

BASIC ELECTRICAL CONCEPTS FOR FIELD MEASUREMENT TECHNICIANS

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The efficient operation and maintenance of electrical and electronic systems utilized in the natural gas industry is substantially determined by the technician's skill in applying the basic concepts of electrical circuitry. This paper will discuss the basic electrical laws, electrical terms and control signals as they apply to natural gas measurement systems.

There are four basic electrical laws that will be discussed. They are:

- Ohm's Law
- Kirchhoff's Voltage Law
- Kirchhoff's Current Law
- Watts Law

To better understand these laws a clear knowledge of the electrical terms referred to by the laws is necessary. These terms are:

- Voltage
- Ohms
- Ampere
- Watt

Voltage

Voltage, otherwise known as electromotive force, electrical potential difference or electric tension is the potential difference between two points, or the difference in electrical potential energy. Voltage is the measure of the total energy required to move a small electrical charge (current) along a path (conductor). Current always flows from higher voltages to lower voltages. The unit of measure is the volt and the mathematical symbol is "E" for electromotive.

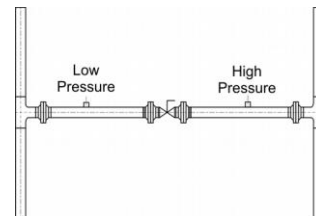
The volt is named in honor of Count Alessandro Giuseppe Antonio Volta. Volta was an Italian physicist known particularly for the invention of the battery. This invention came about due to a famous professional disagreement with Luigi Galvani, an Italian professor of anatomy.

Galvani caused muscular contraction in a frog by touching its nerves with an electrostatically charged

metal. Later, he was able to cause muscular contraction by touching the nerve with different metal probes without electrical charge. He concluded that the animal tissue contained an innate vital force, which he termed "animal electricity". In fact, it was Volta's disagreement with Galvani's theory of animal electricity that led Volta, in 1800, to build the voltaic pile to prove that electricity did not come from animal tissue but was generated by contact of different metals in a moist environment. This process is now known as a galvanic reaction.

Recently there is a growing dispute over the invention of the battery. It has been suggested that the Bagdad Battery discovered in 1938 near Bagdad was the first battery. The Bagdad battery may have been used by Persians over 2000 years ago for electroplating.

Voltage can be referred to as the amount of electrical pressure in a circuit. A simple analogy for an electrical circuit is the pressure in gas piping systems as seen in the illustration below. When the valve separating the high pressure piping from the low pressure piping is opened, the pressure difference will force gas to flow from the high pressure side to the low pressure side. The flow rate will depend on the pressure difference.



In an electrical circuit, current always flows from higher voltages to lower voltages just as gas in a piping system will always flow from higher pressure to lower pressure.

Polarity is the relative positive (+) or negative (-) state of an object. Polarity does not always have a zero point even though ground is often defined as zero voltage. A part of a circuit that is more positive than another relative to ground has a positive polarity. The less positive part of a circuit relative to ground has a negative polarity.

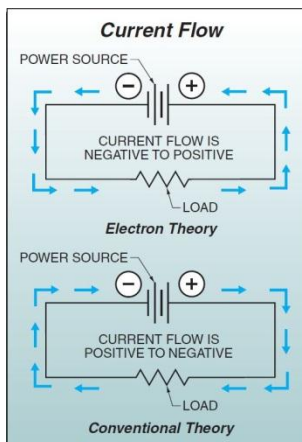
Ohm

The ohm is the unit of measure used to refer to the opposition or resistance to electrical current flow within an electrical circuit. An ohm is the amount of resistance of a conductor in which a voltage of 1 volt causes a current flow of 1 amp. The Greek omega (Ω) is often used to represent ohms. The mathematical symbol for resistance is "R".

The unit of measure for resistance is named after George Simon Ohm, a German physicist. As a high school teacher, Ohm began research with the recently invented electrochemical cell, invented by Alessandro Volta. Using equipment of his own design, Ohm determined that there is a direct proportionality between the potential difference (voltage) applied across a conductor and the resultant electric current. This relationship is known as Ohm's Law.

Ampere

Current is the flow of a charge passing between two points in a circuit. Current flow is energy and is used to produce work. Early scientists believed that charges flow from positive to negative. Later, when atomic structure was studied, the concept of electron flow from negative to positive was introduced. The two different theories of current flow are called *electron current flow* and *conventional current flow*. Electron current flow is current flow from negative to positive. Conventional current flow is current flow from positive to negative.



