CLEAN VEHICLE EDUCATION FOUNDATION

Technology Committee Bulletin

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Natural Gas Metering
Utility Metering vs. CNG Dispenser Metering

The natural gas vehicle industry worked with the Weights & Measures Division of the National Institute of Standards and Technology to define a Gasoline Gallon Equivalent (GGE) of natural gas dispensed as compressed natural gas (CNG). Weights & Measures adopted the definition of a GGE in 1994. A GGE is a recognized and approved unit of measurement for CNG.

A GGE is defined in Weights & Measures Handbook 44 – "Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices". A GGE is defined as 5.660 pounds of natural gas. In 1994, the lower heating value (LHV) of gasoline in the U.S. was 114,118 Btu/gallon. In order to create a national standard for GGE – a database of 6,811 natural gas samples from across the U.S. were used to calculate an average composition for natural gas. The average LHV for these natural gas samples was 923.7 BTU/standard cubic foot of gas (SCF). The average density of these samples was 0.0458172 pounds per standard cubic foot of gas. This average LHV and density were used to calculate the 5.660 pounds of natural gas per GGE by the following:

$$\frac{923.7 \text{ Btu/SCF}}{0.0458172 \text{ pounds/SCF}} = 20{,}160.551 \text{ Btu/pound}$$

$$\frac{114{,}118 \text{ Btu/gallon}}{20{,}160.551 \text{ Btu/pound}} = 5.660 \text{ pounds/gallon}$$

This definition is based upon the "average" LHV Btu content of natural gas across the country as it was in 1994. The 5.660 pounds per GGE is fixed even though natural gas composition varies across the U.S. and can vary in a given region on a day-to-day or month-to-month basis. The definition is also independent of the changing Btu content of gasoline over the years. The definition of GGE says essentially that if/when one dispenses 5.660 pounds of natural gas (regardless of gas composition) – one can define that as one GGE.

Measurement of CNG for Vehicle Fuel:

The natural gas vehicle fueling industry uses Micro Motion mass flow meters in dispensers for natural gas retail sales of CNG fuel. These meters measure units of mass (pounds) not volume of natural gas as required by NIST Handbook 44. They are calibrated to a U.S. Weights and Measures standard of 5.660 pounds of CNG per gasoline gallon equivalent. The Micro Motion meter accuracy from technical specification literature is ± 0.5% per batch of fuel delivered (more accurate than the utility meter accuracy requirements of -2% to +1%). Because the meter measures in pounds and not gas volume – there is no need for the meter to correct the mass measurement for temperature, meter pressure, or atmospheric pressure/altitude at the meter – which greatly improves accuracy over utility meters that measure the volume of gas. Attached is a Gas Technology Institute paper "Evaluation of Mass Flowmeters for CNG Fueling Dispensers" that notes the test accuracy of two Micro Motion meters as -0.2 to +0.3% and +0.1 to +0.3% -- better than the accuracy represented in the technical specification literature.

Utility Measurement of Natural Gas:

Utilities bill and sell natural gas in units of therms (1 therm equal to 100,000 Btus). Gas is measured in volume (cubic feet of natural gas) at the utility meter. To convert cubic feet of gas to therms a utility must know the HHV of natural gas in Btus/CF by calculation from the composition of the natural gas. They then multiply the HHV time the measured SCF of natural to get the total Btus delivered. Dividing that number by 100,000 equal the number of therms used and is the basis for billing the customer. The price of gas in $/therm can then be applied to the number of therms used to calculate the customer's bill.

The California Public Utility Commission's General Order 58A defines the metering specifications for California gas utilities. The order requires a meter accuracy of -2% to +1%. This tolerance is far less accurate than the accuracy of Micro Motion mass measurement meters.

HHV of a gas is determined by the chemical composition of the gas. Attached is a pdf file of a spreadsheet developed by the Gas Research Institute (now Gas Technology Institute) in the 90s. This spreadsheet converts gas composition to Btus (HHV). Small changes in gas composition change the HHV Btu content of the gas. This calculator can also calculate the pounds per GGE of the gas (remembering that a gallon equivalent is equal to 114,118 Btus (LHV). In the example in the spreadsheet, a typical pipeline gas composition yields a pounds per GGE of 5.589 pounds per GGE. Regardless of this pounds per GGE – a CNG dispenser will dispense 5.660 pounds of gas and record that volume as one GGE. In this scenario, the CNG dispenser will deliver 1.2% more natural gas (5.660 pounds/GGE) than the gas composition would dictate (5.589 pounds/GGE). It can't be stressed enough that utility measurement of natural gas is based on HHV (1,032.3 per CF in this example) while CNG is based on LHV (931 Btu/CF in this example). The LHV of the gas example (931 Btu/CF) doesn't agree with the Weights & Measures LHV of 923.7 Btu/CF used in the definition of GGE (above) for a national average composition of natural gas.

Utility measurement of gas volumes is further complicated by the fact that gas volume readings have to be corrected for gas temperature at the meter, meter gas pressure, and barometric pressure/altitude. These correction factors introduce additional error into the equation.

Gas composition in a utility system is not constant. It varies from day to day. Attached is a record of gas composition at a utility metering station that shows the range of fluctuations in gas composition within a utility system. This example is used to make a point that composition does change – and therefore Btu content per cubic feet of gas is also changing. A Micro Motion meter that measures mass can detect and record changes instantaneously. A utility has to make adjustments on a monthly basis to a customer's bill.

The GRI 1992 report 92-0123 "Variability of Natural Gas Composition in Select Major Metropolitan Areas of the United States", pages 98 through 117 show statistics regarding composition variability of several California cities.

Discussion of Mass Metering vs. Utility Gas Metering:

The definition of GGE is precise – 5.660 pounds of natural gas and is based upon the LHV of gas. This specific value was based on average gas composition across the U.S. in a 1994 sampling. This number is independent of gas composition that has been shown to vary considerably across the U.S. and even day to day within a region. As gas composition varies, the amount of gas in cubic feet per pound differs – but the output of a mass meter will always be 5.660 pounds per GGE. Mass measurement of natural gas does not require pressure correction, temperature correction, and barometric pressure correction as utility volumetric measurement requires. Mass measuring meters (Micro Motion) are more accurate than their utility meter counterparts.

Given the number of factors involved, it is nearly impossible to have a situation where on a monthly basis a utility meter that reads in volume (and HHV) will ever agree with a mass flow metering measuring in pounds. A variance between a volumetric meter and a mass flow meter does not mean that there has been a gas leak where gas has escaped. A variance will generally mean that because of gas composition, and the requirement that a GGE equals 5.660 pounds, the mass flow meter is delivering more or less than 114,118 Btus (LHV)/gallon used in the definition of GGE.

Attachments