CALCULATING THE SPEED OF SOUND IN NATURAL GAS -- AGA REPORT NO. 10 TO AGA REPORT NO. 8

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Introduction

The speed of sound in natural gas is the velocity a sound wave travels in the gas. There are a number of gas properties that affect the speed of sound and they include the composition of the gas, the pressure of the gas, and the temperature of the gas. The American Gas Association (AGA) Report No. 10, *Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases,* first published in 2003 provided an accurate method for calculating the speed of sound in natural gas and other related hydrocarbon fluids.

Purpose of AGA Report No. 10

The development of ultrasonic flow meters prompted the development of AGA Report No. 10 (AGA 10). The ultrasonic meter determines the speed of sound in the gas as it calculates the flow of gas through the meter. In order for one to check the accuracy of the speed of sound measured by the ultrasonic meter, it was necessary to have an accurate method to calculate the speed of sound in natural gas. AGA 10 was developed to do just that. The speed of sound calculated by the method in AGA 10 compares very favorably to the speed of sound determined by the highly accurate research that was the basis for the report. The information in AGA 10 is not only useful for calculating the speed of sound in natural gas, but also, other thermodynamic properties of hydrocarbon fluids for other applications, such as the compression of natural gas and the critical flow coefficient represented by C*.

The audience for the revised AGA Report No. 8 is the same as it was for AGA 10 which includes measurement engineers involved with the operation and start-up of ultrasonic meters, sonic nozzles, and other meter types that are involved in applying the principles of natural gas thermodynamics to production, transmission, or distribution systems.

The methods for calculating the speed of sound in AGA 10 were an extension of the information contained in AGA Report No. 8 (AGA 8), *Compressibility Factors of Natural Gas and Other Related Hydrocarbon Gases,* and it does contain excerpts from AGA 8. This is especially true since the speed of sound is related to the compressibility of the gas.

Why the Return to AGA Report No. 8

With the expanded research done primarily by the GERG (Groupe European de Recherches Grazieres) between1985-1990 it was apparent that the equations equation of state developed for the 1985 version of AGA 8 needed to be improved. Since it was necessary to update the equations in AGA 8, it was decided to include the calculation for the Speed of Sound in the revised AGA 8 since the method to calculate the speed of sound in AGA 10 was derived from the equations in the original AGA 8 and retire the AGA Report No. 10.

Applicable Gas Compositions

The calculations described in AGA 8 Part 1 are only for the gas phases with characteristics within the ranges outlined in Table1which have changed from the original version. For the liquid phase, mixed phase and saturation properties including dew point see AGA 8 Part 2.

The DETAIL equation of state can be applied, as shown in Figure 1, for temperatures above -200 °F and pressures up to 40,000 PSIA. The upper temperature limit is approximately 350 °F or the onset of decomposition of the gas components. For applications outside of these ranges, refer to AGA Report No. 8 Part 2.