The ampere (A) is the term used to refer to electrical current moving in an electrical circuit. Electrical current is the movement of negatively charged particles called electrons within the circuit. By definition, one ampere is the equivalent of 6.241×10^{18} electrons per second when

driven by a voltage potential of 1 volt. The mathematical symbol for ohms is "Ω" for intensity.

The ampere or amp is named after André-Marie Ampère for his work in electromagnetism. The ampere as a unit of measure for electrical current is based on the work of Charles Coulomb, a French physicist best known for developing the definition of the electrostatic force of attraction and repulsion.

Now that we have covered the meaning of the electrical terms referred to in the electrical laws we can take a closer look at the laws themselves.

Ohm's Law

Ohm's Law states the mathematical relationship between voltage, current and resistance. Simply stated, Ohm's Law says that current is directly related to voltage and inversely related to resistance. Using this law you can calculate any one of the three quantities (amperes, volts, or ohms) if the other two are known.

$$E = I \times R$$

Or: volts = amps x ohms

With a little algebra magic this formula can be re-stated as:

$$I = \frac{E}{R}$$

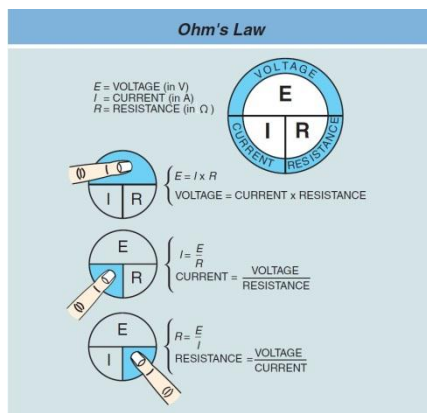
Or

$$R = \frac{E}{I}$$

If any two values are known the third can be calculated. The important thing to remember is the stated relationships. If one value changes, at least one other value must also change in order to stay equal. For example, current in a circuit increases when the voltage is increased and the resistance remains the same. Current in a circuit decreases when the resistance is increased but the voltage remains the same.

A convenient way to remember relationships among E, I and R is to visualize the three quantities in a circle as shown here. By covering the quantity to be determined, the other two appear in the form needed to solve the problem.





Ohm's Law is the most important and most often applied law in electricity and in electrical maintenance work. To understand electricity and work in electronics you must thoroughly understand Ohm's Law and know how to apply it effectively in solving electrical problems.

Kirchhoff's Laws

Kirchhoff's circuit laws are based on the work of Gustav Kirchhoff and generalized from the work of George Ohm (Ohm's Law). In general terms, Kirchhoff's voltage law states that within an electrical circuit, the voltage rise (voltage applied to a circuit) is equal to the voltage drop (voltage lost to resistance).

Kirchhoff's current law states that the current in a parallel circuit are additive. For example, if you had three lamps plugged into a single 120 Vac plug, the total circuit current would be equal to the sum of the individual lamp currents. More important to a gas measurement technician is that the law indicates that within a series circuit, whatever current exists at any point in a circuit exists at every point of a circuit. We will examine this closer later on.

Watt's Law

Electrical power is the rate at which energy is expended by (or supplied to) an electrical circuit. Another way to express that is to say that a watt is the measure of the work performed within an electrical circuit. Electrical power is expressed in Watts.

Watt's Law and the unit of measure for electrical power, the watt, are named in honor of James Watt for his work in the development of the steam engine. James Watt himself did not explore electrical issues.

Watt's Law is actually the work of James Prescott Joule. Joule was an English brew-house manager and science hobbyist. He studied the possibilities of replacing the

Watts steam engines in his brew houses with the newly invented electric motor. The desire to make better beer combined with his "hobby" resulted in the discovery of the nature of heat and its relationship to mechanical work. This led to the theory of conservation of heat and energy that resulted in the development of the first law of thermodynamics.

The number of watts of power expended or supplied to an electrical circuit may be determined by Watt's Law which expresses the electrical power by an equation involving voltage (E) and current (I). Watt's Law is stated in a mathematical equation as:

$$P = I \times E$$

Where P is the electrical power measured in watts.

Once again, with a little algebra magic this formula can be re-stated as:

$$I = \frac{P}{E}$$

Or

$$E = \frac{P}{I}$$

A method which may be used to remember the relationship among P, E, and I is to visualize the three quantities in a circle arrangement as shown here. . By covering the quantity to be determined, the other two appear in the form needed to solve the problem.



Ohm's Law and Watt's Law can be combined as shown here:

