Bristol

What is AGA 11 and How is it Implemented in Software?

By Kevin Finnan

Since AGA Report No. 11 was published in 2003, Coriolis meters have been applied throughout the natural gas industry for custody transfer measurement. Many Emerson customers have found the Coriolis meter to be the best choice for a broad range of flow conditions.

As the report states, it was developed to assist designers and users in operating, calibrating, installing, maintaining and verifying Coriolis flow meters for natural gas flow measurement.

Applying a gas flow computer to a Coriolis meter installation might, at first, present a quandary. The volumetric meters to which we have become accustomed require an equation to correct flow to standard conditions. But a Coriolis meter provides a measurement of mass flow rate; therefore, no equation is required. What's a flow computer to do?

As the AGA 11 report points out, users often require a calculation of volumetric flow rate at standard conditions. It could be required by contract or perhaps necessary simply for consistency in reporting when the system uses a variety of meters, including mass and volumetric types.

Users often also require an energy rate, which could be determined by multiplying the volumetric rate by the BTU content per standard volume unit. In many cases, a full composition analysis is available for determination of the BTU content. That composition is also used by AGA8 Detail in calculating compressibility and, as AGA 11 further states, the gas density.

While that answers part of the question regarding what a flow computer can do, you can likely also see that the flow computer additionally performs the alarming, audit trail logging, historical data logging, calibration and security functions, which are defined in API Chapter 21.1. These functions are necessary regardless of the meter type.

Relationship of Mass Flow Rate to Volumetric Flow Rate at Standard Conditions

To calculate the volumetric flow rate at standard conditions, AGA 11 provides a derivation that is based on the conservation of mass and the non-ideal gas law.

Although in the future we expect to offer a function block that provides this operation, it can also easily be done without one, as shown here.

All equation references, included herein, are those in Appendix D in the AGA 11 report.

The volumetric flow rate, at base conditions, is equal to the mass flow rate divided by the density at base conditions.

Expressed as an equation, that is as follows:

$$q_b = q_m / \rho_b \qquad \text{(D.2)}$$

Where:

q_b = volumetric flow rate at base (standard) conditions

q_m = mass flow rate that is measured by the Coriolis meter

ρ_b = density at standard conditions

The density at standard conditions is derived from the non-ideal gas law and is calculated by AGA8 Detail.

If you're using AGA8 Detail, calculation of the volumetric flow at standard conditions is a snap. You just use equation D.2, above.

Even with such a simple equation as D.2, our usual warning, "watch those units," applies. The mass, volume and time units must match throughout. Mass will cancel out, leaving you with volume per unit time.

In Appendix D, AGA 11 provides a brief derivation of density at standard conditions. Serious programmers are referred to AGA Report No. 8, particularly Appendix C.3. The short-cut provided, here, is equation C.3-8 in AGA 8. Please note that this is for information purposes. If you use AGA8 Detail, this work has been done.

$$\rho_b = (P_b\, M_r) / (Z_b\, R\, T_b) \qquad \text{(D.4)}$$

Where:

ρ_b = density (referred to as mass density) at standard conditions

P_b = absolute pressure of the gas at standard conditions

M_r = molar mass (mass per mole) at standard conditions

Z_b = compressibility at base conditions

R = universal gas constant

T_b = absolute temperature of the gas at standard conditions

You can probably tell, at this point, that AGA8 Detail is highly recommended because the full composition is available for determination of the molar mass. Otherwise, users of AGA8 Gross or NX-19 are left to estimate it and use the equation, above. AGA8 Appendix C.3 provides an equation for determination of Mr for users of AGA8 Gross.

Relationship of Actual Volumetric Flow Rate and Flow Rate at Standard Conditions

Some Coriolis meter users further require a calculation of the actual, otherwise referred to as the uncorrected, volumetric flow rate. AGA 11 doesn't fail us, here. The relationship between the actual volumetric flow rate and the flow rate at standard conditions is provided in equation form:

$$q_b = q_f\, (P_f\, T_b\, Z_b) / (P_b\, T_f\, Z_f) \qquad \text{(D.9)}$$

Where:

q_b = volumetric flow rate at standard conditions

q_f = volumetric flow rate at actual (line) conditions

P_b = absolute pressure of the gas at standard conditions

P_f = absolute pressure of the gas at actual (line) conditions

Z_b = compressibility at base conditions

Z_f = compressibility at actual (line) conditions

T_b = absolute temperature of the gas at standard conditions

T_f = absolute temperature of the gas at actual (line) conditions

A twist here is the introduction of actual conditions for pressure and temperature. In the discussion of determination of volumetric flow rate at standard conditions, AGA 11 clearly stated that pressure and temperature measurements are not required.

The question is, are live measurements of pressure and temperature available? The answer is that they are not necessarily so. AGA 11 does discuss use of a pressure measurement for pressure compensation, including directions for its location with respect to the meter. In addition, our experience shows that users often also install a device for temperature measurement.

Bottom line is that, if determination of the actual volumetric flow rate is required, live measurements of line pressure and temperature are required. In addition, the issue of locations of these measurements likely needs further study.

In any event, equation D.9 can be solved for qf as follows:

$$q_f = q_b\, (P_b\, T_f\, Z_f) / (P_f\, T_b\, Z_b)$$

Once again, our usual warnings: watch those units and beware that the pressure is in absolute (not gauge) units. Less of a warning is that goes for temperature, which is also in absolute units.

Otherwise, happy programming!

References:

AGA Transmission Measurement Committee Report No. 8, Compressibility Factors of Natural Gas and Other Related Hydrocarbons, Second Edition, November 1992

AGA Report No. 11, Measurement of Natural Gas by Coriolis Meter, Copyright 2003

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