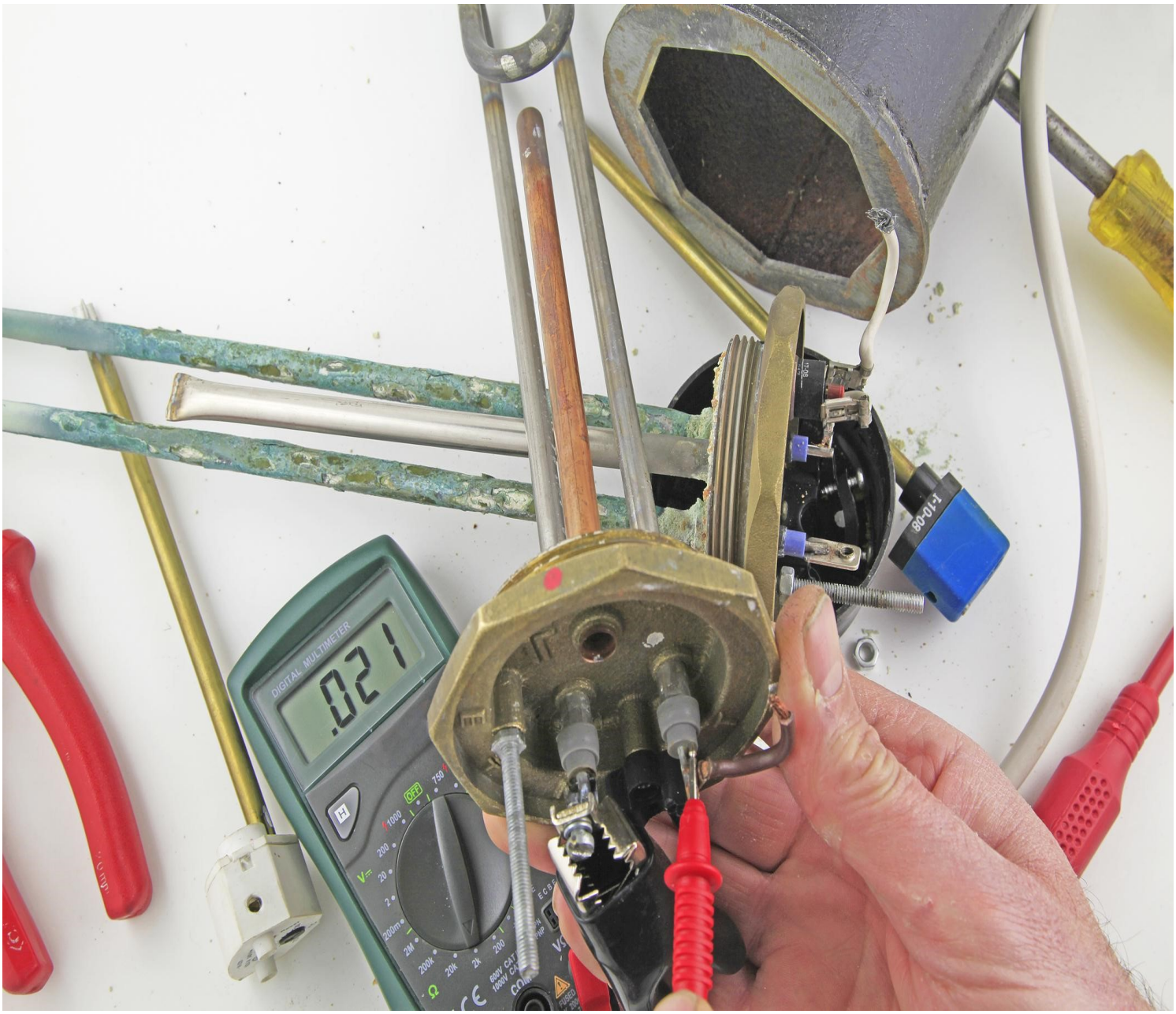
What is Ohm’s Law and how does it apply to thermal systems?