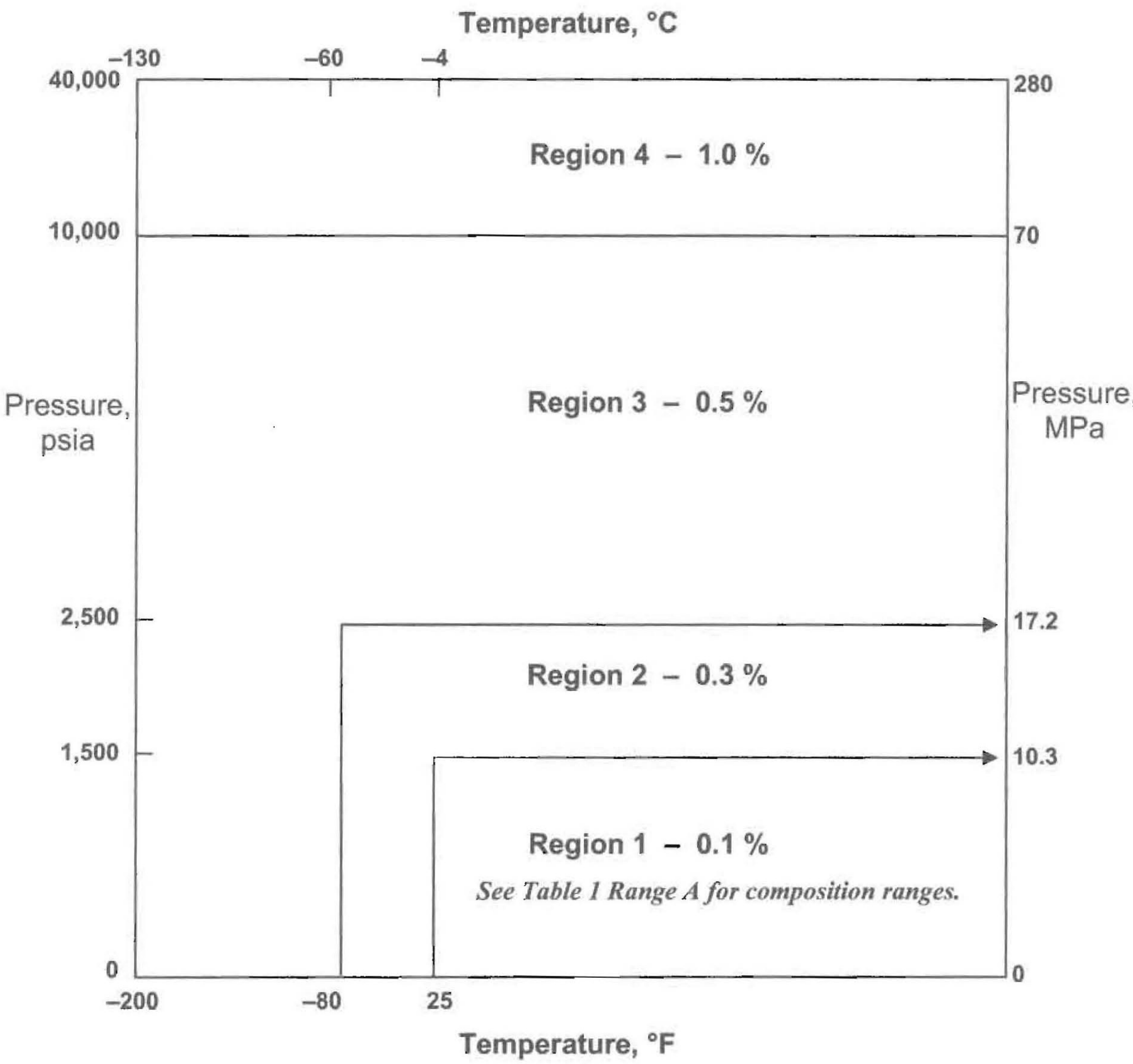

Figure 1. Overview of uncertainties for natural gas compressibility factors with the DETAIL equation of state (not to scale). The upper temperature limit is the onset of decomposition of the components in the gas.
Note: ***This figure is not intended for contractual use. Table 1 should be consulted for specific uncertainty information.***

A database for mixtures with water, heavy hydrocarbons, or hydrogen sulfide in natural gas is not presently available for the determination 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 and the hydrocarbon dew point for mole percent heavy hydrocarbons.

Figure 1 gives a simple overview of typical uncertainties for the DETAIL equation of state, but should not be used as a basis to estimate the uncertainties in calculated properties. Rather, Table 1 lists comprehensive ranges for which the uncertainties are less than 0.1 % (details are given in Reference [5]). Three different sets of ranges are defined below, each having its own range of validity for temperature, pressure, and component fractions.

Range A in Table 1 shows the limits of the mole percent of components in a natural gas mixture in which the uncertainties in compressibility factors are less than 0.1 % for temperatures above 25 °F (–4 °C), pressures less than 1500 psia (10.3 MPa), heating values from 630 to 1200 Btu/scf, and relative densities from 0.554 to 0.91. However, a mixture with compositions near the upper limits of every component in this range, except methane and nitrogen, will have an uncertainty higher than 0.1 %. Most typical natural gases do not fall under such a condition. This was verified through the use of the 200 gas compositions available in the supplementary material. Deviations between the DETAIL and GERG equations of state were compared for each gas composition – those that met the 0.1 % uncertainty limit fell within the ranges listed in Range A of Table 1, or were slightly outside this range at the lower temperature limit with pressures slightly below the upper pressure limit. Several of the limits listed in this range have been modified from those given in Reference [5] to give better results. The regions in Figure 1 with uncertainty limits of 0.3 %, 0.5 %, and 1.0 % are also based on the Range A compositions. However, it is important to make use of a phase diagram to ensure that states are not in the 2-phase or in the critical region. The DETAIL equation of state should not be used for states at pressures exceeding the dew or bubble point (including 2-phase states). This applies for Ranges B and C as well.

Range B in Table 1 shows the maximum allowable mole percent composition for temperatures above 25 °F (–4 °C), but with pressures less than 300 psia (2 MPa), heating values from 680 to 1500 Btu/scf, and relative densities from 0.47 to 0.91. Range B allows higher upper range values of the compositions for operations below 300 psia.

Range C in Table 1 has a composition range that is much smaller than the other ranges, but allows temperatures down to 17 °F (–8 °C) and pressures up to 3000 psia (21 MPa).

