AGA Report No. 10

Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases

Catalog # XQ0310

Prepared by

Transmission Measurement Committee

AGA American Gas Association

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FOREWORD

This report outlines a method for the calculation of the speed of sound in natural gas and the individual components that make up natural gas. It also calculates the entropy, enthalpy and C* coefficient for sonic nozzles. This information is based on research that was developed and managed by the Gas Technology Institute (formerly the Gas Research Institute). The research indicates that the calculation is highly accurate and is consistent with the equation-of-state used in AGA Report No. 8, *Compressibility Factors of Natural Gas and Other Related Hydrocarbon Gases*. The original work for AGA Report No. 8 was developed under the auspices of the Gas Research Institute's Basic Fluid Properties Research Program, the AGA Transmission Measurement Committee, the Gas European de Researchers Group (GERG), members of the American Petroleum Institute (API) and the International Standards Organization (ISO).

The purpose of this report is to provide the natural gas industry with a method for solving problems involving thermodynamics. Industry's incentive for establishing these methods was spurred by the advent of ultrasonic gas meters. However, the value of these methods is apparent for other applications of natural gas thermodynamics, such as compression.

The audience of the report is gas measurement engineers, especially those supporting ultrasonic meters, as well as those who intend to apply the principles of thermodynamics to gas production, transmission or distribution.

The intended benefits to users of this report are:

- clear traceability to recognized scientific sources
- extensive testing and validation
- an implementation example upon which to build

The report is based on scientific data collected for pure gases and natural gas mixtures. As such, the range of application is focused on the single-phase natural gas mixtures common to industry. The performance of the methods is intended to meet the needs of the gas industry. Caution is advised to users applying this technology to other purposes and other fluids.

It may become necessary to make revisions to this document in the future. Whenever any revisions are advisable, recommendations should be forwarded to the **American Gas Association**, 400 N. Capitol Street, NW, 4th Floor, Washington, DC 20001, USA. A form has been included at the end of this report for that purpose.

ACKNOWLEDGEMENTS

AGA Report No. 10, *Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases*, was developed by an AGA Transmission Measurement Committee task group chaired by **Jerry Paul Smith** (retired), Williams Gas Pipeline-Transco. AGA is especially thankful for the significant contributions of **Warren Peterson**, TransCanada PipeLines, who prepared the first draft of this report and wrote the computer program to calculate the speed of sound and other related properties. He also completed the final version of this report.

Those who deserve special recognition and appreciation for their help, suggestions and guidance in finalizing this report are — Dr. Eric Lemmon, National Institute of Standards and Technology; Paul J. LaNasa, CPL & Associates; Dr. Kenneth Starling, Starling Associates, Inc.; and Dr. Jeff Savidge, Consultant.

This report was originally initiated under the chairmanship of late Ron Rich, Natural Gas Pipeline, who could not complete it because of his untimely death. He is respectfully remembered and recognized for his contributions in initiating this document.

Others who participated during the development of this report, reviewed the final draft or provided comments and should also be acknowledged are:

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The experimental data and modeling efforts used to develop and analyze both the speed of sound data and the associated models were obtained from various independent laboratories and research sources. Significant amounts of data were obtained through Gas Technology Institute's (formerly the Gas Research Institute) speed of sound and physical properties basic research program. Laboratories in both the United States and Europe carried out the research work. Contributions of all the research organizations and laboratories are acknowledged.

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1. Introduction

1.1. Scope

This document contains information for computation of sound speed in natural gas and other related hydrocarbon gases. Procedures are included for computation of several related gas properties, including heat capacity, enthalpy, entropy and the critical flow coefficient, C*.

The methods in this document are extensions to *Compressibility Factors for Natural Gas and Other Hydrocarbon Gases*, AGA Transmission Measurement Committee Report No. 8, Second Edition, Second Printing (1994). This document contains excerpts from Report No. 8, but intentionally does not reproduce the full report.

Similarly, the methods for computing the critical flow coefficient, C*, are based on the information in appendix E of *ASME/ANSI MFC-7M-1987*. Users are referred to this source for background and pertinent references.

Procedures for computing other natural gas properties, such as volumetric heating value and relative density, fall outside of the scope of this report and are not included.

1.2. Background

This is the first AGA document on speed of sound. It is based on a large database of high-accuracy basic physical property research data obtained through research sponsored by the Gas Research Institute in cooperation with the AGA, API and GERG.

The methods presented in this AGA document utilize high-accuracy calculation procedures and related equations-of-state already implemented by AGA, API and ISO.

For continuity and ease of application, the original AGA Report No. 8 solution methods have been carried forward with little change. Computer code development for Report No. 10 will be modest and incremental to most existing AGA Report No. 8 implementations.

1.3. Field of Application

High-accuracy sound speed information is needed in a variety of gas flow measurement applications, such as ultrasonic meters and critical flow nozzles, as well as analytical applications such as transducers and densitometers.

This report provides the information needed to compute the speed of sound in natural gas and other related hydrocarbon gases. The equations utilized are consistent with AGA Report No. 8, API MPMS Chapter 14.2 and ISO Standard 12213 Part 2.

1.4. Types of Properties

The methods in this document may be used to compute a number of gas properties including speed of sound, enthalpy, entropy, heat capacity and critical flow coefficient.

In conjunction with the methods in AGA Report No. 8, procedures can be developed to support a variety of applications including sonic nozzles, compressor efficiency and heat exchanger calculations.

1.5. Types of Gases

This report is intended for natural gases and other related hydrocarbon gases. Table 1 identifies the ranges of gas characteristics for which this report can be used. The normal range column gives the range of gas characteristics for which the average expected uncertainty corresponds to the uncertainties identified in Figure 1. The expanded range of gas characteristics has an uncertainty, which is expected to be higher, especially outside of region 1 of Figure 1. The use of this report for computations of the physical properties of gases with component mole percentages outside the ranges given in Table 1 is not recommended.

An accepted database for water, heavy hydrocarbons and hydrogen sulfide in natural gases currently is not available for determinations of uncertainties of calculated gas properties. Therefore, as a practical matter, the only limitation is that the calculation is for the gas phase. Thus, the limits are the water dew point for mole percent water, the hydrocarbon dew point for mole percent heavy hydrocarbons, and pure hydrogen sulfide. The presentation of methods for calculations using the various heavy hydrocarbon fraction characterization methods used in the hydrocarbon industry is beyond the scope of this report.

Quantity	Normal Range	Expanded Range
Relative Density *	0.554 to 0.87	0.07 to 1.52
Gross Heating Value **	477 to 1150 Btu/scf	0 to 1800 Btu/scf
Gross Heating Value ***	18.7 to 45.1 MJ/m^3	0 to 66 MJ/m^3
Mole Percent Methane	45.0 to 100.0	0 to 100.0
Mole Percent Nitrogen	0 to 50.0	0 to 100.0
Mole Percent Carbon Dioxide	0 to 30.0	0 to 100.0
Mole Percent Ethane	0 to 10.0	0 to 100.0
Mole Percent Propane	0 to 4.0	0 to 12.0
Mole Percent Total Butanes	0 to 1.0	0 to 6.0
Mole Percent Total Pentanes	0 to 0.3	0 to 4.0
Mole Percent Hexanes Plus	0 to 0.2	0 to Dew Point
Mole Percent Helium	0 to 0.2	0 to 3.0
Mole Percent Hydrogen	0 to 10.0	0 to 100.0
Mole Percent Carbon Monoxide	0 to 3.0	0 to 3.0
Mole Percent Argon	#	0 to 1.0
Mole Percent Oxygen	#	0 to 21.0
Mole Percent Water	0 to 0.05	0 to Dew Point
Mole Percent Hydrogen Sulfide	0 to 0.02	0 to 100.0

* Reference Conditions: Relative Density at 60° F, 14.73 psia.

** Reference Conditions: Combustion at 60° F, 14.73 psia; density at 60° F, 14.73 psia.

*** Reference Conditions: Combustion at 25° C, 0.101325 MPa; density at 0° C, 0.101325 MPa.

The normal range is considered to be zero for these compounds.

Table 1: Range of Gas Mixture Characteristics Consistent with this Report

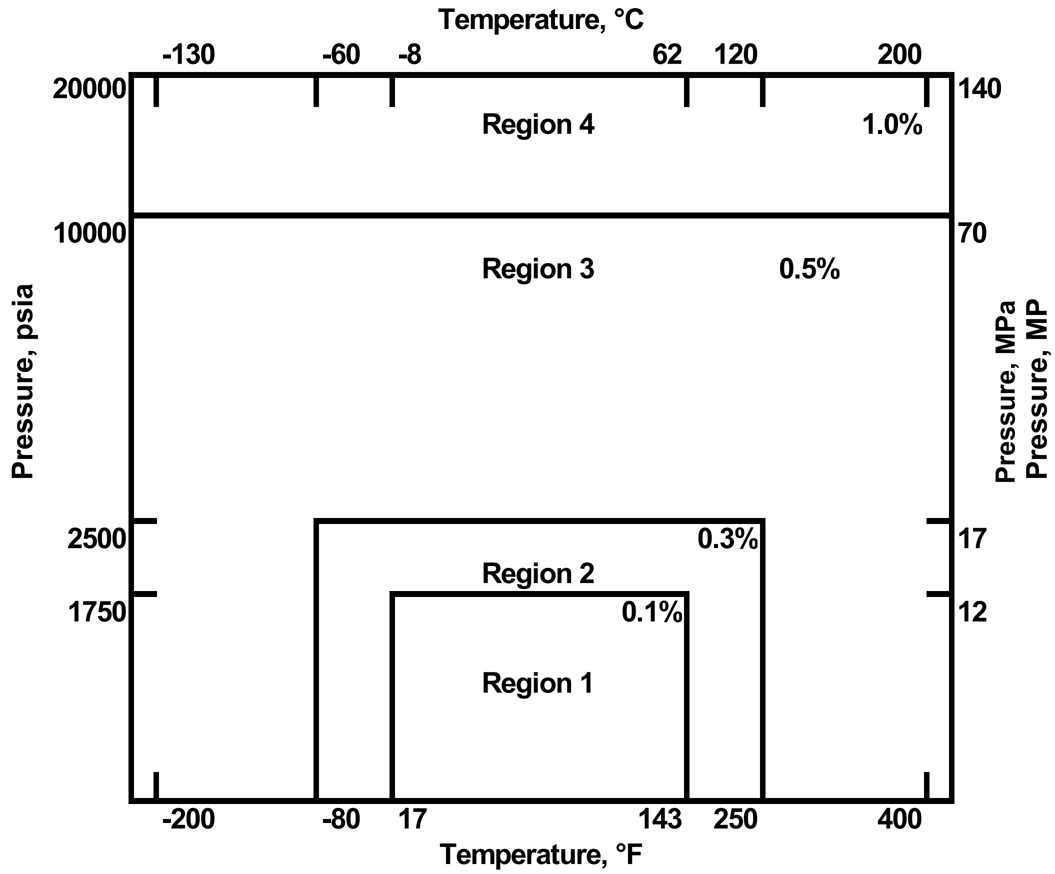

Figure 1: Targeted Uncertainty for Natural Gas Speed of Sound
Using the AGA Report No. 10 Method

1.6. Types of Conditions

This report is for the gas phase only. The methods can be applied for temperatures from -130° C to 200° C (-200° F to 400° F) at pressures up to 138 MPa (20,000 psia). Application at extreme conditions should be verified by other means (e.g., experimental verification). Use of the calculation method is not recommended within the vicinity of the critical point. For pipeline-quality gas, this is usually not a constraint because operating conditions near the critical point generally are not encountered.