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Thermocouple technology: A matter of resistance and metal

by Jesse Yoder

At temperatures above 1,200°F the thermocouple rules.

A thermocouple is composed of two wires made from dissimilar metals. At one end, the two wires join. It is at this point the instrumentÆs joined wires face the process temperature. This is the measurement junction.

A reference, or cold junction, forms at the other end of the conductor. This reference junction normally forms where the conductor connects to the measurement device.

Manufacturers either solder or weld the wires together at the measuring junction.

There are three types of thermocouple measuring junctions:

- An *exposed junction* has no protective assembly or tube covering it. Exposed junctions have the fastest response time, the lowest radiation error, and the least conduction error. Disadvantages are susceptibility to corrosion and fragility. Exposed junction thermocouples are also prone to pick up stray electromagnetic signals unless this is guarded against.

- A *grounded junction* is similar to an exposed junction, except that a protective metallic sheath encloses the elements and insulation. In a grounded junction, the thermocouple wires weld directly to the surrounding sheath material, forming a completely sealed junction. A grounded junction is more rugged and capable of tolerating physical and mechanical abuse. It is also more resistant to corrosion and oxidation. A disadvantage is its slower response time. Grounded junction thermocouples are also more susceptible than exposed junction thermocouples to conduction error and radiation error. Like exposed junction thermocouples, they are prone to pick up stray electromagnetic signals.

- An *ungrounded junction* is like a grounded junction except the junction of the thermocouple wires does not connect electrically to the metallic sheath. An electrical insulator separates the junction from the tip of the closed—end sheath. Like the grounded junction, an ungrounded junction is rugged and tolerant of abuse. It also gets protection from electromagnetic interference. Its disadvantages are slow response time and susceptibility to both conduction and radiation errors.

Thermoelectricity flows

When the measuring junction and the reference junction have different temperatures, a continuous current flows through the circuit. It continues to flow as long as there is a difference in temperature between the two junctions.

Thomas Seebeck discovered this phenomenon in 1821; it is called the Seebeck (and the thermoelectric) effect. The resulting voltage, called the Seebeck voltage, is a function of the difference in temperature between the measuring junction and the reference junction. It is nonlinear with respect to temperature, although it is approximately linear for small changes found in temperature.

Measuring the Seebeck voltage directly with a voltmeter at the reference junction does not give an accurate result because the connection between the thermocouple wires and the voltmeter leads creates a new thermoelectric circuit.

Reference the junctions
Because the voltage read by the voltmeter is proportional to the difference in temperature between the measuring junction and the reference junction, it is necessary to know the temperature at the reference junction to determine the temperature at the measuring junction.

Several methods are used to calibrate the circuit and to measure the reference junctionÆs temperature:

- A junction is created within the circuit and inserted into an ice bath. This junction now becomes the reference junction, and it is 32°F. The measuring junction is derived by adding the known voltage from the reference junction to the voltage from the measuring junction. The term cold junction compensation comes from this practice of creating a reference junction in an ice bath.

- Hardware compensation uses a variable voltage source inserted into the thermoelectric circuit. This voltage source generates a compensating voltage per the ambient temperature. It adds a voltage that cancels extraneous thermoelectric signals. Canceling these signals leaves only the true measuring junction voltage. Hardware compensation has an advantage in that it doesnÆt require actually measuring the ambient temperature at the reference junction. A disadvantage of this method is that a separate compensation circuit is needed for each thermocouple type. The circuitry used in hardware compensation also adds some error in the temperature measurement.

- Software compensation measures the temperature at the reference junction using a thermistor or an integrated circuit sensor. Once you know the temperature of the reference junction, the software calculates the temperature at the measuring junction using tables that correlate specific temperatures for specific voltage values for different thermocouple types.

Temperature ranges differ
Two dissimilar metals make up thermocouples. Their classification results from the type of metal used to make them. Industry specifications recognize a number of types of thermocouples, with a letter designating each type. Some common types are K (the most widely used), J, T, and E.

Different thermocouple types have different temperature ranges. These ranges are not absolute because wire thickness affects temperature range.

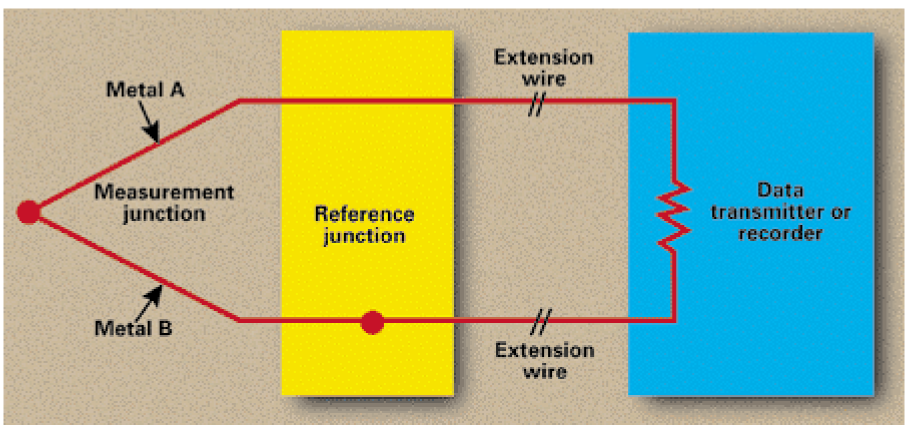
There are certain competitive technologies to the thermocouple in some temperature ranges. But in specific industries and applications and at temperatures above 1,200°F, the thermocouple rules.

Examples would include heat treating, certain oven control applications, jet engine testing, and steel and metal fabrication. In fact, some of the more exotic thermocouples, such as those made from platinum and tungsten, are used in these applications.

Additional Information

Figures and Graphics

- Thermocouple circuit



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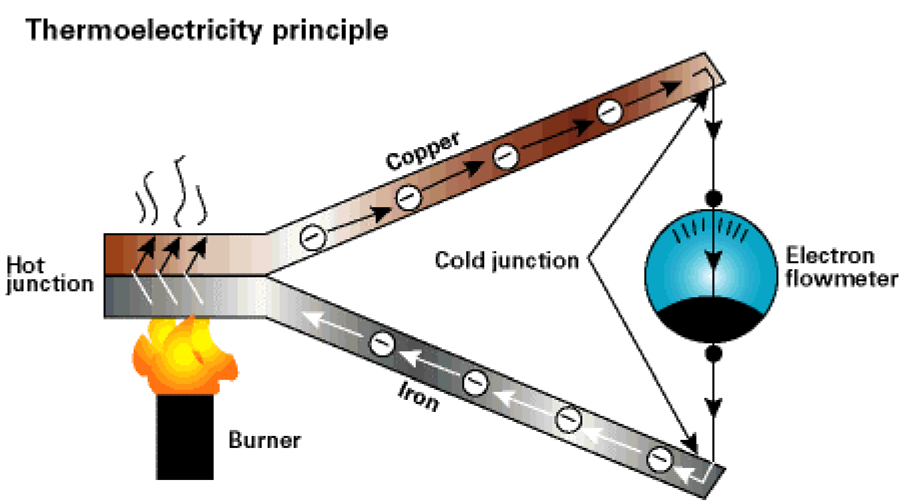

Author Information

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