



AGA Report No. 11 API MPMS Chapter 14.9

**Measurement of Natural Gas by
Coriolis Meter**

Prepared by
Transmission Measurement Committee

Second Edition, February 2013



AGA Report No. 11 □ API MPMS Chapter 14.9

Measurement of Natural Gas by Coriolis Meter

**Prepared by
Transmission Measurement Committee**



Second Edition, February 2013

Copyright 2013 © American Gas Association
All Rights Reserved

Catalog # XQ1301

DISCLAIMER AND COPYRIGHT

The American Gas Association's (AGA) Operations and Engineering Section provides a forum for industry experts to bring their collective knowledge together to improve the state of the art in the areas of operating, engineering and technological aspects of producing, gathering, transporting, storing, distributing, measuring and utilizing natural gas.

Through its publications, of which this is one, AGA provides for the exchange of information within the natural gas industry and scientific, trade and governmental organizations. Many AGA publications are prepared or sponsored by an AGA Operations and Engineering Section technical committee. While AGA may administer the process, neither AGA nor the technical committee independently tests, evaluates or verifies the accuracy of any information or the soundness of any judgments contained therein.

AGA disclaims liability for any personal injury, property or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of or reliance on AGA publications. AGA makes no guaranty or warranty as to the accuracy and completeness of any information published therein. The information contained therein is provided on an "as is" basis and AGA makes no representations or warranties including any expressed or implied warranty of merchantability or fitness for a particular purpose.

In issuing and making this document available, AGA is not undertaking to render professional or other services for or on behalf of any person or entity. Nor is AGA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

AGA has no power, nor does it undertake, to police or enforce compliance with the contents of this document. Nor does AGA list, certify, test or inspect products, designs or installations for compliance with this document. Any certification or other statement of compliance is solely the responsibility of the certifier or maker of the statement.

AGA does not take any position with respect to the validity of any patent rights asserted in connection with any items that are mentioned in or are the subject of AGA publications, and AGA disclaims liability for the infringement of any patent resulting from the use of or reliance on its publications. Users of these publications are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Users of this publication should consult applicable federal, state and local laws and regulations. AGA does not, through its publications intend to urge action that is not in compliance with applicable laws, and its publications may not be construed as doing so.

Changes to this document may become necessary from time to time. If changes are believed appropriate by any person or entity, such suggested changes should be communicated to AGA in writing *and sent to: Operations & Engineering Section, American Gas Association, 400 North Capitol Street, NW, 4th Floor, Washington, DC 20001, U.S.A. Suggested changes must include: contact information, including name, address and any corporate affiliation; full name of the document; suggested revisions to the text of the document; the rationale for the suggested revisions; and permission to use the suggested revisions in an amended publication of the document.*

Copyright © 2013, American Gas Association, All Rights Reserved.

FOREWORD

This report has been written in the form of a performance-based specification. If this performance-based specification is used, Coriolis meters shall meet or exceed the function, accuracy, and testing requirements specified in this report and designers shall follow the applicable installation recommendations.

This report is split into two distinct sections – the main body of the report and a series of appendices. The main body should be considered normative as it describes working practice when applying and using Coriolis meters to measure natural gas flow. The appendices are informative and contain additional material, background and examples of how Coriolis meters are installed and operated.

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, it may be necessary to flow-calibrate each meter on a gas similar to that expected in service.

In order to guide the designer 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 the Appendix C prior to applying the general concepts and guidelines of this report.

This report offers general criteria for the measurement of natural gas by Coriolis meters. It is the cumulative result of years of experience of many individuals and organizations acquainted with measuring gas flow rate and/or the practical use of Coriolis meters for gas measurement. Changes to this report may become necessary from time to time.

ACKNOWLEDGEMENTS

The revision work of this report was undertaken by a task group the Transmission Measurement Committee (TMC). The task group was **chaired by Angela Floyd** who was with ConocoPhillips during the development and finalization of this report. Angela was supported by the **vice chair, Karl Stappert** with Micro Motion. A special subcommittee of the task group was formed later to assemble additional technical information, compose the drafts of the revised report for balloting and finally resolve the ballot comments and prepare the final report.

