two categories, smaller than 12" and meters which are 12" and larger. The division was created to allow looser performance requirements for smaller meters where tolerances are more difficult to maintain. The flow regime is also divided into regions. Essentially there are two regions, one low flow region and one high flow region. The flowrate dividing them is called the transition flowrate. Manufacturers are to provide the numerical values for minimum, maximum, and transition flowrates. There is a requirement that the maximum value be at least ten times greater than the transition flowrate.

The maximum error allowable for an ultrasonic flow meter is +/- 0.7% for large meters and +/- 1.0% for small meters. This error expands to +/- 1.4% below the transition flowrate. Within the error bands, the error curve for any individual meter may not span more than 0.7%, or one half the height of the error bounds for large meters. This is the linearity specification written in terms of the error curve. The repeatability of the meters must be +/- 0.2% for the higher velocity range and is doubled for the lower. These limits specify the performance of the meter prior to the application of any flow calibration adjustment, or in other words are a dry calibration requirement. A.G.A.-9 was written in this fashion to provide a very clear and logical picture in which to view a meter's performance based on readily available data, the error curve. The dry calibration requirement itself was deemed necessary to discourage any haphazard construction of meters with the intention of "correcting" them in the final stages through flow calibration.

Individual Meter Testing Requirements

Individual meters are to be tested to strict tolerances for leaks and imperfections. A.G.A.-9 also specifies a Zero-flow Verification Test and a Flow-Calibration Test procedure (although a flow-calibration is not required). These requirements were written mainly for consistency. After flow calibration, the user is given any number of options for adjustment (within the dry calibration limits described above), however the flow-weighted mean error method is suggested. More sophisticated multi-point schemes are also allowed.

Installation Requirements

A.G.A.-9 was written from the perspective of experienced gas measurement experts however each person freely admitted that they were still learning. This is evident and factually stated in the sections on installation requirements. Rather than specify numerical values for up- and down-stream pipe diameters, A.G.A.-9 requires test-supported recommendations from manufacturers of ultrasonic flow meters. These recommendations can take one of two forms. The manufacturer may define an up- and down-stream meter configuration which will not be biased by more than 0.3% from an installation effect (both with and without a flow conditioner) or the manufacturer may specify the flow profile deviation which will not bias the output of the meter by more than 0.3%. The user is also cautioned that protrusions, internal surface condition, thermowell position, valve noise, and flow conditioners may influence the meter's performance characteristics.

ACKNOWLEDGEMENT

Grateful acknowledgement is given to John Stuart for his contributions to this paper, accompanying presentation, and A.G.A.-9. It is this author's opinion that without John's diligent work ethic and patience there would be no A.G.A.-9.

New A.G.A. Report No. 9, Measurement of Gas by Multipath Ultrasonic Gas Meters

JOHN W. STUART, Principal Engineer, Pacific Gas and Electric Company

ABSTRACT

The new technology of multipath ultrasonic gas meters has been rapidly accepted by pipelines throughout the world as the meter of choice for high capacity meter stations. A.G.A.'s Transmission Measurement Committee has just finished writing *Report No. 9, Measurement of Gas by Ultrasonic Meters.* The contents of this new recommended practice for ultrasonic meters is summarized.

BACKGROUND

Ultrasonic technology has been used for liquid metering since the 1950's. In the early 80's, British Gas developed a multipath ultrasonic meter (UM) suitable for natural gas applications. During the past few years, several hundred multipath ultrasonic gas meters have been installed in pipelines all over the world. Indeed, the UM is the most significant metering technology adopted by the gas industry since the high pressure turbine meter was introduced in the 1960's.

STATE OF TECHNOLOGY

In 1995, GERG (Group European of Research Gas) published a very comprehensive technical monograph, *Present Status and Future Research on Multipath Ultrasonic Gas Flow Meters.* In 1996, A.G.A. published an Engineering Technical Note, *Ultrasonic Flow Measurement for Natural Gas Applications.* At the time this paper was written, UMs have been approved for legal metrology in twelve countries. Now that UMs have been accepted by the gas industry because of their high accuracy and low maintenance costs, the process of developing national and international standards is under way.

