AGA 7 - UNDERSTANDING AND APPLYING THE MEASUREMENT REPORT FOR TURBINE METERS

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ABSTRACT

This paper provides an overview of the 2006 revised AGA 7 document, which updates the recommended practice for measurement of natural gas by turbine meter into the form of a performance-based specification.

BACKGROUND

The prior, now superseded, revision of AGA 7 was published in 1996. Since then, a lot has changed in the field of gas measurement and with the turbine meters used, for instance: The introduction, by several manufacturers, of high capacity turbine meter models, with 30° vs. 45° rotor blades, for both single and dual rotor models; The increased field use of dual-rotor turbine meters; Tighter limits on lost and unaccounted for gas; Increased use of out-sourced services for meter station engineering design, construction and operations; The startup of several high capacity flow calibration facilities in North America; Interest in the potential benefits of Reynolds number equivalence flow calibrations using gases heavier than natural gas; Also the move towards performance-based specifications for all types of measurement devices. All together, these have re-enforced the need for the AGA 7 update.

AGA committee task group work for the revision began in the year 2000. In support of the revision, a significant amount of research and independent verification testing was conducted. The work was needed to update the performance capabilities of turbine meters commonly used in North America for natural gas transmission and distribution measurement. This included testing of turbine meters, from a representative cross-section of meter models and sizes, (i.e., standard and extended capacity, single rotor and dual rotor), currently available from various manufacturers. The areas of research investigation were: measurement performance, repeatability, range of flow operation, pressure effects, cartridge interchangeability, and piping installation influences.

INTRODUCTION

A lot has changed in the new AGA 7 – 2006 document. (It is recommended that a copy of AGA 7 be obtained and used to view the cited sections, figures and tables, while going through this paper.)

In general, much attention was given to the overall organizational structure, the concise presentation of the information, as well as the terms and wording used in the new document.

Throughout the document, will be found the deliberate placement and use of the words “shall”, “should” and “may”. The word “shall” is used to indicate a requirement for compliance, (for instance, where pressure containment integrity/safety is a concern or where information is necessary for the correct configuration, set-up and use of turbine meters to insure optimal measurement performance). The word “should” is used as a recommendation for action or compliance. For example, manufacturers should be consulted if the intended turbine meter applications have gas quality issues that could affect the measurement error or service life. The word “may” is used to designate optional features or provisions. For example, sealing arrangements may be provided on the meter for metrological assurance.

Also, throughout the document, references are made to the published research results conducted and relied on for guiding the revision. However, in most cases, the detailed results of the research reports are not included in the AGA 7 document, due either to the page space that would be necessary for adequate coverage or in consideration of the potential loss of content by condensing the test results. Users of turbine meters are encouraged to obtain these research reports, and consider them in their entirety, for the information that would apply to the intended turbine meter measurement application(s).

Significant areas of change:

- Performance based language and tolerances
- Calibration guidelines recommended
  - Elevated pressure and full flow
  - Use of equivalent Reynolds number
- Upstream flow conditioner options
  - Traditional 19 tube bundle
  - Isolating flow conditioner
  - or None
- Integral flow conditioning
  - Required for short and close-coupled
- Dual-rotor turbine meter benefits
- Output adjustments and linearization

Parts of the prior revision did not make it into the new document, with the intent of transfer to other AGA documents or industry publications for better subject coverage and for more appropriate referencing.

- Tube bundle conditioner construction details
- Accessory devices and instrument details
- Flow pulsation Index calculation equations
- Calibration and field proving methods
- Turbine meter theory & Figures on rotor slip (Reynolds number and density effects)
- Figures showing performance curve shapes (atmospheric and pressure)

Following are discussions on the significant changes of the 2006 revision, referenced section by section.

TERMINOLOGY, (AGA 7 – 2006, SECTION 2)
This is a newly created section in which, important terms and variables are defined as they relate to turbine meter measurement. Where possible, effort was made to harmonize definitions with other flow measurement documents, both US and international.

Nearly as important as the terms and definitions included within the document, were those chosen to be avoided. For example: The terms accuracy, uncertainty and module are not used. In place of accuracy the terms operating characteristics, measurement performance or error are used. Measurement cartridge is used in place of measuring mechanism or module. And the term uncertainty is relegated to other documents that deal more specifically with test system error capabilities.

Note that the terminology section is placed as one of the first sections in the document due to its intended importance. Please resist the human tendency to skip over it. A significant amount of committee effort went into finalizing these definitions.

OPERATING CONDITIONS
(AGA 7 - 2006, SECTION 3)
A section previously titled “Operation” has been reorganized. New information is provided, such as in the Section 3.1, suggesting considerations of gas quality, (i.e., near dew point conditions, total sulfur content, contaminants), relating to turbine meter operation. Other areas presented for consideration are: Operating pressures; Temperatures; Effects of Gas Density; Flow Rate; Piping and Flow Profiles. Note that the research report cited, (Reference 2, GRI Topical Report GRI-01-0226), was conducted using installation configurations, as represented in AGA 7 – 2006, Section 7, to determine the effects on turbine meter error.

METER DESIGN REQUIREMENTS
(AGA 7 -2006, SECTION 4)
A section previously titled “Construction”, had similar content, but used more informational style language. The revision reorganizes the section and relocates some information, (for instance, the schematic figures are separated to Appendix A). The language used in the new revision is specification style, rather than informational, requiring that codes and standards must be met and that minimum features and information be provided. Additionally, specifications of the user and/or designer must also be considered.

PERFORMANCE REQUIREMENTS
(AGA 7 – 2006, SECTION 5)
The predecessor section 5 in AGA 7 – 1996 was labeled “Performance Characteristics” and content was basically informational. In the revision, a number of new terms are introduced along with performance specification requirements.

The new term, transition flow rate (Q_t) is the flow rate through the meter at which performance may change, (Q_t shall not be greater than 0.2 $Q_{max)}$. Also, flow rate limits for Q_{min}, Q_t and Q_{max} shall be specified for each meter design and size. Note that, defining Q_t allows for taking advantage of the expanded +/-1.5% maximum error specification for flow rates below Q_t and down to Q_{min}. This expanded error tolerance in the low flow rate atmospheric calibration region permits better adjustment or setting of the high flow rate portion and/or more optimal K-factor setting of an elevated pressure calibration for a turbine meter.

Tolerances for atmospheric pressure performance are specified, numerically, in section 5.1 and, graphically, in Figure 1. The traditional and familiar maximum error range of +/-1.0% is retained for atmospheric pressure. However, it is recognized that turbine meter performance can improve dramatically with flow calibration at elevated pressures. Improvements in the range of +/-0.5% and even to +/-0.25% error are obtainable in pressure calibrations of turbine meter over flow rate turndowns of 10 to 1 or greater. Although not a requirement, (i.e., Section 5.1 Note 3, sections 5.3, and 6.3), users are encouraged to have turbine meters calibrated at the applicable operating conditions, (i.e., at the expected service pressure and flow rate range).

Another new specification is the “Maximum peak-to-peak error” limit of 1.0% error above Q_t flow rate. This 1.0% band may be offset within the overall +/-1.0% maximum error range, allowing for some latitude in making the best setting of an elevated pressure calibration on that meter. Or, in the case of atmospheric calibration only, the margin around the 1.0% band and between the overall +/-1.0% allows the meter setting to

be targeted for best performance at the projected operating pressure.

A repeatability tolerance of +/-0.2% error from Q_{min} to Q_{max} at atmospheric pressure is stated. Although turbine meters are typically capable of a tighter limit, (i.e., +/-0.1% as shown in prior version), this +/-0.2% tolerance is stated without qualifying the calibration method or the random error influences of the system.

