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Measurement of Natural Gas by Coriolis Meter

Prepared by

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FOREWORD

This report is published in the form of a performance-based specification for Coriolis meter for natural gas flow measurement. It is the result of collaborative effort of natural gas users, Coriolis meter manufacturers, flow measurement research organizations and independent consultants forming Task Group 11 of AGA's Transmission Measurement Committee (TMC). In addition, comments to this report were made by the Alternative Meter Task Group under the Committee on Gas Flow Measurement (COGFM) of the American Petroleum Institute (API). Throughout the process, AGA Task Group 11 met several times and developed drafts reflective of comments received.

This report contains general guidance and information for consideration. The material may not be adequate under all conditions and does not restrict the use of other methods. Use of this publication is entirely within the control and discretion of the user and is wholly voluntary. Any use should be taken after an independent review of the applicable facts and circumstances.

At the time the writing of this report was initiated, all the known manufacturers of Coriolis meter for natural gas flow measurement were invited to join Task Group 11 and participate in the process of developing this report. Changes to this report may become necessary from time to time. If changes in this report are believed appropriate by any manufacturer, individual or organization, such suggested changes should be communicated to AGA by completing the last page of this report titled "**FORM FOR SUGGESTION TO CHANGE IN THE AGA REPORT NO. 11**" and sending it to: **Operating Section, American Gas Association, 400 North Capitol Street, NW, 4th Floor, Washington, DC 20001, U.S.A.**

Methods for verifying a meter's accuracy and/or applying a Flow Weighted Mean Error (FWME) correction factor to minimize the measurement uncertainty are contained in Appendix A - *Coriolis Gas Flow Meter Calibration Issues*. Depending on the design, a flow calibration of each meter on a gas similar to that which it will be applied may be necessary. In order to guide the designers and users in the specification of a Coriolis meter, Appendix B – *Coriolis Meter Data Sheet,* has been provided.

As a reference for background information on Coriolis natural gas metering, Appendix C - AGA Engineering Technical Note XQ0112 - *Coriolis Flow Measurement for Natural Gas Applications*, is provided. Due to the unique principle of operation and atypical performance characteristics of Coriolis mass flow meters, in comparison to volumetric flow meters, readers who are not familiar with the technology are encouraged to read this document prior to applying the general concepts and guidelines of this report.

As a reference for assessing the applicability of Coriolis meter technology to natural gas flow measurement, Appendix D - Gas Research Institute Topical Report GRI-01/0222 - *Metering Research Facility Program, Coriolis Mass Flow Meter Performance with Natural Gas*, is provided. This report outlines methods for baseline and installation effects testing of Coriolis meters for natural gas applications. The test data presented are an indicator of the state of Coriolis technology at the time of the tests. This report is intended as a general guide of testing methods to be used for the qualification of Coriolis meters as meeting the performance specifications of this report and the identification of the flow conditioning requirements of a particular meter design.

ACKNOWLEDGEMENTS

Report No. 11, Measurement of Gas by Coriolis Meters, was developed by a Transmission Measurement Committee (TMC) task group, **chaired by Stephen Baldwin, Unocal Corp.** Subsequently, a special subcommittee of the task group was formed to assemble technical information, compose drafts of the report, evaluate and resolve comments received through balloting, and prepare a final report.

The members of the special subcommittee, who devoted an extensive amount of their time, deserve special thanks:

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1. Introduction

1.1. Scope

This report was developed to assist designers and users in operating, calibrating, installing, maintaining and verifying Coriolis flow meters used for natural gas flow measurement. Coriolis meters infer mass flow rate by measuring tube displacement resulting from the Coriolis effect. The scope of this document is limited to the measurement of natural gas and associated hydrocarbon gases either as pure hydrocarbons, as a mixture of pure hydrocarbons, and diluents. Although not within the scope of this document, Coriolis meters are used to measure a broad range of compressible fluids (gases), other than natural gas.

This report is applies to Coriolis meters used in medium to high-pressure natural gas applications. Typical applications include measuring single-phase gas flow found in production, process, transmission, storage, distribution, and end-use fuel measurement systems.

1.2. Principle of Measurement

Coriolis meters operate on the principle of the apparent bending force known as the Coriolis force (named after the French mathematician Gustave-Gaspard de Coriolis). When a fluid particle inside a rotating body moves in a direction toward or away from a center of rotation, that particle generates an inertial force (known as the Coriolis force) that acts on the body. In the case of a Coriolis flow meter, the body is a tube through which fluid flows. Coriolis meters create a rotating motion by vibrating the tube or tubes through which the fluid flows. Coriolis meters have the inherent ability to measure flow in either direction with comparable measurement accuracy in either flow direction. The inertial force that results is proportional to the mass flow rate. Numerical calculation techniques utilizing the calculated base density of the gas are used to convert the measured mass flow rate into standard volumetric flow rate. At the date of publication of this report the flowing density of a gas as indicated by a Coriolis meter is not of sufficient accuracy to be used to infer the flowing volume of gas and shall not be used for this purpose. Appendix C (Engineering Technical Note), Section 2.1, 3.2, and Appendix D of the Engineering Technical Note discusses in detail the conversion of mass flow rate to standard volume. For more information on the theory and physical dynamics that govern the operation of Coriolis meters, refer to Appendix C, Section 2.1.

2. Symbols

Symbol	Represented Quantity
E_i	Flow rate error at the tested flow rate (Q_i)
E_{icf}	Adjusted error at each calibration/tested flow rate (Q_i)
F	Meter factor
G_r	Real gas relative density (specific gravity) of the gas flowing
FT_i	The time interval divided by the time specified by (FT_{tp}), that the meter will operate at the tested flow rate (Q_i)
FT_{tp}	A time interval that is proportional to the meter's life cycle in field service
$FWME$	Flow Weighted Mean Error
g_c	Dimensional conversion constant
K	Pressure loss coefficient
P_b	Pressure base (absolute)
P_{Effect}	Pressure effect
$P_{\max}$	Maximum operating pressure
$P_{\min}$	Minimum operating pressure
Q_i	Actual measured gas flow rate passing through a meter under a specific set of test or operating conditions
$Q_{\max}$	Maximum allowable flow rate through the meter, as specified by the meter manufacturer
$Q_{\min}$	Minimum allowable flow rate through the meter, as specified by the meter manufacturer
Q_t	Transitional flow rate at which the maximum permissible measurement error changes
T_b	Temperature base (absolute)
v	Velocity of flowing gas
WF_i	Weighting factor for a tested flow rate (Q_i)
ZS	Zero Stability
ρ_f	Density at flowing conditions
ΔP	Pressure drop or pressure loss across meter

3. Terminology

For the purposes of this report, the following definitions apply:

Allowable Pressure Drop:	The differential pressure available for consumption by the metering module without affecting the measuring system's performance as specified by the designers.
Ancillary device:	A device intended to perform a particular function, directly involved in elaborating, transmitting or displaying measurement results. Main ancillary devices are: - Repeat indicating device - Printing device - Memory device - Totalizing indicating device - Conversion device (An ancillary device may be integrated into the transmitter (e.g. flow computer or calculator), into the meter, or may be linked to the transmitter by means of an interface)
Auditor:	Representative of the operator or other interested party who audits the measuring system. Also referred to as the 'inspector.'
Base conditions:	Specified pressure and temperature from which the measured mass of gas accumulated is converted to the volume.
Calibration factor:	Manufacturer flow calibration scalars that are applied to the meter's output(s) value to adjust the output(s) value(s) to the as-built performance; (i.e. zero, span, linearity, etc.) of the sensor.
Compressibility:	A factor calculated by taking the ratio of the actual volume of a given mass of gas at a specified temperature and pressure to its volume calculated from the ideal gas law at the same conditions.
Designer:	An organization, that designs and constructs metering facilities and purchases Coriolis meters.
Drift:	A slow change of a metrological characteristic of a measuring instrument.
Drive signal:	An electrical signal produced by the transmitter to initiate and maintain cyclic vibration of the sensor (measuring transducer) flow tube(s).
Error:	The difference between a measured value and the 'true' value of a measured quantity. (Note: The 'true' value cannot usually be determined. In practice, a conventional recognized 'standard' or 'reference' value is typically used instead.)

Flow-influencing device:	An element or device, other than ancillary, which could have an influence on the measurement of the measured quantity. The main flow-influencing devices are: - Filter - Branch or by-pass line - Valves - Pressure reducing devices located upstream or downstream of the flow sensor - Piping characteristics
Flow tube(s):	The sensing element (measuring transducer) through which the gas flows.
Flow weighted mean error:	The calculation of the FWME of a meter from actual flow test data is a method of calibrating a meter when only a single correction factor correction is applied to the meter output. FWME is only one of many techniques for adjustment of a Coriolis meter calibration to minimize the flow measurement uncertainty of the meter. Note: FWME is calculated per equation (A.1) in Appendix A.
Influence quantity:	A quantity that is not the measured quantity but that affects the result of the measurement.
Installation effect:	Any difference in performance of a component or the measuring system arising between the calibration under ideal conditions and actual conditions of use. This difference may be caused by different flow conditions due to velocity profile, perturbations, or by different working regimes (pulsation, intermittent flow, alternating flow, vibrations, etc.).
Maximum peak-to-peak error:	The largest allowable difference between the upper-most error point and the lower-most error point as shown in Figure 6.1 and Section 6.4. This applies to all mean error values in the flow rate range between Q_t and Q_{max}.
Maximum permissible error:	(MPE), The extreme error of a meter's indicated value in percent of the reference value it is compared to. (See Section 7.1)
Mean error:	The arithmetic mean of all the observed errors or data points for a given flow rate.
Measuring system:	A system that includes the metering module and all the ancillary devices.
Measuring transducer:	A device that provides an output quantity having a determined relationship to the input quantity.

Measurement uncertainty: Parameter associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measured quantity.

Meter: A measurement instrument comprised of the sensor, measuring transducers and transmitter(s) intended to measure continuously, memorize, and display the volume or mass of gas passing through the sensor at metering conditions. Note: The display may be a remote indicating device.

Meter factor: A scalar factor (F) that may be applied to the meter's output(s) value(s) to change the output(s) value(s) by a constant percentage at all flow rates (Q_i), compensating for systematic error.

Metering conditions: The conditions of the gas, at the point of measurement, which the flow rate is measured, (temperature, pressure, composition, and flow rate of the measured gas).

Metering module: The subassembly of a measuring system, that includes only to the sensor(s) and all other devices (i.e. flow conditioners, straight pipe, and/or metering tubes) required to ensure correct measurement of the measuring system's gas circuit.

Meter manufacturer: An organization that designs, manufactures, sells, and delivers Coriolis meters.

Operating range: The range of ambient conditions, gas temperature, gas pressure, and gas flow rate over which a meter is designed to operate accurately.

Operator: An organization, that operates Coriolis meters and performs normal maintenance, also known as the "user".

Percent (%) error: ([Measured value – reference value]/reference value) x 100

Performance test: A test intended to verify whether the measuring equipment under test is capable of accomplishing its intended functions.

Pickoff: Electrical devices mounted at the inlet and outlet of the flow tube(s) that create signals due to the cyclic vibration of the sensor (measuring transducer). The signals are used by the transmitter to determine the magnitude of the Coriolis force and maintain the cyclic vibration of the flow tube(s).

Pressure loss: Permanent pressure reduction across or through any device, vessel, or length of pipe within a flowing stream.

Reference: A meter or test facility that is traceable to a recognized national or international measurement standard.