During the past few years, research results and flow calibration data have shown that UMs are very accurate when measuring gas with a good flow profile as found in calibration facilities. However, when measuring flow profiles disturbed by some combinations of upstream fittings and valves, UMs have exhibited a small amount of error. The amount of error is dependent on the type and severity of flow disturbance, and each manufacturer's unique methods of compensating for non-ideal profiles.

Therefore, unlike A.G.A.-3, no specific meter designs, or upstream piping configurations are recommended in A.G.A.-9. Instead the manufacturers are requested to provide technically defensible test data that demonstrate that their meters meet or exceed the performance requirements of A.G.A.-9 when installed in a piping system compatible with their meter.

PURPOSE OF A.G.A. REPORT

A.G.A.-9 will be published as a recommended practice and has been written in the format of a performance based specification. Specifications for meter accuracy, functionality, and various testing requirements are included along with some installation recommendations for the user. The intent is that A.G.A.-9, as a recommended practice, will be suitable for referencing in the following types of documents by anyone wishing to use UMs:

- Bid Specifications for furnishing and delivering an ultrasonic meter (Material Purchase Specifications)
- Engineering Contracts for A&E firms designing and constructing metering stations with ultrasonic meters
- Inter-Pipeline Operating Agreements for mutual agreement of using ultrasonic meters for custody transfer
- State and Federal Tariffs and Regulations for including ultrasonic meters as an alternative to orifice meters

SUMMARY OF A.G.A.-9 CONTENTS

Scope

The scope of A.G.A.-9 is limited to multipath ultrasonic natural gas flow meters, 6" and larger in diameter. Typical applications include measuring large flow rates at transmission pipeline interconnects, storage facilities, gas processing plants, city gate stations, and at power plants or other large end-use customer meter sets.

Principle of Measurement

Ultrasonic meters derive the gas flow rate by measuring the transit times of high frequency sound pulses. Transit times are measured for sound pulses traveling diagonally across the pipe, downstream with the gas flow, and upstream against the gas flow. The <u>difference</u> in these transit times is proportional to the average gas flow velocity along the acoustic paths. Numerical calculation techniques are then used to calculate the average axial gas flow velocity and the flow rate (acf/hr) through the meter.

The flow rate capacity range of an UM is determined by the actual velocity of the gas flowing through the meter, typically from 1 ft/s (0.3 m/s) to over 70 ft/s (21 m/s). Inherent in their design, UMs are bi-directional, measuring flow in either direction with equal accuracy.

The accuracy of an ultrasonic gas meter depends on;

- precise measurements of the meter body geometry,
- the accuracy of the transit time measurements,
- the quality of the flow profile and uniformity of the gas, and
- the flow profile integration technique.

Accuracy Requirements

A.G.A.-9 requires that the manufacturers test each UM design in a flow calibration facility to demonstrate that the UM <u>design</u> can meet the accuracy requirements specified below without actually adjusting or calibrating each meter.

- Maximum permissible error: ±0.7% of measured value
- Mean Flow Weighted Error (see below): less than ±0.5%

To further reduce a meter's measurement uncertainty, the user may as an option, have individual meters calibrated, i.e. output factors adjusted, based on flow tests at a calibration facility.

Presented at A.G.A. Operations Conference, May 19-21, 1997, Nashville Tennessee.

Users of UMs should also carefully follow the manufacturers installation recommendations, as any installation effects will add to the overall measurement uncertainty after the meter is installed.

The Flow Weighted Mean Error (FWME) is introduced as a way to quantify a meter's performance with a single number. FWME was developed in Europe, and uses a weighting factor proportional to the tested flow velocity to emphasize the accuracy at higher flow rates. FWME = SUM [(*Vi/Vmax*) • *Ei*] / SUM (*Vi/Vmax*), where *Vi/Vmax* is the weighting factor, and *Ei* is the error deviation indicated at the tested flow velocity *Vi*.

Electronics Design Tests

Manufacturers must also test the design of their electronic systems, including power supplies, microprocessors, ultrasonic transducers, and signal processing components. Unlike most traditional gas meters, ultrasonic meters inherently have an embedded microprocessor system. Therefore, A.G.A.-9 has included by reference, a international standardized set of testing specifications applicable to gas meter electronics. These electrical and mechanical tests serve to demonstrate the acceptable performance of the meter's design under different influences and disturbances; e.g., temperature, humidity, vibration, static electricity, voltage spikes, and radio transmissions.