In this AGA 8, Part 1, document the upper pressure limit for 0.1 % uncertainty has been changed from 1750 psia to 1500 psia (12 MPa to 10.3 MPa), and the lower temperature limit has been changed from 17 °F (–8 °C) to 25 °F (–4 °C) based on work presented in Reference [5]. However, uncertainties in the DETAIL equation of state are often below 0.1 % far outside the ranges listed in Table 1, especially at temperatures above 40 °F. For continued use of the DETAIL equation of state outside the ranges listed in Table 1, comparisons can be made between this and the GERG-2008 equation of state. When the difference is less than 0.1 %, the DETAIL equation of state can be used with a stated uncertainty of 0.1 %. The Excel application given in the supplementary material will calculate the difference between the DETAIL and GERG-2008 equations for any gaseous state. Other tools can also be used (*e.g.*, Reference [6]) to ascertain the differences in the calculations between the two equations. When exceeding the limits of Table 1 but claiming the 0.1 % uncertainty, users should specify the method or software used to arrive at this claim.

Table 1 – Ranges for Temperature, Pressure, Heating Value, and Relative Density with Uncertainties Less than 0.1 % in Compressibility Factors of Natural Gas Calculated with the DETAIL Equation of State

	Range A	Range B	Range C
Lower temperature limit	**25 °F**	25 °F	17 °F
	–4 °C	–4 °C	–8 °C
Upper pressure limit	**1500 psia**	300 psia	3000 psia
	10.3 MPa	2.1 MPa	21 MPa
Gross heating value†			
Btu/scf	**630 to 1200**	680 to 1500	960 to 1090
MJ/m^3	**23.5 to 44.7**	25.3 to 56	35.8 to 40.6
Relative density†	**0.554 to 0.91**	0.47 to 0.91	0.554 to 0.64
Upper composition limits (mole percent)			
Methane	**100.0**	100.0	100.0
Nitrogen	**50.0**	50.0	3.0
Carbon dioxide	**30.0‡**	80.0	3.0
Ethane	**10.0**	25.0	4.0
Propane	**4.0**	6.0	2.0
Isobutane	**0.4**	1.5	0.1
n-Butane	**0.6**	6.0	0.4
Isopentane	**0.3**	2.0	0.1
n-Pentane	**0.3**	2.0	0.1
Total pentanes	***0.3***	*2.0*	
n-Hexane	**0.12**	0.2	0.03
n-Heptane	**0.04**	0.2	0.01
n-Octane	**0.03**	0.2	0.003
n-Nonane	**0.03**	0.2	0.003
n-Decane	**0.03**	0.2	0.003
Total hexanes plus	***0.15***		
Total heptanes plus	***0.04***		
Hydrogen	**5.0**	100.0	1.0
Oxygen	**0.2**	1.0	0.2
Carbon monoxide	**1.0**	10.0	1.0
Water	**0.05**	1.4	0.005
Hydrogen sulfide	**0.1**	4.0	0.1
Helium	**0.4**	5.0	0.4
Argon	**0.2**	3.0	0.2

Note: The above table provides component mole percent limits under the specified ranges of pressure, temperature, Btu value, and relative density for states with an uncertainty in density generally less than 0.1 %. The composition limits for different pressures, temperatures, Btu values, and relative densities outside of these ranges can he determined from the Excel spreadsheet provided in the supplementary material.

†Values are based on a methane lower limit composition of 60 mole percent. Reference conditions in U.S. customary units are (60 °F, 14.73 psia; density at 60 °F, 14.73 psia) and in SI units are (15 °C, 0.101325 MPa; density at 0 °C, 0.101325 MPa).

‡**The upper limit for the mole percent of CO_2 is reduced under the following conditions:**

$x_{CO2,max} = 20$ % when $x_{N2} > 7$ % | $x_{CO2,max} = 5$ % when $x_{C3} > 2$ %

$x_{CO2,max} = 10$ % when $x_{N2} > 15$ % | $x_{CO2,max} = 10$ % when $x_{iC4} > 0.1$ %

$x_{CO2,max} = 7$ % when $x_{C3} > 1$ % | $x_{CO2,max} = 10$ % when $x_{nC4} > 0.3$ %

See the discussion in Section 1.3.1 for further information.

Calculation Method

The equations used for calculating the speed of sound are shown below and are extremely difficult to solve without the use of a computer. They are best solved using programs that are available from various sources. They make the job of calculating the speed of sound a rather simple task, once you have the accurate input data.

The reliability of the calculation results is dependent on the accuracy of the determination of the composition, the flowing temperature, and the flowing pressure of the natural gas under consideration. Changes in the flowing pressure has a lesser degree of an effect on the accuracy of the calculations than changes of a similar amount in either of the other two inputs. In other words, an error of 1 psi in the flowing pressure measurement has a much less effect on the accuracy of the speed of sound calculation than an error of 1 degree in the flowing temperature measurement.

