2013 Western Gas Measurement Short Course
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MEASUREMENT STANDARDS UPDATE

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Introduction

Standardization of the methods used to measure natural gas flowing through a pipeline is valuable for many reasons. It provides a framework for designing, constructing, operating, and maintaining the measurement equipment in a consistent manner, which helps minimize cost and ensures consistent performance of the metering systems. Those metering technologies that receive consensus recognition as a "standard" method are typically selected for custody transfer measurement applications. Written standards for the metering technologies used at custody transfer points can be referenced in sales contracts and pipeline tariffs, which helps minimize the likelihood of custody disputes and possible litigation.

Both national and international standards for natural gas flow metering methods exist. Some of the principal standards writing groups include, among others:

- International Organization for Standardization
- International Organization of Legal Metrology
- American Gas Association
- American National Standards Institute
- American Petroleum Institute
- American Society of Mechanical Engineers
- Gas Processors Association

The focus of this paper is on United States standards, guidelines, and recommended practices pertaining to dry natural gas volume/mass measurement and energy content/heating value determination. Particular emphasis is given to those documents that have been recently updated or are in the process of being updated. Technical details are provided on new standards and anticipated changes to existing standards. Estimated publication dates for both new and revised standards are also provided.

American Gas Association (AGA)

The earliest American flow metering "standard" was written by the AGA and published in 1930. It was AGA Report No. 1 and pertained to orifice flow meters. This report was published after approximately 27 years of orifice metering research, which provided the technical underpinnings for the contents of this report. Since 1930, the AGA has produced many reports pertaining to natural gas measurement. The AGA describes its reports as recommended practices, but the United States natural gas industry and, in some cases, the U.S. federal government, have adopted many of these recommended practices as de facto "standards" for custody transfer applications.

The principal AGA reports pertaining to natural gas measurement (for high volumetric flow rate applications) include the following:

Report No.3: "Orifice Metering of Natural Gas - Parts 1 through 4"

Report No.4A: "Natural Gas Contract Measurement and Quality Clauses"

Report No.5: "Measurement of Natural Gas Energy by Direct, Indirect, and Inferential Methods"

Report No.6: "Field Proving of Gas Meters Using Transfer Methods"

Report No.7: "Measurement of Natural Gas by Turbine Meters"

Report No.8: "Compressibility Factor of Natural Gas and Related Hydrocarbon Gases"

Report No.9: "Measurement of Gas by Multipath Ultrasonic Meters"

Report No.10: "Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases"

Report No.11: "Measurement of Natural Gas by Coriolis Meter"

"Gas Quality Management Manual"

The AGA also offers a Gas Measurement Manual. This manual was originally conceived by the AGA Measurement Committee in 1956 and first published in 1965. It provides a relatively comprehensive treatment of nearly all aspects of natural gas measurement.

The AGA reports that have been recently updated, are in the process of being updated, or are about to be published for the first time include Report Nos. 3, 6, 8, 9, 10, and 11, plus the Gas Quality Management Manual. The status of each of these is discussed in the following paragraphs.

AGA Report No. 3

Report No. 3 (AGA-3) for orifice flow meters includes four parts:

Part 1: General Equations and Uncertainty Guidelines

Part 2: Specification and Installation Requirements

Part 3: Natural Gas Applications

Part 4: Background, Development Implementation Procedure

AGA-3, Part 1

A revision of AGA-3, Part 1 was issued in September of 2012. The table of contents of the latest version of Part 1 is as follows:

- Introduction - including scope
- Normative References (New)
- Terms, Definitions, and Symbols (Updated)
- Field of Application
- Method of Calculation
- Orifice Flow Equations
- Empirical Coefficient of Discharge
- Empirical Expansion Factor for Flange-Tapped Orifice Meters (Revised)
- In-situ Calibration
- Fluid Physical Properties
- Unit Conversion Factors
- Practical Uncertainty Guidelines
- Appendices
  - Discharge Coefficients for Flange-Tapped Orifice Meters (Informative)

- Adjustments for Instrument Calibration and Use (Informative)
- Buckingham and Bean Empirical Expansion Factor (*Y*) for Flange-tapped Orifice Meters (New) (Informative)

• Bibliography

The term *normative* refers to information or documents that are indispensable for the application of the document that contains them. For International Organization of Standardization (ISO) and International Electrotechnical Commission (IEC) documents, both dated and undated references may be used. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

The term *informative* refers to information or documents that are supplementary, and are typically contained in a bibliography. Elements of the ISO or IEC documents that are supplementary, including informative references, are elements that provide additional information intended to assist in the understanding or use of the document.