By: - April 05, 2021



Ohm’s Law has been a crucial feature of our electrical resistance understanding since 1827. We examine what this law describes and how it can help you improve the efficiency of your thermal system using power and temperature controllers.

Electric current definitions

Since the German physicist Georg Ohm first discovered the law, it has improved our understanding of how electrical circuits work. It's important to review the basic definitions of electric currents before discovering how this law shapes the way electric heating products operate in your facility. Reviewing Ohm's Law is critical to an in-depth understanding of electrical resistance and how it affects your process.

Current, wattage, voltage and resistance

Ohm's Law is expressed in a formula that affects these key features of electricity. Here are the definitions and abbreviations of these features of an electric circuit:

- ●Current (I): Measured in amps (A), current is the movement of electrons through a conductor.
- ●Voltage (E): The electric current force is known as electrical potential and is expressed in volts (V).
- ●Resistance (R): Measured in ohms (Ω), resistance is the total opposition of the flow of the electric current.
- ●Wattage (W): Watts (W) express the amount of power delivered by a resistance element in a heater in a given period of time. You can calculate the wattage use (about:blank) of an electric heater to determine the electrical usage of a thermal system.

Ohm's Law

Ohm's Law was a foundational discovery in the field of electronics and thermal systems. In the 1820s, Ohm concluded that the current passing through a metal conductor was directly proportional to the voltage applied across that conductor.

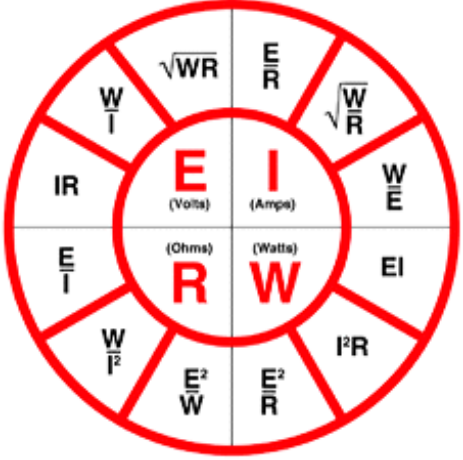
Expressing this in a mathematical form, the result is the basic equation:

- ●Voltage = Current x Resistance, so E = I x R

Put another way, the voltage of a circuit equals the current multiplied by the resistance. OEMs and design engineers use this formula to determine the resistance without turning off an electric system. Measuring the resistance of materials in an operating circuit isn't possible without the use of this formula.

The (about:blank)Ohm's Law Circle (about:blank) is a popular reference tool that expresses how to rearrange the formula in order to calculate the desired variable. These expressions are all the same basic formula, but they can be conveniently rearranged for quick reference when varying factors are constant or unknown. Take a look at the equation to see how wattage relates. The power in watts (W) is equal to the voltage in volts (E) times the current in amps (I). Or mathematically:

- ●Wattage = Voltage x Current, so W = E x I



- # Applying Ohm’s Law to thermal systems

To understand how the resistance of an electric circuit affects your thermal system, review different circuit setups and heating solutions. This knowledge helps you purchase the optimal electric heater and controller for your application.

Determining current

Identifying the amount of current that will be flowing in your system is important for ensuring that system components are protected with proper fusing or circuit breakers. Current also can be determined using Ohm’s law. The current I in amps (A) is equal to the voltage E in volts (V) divided by the resistance R in ohms (Ω).

- ●Current = Voltage / Resistance, so I = E/R

For example, if a heater measures 100 ohms and voltage delivered to the system is 240 volts, what is the current in amps? I = 240/100, so I = 2.4 amps.

Calculating resistance of series and parallel circuits

Electric circuits are made up of four basic components. These four components can be set up in either a series or parallel circuit to power your heating products:

- ●Resistive device (heating elements)
- ●Voltage source
- ●Current path
- ●Switch

A series circuit connects heaters end to end. The resistance of each heater must be added together to reach the total circuit resistance. Parallel circuits offer increasing opportunities for the electricity to flow, so adding heating products to a parallel circuit reduces the total resistance. Simply set the voltage of Ohm’s Law as constant and calculate the resistance of your system.

