CONVERSION FROM VOLUME TO ENERGY MEASUREMENT

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The purchase, transport, and sale of natural gas as a commodity with a specific energy value per cubic foot has transformed the natural gas industry from one of a system based on volume measurement to a system based on energy measurement. The following discussion will review the evolution of natural gas industry from a system of volume measurement to the present system of energy measurement.

Natural gas has served as an important fuel through the centuries. It is believed that the first commercial use of natural gas was by the Chinese in 900 BC. The Chinese used a system of hollow bamboo to transport the natural gas from shallow wells. The gas was used as a fuel to extract salt from sea water. In 1816 manufactured gas from coal was first used in the United States to fuel gas lights. In 1821 near Fredonia, New York the first natural gas well was drilled in the United States. William Hart, a gunsmith, drilled the twenty-seven foot deep well near a creek outside Fredonia where gas bubbles had been noticed. As a result of this well, Hart is considered the father of the natural gas industry in the United Sates. In 1843 cast iron pipe started replacing wooden pipelines and the use of iron pipe provided the first reliable and safe method of transporting gas to market.

As the industrial revolution progressed in the United States, the need for natural gas as a fuel also developed. After the commercial discovery of crude oil at Titusville, PA in 1859, oil was produced as a primary fuel and natural gas was produced as a by-product. The natural gas had little value as compared to oil and there were only rudimentary pipelines to transport natural gas to market. Crude oil, on the other hand, was sold by the wooden barrel and could be easily transported by wagon, barge, or rail car.

In the early 1900s, with advances in drilling technology and the invention of the rotary drill, wells could be drilled faster and deeper. As a result, more and more gas was discovered which had no market. Much of the gas was just flared and wasted to continue oil production. Entrepreneurs saw a business opportunity here. They reasoned that pipelines could be built to the gas fields, the gas bought for pennies per thousand cubic foot, and then transported and sold for a profit. This was the beginning of a viable new gas transmission industry.

The natural gas bought at the wellhead by pipelines was measured by volume in cubic feet and was considered to have a standard heating value range suitable for marketing. The gas was treated as a commodity transported in a regulated pipeline environment. Typically, the federal government regulated the interstate gas moved across state lines and the state governments regulated the intrastate gas moved within the state. The gas was bought and sold by volume and the energy value of the gas was determined only on a limited basis by calorimeter.

In 1978 The Natural Gas Policy Act was passed by Congress as a method of leveling out the large price difference between the state and federally regulated gas. This act also specified that natural gas was to be bought and sold on the basis of its actual energy content per cubic foot. As a result, The Natural Act Policy Act of 1978 changed the way gas was valued as a commodity. The new standard combined volume measurement and gas heating value measurement to produce an energy measurement system for natural gas.

TERMS USED IN ENERGY MEASUREMENT

BTU (British Thermal Unit) — A BTU is defined as the quantity of heat that must be added to one pound of pure water to raise its temperature from 58.5 degrees Fahrenheit to 59.5 degrees Fahrenheit under standard pressure. A BTU is generally thought of as the heat required to raise the temperature of one pound of water one degree Fahrenheit.

Standard Cubic Foot — A standard cubic foot is defined as the quantity of gas occupying a cubic foot of space at a specified temperature and pressure.

Total or Gross Heating Value — The total heating value is defined as the number of British Thermal Units produced by combustion of gas at constant pressure of the amount of gas which will occupy a volume of one cubic foot at 60 degrees Fahrenheit at the reference base pressure, with air at the same temperature and pressure as the gas, when the products of combustion are cooled to the initial temperature of the gas and air, and the water vapor formed by combustion is condensed to the liquid state.

Net Heating Value — The net heating value is defined as the number of British Thermal Units produced by the combustion of gas at a constant pressure of the amount of gas which will occupy a volume of one cubic foot at 60 degrees Fahrenheit at the reference base pressure, with air at the same temperature and pressure as the gas, when the water vapor formed as product of combustion remains in the vapor state. As a result, the Net Value is less than the Gross Heating Value by an amount equal to the heat evolved by the condensation of the water from a vapor state to a liquid state.

Saturated Gas Heating Value — The saturated gas heating value may be defined as either the Gross or Net heating Value of a standard cubic foot of gas at base conditions which is saturated with water.

Dry Gas Heating Value — The Dry Gas Heating Value may be defined as either Gross or Net Heating Value of a standard cubic foot of gas at base conditions which contains no water vapor. The Dry Gas Heating Value is a larger amount than the Saturated Gas Heating Value of a standard cubic foot of gas because the dry cubic foot contains no water vapor molecules.

Standard Base Conditions — The standard temperature base is 60 degrees Fahrenheit. Standard pressure is typically referred to as 14.73 PSIA.

Dekatherm — A dekatherm (dth) is a unit of heat equivalent in energy to 10 therms or 1,000,000 BTU. One dekatherm is equivalent to 1,000 cubic feet of 1000 BTU per cubic foot gas.

EQUIPMENT USED FOR HEATING VALUE DETERMINATION

Three types of equipment used for heating value determination in natural gas are the Cutler-Hammer type recording calorimeter, the gas chromatograph, and the inferential calorimeter. The Cutler-Hammer and the inferential calorimeter have an operating principle based on the actual combustion of gas where as the gas chromatograph operates on a principle based on the measurement of the molecular composition of the gas. A review of each of these three types of analytical instruments is as follows:

Cutler-Hammer Recording Calorimeter — The Cutler-Hammer type of calorimeter is composed of a tank unit and a recorder. Within the tank unit the actual caloric measurement takes place. The tank is filled with water which is maintained at a constant temperature. A flow of test gas and a separate flow of heat absorbing air are passed through water sealed meters in the tank unit. The test gas and the heat absorbing are maintained at a fixed ratio. As the test gas is burned its heat is thermally transferred to the heat absorbing air. The water vapor formed from the combustion process is allowed to condense to its liquid state and release its latent heat of vaporization. As a result, all the heat produced by combustion of the gas, including the latent heat of vaporization of the water vapor, is a measurement of the total heating value of the gas. This instrument is calibrated with a natural gas standard of certified heating value.