The principal technical change in the newly-revised Part 1 is with the expansion factor coefficient correlation (i.e., the term that accounts for the effect of line pressure changes in the orifice equation that is used to calculate flow rate). A new correlation is included. The expansion factor coefficient correlation referenced in the previous version of AGA Report No. 3, Part 1 (i.e., the Buckingham equation) was different than one adopted some time ago by the ISO for its orifice meter standard. The differences between the two correlations were only significant in instances in which the differential pressure across the orifice plate was high and the line pressure was low (i.e., less than about 250 psia).

Subsequently, additional flow tests were run at Southwest Research Institute and the Colorado Engineering Experiment Station to better compare the two correlations. Eventually, a new correlation, that is different than the Buckingham equation and the new ISO equation, was developed for inclusion in the newly-revised AGA-3, Part 1. In the new document, it is being left to the meter operator's discretion to choose between the Buckingham equation and the new expansion factor correlation.

AGA-3, Part 2

AGA-3, Part 2 was last revised in the year 2000. A draft of a new revision of AGA-3, Part 2 was first balloted in 2011 and work has continued since.

It is expected that the revised document likely will incorporate previously published errata and some reported comments. Also, the "grandfather" clause may possibly be revised. This clause addresses previously installed measurement equipment and whether or not that equipment must comply with any new requirements included in the new-revised document.

It is also expected that the revised Part 2 likely will include additional guidance on the proper use of thermowells for bi-directional flow applications utilizing flow conditioners. There may also be additional annexes. It is anticipated that the revised AGA-3, Part 2 will be published before the end of 2013.

AGA-3, Part 3

AGA-3, Part 3 was last revised in 1992. A new revision is currently in process and should be

available before the end of 2013. The new revision is expected to incorporate previously published errata. It should also include individual thermal expansion coefficients for 304 and 316 stainless steel orifice plates in addition to the previous coefficient for "generic" stainless steel.

Energy calculation language included in the current version of Part 3 is expected to be eliminated and replaced with a reference to American Petroleum Institute (API) Manual of Petroleum Measurement Standards (MPMS), Chapter 14.5 (which is also Gas Processors Association (GPA) Standard 2172).

The revised Part 3 is also expected to include updated example calculations illustrating use of the new expansion factor correlation. In addition, reference to the factors approach for pipe taps is expected to be removed, instead referring to the previous version of the report. For those unfamiliar with the factors approach, it a version of the orifice flow rate equation. The factors approach version for flange-tapped orifice flow meters is shown in Equations 1 through 4.

Upstream tap:

$$Q_v = C(P_{f1}h_w)^{0.5} \quad \text{(Eq. 1)}$$

$$\text{where } C = F_n(F_c + F_{st})Y_1F_{pb}F_{tb}F_{tf}F_{gr}F_{pb} \quad \text{(Eq. 2)}$$

Downstream tap:

$$Q_v = C(P_{f1}h_w)^{0.5} \quad \text{(Eq. 3)}$$

$$\text{where } C = F_n(F_c + F_{st})Y_2F_{pb}F_{tb}F_{tf}F_{gr}F_{pb} \quad \text{(Eq. 4)}$$

In Equations 1 through 4, the following apply:

D = Meter tube internal diameter, calculated at T_f

Input d = Orifice plate bore diameter, calculated at T_f

Input T_f = Absolute flowing temperature

Input P_{f1} = Absolute flowing pressure

Input h_w = Orifice differential pressure

Input T_s = Standard Temperature

Input P_s = Standard Pressure

Input Q_v = Volume flow rate at standard conditions

C = Composite orifice flow factor

F_n = Numeric conversion factor

F_c = Orifice calculation factor

F_{st} = Orifice slope factor

Y_1 = Expansion Factor (upstream tap)

Y_2 = Expansion Factor (downstream tap)

F_{pb} = Base pressure factor

F_{tb} = Base temperature factor

F_{tf} = Flowing temperature factor

F_{gr} = Specific gravity factor

F_{pv} = Supercompressibility factor

AGA-3, Part 4

AGA-3, Part 4 was last updated in 1992. There is no timeline yet for completion of a revision to Part 4, although work on this is underway. Changes to this document will take into account the recent and pending revisions to the other three parts of AGA-3.

AGA Report No. 6

Report No. 6 (AGA-6), entitled "Field Proving of Gas Meters Using Transfer Methods," is undergoing a complete re-write. The scope of the document is being expanded to address not only critical flow proving (i.e., the focus of the original document), but other field proving methods (e.g., master meters) as well. The revised edition should be available before the end of 2013. Work on this revision has taken

several years. The table of contents of the revised document is expected to be along the lines of the following:

- Purpose
- Scope
- Terminology
- Theory
- Proving Meters Using Critical Flow Devices
- Proving Field Meters with Master Meters
- Application of Field Proving Results
- References
- Appendices
  - Mater Meter Considerations
  - Critical Flow Venturi Nozzle (CFVN) Information
  - Uncertainty
  - Calculation Examples
  - Fluid Properties
  - AGA Transmission Measurement Committee Report No. 6, Part 4, Critical Flow Prover (1975)

AGA Report No. 8

Report No. 8 (AGA-8), entitled "Compressibility Factor of Natural Gas and Related Hydrocarbon Gases," was last updated in 1994. The National Institute of Standards and Technology (NIST) and the European Gas Research Group (GERG) collaborated on an improved equation of state for natural gas blends and other gaseous mixtures. This new equation of state was made public in 2008. As a result, the AGA Transmission Measurement Committee (TMC) is re-visiting AGA-8. The API and the ISO are also studying the situation. The latest estimate is that it could be at least two years before a revised AGA-8 report will be forthcoming.

The AGA TMC is planning to develop guidelines on how AGA-8 should be applied by setting boundaries for different levels of uncertainties. The new version of AGA-8 will likely include three parts, similar to ISO 20765. The three parts are anticipated to be:

- Part 1 - Gross Computational Methods
- Part 2 - Detailed Computational Methods (GERG 2008)
- Part 3 - Physical properties, e.g., speed of sound, vapor-liquid equilibrium, etc.

AGA-8 currently documents two possible ways to compute the compressibility factor for natural gas. One method is referred to as the *gross method*; the other is referred to as the *detailed method.* The *gross method* is supposed to be simpler to implement and require less computing power than the *detailed method.* There are two major distinctions between the gross and detailed methods. First, the *gross method* accepts a limited amount of compositional data on the natural gas mixture (specific gravity, percent CO_2 and N_2), while the *detailed method* requires a "total" compositional analysis. What constitutes a total analysis depends on each measurement site. Generally, hydrocarbon constituent composition through C_6 is considered a total analysis. Sometimes C_7 or C_8 or C_9 might need to be included. The *detailed method* of the equation will support this, if needed.

Second, the *gross method* is applicable over a narrower range of operating conditions than the *detailed method*. The *gross method* was designed to be applicable for "pipeline quality" natural gas at normal pipeline pressures and temperatures. For example, the gross method supports up to 0.02% hydrogen sulfide, while the detailed method supports up to 100% hydrogen sulfide. In the AGA-8 table showing the range of applicability for the two methods, the Normal

Range column applies to the *gross method* and the Expanded Range column applies to the *detailed method.*

AGA Report No. 9

Report No. 9 (AGA-9), entitled "Measurement of Gas by Multipath Ultrasonic Meters," was last revised in 2007. A new effort has just been launched by the AGA to revise the document yet again. However, it is too early in the process to say what changes or additions to the report may be forthcoming or when the revision may be complete.

AGA Report No. 10

Report No. 10 (AGA-10), entitled "Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases," was produced in 2003. Any update to this report will likely be linked to the revision of AGA-8. It is possible that AGA-10 could be folded into AGA-8 rather than remain a standalone document.