The members of the special subcommittee who devoted an extensive amount of their time and deserve special thanks are –

Kerry Checkwitsch, Spectra Energy Transmission
Craig Chester, Williams Gas P/L
John Daly, GE Sensing
Robert DeBoom, Consultant
Robert Fallwell, TransCanada P/L
Ron Gibson, ONEOK, Inc.
Terry Grimley, Southwest Research Institute (SwRI)
John Hand, Spectra Energy Transmission
Michael Keilty, Endress + Hauser Flowtec AG
Allen Knack, Consumers Energy
Brad Massey, Southern Star Central Gas P/L
Paul LaNasa, CPL and Associates
Stephanie Lane, Micro Motion, Inc.
Dannie Mercer, Atmos Energy Corporation
Gary McCargar, ONEOK, Inc.
Bill Morrow, Telvent
Mark Pelkey, National Fuel Gas Supply Corporation
Dan Rebman, Universal Ensco
Don Sextro, Targa Resources, Inc.
Martin Schleich, Daniel Measurement and Control, Inc.
Tushar Shah, Eagle Research Corp.
James N. Witte, El Paso Pipeline Group

AGA acknowledges the contributions of the above individuals and thanks them for their time and effort in getting this document revised.

Christina Sames
Vice President
Operations and Engineering

Ali Quraishi
Director
Operations and Engineering

TABLE OF CONTENTS

DISCLAIMER AND COPYRIGHT	III
FOREWORD	IV
ACKNOWLEDGEMENTS	V
1 INTRODUCTION	1
1.1 SCOPE	1
1.2 PRINCIPLE OF MEASUREMENT	1
2 TERMINOLOGY, UNITS, DEFINITIONS & SYMBOLS	1
2.1 TERMINOLOGY	1
2.2 ENGINEERING UNITS	2
2.3 TERMS AND DEFINITIONS	2
2.4 SYMBOLS	6
3 OPERATING CONDITIONS	8
3.1 GAS QUALITY	8
3.2 OPERATING PRESSURES	8
3.3 TEMPERATURE: GAS AND AMBIENT	8
3.4 GAS FLOW CONSIDERATIONS	8
3.5 UPSTREAM PIPING AND FLOW PROFILES	9
4 METER REQUIREMENTS	9
4.1 CODES AND REGULATIONS	9
4.2 QUALITY ASSURANCE	9
4.3 METER SENSOR	9
4.3.1 <i>Pressure Rating</i>	9
4.3.2 <i>Corrosion Resistance</i>	9
4.3.3 <i>Meter Lengths and Diameters</i>	10
4.3.4 <i>Pressure Measurement</i>	10
4.3.5 <i>Miscellaneous</i>	10
4.3.6 <i>Meter Body Markings</i>	10
4.4 ELECTRONICS	10
4.4.1 <i>General Requirements</i>	10
4.4.2 <i>Output Signal Specifications</i>	11
4.4.3 <i>Electrical Safety Design Requirements</i>	11
4.4.4 <i>Cable Jackets and Insulation</i>	11
4.5 COMPUTER PROGRAMS	11
4.5.1 <i>Firmware</i>	11
4.5.2 <i>Configuration and Maintenance Software</i>	11
4.5.3 <i>Inspection and Auditing Functions</i>	12
4.5.4 <i>Alarms</i>	12
4.5.5 <i>Diagnostic Measurements</i>	12
4.6 DOCUMENTATION	13
4.7 MANUFACTURER TESTING REQUIREMENTS	13
4.7.1 <i>Static Pressure Testing</i>	13
4.7.2 <i>Alternative Calibration Fluids</i>	13
4.7.3 <i>Calibration Requirements</i>	14
4.7.4 <i>Calibration Test Reports</i>	14
4.7.5 <i>Quality Assurance</i>	14