Formulas for Calculation of the Speed of Sound

As one can see from the formulas on the following pages, these calculations are for people that are expert mathematicians. These equations are directly from AGA 8. They are extremely difficult for people without a degree in mathematics to perform and even then, it would take a while if they do the calculations without the use of a computer. It is certainly something that most people would not want to attempt without access to a computer. There are a number of commercially available programs that can be purchased and used for these calculations. It is relatively easy to make the calculations using the computer programs. The inputs required are a complete gas analysis at least through C_{6+} or higher, the flowing pressure, and the flowing temperature.

Nomenclature used in the equations

W = gas speed of sound
c_v = constant volume heat capacity (real gas)
T = absolute gas temperature
P = absolute gas pressure
s = molar entropy (J/mol·K)
h = molar enthalpy (J/mol)
k = isentropic exponent
h = Molar Helmholtz energy (J/mol)
c_p = constant pressure heat capacity (real gas)
R = universal gas constant
M_r = molar mass
u = molar energy (J/mol)
Z = compressibility factor
g = molar Gibbs energy (J/mol)
d = molar density (mol/dm^3)

The AGA Report No. 10, *Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases*, on the calculation of speeds of sound from the DETAIL equation of state, obtained values through numerical integration of the compressibility factor equation. The equations presented here for the calculation of thermodynamic properties are implemented through differentiation of the fundamental Helmholtz energy equation. This results in faster calculations through direct computation of the required derivatives and is more precise since finite differences are not required.

The equations used for calculating compressibility factor, pressure, and the derivatives of pressure with respect to density and temperature are given in the following equations:

$$Z = \frac{P}{dRT} = 1 + \frac{d}{RT}\left(\frac{\partial a^r}{\partial d}\right)_T \quad (4\text{-}22)$$

$$P = d^2\left(\frac{\partial a}{\partial d}\right)_T = dRT + d^2\left(\frac{\partial a^r}{\partial d}\right)_T \quad (4\text{-}23)$$

$$\left(\frac{\partial P}{\partial d}\right)_T = RT + 2d\left(\frac{\partial a^r}{\partial d}\right)_T + d^2\left(\frac{\partial^2 a^r}{\partial d^2}\right)_T \quad (4\text{-}24)$$

$$\left(\frac{\partial^2 P}{\partial d^2}\right)_T = 2\left(\frac{\partial a^r}{\partial d}\right)_T + 4d\left(\frac{\partial^2 a^r}{\partial d^2}\right)_T + d^2\left(\frac{\partial^3 a^r}{\partial d^3}\right)_T \quad (4\text{-}25)$$

$$\left(\frac{\partial P}{\partial T}\right)_d = dR + d^2\left(\frac{\partial^2 a^r}{\partial d \partial T}\right) \tag{4-26}$$

The equations for calculating entropy s, energy u, enthalpy h, Gibbs energy g, isochoric heat capacity c_v, isobaric heat capacity c_p, speed of sound w, Joule-Thomson coefficient μ, and the isentropic exponent κ are given below. Additional equations for other properties and alternative methods for expressing Helmholtz equations are given in Lemmon *et al.* (see Reference [7]).

$$s = -\left(\frac{\partial a}{\partial T}\right)_d = -\left(\frac{\partial a^0}{\partial T}\right)_d - \left(\frac{\partial a^r}{\partial T}\right)_d \tag{4-27}$$

$$u = a + Ts \tag{4-28}$$

$$h = u + \frac{P}{d} \tag{4-29}$$

$$g = a + \frac{P}{d} \tag{4-30}$$

$$c_v = \left(\frac{\partial u}{\partial T}\right)_d = T\left(\frac{\partial s}{\partial T}\right)_d = -T\left(\frac{\partial^2 a}{\partial T^2}\right)_d = -T\left[\left(\frac{\partial^2 a^0}{\partial T^2}\right)_d + \left(\frac{\partial^2 a^r}{\partial T^2}\right)_d\right] \tag{4-31}$$

$$c_p = c_v + \frac{T}{d^2}\left(\frac{\partial P}{\partial T}\right)_d^2 \left(\frac{\partial P}{\partial d}\right)_T^{-1} = c_v + T\frac{\left[R + d\left(\frac{\partial^2 a^r}{\partial d \partial T}\right)\right]^2}{\left[RT + 2d\left(\frac{\partial a^r}{\partial d}\right)_T + d^2\left(\frac{\partial^2 a^r}{\partial d^2}\right)_T\right]} \tag{4-32}$$

$$w^2 = \frac{1000\, c_p}{Mc_v}\left(\frac{\partial P}{\partial d}\right)_T = \frac{1000\, c_p}{Mc_v}\left[RT + 2d\left(\frac{\partial a^r}{\partial d}\right)_T + d^2\left(\frac{\partial^2 a^r}{\partial d^2}\right)_T\right] \tag{4-33}$$

$$\mu = \frac{1}{c_p d}\left[\frac{T}{d}\left(\frac{\partial P}{\partial T}\right)_d \left(\frac{\partial P}{\partial d}\right)_T^{-1} - 1\right] \tag{4-34}$$

$$\kappa = \frac{w^2 M}{ZRT} \tag{4-35}$$

$$w^2 = \frac{1000\,c_p}{Mc_v}\left(\frac{\partial P}{\partial d}\right)_T = \frac{1000\,c_p}{Mc_v}\left[RT + 2d\left(\frac{\partial a^r}{\partial d}\right)_T + d^2\left(\frac{\partial^2 a^r}{\partial d^2}\right)_T\right] \tag{4-33}$$

$$\mu = \frac{1}{c_p d}\left[\frac{T}{d}\left(\frac{\partial P}{\partial T}\right)_d\left(\frac{\partial P}{\partial d}\right)_T^{-1} - 1\right] \tag{4-34}$$

$$\kappa = \frac{w^2 M}{ZRT} \tag{4-35}$$

The following nomenclature is used to simplify the appearance of the derivative equations:

$$\zeta_n = C_n^* T^{-u_n} \tag{4-36}$$

$$\psi_n = C_n^* T^{-u_n} D^{b_n} \exp\left(-c_n D^{k_n}\right) \tag{4-37}$$

$$\omega_n = c_n k_n D^{k_n} \tag{4-38}$$

$$\beta_n = b_n - \omega_n \tag{4-39}$$

$$\xi_{i,k} = \vartheta_{i,k}^{o} / T \tag{4-40}$$

Ultrasonic Meter Operation

An ultrasonic meter uses transducers to create sound pulses that travel across the flowing gas stream both with the flow and against the flow of gas. The difference in the transit times can be used to calculate the velocity of the gas in the pipe. The speed of sound in the gas can be calculated by dividing the distance between the transducer faces, known as path length, by the time required for a pulse to travel that distance. The path lengths are measured very accurately in the manufacture of the meters. One of the meter diagnostics is comparing the speed of sound determined by the meter to the theoretical speed of sound in the gas as calculated by AGA 8.

As mentioned earlier, the three inputs to the equations are gas composition, flowing gas pressure, and flowing gas temperature. Table 2 demonstrates the effect a change in the temperature and a change in the pressure can have on the calculation of the speed of sound. The gas composition used for these calculations is the Gulf Coast Gas shown in Table 3.

Table 2: Speed of Sound (in ft/sec) Variation as a Function of Gas Pressure and Temperature
(For the Gulf Coast Gas composition shown in Table 4)

Temperature → / **Pressure ↓**	**30°F**	**31°F**	**35°F**	**40°F**	**60°F**	**70°F**	**90°F**	**100°F**	**120°F**
200 psig	1,351.1	1,352.6	1,358.5	1,365.9	1,394.4	1,408.3	1,435.1	1,448.1	1,473.4
201 psig	1,351.0	1,352.5	1,358.4	1,365.8	1,394.3	1,408.2	1,435.0	1,448.0	1,473.4
202 psig	1,350.9	1,352.4	1,358.3	1,365.7	1,394.3	1,408.1	1,434.9	1,448.0	1,473.3
205 psig	1,350.5	1,352.0	1,358.0	1,365.4	1,394.0	1,407.9	1,434.8	1,447.8	1,473.2
210 psig	1,350.0	1,351.5	1,357.5	1,364.9	1,393.6	1,407.5	1,434.4	1,447.5	1,472.9
500 psig	1,321.6	1,323.4	1,330.4	1,339.1	1,372.4	1,388.4	1,418.9	1,433.6	1,461.9
501 psig	1,321.5	1,323.3	1,330.3	1,339.0	1,372.4	1,388.3	1,418.9	1,433.6	1,461.9
502 psig	1,321.4	1,323.2	1,330.3	1,338.9	1,372.3	1,388.3	1,418.8	1,433.5	1,461.9
505 psig	1,320.7	1,323.0	1,330.0	1,338.7	1,372.1	1,388.1	1,418.7	1,433.4	1,461.8
510 psig	1,320.7	1,322.5	1,329.6	1,338.3	1,371.8	1,387.8	1,418.5	1,433.3	1,461.7
1,000 psig	1,296.3	1,298.4	1,306.8	1,317.1	1,356.2	1,374.6	1,409.7	1,426.4	1,458.3
1,001 psig	1,296.3	1,298.4	1,306.8	1,317.0	1,356.2	1,374.6	1,409.7	1,426.4	1,458.3
1,005 psig	1,296.2	1,298.4	1,306.7	1,317.0	1,356.2	1,374.7	1,409.7	1,426.4	1,458.4
1,010 psig	1,296.2	1,298.3	1,306.7	1,317.0	1,356.2	1,374.7	1,409.7	1,426.5	1,458.5

From Table 2, one can see that the speeds of sound are affected much less by a small pressure change than it is by a small temperature change. For example, a one pound change in pressure from 200 psig to 201 psig only changes the speed of sound by 0.1 ft/sec, if at all; whereas a temperature change of one degree Fahrenheit can change the speed of sound at 200 psig from 1.5 ft/sec to as much as 2.1 ft/sec at 1,000 psig. At pressures in the 1,000-psig range, it can require more than a 10 psig change in pressure to cause the speed of sound to change by 0.1 ft/sec.