AGA Report No. 11

Report No. 11 (AGA-11), entitled "Measurement of Natural Gas by Coriolis Meters," was first produced in 2003. A revised document was released in February 2013. This is a major revision that includes a significant expansion of the original document, with more in-depth technical guidance provided in the revised edition. The table of contents of the revised edition of AGA-11 is as follows:

- Introduction
- Terminology, Units, Definitions, & Symbols
- Operating Conditions
- Meter Requirements
- Meter Selection Considerations
- Performance Requirements
- Gas Flow Calibration Requirements
- Installation Requirements
- Mass Verification & Flow Performance Testing
- Coriolis Meter Measurement Uncertainty Determination
- Reference List
- Appendices
  - Coriolis Gas Flow Meter Calibration Issues
  - Coriolis Meter Data Sheet
  - AGA Engineering Tech Note on Coriolis Flow Measurement for Natural Gas Applications
  - Examples of Overall Measurement Uncertainty Calculations - Coriolis Meter (New)
  - AGA-11 Measurement System (New)
  - Coriolis Sizing Equations (New)

AGA Gas Quality Management Manual

This is a new document (over 200 pages in length) that will provide reference guidelines and the "framework" necessary for gas system operators to assess, monitor, and manage variables that define a Gas Quality Management Plan. Development of the Manual has been ongoing for approximately eight years. The Manual is expected to be available before the end of 2013.

The table of contents of the Manual is as follows:

- Overview - including scope
- Understanding Natural Gas Constituents and Properties
- Understanding Pipeline System Impacts
- Monitoring Gas Quality
- Determining and Maintaining Historical Gas Quality Data

- Developing a Gas Quality Management Plan
- Appendices (14 total)

AGA Gas Measurement Manual

Several sections of the Gas Measurement Manual (i.e., Parts 1, 2, 4, 16, and 17) are under revision. A publication date for these revisions has not yet been set.

Additional Comments on the AGA Reports

In 2012, the U.S. Bureau of Safety and Environmental Enforcement ((BSEE) and formerly the Minerals Management Service) began referencing in the Federal Register (30 CFR Part 250 - pertaining to oil and gas operations on the Outer Continental Shelf) certain AGA (and API MPMS) measurement standards; including those for orifice, turbine, ultrasonic, and Coriolis flow meters. These apply to operations at those production leases over which the Bureau has jurisdiction.

American Petroleum Institute

The principal API standards pertaining to natural gas measurement (for high volume applications) include the following, which are all part of the API Manual of Petroleum Measurement Standards:

Chap. 14.1: "Collecting and Handling of Natural Gas Samples for Custody Transfer" (Similar to GPA 2166)

Chap 14.2: "Compressibility Factors of Natural Gas and Other Related Hydrocarbon Gases" (Same as AGA Report No. 8)

Chap. 14.3: "Concentric, Square-Edged Orifice Meters - Parts 1 through 4" (Same as AGA Report No. 3 and GPA 8185)

Chap. 14.5: "Calculation of Gross Heating Value, Relative Density, Compressibility, and Theoretical Hydrocarbon Liquid Content for Natural Gas Mixtures for Custody Transfer" (Same as GPA 2172)

Chap. 14.9: "Measurement of Natural Gas by Coriolis Meter" (Same as AGA Report No. 11)

Chap. 21.1: "Flow Measurement Using Electronic Metering Systems, Section 1: Electronic Gas Measurement" (Same as AGA Report No. 13)

Chap. 22.2: "Testing Protocols - Differential Pressure Flow Measurement Devices" (Formerly MPMS Chapter 5.7)

As noted above, many of the API standards are the same as or similar to AGA and/or GPA documents.

API MPMS, Chapter 14.1

Chapter 14.3, entitled "Collecting and Handling of Natural Gas Samples for Custody Transfer," was last revised in 2006. Efforts are underway on a new revision. A sampling "checklist" was developed in 2011 for inclusion as an informative appendix addressing sampling issues from the Department of the Interior. A further investigation of the definitions of "theoretical," "observable," and "operational" dew point obtained from a chilled mirror dew scope is planned. No date has been given yet when the new revision will be available.

