FUNDAMENTALS OF GAS MEASUREMENT II
Class # 1150

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A knowledge of the Fundamentals of Gas Measurement is essential for all technicians and engineers that are called upon to perform gas volume calculations. These same people should have at least a working knowledge of the fundamentals to perform their everyday jobs including equipment calibrations, specific gravity tests, collecting gas samples, etc.

To understand the fundamentals, one must be familiar with the definitions of the terms that are used in day-to-day gas measurement operations. They also must know how to convert some values from one quantity as measured to another quantity that is called for in the various custody transfer agreements.

Below are listed some of the most commonly used terms and their definitions along with some examples of various conversions that must be made from time to time by people working in the natural gas industry:

GAS - That state of matter that has neither independent shape nor volume. It expands to fill the entire container in which it is held. Gas is one of the three forms of matter. The other two are liquids and solids.

NATURAL GAS - A naturally occurring mixture of hydrocarbon and nonhydrocarbon gases found in porous geologic formations beneath the earth's surface, often in association with petroleum. Natural gas normally has methane as its principal constituent.

- ***Dry*** - Gas whose water content has been reduced by a dehydration process. Gas containing little or no hydrocarbons commercially recoverable as liquid product.

- ***Wet*** - Gas that has not been dehydrated and is partially or totally saturated with water vapor. It also can mean gas that is unprocessed or partially processed and has been produced from a strata containing condensable hydrocarbons.

- ***Sweet*** - Gas found in its natural state, containing such small amounts of compounds of sulfur that it can be used without purifying.
- ***Sour*** - Gas found in its natural state, containing such amounts of compounds of sulfur as to make it impractical to use, without purifying.

PRESSURE - Defined as force per unit area. Some units of pressure are: pounds per square inch (PSI or lb/in^2); pounds per foot square (PSF or lb/ft^2).

- **Atmospheric Pressure** - force per unit area created due to weight of the atmosphere (air and water vapor) surrounding the earth; the average atmospheric pressure at sea level has been defined at 14.696 pounds per square inch. Atmospheric pressure decreases approximately one pound per square inch for each 2000 ft. rise in elevation above sea level; also, referred to as barometric pressure.

- **Gauge Pressure** - measurement of pressure that is greater than atmospheric pressure. Designated by the symbol PSIG.

- **Vacuum** - measurement of pressure, which is less than atmospheric pressure. Usually designated in inches of mercury.

- **Absolute Pressure** - pressure above that of a perfect vacuum; provides an unchanging, invariable reference point for pressure measurement; the sum of the gauge pressure and the atmospheric pressure; used in all gas law equations; designated by the symbol PSIA.

EXAMPLE: If the absolute pressure is 57.6 PSIA and the elevation is 2500 ft., what is the approximate gauge pressure?

14.696 PSIA - (1 PSI/2000 ft)(2500 ft) = 13.44 PSI or 13.4 PSIA

57.6 PSIA - 13.4 PSIA = 44.2 PSIG

♦ **Base Pressure** - standard used for determination of gas volumes; volumes are measured at operating pressures and then converted to the appropriate base pressure volume; normally, this base pressure value is defined by a legal document of the state in which the gas is produced (14.65 PSIA in Texas and Oklahoma; 15.025 PSIA in Louisiana and Mississippi).

Pressure is also stated in inches of water (in. H_2O) and inches of mercury (in. Hg) in the measurement of natural gas. This is another way of stating the pressure exerted by a column of water or mercury so many inches high.

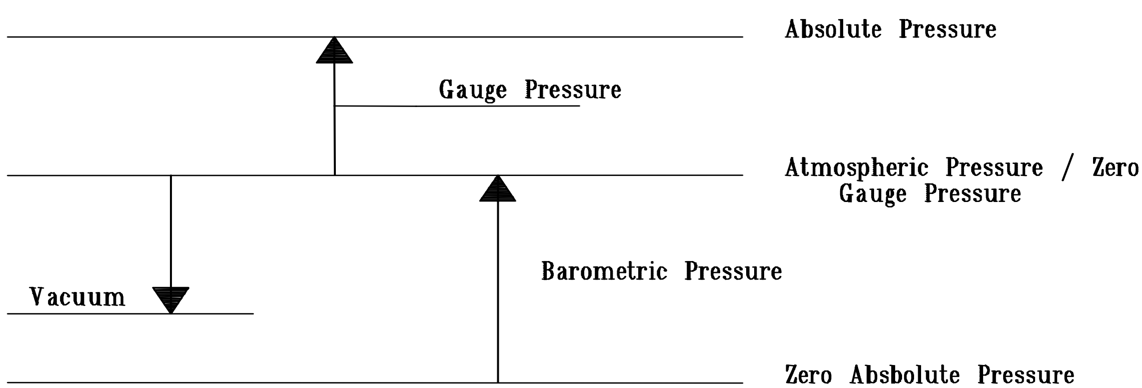
EXAMPLE: What pressure, in PSI, is exerted by a column of water 12" high?
(Density of water = 62.4 lb/ft^3) What pressure, in PSI, is exerted by a column of mercury 12" high?
(specific gravity of Hg= 13.56)

12" of H_2O: (62.4 lb/ft^3)(1 ft^2/144 in^2) (1 ft) = 0.433 PSI

12" of Hg: (62.4 lb/ft^3)(13.56)(1 ft^2/144 in^2)(1 ft) = 5.876 PSI

EXAMPLE: How many inches of mercury represents a perfect vacuum?
(Assume atmospheric pressure =14.696 PSI)

(14.696 lb/in^2)(144 in^2/ft^2)(1 ft^3/62.4 lb)(1/13.56)(12 in/ft) = 30.01 inches of Hg



VOLUME - Space occupied, as measured in three dimensions. Some units of volume are cubic inches (in^3); cubic feet (ft^3); cubic centimeters (CM^3); and cubic meters (M^3).

EXAMPLE: What is the volume of a box measuring 12 inches x 12 inches x 12 inches?
(12in)(12in)(12in) = 1728 in^3 or 1 ft^3

- **Compressibility** - property of a material that allows it to decrease in volume when subjected to an increase in pressure.

EXAMPLE: If a gas occupies 98 cubic feet at 60°F and 14.73 PSIA, how many cubic feet will it occupy at 60°F and 20.05 PSIA?

($98\ ft^3$/20.05 PSI)(14.73 PSI) = $72\ ft^3$
A compression or reduction in the actual volume of $26\ ft^3$ (Boyles Law)

- **Compressibility Factor** - a factor used to correct gas volumes for the deviation from an ideal gas behavior at elevated pressures; this deviation is caused by the interaction of the molecules of the substance; usually represented by the symbol Z. This factor is used in displacement or linear measurement.

- **Supercompressibility Factor** - represented by the symbol F_{pv} and is equal to the square root of Z_b divided by the square root of Z_f and is used in the Buckingham equation for orifice measurement.

- **Specific Volume** - volume occupied by a unit weight of a substance (liquid, vapor and/or gas) at specific temperature and pressure conditions.

- **Cubic Foot** - the most common unit of measurement of gas volume; the volume of a cube with the dimensions of one foot (12 inches) on each of its three sides.

- **Standard Cubic Foot** - the quantity of gas occupying a cubic foot of space at specific conditions of temperature and pressure. Generally, in natural gas measurement the conditions are 60°F and 14.73 PSIA.

<u>TEMPERATURE</u> - Degree of "hotness" or "coldness" measured on a definite scale.

- **Ambient Temperature** - measurement of the temperature of the atmosphere or other fluid that completely surrounds the location under consideration.

- **Zero Absolute Temperature** - point at which all molecular activity ceases to exist.

- **Absolute Temperature** - measurement against a fixed zero point (absolute zero); an unchanging, invariable reference point for temperature measurement; used in all gas law equations.

- **Base Temperature** - standard used for determination of gas volumes; normally, this value is defined by legal documents (generally 60°F).

- **Dew Point Temperature** - the temperature at which a vapor begins to condense and deposit as a liquid at a given pressure.

Common scales used are Celsius (°C) and Fahrenheit (°F).

- **Scale Conversions** -

When converting from Celsius to Fahrenheit:

$$°F = \frac{9}{5}\ °C + 32°F$$

When converting from Fahrenheit to Celsius:

$$°C = \frac{5}{9}\ (°F - 32°F)$$

♦ **Absolute Scales** - Rankine = °R
Kelvin = °K

♦ **Absolute Scale Values** -

°R = °F + 459.67 or Absolute Zero = - 459.67°F = 0°R

°K = °C + 273.15 or Absolute Zero = - 273.15°C = 0°K

RELATIONSHIPS OF VARIOUS TEMPERATURE SCALES
(Rounded Values)

°F	°R		°K	°C
212	672	Boiling Point of Water	373	100
32	492	Freezing Point of Water	273	0
-40	420	°C = °F	233	-40
-460	0	Absolute Zero	0	-273

MASS - Measure of the amount of substance or matter such as pounds mass or kilogram mass.

♦ **Density** - mass of substance or matter per unit volume such as pounds per cubic foot (lb/ft^3) or kilograms per cubic meter (Kg/M^3).

♦ **Relative Density or Specific Gravity** - the ratio of the density of a substance to the density of a reference substance, both at specified physical conditions; as applied to gas, air is the reference substance. Two relative density definitions are recognized in gas measurement:

1. ***Real Relative Density*** - The density ratio between a gas and air determined by measurement with both at the same temperature and pressure.

2. ***Ideal Relatively Density*** - The ratio of the molecular weight of a gas to the molecular weight of air. (Molecular weight of air = 28.9625 per GPA 1-1-2009)

EXAMPLE: What is the Ideal Relative Density of methane (16.043) when referenced to air (28.9625)
Ideal Relative Density CH_4 16.043/28.9625 = 0.5539

♦ **Specific Weight** - weight per unit volume; sometimes incorrectly referred to as "density".

HEATING VALUE - Quantity of heat produced from the complete combustion of a unit quantity of a fuel.

♦ **Gross Heating Value** - obtained when all the products of combustion are cooled to the original temperature of the mixture before combustion, and the water formed by combustion is condensed to the liquid state.

♦ **Net Heating Value** - heat evolved by complete combustion of gas with all water formed by combustion remaining in the vapor state.

♦ **British Thermal Unit (BTU)** - is equal to 1,055.05585265 joules (exact) or rounded to 1,055.056 joules.

♦ **Therm** -a unit of heating value equivalent to 100,000 BTU's.

♦ **Dekatherm** - a unit of heating value equivalent to 10 therms or 1,000,000 BTU's.

♦ **Quad** - a unit of heating value equivalent to a quadrillion BTU's or 1,000 x 10^{12} BTU's.

To convert from a saturated BTU at standard conditions (14.73 PSIA & 60°F) to a dry BTU at standard conditions, multiply the saturated BTU value by 1.01771.

To convert from a dry BTU at standard conditions (14.73 PSIA & 60°F) to a saturated BTU at standard conditions, multiply the dry BTU by 0.9826.

EXAMPLE: What is the saturated (wet) BTU value for a gas that has a dry BTU of 1125 at standard conditions?

(1125 BTU Dry)(0.9826 BTU Wet/1 BTU Dry) = 1105.4 BTU Wet

EXAMPLE: Company X buys 2,950 MCF of dry natural gas from Company Z at Company Z's contract conditions. Company Z uses 60°F and 14.65 PSIA as its standards, while Company X uses 60°F and 14.73 PSIA as its standards. How many dekatherms dry has Company X purchased from Company Z at Company X's standards? How many dekatherms wet? (BTU=1150 Dry @ 14.73 PSIA & 60°F)

(2950 MCF)(1150 BTU Dry)(14.65 PSIA/14.73 PSIA)(1/1000) = 3374.1 MMBTU Dry or Dekatherms Dry

(3374.1 MMBTU Dry)(0.9826 BTU Wet/1 BTU Dry) = 3315.4 MMBTU Wet or Dekatherms Wet

Ultrasonic – Sound waves that are above 20,000 vibrations per second.

Ultrasonic Meter – a flowmeter used (1) to measure the transit times of an acoustic pressure wave both with and against the flow (time-of-flight meter) to infer the velocity in a pipe or (2) to reflect sonic energy from scatters in a fluid back to a receiver (Doppler meter) to measure volumetric flow rate.

Flow Conditioner - A device that can be inserted into a meter run to remove swirl and/or to change the flow profile. Some examples are the 19-tube bundle, perforated plates, perforated plates in combination with a short tube bundle and the vortex type flow conditioner.