

OWNER

AGA 8 Detail and GERG-2008 Comparison and AGA 10 Speed of Sound

Calculation



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ISSUE SUMMARY AND APPROVAL

This page records each issue of MEA-CAL-003. The preparer, reviewer and approver sign for each revision.

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Rev.	Discipline	Prepared by	Reviewed by	Approved by
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1. OBJECTIVE

This calculation compares the two equations of state that AGA Report No. 8 allows for custody measurement, the Part 1 Detail characterization method and the Part 2 GERG-2008 equation, for the station's lean, design and rich gases across the metering range. It quantifies the effect of the choice on custody volume, and it sets the tolerance for the ultrasonic meter speed-of-sound check, which compares each meter's measured speed of sound with the value calculated per AGA Report No. 10.

2. METHODOLOGY

The Detail and GERG-2008 equations were evaluated with an implementation that follows the NIST reference code for AGA 8 line by line. Before use, TORUS checked it against the published NIST example (a 21-component gas at 400 K and 50,000 kPa): density, compressibility and speed of sound matched to every printed digit for both equations. The GERG-2008 property package used elsewhere in this volume (CoolProp 8.0) was compared with the reference implementation over 26 single-phase points.

The effect of the equation choice on volume follows from the measurement equation. The actual volume from the meter is common to both, so only the ratio Z_b/Z_f differs:

$$\frac{Q_{b,GERG}}{Q_{b,Detail}} - 1 = \frac{Z_{b,G}/Z_{f,G}}{Z_{b,D}/Z_{f,D}} - 1$$

The AGA 10 speed of sound is the thermodynamic speed of sound of the Detail equation. Its uncertainty at the meter combines the temperature, pressure and composition uncertainties of MEA-CAL-002, each multiplied by a numerical sensitivity, with the stated equation uncertainty. The diagnostic tolerance is the expanded uncertainty of the difference between the meter's measurement and the calculation.

The AGA 8 gross characterization methods were not evaluated. They are intended for use when a full analysis is not available, which is not the case here, and the flow computer is specified to use Detail or GERG-2008 only.

3. DESIGN INPUTS

Table 3-1 lists the inputs.

Table 3-1: Design Inputs

Input	Value	Source
Lean, design and rich compositions (hexanes plus as n-hexane)	Mole fractions per basis	GEN-DB-001, Section 5.1

Input	Value	Source
Comparison range	700 to 1,200 psig, 30 to 120 °F	Covers meter conditions of C1 to C7 with margin
Meter conditions per case	887 to 1,137 psig, 44 to 119 °F	MEA-CAL-001
Temperature and pressure standard uncertainty	0.222 °F and 0.30 psi	MEA-CAL-002
Composition standard uncertainties	Per component	MEA-CAL-002
AGA 10 equation uncertainty	0.1 % at $k = 2$	AGA Report No. 10
Meter average speed of sound after delay calibration	±0.05 %	Typical, HOLD H-15

4. ASSUMPTIONS

1. Hexanes plus are represented as n-hexane. A heavier C7+ fraction lowers the speed of sound and slightly increases the Detail and GERG difference. *Verification required with the extended analysis (HOLD H-12).*
2. The meter's average speed-of-sound uncertainty of ±0.05 % applies after transducer delay calibration at the flow laboratory. *Verification required (HOLD H-15).*

5. REFERENCES

1. AGA Report No. 8 Part 1 (2017), Detail characterization method, and Part 2 (2017), GERG-2008.
2. AGA Report No. 10 (2003), Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases.
3. AGA Report No. 9 (2022), Measurement of Gas by Multipath Ultrasonic Meters.
4. NIST AGA8 reference code and example output.
5. GEN-DB-001, Basis of Design; MEA-CAL-001 and MEA-CAL-002.

6. CALCULATION

6.1. VALIDATION

Table 6-1 shows the reference example. The implementation reproduces NIST's published values exactly.