Note also that in 2012, the BSEE began referencing Chapter 14.1 in the Federal Register (30 CFR Part 250) for auditing purposes for those production leases over which it has jurisdiction.

API MPMS, Chapter 14.5

Chapter 14.5, entitled "Calculation of Gross Heating Value, Relative Density, and Compressibility Factor for Natural Gas Mixtures from Compositional Analysis," is being considered for revision. In 2011, an effort was begun to harmonize Chapter 14.5 (a.k.a., GPA 2172) with AGA Report No. 5 and ISO 6976 ("Natural Gas - Calculation of Calorific Values, Density, Relative Density and Wobbe Index from Composition") as part of the current work to revise ISO 6976. Gaps and conflicts between the documents were identified, but it has been concluded that ISO harmonization is not practical.

API MPMS, Chapter 21.1

A revision of Chapter 21.1, entitled "Flow Measurement Using Electronic Metering Systems," was released in February 2013. The original standard was published in 1993 (and reaffirmed in 2005). The new edition reflects the significant changes in technology that have transpired since the early 1990s. The new document addresses both linear (i.e., turbine, ultrasonic, Coriolis, vortex, etc.) and differential (i.e., orifice, cone, etc.) meters. The previous version basically addressed only orifice and turbine flow meters. Emphasis is placed on the ability to verify quantities and examples are included to aid in verification efforts. (An ad hoc committee has also been formed to explore the possibility of developing a standard for "Wireless Communication for Use in Electronic Flow Measurement Systems.")

The table of contents of the revised Chapter 21.1 is as follows:

- Scope
- Normative References
- Descriptions, Definitions, and Symbols
- Electronic Gas Measurement System Algorithms
  - Differential Meter Measurement
  - Linear Meter Measurement
- Audit and Record Requirements
- Data Availability
- Commissioning
- Equipment Verification and Calibration
- Security and Data Integrity
- Appendices
  - Rans Methodology for Estimating Sampling Frequency and Calculation Algorithm Errors (Informative)
  - Averaging Techniques (Normative)
  - Correction Methodology (New - Informative)
  - Calculation of Normal Operating Range and Percent Fluctuation (New - Normative)
  - Example Flow Computer Variable Input Type Testing - Differential Meters (New - Informative)
  - Example Commissioning Checklist (New - Informative)

The scope of the revised document is depicted in the following figure, Figure I:

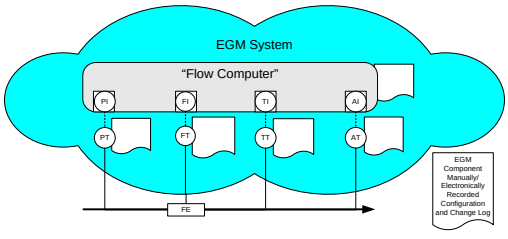

Figure I. Example

Electronic gas measurement (EGM) systems may be comprised of a number of components which work together to measure and record gas flow as shown above. The components contained in the cloud depicted in Figure I above are considered

part of the EGM system. The components may be considered individually or be integral parts of the EGM system and the calculations may be performed on-site and/or off-site.

API MPMS, Chapter 22.2

Chapter 22.2., entitled "Testing Protocol for Differential Pressure Flow Measurement Devices," was first issued in 2003 and revised in 2006. A second revision to the document was originally balloted in 2011 and work has continued on it since. The latest expectation is that it will be published before the end of 2013. Principal changes to the new revision will likely include: (1) guidance on how to handle pre-existing test data, (2) addition of a fourth meter geometry test for "ideal" flow conditions, and (3) changing the document format to be consistent with the ISO format.

Other API Development Initiatives

The API is also developing the following documents for inclusion in the API MPMS. Timelines for publication of these have not yet been announced by the API.