5	METER SIZING SELECTION CRITERIA	15
5.1	MINIMUM FLOW RATE	15
5.2	TRANSITIONAL FLOW RATE	15
5.3	MAXIMUM FLOW RATE	15
5.3.1	<i>Meter Pressure Loss (ΔP)</i>	15
5.4	METER SIZING METHODOLOGY	17
6	PERFORMANCE REQUIREMENTS	19
6.1	MINIMUM PERFORMANCE REQUIREMENTS	19
6.2	PERFORMANCE ENHANCEMENTS	20
7	GAS FLOW CALIBRATION REQUIREMENTS	20
7.1	FLOW CALIBRATION TEST	21
7.1.1	<i>Preparation for Flow Calibration</i>	21
7.1.2	<i>Calibration of Metering Module</i>	21
7.2	CALIBRATION ADJUSTMENT FACTORS	22
7.3	CALIBRATION REPORTS	22
7.4	ADDITIONAL CONSIDERATIONS	23
7.4.1	<i>Pressure Effect Compensation</i>	23
7.4.2	<i>Coriolis Flowmeter Diagnostics</i>	24
7.5	FINAL CONSIDERATIONS	24
8	INSTALLATION REQUIREMENTS	24
8.1	GENERAL REQUIREMENTS	24
8.1.1	<i>Temperature</i>	24
8.1.1.1	Ambient	24
8.1.1.2	Process	24
8.1.2	<i>Pressure</i>	25
8.1.3	<i>Vibration</i>	25
8.1.4	<i>Electrical Noise</i>	25
8.2	METER MODULE DESIGN	25
8.2.1	<i>Piping Configuration</i>	25
8.2.2	<i>Flow Direction</i>	27
8.2.3	<i>Protrusions</i>	27
8.2.4	<i>Meter Mounting</i>	27
8.2.5	<i>Orientation</i>	28
8.2.6	<i>Filtration</i>	28
8.2.7	<i>Provision for Sample Probe(s)</i>	28
8.2.8	<i>Gas Velocity</i>	28
8.2.9	<i>Multiple Meters in Close Proximity</i>	28
8.2.10	<i>Performance Baseline</i>	28
8.3	ASSOCIATED FLOW COMPUTER	29
8.3.1	<i>Flow Computer Calculations</i>	29
8.4	MAINTENANCE	30
9	METER VERIFICATION AND FLOW PERFORMANCE TESTING	31
9.1	FIELD METER VERIFICATION	31
9.2	FLOW PERFORMANCE TESTING	32
9.2.1	<i>Verification of Gas Calibration Performance through Alternative Fluids Flow Test</i>	33
9.2.2	<i>Field/In-situ Flow Performance Test</i>	33
9.3	RECALIBRATION	34

10	CORIOLIS METER MEASUREMENT UNCERTAINTY DETERMINATION.....	34
10.1	TYPES OF UNCERTAINTIES	34
10.1.1	<i>Meter Calibration Uncertainty</i>	34
10.1.2	<i>Uncertainties Arising from Differences between the Field Installation and the Calibration Lab</i>	34
10.1.2.1	Parallel Meter Runs.....	35
10.1.2.2	Installation Effects	35
10.1.2.3	Pressure and Temperature Effects.....	35
10.1.2.4	Gas Quality Effects	35
10.1.3	<i>Uncertainties Due to Secondary Instrumentation</i>	35
10.2	UNCERTAINTY ANALYSIS PROCEDURE	36
11	REFERENCE LIST.....	37
APPENDIX A	CORIOLIS GAS FLOW METER CALIBRATION ISSUES	A-1
A.1	GENERAL	A-1
A.2	FLOW CALIBRATION DATA EXAMPLE	A-1
A.3	METHODS FOR CORRECTING CORIOLIS FLOW MEASUREMENT ERRORS	A-3
A.4	FLOW-WEIGHTED MEAN ERROR (FWME) CALCULATIONS	A-4
A.5	FLOW-WEIGHTED MEAN ERROR (FWME) – EXAMPLE CALCULATION.....	A-5
APPENDIX B	EXAMPLE CORIOLIS METER DATA SHEET	B-1
APPENDIX C	AGA ENGINEERING TECHNICAL NOTE ON CORIOLIS FLOW MEASUREMENT.....	C-1
APPENDIX D	EXAMPLES OF OVERALL MEASUREMENT UNCERTAINTY CALCULATIONS – CORIOLIS METER.....	D-1
D.1	GENERAL	D-1
D.2	MATHEMATICAL MODEL	D-1
D.3	CONTRIBUTORY VARIANCES.....	D-1
D.3.1	<i>Uncertainty in the Mass Flow Rate</i>	D-1
D.3.2	<i>Uncertainty in Flow Pressure Effect Compensation Factor (F^p)</i>	D-2
D.3.3	<i>Uncertainty in the Determination of Base Density (ρ_b)</i>	D-3
D.4	COMBINED UNCERTAINTY	D-3
D.5	EXPANDED UNCERTAINTY	D-3
APPENDIX E	CORIOLIS GAS FLOW MEASUREMENT SYSTEM.....	E-1
E.1	CORIOLIS MEASUREMENT SYSTEM ARCHITECTURE	E-1
E.2	TRANSMITTER TO FLOW COMPUTER INTERFACE.....	E-2
E.2.1	<i>Unidirectional Discrete I/O Interface</i>	E-2
E.2.2	<i>Bidirectional Communications Interface</i>	E-3
E.3	TRANSMITTER	E-3
E.3.1	<i>Transmitter Flow Calculations</i>	E-3
E.3.2	<i>Transmitter Algorithms and Variables of Metrological Interest</i>	E-3
E.4	FLOW COMPUTER MEASUREMENT METHODS	E-4
E.4.1	<i>Flow Computer Calculations</i>	E-4
E.4.2	<i>Sampling Rate</i>	E-10
E.4.3	<i>No Flow Cut Off</i>	E-10
E.4.4	<i>Quantity Calculation Period (QCP)</i>	E-11
E.4.5	<i>Average Value Determination for Live Inputs</i>	E-11
E.4.6	<i>Relative Density, Density, Heating Value and Composition</i>	E-11