This shows that if a calculated speed of sound is used to verify that the speed of sound determined by your meter is correct, you must have very accurate temperature measurements. The pressure is also very important in calculating the standard volumes but a small change in the pressure does not affect the speed of sound calculation nearly as much as does a corresponding change in the temperature. Stated another way, a 1 psig change in pressure does not affect the speed of sound calculation nearly as much as a 1 degree change in the temperature. The speed of sound determined by the meter should agree with the speed of sound calculated by using AGA 8 within ±0.2%.

The composition of the gas used to calculate the speed of sound in Table 2 is the Gulf Coast Gas composition from AGA 8. This composition was determined by averaging a large number of gas samples collected by various companies that operate facilities both onshore along the Gulf of Mexico Coast and offshore in the Gulf of Mexico. The Gas Research Institute (GRI) reference compositions of the Gulf Coast Gas, the Ekofisk Gas, the Amarillo Gas, and air are included in Table 3.

A comparison of how the composition of a gas affects the speed of sound in the gas is shown in Table 4. The comparison is made at several pressures and temperatures. The composition of the Ekofisk gas has a high ethane content, nearly 8.5 mole percent as compared to the ethane content of 1.8 mole percent in the Gulf Coast gas. The Ekofisk gas has no hexanes and heavier hydrocarbon components, whereas, the composition of the Gulf Coast gas contains a small amount of n-hexane. The Ekofisk gas also has five times the amount of propane, and the other components are also greater except for the hexanes and the methane, which is only 85.9063 mole percent compared to 96.5222 mole percent in the Gulf Coast gas. As one can see from the values in Table 4, there can be a significant difference in the speed of sound calculated for the same conditions when the gas composition is changed.

Table3: Reference Gas Compositions

Components in Mole Percent	Gulf Coast Gas	Ekofisk Gas	Amarillo Gas	Air
Speed of Sound @14.73 & 60°F	1,412.4	1,365.6	1,377.8	1,118.05
Gr	0.581078	0.649521	0.608657	1.00
Heating Value	1,036.05	1,108.11	1,034.85	
Methane	96.5222	85.9063	90.6724	
Nitrogen	0.2595	1.0068	3.1284	78.03
Carbon Dioxide	0.5956	1.4954	0.4676	0.03
Ethane	1.8186	8.4919	4.5279	
Propane	0.4596	2.3015	0.8280	
Iso-Butane	0.0977	0.3486	0.1037	
Normal Butane	0.1007	0.3506	0.1563	
Iso-Pentane	0.0473	0.0509	0.0321	
Normal Pentane	0.0324	0.0480	0.0443	
Normal Hexane	0.0664	0.0000	0.0393	

Table 4: Comparison of Speed of Sound (in ft/sec) in Gulf Coast Gas and Ekofisk Gas at Same Conditions

Temperature → Pressure ↓	30°F Gulf Coast	30°F Ekofisk	60°F Gulf Coast	60°F Ekofisk	120°F Gulf Coast	120°F Ekofisk
200 psig	1,351.1	1,260.3	1,394.4	1,301.8	1,473.4	1,377.1
201 psig	1,351.0	1,260.2	1,394.3	1,301.7	1,473.4	1,377.1
205 psig	1,350.5	1,259.6	1,394.0	1,301.2	1,473.2	1,376.8
210 psig	1,350.0	1,258.9	1,393.6	1,300.6	1,472.9	1,376.4
500 psig	1,321.6	1,220.0	1,372.4	1,270.6	1,461.9	1,358.7
501 psig	1,321.5	1,219.9	1,372.4	1,270.5	1,461.9	1,358.7
505 psig	1,320.7	1,219.4	1,372.1	1,270.2	1,461.8	1,358.5
510 psig	1,320.7	1,218.8	1,371.8	1,269.7	1,461.7	1,358.2
1,000 psig	1,296.3	1,180.0	1,356.2	1,241.7	1,458.3	1,345.5
1,001 psig	1,296.3	1,179.9	1,356.2	1,241.7	1,458.3	1,345.5
1,005 psig	1,296.2	1,179.8	1,356.2	1,241.7	1,458.4	1,345.5
1,010 psig	1,296.2	1,179.8	1,356.2	1,241.6	1,458.5	1,345.5

Figure 2 shows the speed of sound for the Gulf Coast gas mixture plotted for four different temperatures and for pressures from near 0 psia to 1,500 psia. This figure clearly shows how the speed of sound varies with the changes in temperature and pressure. This covers a large span of the normal operating pressures and temperatures except for most gas storage operations.

Figure 3 shows the speed of sound in four different gases, including air from near 0 psia to 1,500 psia at 60°F. This demonstrates, in graphical form, how the speed of sound varies for gases with different compositional mixtures at various pressures. Air, being composed of primarily of nitrogen, carbon dioxide, and oxygen, is included as a reference.

As stated previously, one of the diagnostics available in the ultrasonic meter is the speed of sound calculated by the meter. One meter manufacturer also has the ability to connect to pressure and temperature transmitters, as well as a gas chromatograph, and bring those inputs into the meter electronics. The meter software then uses the AGA-10 calculation method, along with pressure, temperature, and gas composition to compute a theoretical or calculated speed of sound. The AGA 8 calculated speed of sound is then compared to the speed of sound measured by the ultrasonic meter. This comparison is one of many diagnostics available in the ultrasonic meter. By using this diagnostic (along with the other available diagnostics), the ultrasonic meter user can then determine the meter's overall health and functionality. Advanced users trend this data over time to observe any potential drifts occurring over time in the ultrasonic meter. A drift in the meter's speed of sound calculation can point to a number of potential problems, including deposit buildup on the wall of the meter or face of the transducers, liquid inside the meter, or, possibly, a transducer that may be beginning to fail. Figure 4 shows one manufacturer's software that does a live comparison of the meter's speed of sound compared to the AGA 8 calculated speed of sound.

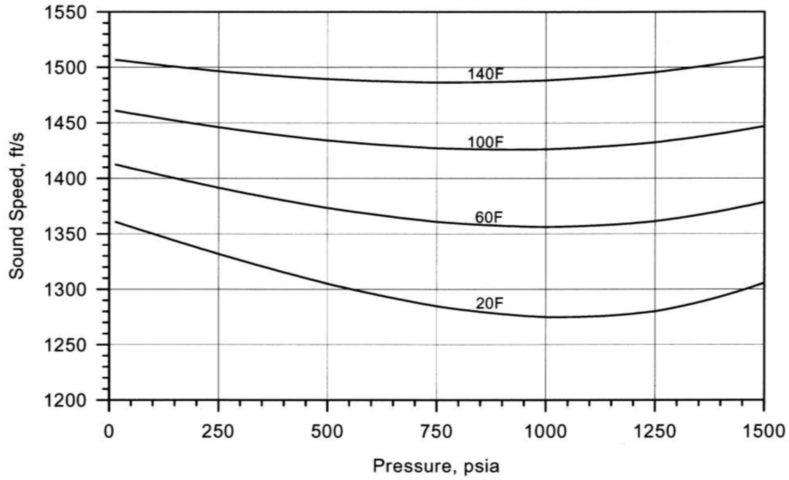

Figure 2: Speed of Sound in 0.58 Gr "Gulf Coast" Gas Below 1,500 psia

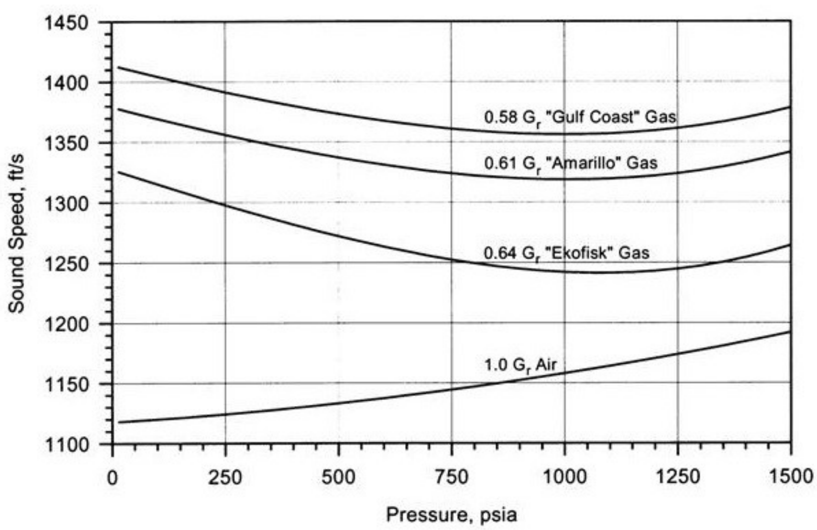

Figure 3: Speed of Sound in Various Gases at 60ºF

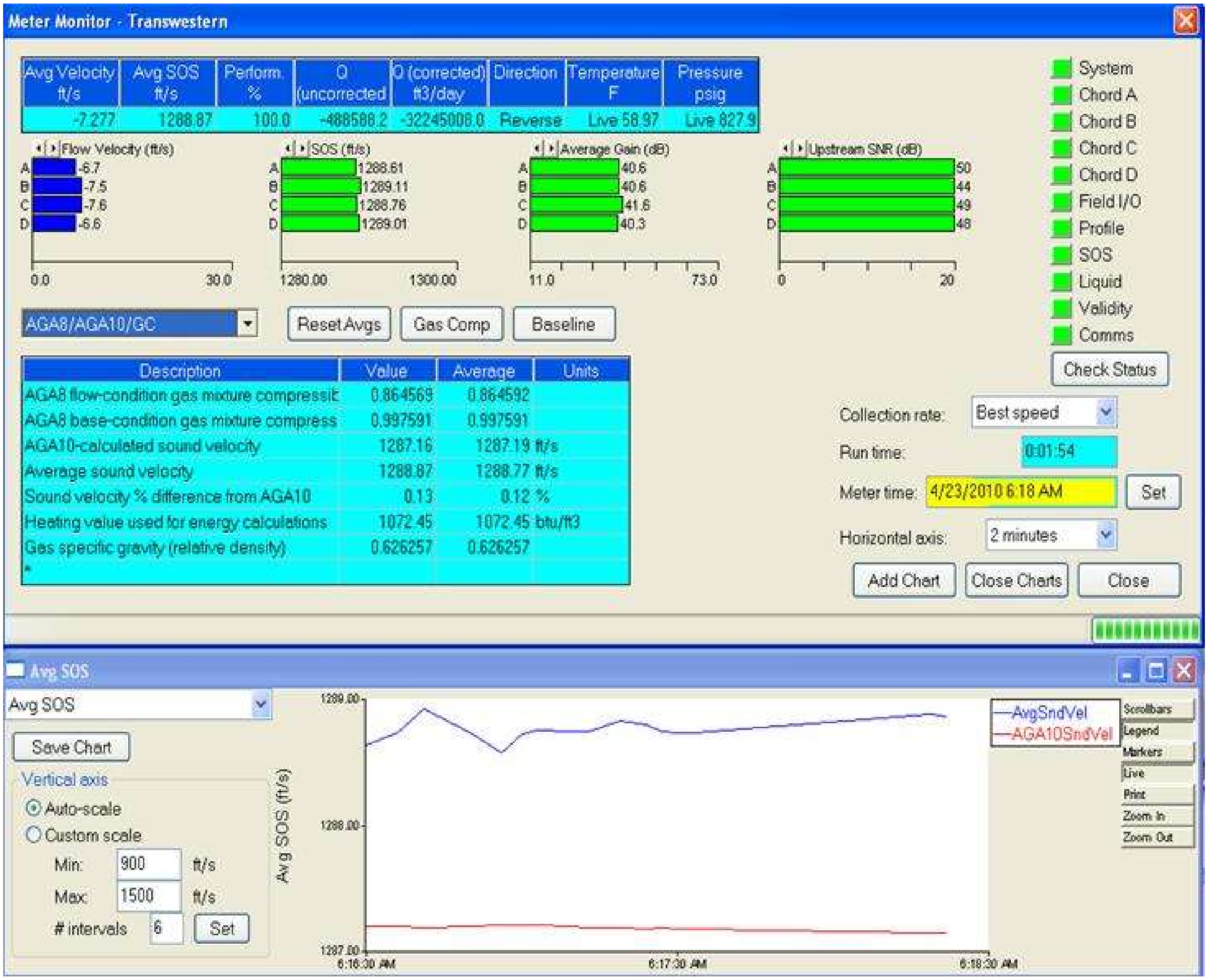

Figure 4: Ultrasonic Meter Software Plotting Meter Speed of Sound vs. AGA-10 Calculated Speed of Sound Summary

Closing

AGA-10 was conceived following the development and wide use of ultrasonic flow meters for custody transfer measurement. With the revision of AGA Report No 8 it was decided that it was necessary to revise AGA Report No 10 and rather than revise AGA 10, since it was based on AGA equations that it was best to include the speed of sound calculation in the revised AGA Report No 8 and eliminate AGA Report No 10. With this revision, AGA Report No 8 includes the equations and calculation methods necessary to compute the speed of sound in natural gas and other hydrocarbon gases. By using the equations laid out in the AGA 8 document, users can accurately calculate speed of sound and, in turn, compare the calculated speed of sound to that of measurement devices, such as ultrasonic meters, for diagnostic purposes.

References

1. AGA Report No. 8, "Compressibility Factors of Natural Gas and Other Related Hydrocarbon Gases," 2nd Printing, American Gas Association, Washington, D.C.,April 2017.

2. AGA Report No. 9, "Measurement of Gas by Multipath Ultrasonic Meters," 2nd Edition, American Gas Association, Washington, D.C., April 2007.

3. AGA Report No. 10, " Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases," American Gas Association, Washington, D.C., January 2003.