Table 6-1: Validation against the NIST Reference Example

Equation	Density (mol/L)	Compressibility	Speed of sound (m/s)	Agreement
Detail	12.807924036	1.17380136415	712.63936841	All digits
GERG-2008	12.798286261	1.17469066638	714.42488406	All digits

The CoolProp GERG-2008 package agrees with the reference implementation within 0.007 % in compressibility and 0.012 % in speed of sound at every single-phase point. It is adequate for design work; the flow computer will still use a certified AGA 8 implementation. At 750 psig and 40 °F CoolProp placed the rich gas inside the two-phase region, consistent with the rich-gas dew point of about 42 °F found in MEA-CAL-004. The rich case is an off-specification upset, not a deliverable gas at that temperature.

6.2. BASE CONDITIONS

At 14.73 psia and 60 °F the two equations agree within 41 ppm in Z_b (Table 6-2), so the difference in volume comes almost entirely from Z_f .

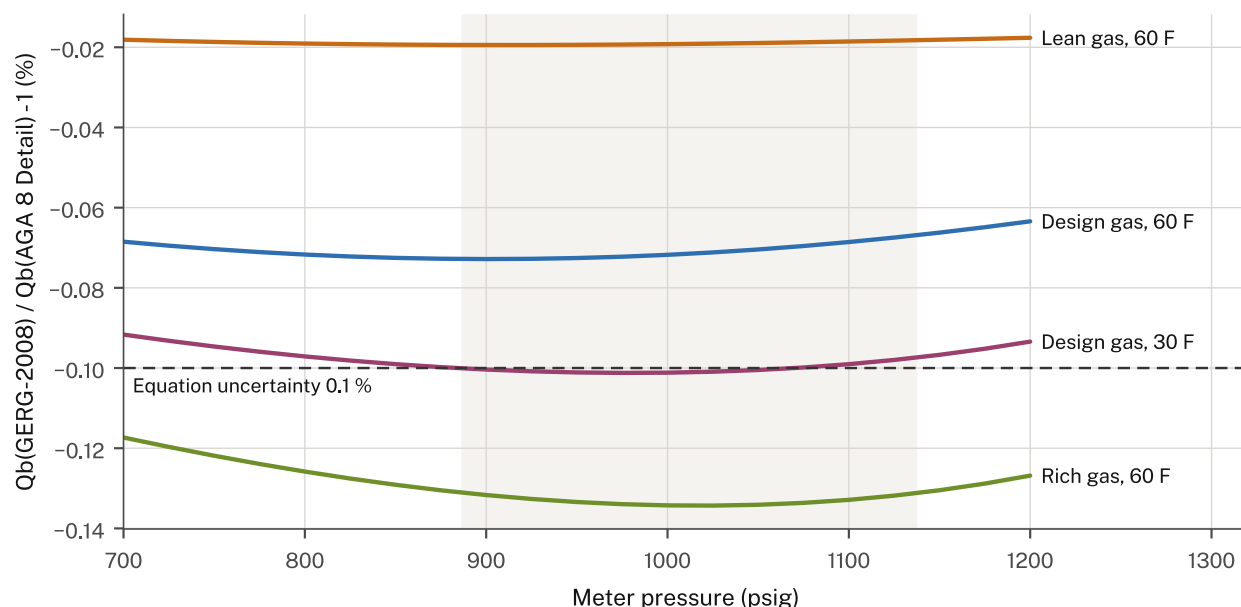
Table 6-2: Compressibility at Base Conditions

Gas	Z_b Detail	Z_b GERG-2008	Difference (ppm)
Lean	0.997823	0.997828	+5
Design	0.997405	0.997428	+24
Rich	0.996986	0.997026	+41

6.3. EFFECT ON VOLUME

Figure 6-1 shows the difference in volume against meter pressure. GERG-2008 always gives slightly less volume than Detail for these gases. The difference grows with heavier gas and lower temperature, the region where the Detail equation extrapolates beyond its fitting data. For the design gas it is 0.06 to 0.07 % at 60 °F and about 0.10 % at 30 °F; for the lean gas it is 0.02 %.

Figure 6-1. Volume by GERG-2008 Relative to AGA 8 Detail



Note 1: The shaded band is the metering pressure range of cases C1 to C7.

Table 6-3 gives the design gas values across the full grid. The largest differences over the grid are 0.022 % for the lean gas, 0.101 % for the design gas and 0.234 % for the rich gas at 30 °F.