E.4.7	Transmitter and Flow Computer Measurement Record	E-11
E.4.7.1	Coriolis Measurement System Configuration Record/Log	E-11
E.4.7.2	Event Record / Log	E-13
E.4.7.3	Data Record	E-13
E.5	ALTERNATIVE METHOD	E-14
E.5.1	Alternative method for Computing Flow and the Recording of Measurement Data	E-14
	using a Constant Gravity or Base Density	
E.5.2	Data Record	E-15
E.6	RECALCULATION METHODS	15
APPENDIX F	CORIOLIS METER SIZING EQUATIONS.....	F-1
F.1	GENERAL.....	F-1
F.2	SIZING EXAMPLE	F-1
F.3	CALCULATION OF FLOW RATE BASED ON PRESSURE DROP	F-3
F.4	CALCULATION OF PRESSURE DROP BASED ON FLOW RATE	F-5
F.5	CALCULATION OF ACCURACY AT FLOW RATE	F-5
F.6	CALCULATION OF VELOCITY AT FLOW RATE	F-6
APPENDIX G	NOTES OF INTEREST.....	G-1
FORM TO PROPOSE CHANGES	H-1

1 INTRODUCTION

1.1 SCOPE

This report was developed for the specification, calibration, installation, operation, maintenance and verification of Coriolis flow meters and is limited to the measurement of single phase natural gas, consisting primarily of hydrocarbon gases mixed with other associated gases usually known as “dilutents.”

Although Coriolis meters are used to measure a broad range of compressible fluids, non-natural gas applications are beyond the scope of this document.

1.2 PRINCIPLE OF MEASUREMENT

Coriolis meters measure mass flow rate by measuring tube displacement resulting from the Coriolis effect. Coriolis meters operate on the principle of the 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 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 equal accuracy; i.e., they are bidirectional. The inertial force that results is proportional to the mass flow rate. The mass flow rate, thus determined, is divided by the gas base density to obtain the base volume flow rate. The flowing density of a gas as indicated by a Coriolis meter is not of sufficient accuracy to be used for the purpose of calculating flowing volume from flowing mass of the gas and shall not be used for this purpose.

2 TERMINOLOGY, UNITS, DEFINITIONS & SYMBOLS

For the purposes of this report, the following terminology, definitions and units apply.

2.1 TERMINOLOGY

Auditor	Representative of the operator or other interested party who audits the measuring system. Also referred to as the “inspector.”
Designer	Representative of the operator that designs and/or constructs metering facilities and specifies Coriolis meters.
Manufacturer	Company that designs and manufactures Coriolis meters.
Operator	Representative of the operator, that operates Coriolis meters and performs normal maintenance, also known as the “user.”
Sensor	An element of a measuring instrument (meter) or measuring chain that is directly affected by the measured quantity.
Transmitter	Part of the measuring system that receives and processes measurement signals from the Coriolis sensor and possibly other associated measuring instruments, such as from a pressure or a temperature device. It includes circuitry that receives and transmits data to the peripheral equipment. It may also be referred to as a signal processing unit (SPU).