Factory Zero Flow Tests

After the fabrication of each meter is completed, the manufacturer must perform a comprehensive set of shop tests to verify that all mechanical and electronic components meet specifications. For example, the internal diameter of the meter, and the distance between ultrasonic transducers must be carefully measured, verified, and documented.

An important test, key to the UM's ability to accurately measure at any flow rate, is the Zero Flow Verification Test done in the shop without any flow. Since UM flow rate measurements use the difference in acoustic pulse transit times, the most demanding test is at zero flow, where the measured transit times, upstream and downstream, must be exactly the same to indicate a zero flow rate. Another shop test is the speed of sound test which uses the average transit times to measure the speed of sound, which is then compared to a theoretical value based on the latest A.G.A.-8 equation of state.

Flow Tests

A flow calibration of each meter should not be necessary to meet the accuracy requirements specified in A.G.A.-9. However, flow calibrations guidelines are provided should a user want to verify the meter's accuracy, or to adjust the meter's output to minimize its measurement uncertainty. Flow calibration tests should be carried out at gas densities and velocities (i.e. flow profiles) near the expected operating condition.

Users are encouraged to release UM test results to the gas industry, before and after calibration factors are applied. This will enable manufacturers to demonstrate the accuracy of their un-calibrated meters, and facilitate research to improve UM technology. The Gas Research Institute currently has a project to collect this type of UM data.

Installation Effects

A.G.A.-9 alerts users that if an UM is installed with certain upstream piping configurations, it may exhibit measurement error if the flow profile has been disturbed to such an extent that the meter's design cannot correctly compensate. Research work on installation effects is on-going, and users should consult with the manufacturer and review the latest test results to determine if a specific UM design may be affected by the planned upstream piping configuration, and to evaluate any benefits of installing a flow conditioner or altering the piping configuration.

Maintenance

Manufacturers are requested to publish recommended maintenance procedures. Periodic maintenance may be as simple as using a remote PC to monitor several diagnostic measurements, such as ultrasonic signal quality and speed of sound for each acoustic path. Also, it may be possible to detect an accumulation of deposits on the transducer faces by measuring a reduction in the received ultrasonic pulse strength.

Whenever possible, users should verify that the UM measurement returns to near zero when gas stops flowing through the meter. When performing this test, users are cautioned that any meter run temperature differences will cause thermal convection currents of gas to circulate inside the meter which the UM can measure as a very low flow rate.

The internal surface of UMs should be kept clean of any deposits, which will reduce the meter's cross-section area. Accurate UM operation depends on knowing the precise cross-section area to convert gas velocity into a cubic volume flow rate. If a layer of deposits accumulate inside the UM, the cross-section area will be reduced, causing a corresponding increase in gas velocity and positive measurement error. For example, a 1/32" thick layer deposited around the inside of a 12" meter will cause a +1% flow rate error!

Inspection and Auditing Functions

UMs are required to have an audit function where the meter's configuration parameters, calibration factors, meter dimensions, and diagnostic values being used by the meter's signal processing system can be examined while the meter is in operation.

Field Verification Tests

A.G.A.-9 requests the manufacturers to develop a field verification test procedure to test various aspects of the UM to assure that it is operating properly and remains within the specified uncertainty limits. These procedures may include a combination of a zero flow verification test, speed of sound measurement analysis, internal inspection, dimension verification measurements, and other mechanical or electrical tests.

The manufacturers should also provide a rigorous uncertainty analysis to demonstrate that their field verifications tests are sufficient to preclude the need for periodic flow calibrations.

Appendix: Ultrasonic Technical Note

Included in the appendix of A.G.A.-9 as a comprehensive source of technical information on ultrasonic gas meters is, A.G.A. Engineering Technical Note M-96-2-3, *Ultrasonic Flow Measurement for Natural Gas Applications.*

CONCLUSION

While the ultrasonic meter has already been approved by the governmental authorities of a dozen foreign countries, the publication of A.G.A-9 will signal the acceptance of this new metering technology by the gas industry in the United States.

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.