Chap. 14.11: "Thermal Cracked Gas"

Chap. 14.12: "Vortex Meters for Gas Flow Measurement" (similar to Chapter 5.9: "Vortex Shedding Flow Meter for Measurement of Hydrocarbon Fluids")

Chap. 22.4: "Testing Protocol for Pressure, Differential Pressure, and Temperature Measuring Devices"

Chap. 22.5: "Testing Protocols - Electronic Flow Computer Calculations"

Chap. 22.6: "Testing Protocol for Gas Chromatographs"

Additional Comments on the API MPMS

The Bureau of Land Management (BLM) Onshore Order 5 (pertaining to natural gas measurement) is likely to eventually incorporate as many MPMS gas measurement standards as possible (e.g. Chapters 14.1, 14.2, 14.3, 14.5, 21.1, 22.2, 22.4, and 22.5). Onshore Order 5 eventually may be incorporated into the Federal Register (43 CFR 3100 - pertaining to oil and gas leasing).

Gas Processors Association

The principal GPA standards pertaining to natural gas measurement (for high volumetric flow rate applications) include the following:

2145-09: "Table of Physical Constants for Hydrocarbons and Other Compounds of Interest to the Natural Gas Industry"

2166-05: "Obtaining Natural Gas Samples for Analysis by Gas Chromatography" (similar to API MPMS, Chapter 14.1)

2172-09: "Calculating Gross Heating Value, Relative Density, Compressibility, and Potential Hydrocarbon Liquid Content for Natural Gas Mixtures for Custody Transfer" (also API MPMS, Chapter 14.5)

2198-03: Selection, Preparation, Validation, Care and Storage of Natural Gas and Natural Gas Liquids Reference Standard Blends

2261-00: "Analysis for Natural Gas and Similar Gaseous Mixtures by Gas Chromatography"

2286-95: Tentative Method of Extended Analysis for Natural Gas and Similar Gaseous Mixtures by Temperature Programmed Gas

GPA 2145

GPA 2145, entitled "Table of Physical Constants for Hydrocarbons and Other Compounds of Interest to the Natural Gas Industry," is scheduled to be revised by January 2014. GPA Section H intends to update Technical Publication TP-17, entitled "Table of Physical Properties of Hydrocarbons for Extended Analysis of Natural Gases," and merge it into GPA 2145, and, at the same time, to update Section 23, entitled "Physical Properties," in the GPSA Engineering Data Book.

GPA 2166

A revision of GPA 2166, entitled "Analysis for Natural Gas and Similar Gaseous Mixtures by Gas Chromatography," was balloted by GPA Section B in 2011 and work on the revision has continued since. No timeline has been announced yet for publication of the revision. This revision likely will include a new scope statement, an updated precision statement, and a summary of the method. Also, there probably will be revisions to the measurement repeatability and reproducibility criteria (i.e., elimination of the "stair steps"). In addition, calculations likely will be removed from this document and included in GPA 2172 instead.

American National Standards Institute (ANSI)

The principal ANSI standards pertaining to natural gas measurement include the following:

B109.1: Diaphragm-Type Gas Displacement Meters (applying to flow meters under 500 cubic feet per hour capacity)

B109.2: Diaphragm-Type Gas Displacement Meters (500 cubic feet per hour capacity and over)

B109.3: Rotary-Type Gas Displacement Meters

A new performance-based B109 document, anticipated to replace the three existing B109 standards, has been developed to facilitate the use of technologies that are not already covered by existing standards. The draft "dot zero" document is largely similar to and consistent with the International Organization of Legal Metrology (OIML) R 137-2 standard (i.e., "Gas Meters - Metrological Controls and Performance Tests"), rather than the current "mechanical" specifications found in Parts 1 through 3 of ANSI B109. In addition, the new document likely will not be limited to "distribution" meters, but can be applied to any application (if desired). The draft document is currently in the comment-resolution stage, but there is no timetable yet for publication.

Conclusions

As noted above, a number of the existing natural gas measurement standards are either in the process of being updated or have recently been updated. In addition, new documents, such as the AGA Gas Quality Management Manual, are about to be released. It is incumbent upon those responsible gas metering system design, specification, operation and maintenance to stay abreast of the latest developments with the national and international measurements standards. That will help ensure that the measurement systems are in compliance with the latest standards and will provide optimum performance.

Most industry standards writing groups are open to anyone desiring to contribute to the process, so anyone so inclined is encouraged to participate in the process.