Two significant research test programs were conducted in support of this section on meter performance. Reference 3, GRI Topical Report GRI-03-0172, was conducted to investigate the effects of pressure and gas density from atmospheric air to 700 psig in natural gas on turbine meter measurement error. The other testing, Reference 4, GRI Topical Report GRI-04/0207, was conducted to determine measurement error due to turbine meter cartridge change-out.

INDIVIDUAL METER TESTS
(AGA 7 – 2006, SECTION 6)

This section starts out with requirements for meter body pressure integrity and leak tightness. However, the majority of the section addresses calibration guidelines, presenting recommended testing conditions and configurations for optimal measurement by the calibrated turbine meter in service. Also methods for re-setting a turbine meter's performance, following calibration, are outlined. These techniques are further expanded upon in Appendix D, with reference to: Change Gears, K-factor(s), Meter Factors, Final Meter Factor, Linearization by Polynomial curve-fitting, Linear Interpolation between table values or Piecewise adjustments in flow rate ranges, and use of Rotor Factors for dual-rotor meters.

Additionally, Reynolds number and density effects are introduced through the presentation of basic formulas and discussion on relationships of density, viscosity and flow rate for equivalent Reynolds numbers. More detailed explanations are provided in Appendix E along with comparative example calculations.

INSTALLATION SPECIFICATIONS
(AGA 7 – 2006, SECTION 7)

The recommended installation configuration meter run is basically unchanged from prior revisions. Figure 2 shows the 10 nominal pipe diameters of straight lengths upstream and 5 PD straight lengths downstream. The dashed outline pipe flange representations shown at each end are optional since these could just as well be welded joints. Similarly, the other dashed outlines represent optional features, (i.e., blow down valve, reference temperature well or sample probe fitting). Note that the reference pressure tap is shown on the meter. Where more than one pressure tap exists, the one used for calibration should be the same used in service. The AGA 7 Figure 3 is a typical meter set using the recommended 10 PD up and 5 PD down. Optional items are shown such as: Bypass line and valve; Block valves at inlet and outlet; Filter or Strainer; Flow limiting orifice; and Small pressure-loading line/valve around the block valves.

The new AGA 7 Figure 4 (Short-Coupled Installation) is a blending of the old and new Figure 3. This shows a 4 PD straight inlet and no additional straight outlet length of pipe. The Note 4 states the requirement that an integral flow conditioner be used in the turbine meter of this type of installation. Turbine meters with integral flow conditioning are required for use in the close-coupled installation as well, (ref: AGA 7 Figure 5). The aspect ratios for effective integral flow conditioners within the nosecone flow passages are shown in the new AGA 7 Figure 6.

The use of a 19 tube bundle, or other flow conditioning element, or none at all, in the upstream straight inlet, is optional for both the 10 PD "recommended" inlet and 4 PD short-coupled installations, (see AGA 7 Figures 2, 3 & 4). Reference 2, GRI Topical Report GRI-01-0226, research results has shown that turbine meters with less than 10 PD straight inlet pipe and without external flow conditioning, are capable of acceptably small measurement error. However, when a flow conditioner is used, then the recommended spacing upstream of the meter inlet is to be followed. The advantage of using some isolating flow conditioners, as an alternative to the traditional tube bundles, is the potential effectiveness for reducing both swirl and asymmetric flow.

Section 7 also covers environmental considerations, associated devices, and precautionary measures that apply to turbine meter installations. The new AGA 7 Tables 1 and 2, (Blow Down Valve Sizing and Sonic Venturi Nozzle / Critical Orifice Sizes, respectively) are from the basic information in the prior AGA 7 sections 3.5.2 and 3.5.3. However, the metric equivalent values are now provided in both tables. Also, the sonic venturi / critical orifice table now include the high capacity turbine meters as well as the maximum plate thickness for critical orifice sizes.

METER MAINTENANCE AND FIELD VERIFICATION CHECKS, (AGA 7 – 2006, SECTION 8)

This section includes, much the same information as in past revisions: the recommended best practices for inspections, cleaning, oiling, and field verification checks. Spin testing, although not a replacement of a calibration check, is still the practical standby for checking mechanical condition of the turbine meter rotor and mechanical output system. However, note that the output readings of some dual-rotor turbine

meters can be used for periodic or continuous checking in-situ.

SINGLE AND DUAL ROTOR TURBINE METER DESIGNS, (AGA 7 – 2006, APPENDIX A)
Schematic drawings of the basic construction features of various single rotor and dual-rotor turbine meters are shown in Figures A.1 thru A.6.

VOLUMETRIC AND MASS FLOW MEASUREMENT (AGA 7 – 2006, APPENDIX B)
This section presents well organized information starting with the basic gas laws and showing the application of pressure, temperature and compressibility multipliers for obtaining flow rate at base conditions from flow rate at flowing conditions. Also shown are the equations for calculating turbine meter rangeability and for mass flow.

COMPUTING FLOW, (AGA 7 – 2006, APPENDIX C)
The proper procedure for reading a meter register to determine the volume accumulated, however simplistic, is necessary information which justifies its inclusion in the document.

METER OUTPUTS AND ADJUSTMENTS (AGA 7 – 2006, APPENDIX D)
The use of change gears, single K-factor, individual K-factors, meter factors and final meter factor are explained through the use of example values presented in tabular format. The linearization methods for reducing a turbine meter's calibration errors throughout a range of flow rates are shown by example applications of polynomial curve fitting, linear interpolation, and piece-wise curve fitting. The unique application of rotor factors associated with dual-rotor turbine meters is presented, along with how rotor factors differ from meter K-factor(s).

CALIBRATION GUIDELINES (AGA 7 – 2006, APPENDIX E)
This section presents one of many excellent uses of the Reynolds number. Explained are the benefits, cautions and how to specify the calibration of turbine meters using gases heavier than natural gas. The objective is to obtain a turbine meter calibration at test conditions, using economical gases, pressures, and flow rates, to predict the meters performance at the expected field conditions, and without any detrimental effects to the meter.

SPIN TIME TESTS, (AGA 7 – 2006, APPENDIX F)
This section contains useful step-by-step procedures for conducting turbine meter spin tests either in-line or out-of-line.

SUMMARY
Borrowing from the AGA 7 (2006) Foreword; "Research conducted in support of this report and cited herein has demonstrated that turbine meters can accurately measure natural gas and, therefore, should be able to meet or exceed the requirements specified in this report when calibrated and installed according to the recommendations contained herein."

AGA Report 7, "Measurement of Natural Gas by turbine meters", having its beginnings nearly thirty years ago, and with input from many industry experts along the way, has helped to establish … A legacy of accurate gas measurement by turbine meters.

And now with the 2006 revision of AGA 7, the potential to be … Even Better!

REFERENCES
A.G.A. Transmission Measurement Committee Report No. 7, "Measurement of Natural Gas by TURBINE METERS" ", American Gas Association, Washington, D.C., February 2006.

A.G.A. Transmission Measurement Committee Report No. 7, "Measurement of Natural Gas by Turbine Meters" ", American Gas Association, Washington, D.C., April 1996 *(Superseded)*.

AGA 7 Reference 2: George, D. L., GRI Topical Report GRI-01-0226, "Metering Research Facility Program: Turbine Meter Research in Support of the Planned AGA Report No. 7 Revision" Gas Research Institute, Des Plaines, Illinois, January 2003.

AGA 7 Reference 3: George, D. L., GRI Topical Report GRI-03-0172, "Metering Research Facility Program: Effects of Line Pressure and Gas Density on Turbine Meter Measurement Accuracy at Conditions from Atmospheric Air to 700 psig in Natural Gas". Gas Research Institute, Des Plaines, Illinois, August 2004.

AGA 7 Reference 4: Siebenaler, S. P., and George, D. L., GRI Topical Report GRI-04/0207, "Metering Research Facility Program: Effects of Turbine Meter Cartridge Changeout on Measurement Uncertainty". Gas Research Institute, Des Plaines, Illinois, USA, March 2005.