A series circuit is characterized by a common current that flows through all of the resistors, as there is only one path the current can follow. The equivalent resistance for a series circuit is the sum of all individual resistances, so $R_{total} = R_1 + R_2 + \ldots + Rn$. A parallel circuit, meanwhile, is characterized by a common potential difference (voltage) across the ends of all resistors. The equivalent resistance for a parallel circuit is calculated according to the following formula: $1/R_{total} = 1/R_1 + 1/R_2 + ... + 1/Rn$.

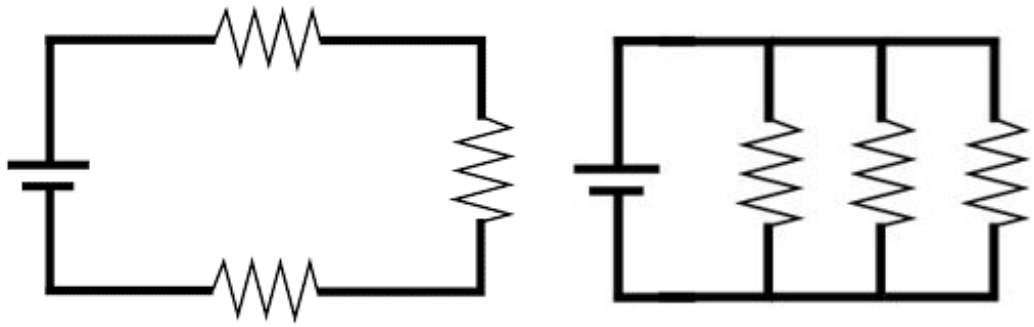


Fig 1. The diagram on the left shows a circuit consisting of a voltage source and three resistors in *series*. The righthand diagram is a circuit with a voltage source and 3 resistors in *parallel*. For example, say you have three heaters, with R1 = 10 ohms, R2 = 16 ohms and R3 = 5 ohms. So, calculating resistance for a series circuit, $R_{total} = 10 + 16 + 5 = 31\ \Omega$. Calculating for a parallel circuit, $1/R_{total} = 1/10 + 1/16 + 1/5$, so $1/R_{total} = .3625$ and $R_{total} = 2.76\ \Omega$.

Notice that placing resistors in series increases the total resistance to more than the resistance of each individual heater, while placing them in parallel reduces the total resistance to less than the resistance of each individual heater.

In parallel circuits, each heating product has the same voltage, while in series, each has the same current. Essentially, wiring in series is only for two heaters of equal wattage and voltage. In addition to offering reduced resistance, a parallel circuit doesn't rely on every heater to maintain a continuous flow of electricity. If a single heater is damaged in a series, the circuit is broken, and the entire line of heaters cease to operate. A single, damaged heater in a parallel circuit only affects the individual heater, so the other heaters can continue to operate.

How to improve a thermal system

Ohm's Law can assist you in troubleshooting your thermal system. If your power and temperature controllers (about:blank) show a fluctuation with the electrical current or heat output, you can use Ohm's Law to validate the static values of circuit components and identify voltage measurements across components.

A high current measurement in your circuit can be caused by either an increase in voltage or a decrease in resistance. Your test instrument can identify any change in voltage allowing you to use Ohm's Law to calculate the resistance to determine if the problem is caused by damaged components or loose electrical connections. In that case, it would actually cause an increase in resistance; low I and high W, with high W meaning more heat at the terminations.

Ohm’s Law is an essential tool used by design engineers to calculate the relationship between voltage, current and resistance. However, it isn’t considered a universal law. Ohm’s Law does not apply in cases where there is an inductive load, or where the resistance is not constant. While most heaters have a stable resistance as temperature increases, some do not. Examples of this include tungsten lamps and silicon carbide heaters.

There are circuit exceptions, particularly when the current flowing isn’t directly proportional to the potential difference across the conductor. Ohm’s Law cannot be applied to devices with a non-linear relationship between voltage and current, such as a thermistor. For more information about Ohm’s Law and its exceptions, contact your Watlow sales representative (about:blank).