

AGA Report No. 9

Measurement of Gas by Multipath Ultrasonic Meters Fourth Edition

**Sponsored by
Transmission Measurement Committee**



**Copyright © 2022 American Gas Association
All Rights Reserved**

Catalog No. XQ2105

DISCLAIMER AND COPYRIGHT

The American Gas Association's (AGA) Operations and Engineering Section provides a forum for industry experts to bring 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 gas industry and scientific, trade and governmental organizations. Each publication is 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, and 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. Any reference to trade names or specific commercial products, methods, commodities or services in this document does not represent or constitute an endorsement, recommendation or favoring nor disapproval, disparage or disfavoring by AGA or any other person of the specific commercial product, commodity or service.

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 report may become necessary from time to time. If changes to 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 Proposal on AGA Report No. 9"*** and sending it to ***Operations & Engineering Section, American Gas Association, 400 North Capitol Street, NW, 4th Floor, Washington, DC 20001, U.S.A.***

Copyright © 2022, American Gas Association, All Rights Reserved.

FOREWORD

This report is a revision of the previous AGA Report No. 9, 2017 edition. It is a performance-based specification for multipath ultrasonic meters for gas flow measurement. AGA's Transmission Measurement Committee (TMC) worked diligently for several years on its revision. It is the result of a collaborative effort of users, meter manufacturers, independent consultants, flow-measurement service providers and research organizations. This report was made available for comments from other relevant AGA committees, the Committee on Gas Fluid Measurement (COGFM) of the American Petroleum Institute (API), Section H of the GPA Midstream Association (GPA), ISO/TC 30/SC 5/WG 1 of the International Organization for Standardization, and the committee for Measurement of Fluid Flow in Closed Conduit of the American Society of Mechanical Engineers (ASME - MFC).

This version of AGA Report No. 9 is intended to supersede all prior versions of this document. However, this document does not reference existing multipath ultrasonic meter installations. The decision to apply this document to existing installations shall be at the discretion of the parties involved.

Research conducted in support of this report and cited herein has demonstrated that multipath ultrasonic meters can accurately measure gas flow and, therefore, should be able to meet the requirements specified in this report when calibrated and installed according to the recommendations contained herein. In consultation with a competent professional, users should follow appropriate installation, use and maintenance of an ultrasonic meter as applicable in each case.

Flow-calibration guidelines are provided for occasions when a flow calibration is requested or required to verify the meter's performance or to apply a calibration factor to minimize the measurement uncertainty. (See Appendix A (Informative))

Unlike most traditional gas meters, multipath ultrasonic meters inherently have an embedded microprocessor system. Therefore, this report includes, by reference, a standardized set of testing specifications applicable to electronic gas meters. These tests, summarized in Appendix B (Normative), are used to demonstrate the acceptable performance of the multipath ultrasonic meter's electronic system under different influences and disturbances.

The flow metering package and/or flow conditioner performance verification test found in Appendix C (Normative) is intended to provide a method by which they can be shown to perform under varying test flow conditions within the limit set in this Appendix.

An example of overall measurement uncertainty calculations is provided in Appendix D (Informative) with assumed numerical values for estimating measurement uncertainty for sites using ultrasonic gas flow meters.

In this document the words shall, should and recommended are to be used to mean as follows:

“Shall” means a requirement to conform to the specific task.

“Should” and “recommended” are used synonymously to indicate good practices to follow, but not required to conform to the specific task.

ACKNOWLEDGEMENTS

AGA Report No. 9, *Measurement of Gas by Multipath Ultrasonic Meters*, was revised by a task group of the American Gas Association's Transmission Measurement Committee under the chairmanship of **Rick Spann** of Dominion Energy Questar Pipeline Services and joint vice chairmanship of **John Lansing** of RMG and **Reese Platzer** of Enterprise Products Partners.

Individuals who made substantial contributions to the revision of this document are:

<u>Name</u>	<u>Company</u>
Belinda Bell	Southern Star Central Gas Pipeline
Ilia Bluvshstein	Union Gas (Retired)
Ron Carnahan	MPLX
Kerry Checkwitch	Enbridge
Duane Harris	SICK, Inc.
David Kanches	Tactical Energy Supply
Marcel Vermuelen	Sensia Global

Other individuals who contributed to the revision of the document are:

<u>Name</u>	<u>Company</u>
Robb Albers	National Fuel Gas Co.
Ardis Bartle	Apex Measurement & Controls
Joel Clancy	CEESI
Michael Frey	Sensia Global
Shane Dolar	Dominion Energy Utah
John Hand	TC Energy
Wayne Haner	TransCanada Calibrations
Dannie Mercer	Atmos Energy
Winston Meyer	CenterPoint Energy
Ryan Nutter	Dominion Transmission
Sam Patel	Consumers Energy
Swarandeeep Sandhawalia	TC Energy
Blaine Sawchuk	Canada Pipeline Accessories
Martin Schleich	Emerson
Tushar Shah	Eagle Research Corporation
Rob Smith	New Mexico Gas Company
Karl Stappert	Emerson

TABLE OF CONTENTS

DISCLAIMERS AND COPYRIGHT	ii
FOREWORD	iii
ACKNOWLEDGEMENTS	iv
1.0 INTRODUCTION.....	1
1.1 Scope	1
1.2 Principle of Measurement.....	1
2.0 TERMINOLOGY, UNITS AND DEFINITIONS	2
2.1 Terminology.....	2
2.2 Engineering Units	2
2.3 Definitions.....	3
3.0 OPERATING CONDITIONS.....	7
3.1 Gas Quality.....	7
3.2 Pressures	7
3.3 Temperatures, Gas and Ambient	7
3.4 Gas Flow Considerations	7
3.5 Upstream Piping and Flow Profiles	8
3.6 Acoustic Noise.....	8
4.0 METER REQUIREMENTS.....	10
4.1 Quality Assurance	10
4.2 Flow Meter Body.....	10
4.2.1 Maximum Operating Pressure	10
4.2.2 Corrosion Resistance	10
4.2.3 Flow Meter Body Length and Internal Diameter	10
4.2.4 Ultrasonic Transducer Ports	11
4.2.5 Pressure Tap	11
4.2.6 Integral Meters.....	11
4.2.7 Miscellaneous	11
4.2.8 Flow Meter Body Markings	11
4.3 Ultrasonic Transducers	12
4.3.1 Specifications	12
4.3.2 Rate of Pressure Change	12
4.3.3 Transducer Tests.....	12
4.4 Electronics.....	12
4.4.1 General Requirements	12
4.4.2 Output Signal Specifications	13
4.4.3 Electrical Safety Design Requirements	13
4.4.4 Component Replacement.....	13
4.5 Meter Firmware and Software	14
4.5.1 Firmware.....	14
4.5.2 Associated Flow Computing.....	14
4.5.3 Alarms	15
4.5.4 Meter Diagnostics.....	15
4.5.5 User Interface Software.....	15
4.5.6 Inspection and Auditing Functions	15
4.6 Individual Meter-Manufacturing Tests and Checks.....	16
4.6.1 Dimensional Measurements.....	16
4.6.2 Leakage Test.....	16
4.6.3 Zero-Flow and SOS Verification Test.....	16
4.7 Documentation	17

5.0	INSTALLATION	19
5.1	Environmental and Process Considerations	19
5.1.1	Ambient and Flowing Temperature	19
5.1.2	External Mechanical Vibration	19
5.1.3	Electrical Noise	19
5.1.4	Process Pulsation	19
5.1.5	Acoustic Noise	20
5.1.6	Filtration and Separation	20
5.2	Metering Package Design Criteria.....	20
5.2.1	Installation Configuration.....	20
5.2.2	Alternative Installation Configuration.....	22
5.2.3	Internal Surfaces	22
5.2.4	Protrusions and Alignment	22
5.2.5	Thermowell(s) and Sample Probe(s).....	22
5.2.6	Flow Conditioning	23
5.3	Orientation of Meters	23
5.3.1	Meter Tube Inspection and Cleaning Ports.....	23
5.3.2	Close-Coupled Series Metering	24
5.4	Handling	24
5.4.1	Preparation and Packaging	24
5.4.2	Lifting and Supports.....	24
5.5	Miscellaneous Design Considerations	24
6.0	FLOW CALIBRATION AND PERFORMANCE REQUIREMENTS	26
6.1	Preparation for Flow Calibration	26
6.2	Metering Package Flow-Calibration Test	26
6.3	Metering Package Performance Requirements	28
6.4	Pressure, Temperature and Gas Composition Influences	30
6.5	Calibration Adjustment Factors	30
6.5.1	Calibration Test Reports.....	31
6.5.2	Final Considerations.....	32
7.0	COMMISSIONING, FIELD VERIFICATION, MAINTENANCE AND RECALIBRATION	33
7.1	Commissioning.....	33
7.2	Field Verification.....	33
7.3	Maintenance.....	33
7.3.1	Inspection	33
7.3.2	Cleaning	34
7.3.3	Component Replacement.....	34
7.4	Recalibration	34
8.0	ULTRASONIC METER MEASUREMENT UNCERTAINTY DETERMINATION.....	35
	REFERENCE LIST	36
	APPENDIX A (INFORMATIVE): MULTIPATH ULTRASONIC METER FLOW- CALIBRATION ISSUES	41
A.1	Why Flow-Calibrate a Multipath Ultrasonic Meter?	41
A.2	Methods for Correcting a USM's Flow Measurement Error.....	42
A.3	Flow-Weighted Mean Error (FWME) Correction	43
A.4	Polynomial Algorithm.....	46
A.5	Multi-Point/Piece-Wise Linear Interpolation	47
	APPENDIX B (NORMATIVE): ELECTRONICS DESIGN TESTING	48
	APPENDIX C (NORMATIVE): FLOW-METERING PACKAGE AND/OR FLOW- CONDITIONER PERFORMANCE VERIFICATION TEST	49
	APPENDIX D (INFORMATIVE): EXAMPLES OF OVERALL MEASUREMENT- UNCERTAINTY CALCULATIONS – ULTRASONIC METER	50
D.1	Meter-Calibration Uncertainty.....	50
D.2	Uncertainties Arising From Differences Between the Field Installation and the Calibration	