Gas Chromatography — Gas chromatography is a physical method of separating a gas into its components and then measuring the quantity of each component in the gas mixture to determine its molecular composition. Once the molecular composition is determined the heating value of the gas is determined by calculation. In practice the gas chromatograph is composed of a sample injection system with a regulated carrier gas supply, thermally stabilized separation columns, a detector, and a recorder. The analytical results from the gas chromatograph can be used to calculate supercompressibility, specific gravity, gallons per thousand cubic feet of liquids, and heating value. The gas chromatograph is calibrated using a natural gas standard with a certified mol composition for each component in the gas.

Inferential Calorimeter — The inferential calorimeter is a combustion type instrument. In practice, the test gas is burned at it stoichiometric or perfect combustion point to obtain an inferred or deduced heating value. This instrument is calibrated with a gas standard of certified heating value.

ENERGY VALUE CALCULATION

When calculating the energy value, it is of utmost importance to have the volume per cubic foot and the BTU per cubic foot on the same pressure base. Also note that a dry BTU per cubic foot has a larger heating value than a saturated BTU per cubic foot and that a cubic foot of gas on a higher pressure base has a larger BTU per cubic foot.

Thermal Calculation Using Volume and BTU — The thermal value for a gas at a standard temperature and pressure is calculated by multiplying the gas volume in cubic feet by its BTU per cubic foot. Standard conditions are 60 degrees and 14.73 PSIA.

Example: What is the energy value of 1,000 cubic foot of gas with a heating value of 1050 BTU per cubic foot.

Energy value = (1,000 cf) (1050 BTU/cf)
= 1,050,000 BTU
= 1.05 MMBTU
= 1.05 Dekatherms

Thermal Correction Factor Using Volume and BTU — The thermal correction factor for a gas at standard temperature and pressure is calculated by dividing the measured heating value per cubic foot by a base of 1,000 BTU per cubic foot. Standard conditions are 60 degrees and 14.73 PSIA.

Example: What is the energy value factor for a gas having a heating value of 1050 BTU per cubic foot at a base heating value of 1000 BTU per cubic foot.

Energy value factor = $\frac{1050 \text{ BTU/cf}}{1{,}000 \text{ BTU/cf}}$
= 1.050

Example: What is the energy value of 1,000 cubic foot of gas which has an energy value factor of 1.050.

BTU Energy value = (1,000 cf) (1.050)
= 1,050

Example: What is the energy value of 1,000 cubic feet of gas which has an energy value factor of 1.050.

BTU Energy value = (1,000 cf) (1.050)
= 1,050

Pressure Base Correction — The measured pressure base may be different from the contract pressure base. Due to the different pressure bases used for reporting volume and heating value, it is usually necessary to put these numbers into a standard base for energy measurement.

Example: What is the heating value and pressure base correction factor for gas measured at a meter pressure base of 14.65 PSIA which has a contract pressure base of 14.73 PSIA at constant temperature.

Heating value correction factor

$$= \frac{14.73 \text{ PSIA}}{14.65 \text{ PSIA}} = 1.0054$$

Volume correction factor

$$= \frac{14.65 \text{ PSIA}}{14.73 \text{ PSIA}} = 0.9946$$

Water Vapor Correction — The heating value of natural gas can be calculated on a saturated base, an actual base, or a saturated base depending on contract requirements. The saturated or the dry heating value factor at a pressure base of 14.73 PSIA and 60 degrees Fahrenheit can be calculated from the partial pressure of water vapor, 0.2563 PSIA, at saturation. The actual heating value is first determined as if dry and then its corrected to actual.

Example: Determine the dry and saturated heating value correction factor at 14.73 PSIA and 60 degrees Fahrenheit.

Dry heating value correction factor

$$= \frac{14.73 \text{ PSIA}}{(14.73 \text{ PSIA} - 0.2563 \text{ PSIA})}$$

= 1.0177

Saturated heating value correction factor

$$= \frac{(14.73 \text{ PSIA} - 0.2563 \text{ PSIA})}{14.73 \text{ PSIA}}$$

= 0.9826

Example: Determine the dry heating value of a gas having a saturated BTU of 1000 at 14.73 PSIA and 60 degrees.

Dry heating value = (1.0177) (1000 BTU/cf)
= 1018 BTU/cf

Example: Determine the actual heating value for a gas having a 45 lbs./MMcf water vapor content. The dry heating value was 1018 at 14.73 PSIA.

Water Vapor Correction Factor (F) is

$$F = 1 - \frac{(45 \text{ lbs})}{(\text{MMcf})} \frac{(21.0181 \text{ cf})}{(\text{lbs})}$$

$$F = 1 - \frac{945.815}{1{,}000{,}000}$$

F = 1 – 0.000946

F = 0.999054

Actual heating value = (1018) (0.99905)
= 1017 BTU/cf

CONCLUSION

This discussion has covered the early history and development of the natural gas industry and the transition of natural gas from a volume based to an energy based commodity. Three types of instruments used to determine the heating value of gas were discussed. Also the definitions used in energy measurement were reviewed and some examples were presented of the calculations which are typically used to convert gas volume to an energy value.