Table 6-3: Design Gas, $Q_{b, GERG}/Q_{b, Detail} - 1$ (%)

Pressure (psig)	30 °F	45 °F	60 °F	90 °F	120 °F
700	-0.092	-0.079	-0.068	-0.052	-0.041
800	-0.097	-0.083	-0.072	-0.055	-0.044
900	-0.100	-0.085	-0.073	-0.057	-0.046
1,000	-0.101	-0.084	-0.072	-0.056	-0.047
1,100	-0.099	-0.081	-0.069	-0.054	-0.046
1,200	-0.093	-0.075	-0.063	-0.051	-0.045

AGA 8 Part 2 presents GERG-2008 as the more accurate equation and states that the two agree within their uncertainty, about 0.1 % in density, for pipeline-quality gas in the normal range, with larger differences for rich gas and at low temperature. The results agree with that statement: the design gas stays at or inside 0.10 % and only the off-specification rich gas at low temperature exceeds it.

6.4. SPEED OF SOUND AT THE METER

Table 6-4 gives the AGA 10 speed of sound for every case. Across 700 to 1,200 psig, 30 to 130 °F and lean to rich gas, the speed of sound ranges from 1,130 to 1,461 ft/s; the transducers and path lengths must operate over that range.

Table 6-4: AGA 10 Speed of Sound at Meter Conditions

Case	Pressure (psig)	Temperature (°F)	Detail (ft/s)	GERG-2008 (ft/s)	Difference (%)
C1	1,137.0	44.2	1,227.4	1,227.1	-0.02
C2	1,042.7	69.6	1,275.9	1,276.3	+0.03
C3	999.9	60.0	1,258.1	1,258.3	+0.02
C4	1,087.0	119.4	1,361.1	1,361.9	+0.06
C5	887.0	59.2	1,259.1	1,259.4	+0.03
C7 (rich)	1,087.0	59.2	1,185.0	1,184.2	-0.07

6.5. DIAGNOSTIC TOLERANCE

At C5 the speed of sound changes by 1.876 ft/s per °F and by -0.033 ft/s per psi. The composition sensitivity was calculated component by component. The uncertainty of the calculated value is:

AGA 10; JCGM 100

$$u_{calc} = \sqrt{0.0330^2 + 0.0008^2 + 0.0868^2 + 0.0500^2} = 0.106 \%$$

where the terms are temperature, pressure, composition and equation. With the meter's own uncertainty of $0.05/\sqrt{3} = 0.029 \%$, the expanded uncertainty of the difference is:

$$U = 2\sqrt{0.106^2 + 0.029^2} = 0.22 \%$$

The result is the same at C2 and C3 (0.22 %). Composition dominates: a 1 mol % error between methane and ethane moves the calculated value by 0.66 %, and between methane and nitrogen by 0.16 %, while a 1 °F temperature error moves it by 0.15 %.

7. RESULTS AND CONCLUSIONS

1. For the design gas at meter conditions, GERG-2008 gives 0.04 to 0.10 % less volume than AGA 8 Detail, 0.07 % at C5. This is within the 0.1 % equation term carried in MEA-CAL-002, but it is a bias, not a random error. Both parties must therefore use the same equation. The flow computer will be configured for AGA 8 Detail with GERG-2008 selectable, and the choice will be written into the Interconnect Agreement with an effective date (HOLD H-01).
2. The speed-of-sound check will alert when a meter differs from the AGA 10 value by more than $\pm 0.25 \%$ over a 1 hour average and alarm at $\pm 0.40 \%$. The alert is set just above the 0.22 % expanded uncertainty so that it does not trip on normal scatter. Path-to-path spread is a vendor diagnostic, typically 0.2 % (HOLD H-15).
3. A sustained deviation between 0.25 and 0.40 % with both meters agreeing points first to the temperature measurement or the chromatograph, not to the meter.
4. Transducers shall operate between 1,130 and 1,461 ft/s.

Owner

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The next step is to rerun this comparison with the extended gas analysis when the Owner provides it (HOLD H-12).