Lab.....	50
D.2.1 Parallel Meter Runs	50
D.2.2 Installation Effects	50
D.2.3 Pressure and Temperature Effects	51
D.2.4 Contamination Effects	51
D.3 Uncertainties Due to Secondary Instrumentation.....	51
D.4 Uncertainty Analysis Procedure	52
D.4.1 General	52
D.4.2 The Mathematical Model	52
D.4.3 Contributory Variances	52
D.4.3.1 Uncertainty in the Uncorrected Volume Flow Rate, Q_f	52
D.4.3.2 Uncertainty in the Measurement of Pressure	53
D.4.3.3 Uncertainty in the Measurement of Temperature	53
D.4.3.4 Uncertainty in the Determination of Compressibility.....	53
D.4.4 Combined Uncertainty (percent).....	54
D.4.5 Expanded Uncertainty	54
APPENDIX E (INFORMATIVE): USM COMMISSIONING AND VERIFICATION CHECKLISTS	55
E.1 Commissioning Checklist	55
E.2 USM Field Verification Checklist	57
FORM FOR PROPOSALS ON AGA REPORT NO. 9	59

1.0 Introduction

1.1 Scope

This report is for multipath ultrasonic transit-time flow meters used for the measurement of natural gas. It may be used for the measurement of other gases in consultation with the meter manufacturer and a competent professional. Multipath ultrasonic meters have at least two independent pairs of measuring transducers (acoustic paths). Applications may include, but are not limited to, measurement of single-phase gas flow through production facilities, transmission pipelines, storage facilities, distribution systems and by end-use customers.

1.2 Principle of Measurement

Transit-time multipath ultrasonic meters are inferential meters that derive the gas flow rate by measuring the transit times of high-frequency sound pulses. Sound pulse transit times are measured between pairs of transducers. Pulses transmitted along the acoustic path in the direction of the gas flow have a greater average velocity relative to pulses transmitted against the gas flow. The difference in the sound pulse transit times is related to the average gas flow velocity along that specific acoustic path. Numerical calculation techniques are used to compute the average axial gas flow velocity and the gas volume flow rate at line conditions through the meter by combining the measurements of all active acoustic paths.

The accuracy of an ultrasonic gas meter depends on several factors, such as:

- Precisely measured dimensions of the flow meter body and ultrasonic transducer locations
- The velocity integration technique inherent in the design of the meter
- The shape of the velocity profile of the flowing gas stream at the meter
- Stability of the flowing gas stream
- The accuracy of transit-time measurements
- Flow calibration

The accuracy of transit-time measurements depends on several factors, including:

- The electronic clock accuracy and stability
- Accurate and consistent detection of sound pulse transit times
- Proper compensation for signal delays of electronic components and transducers
- Dimensional integrity of the flow meter body

Ultrasonic meter (USM) accuracy is dependent on these fundamental characterizations and their continued integrity over time. These accuracy dependencies may be adversely influenced by operational degradation of the USM over time (e.g., erosion, corrosion and dirt build up on internal meter surfaces, electronics drift, etc.). Emphasis on USM diagnostic data collection and interpretation in this document is made to impress upon users the need to monitor USM integrity so that accuracy is maintained.