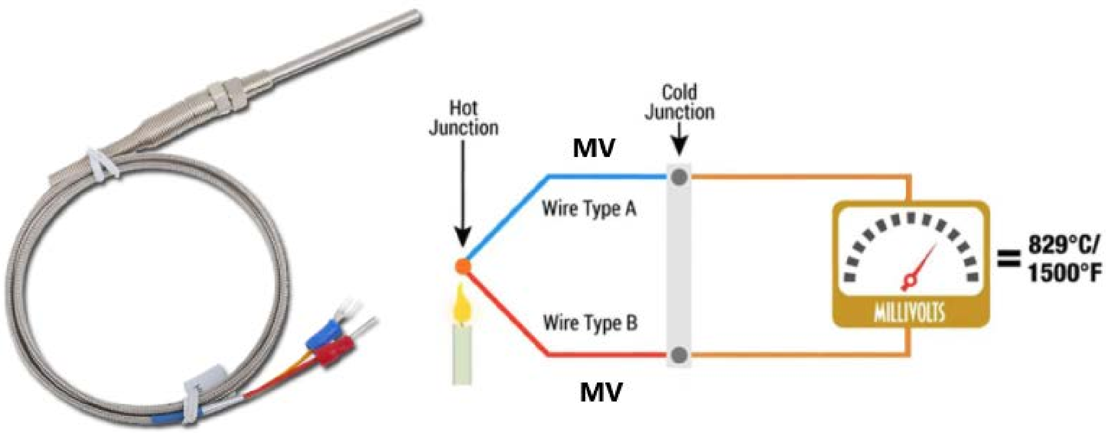
Thermocouple How it Works



Thermocouples sensors found in many industrial applications. Find out what thermocouples are, how they work, and why they are so popular.

In 1821, the German physicist Thomas Johann Seebeck discovered that when different metals are joined at the ends and there is a temperature difference between the joints, a magnetic field is observed. At the time, Seebeck referred to this consequence as thermo-magnetism. The magnetic field he observed was later shown to be due to thermo-electric current. In practical use, the voltage generated at a single junction of two different types of wire is what is of interest as this can be used to measure temperature at very high and low temperatures. The magnitude of the voltage depends on the types of wire being used. Generally, the voltage is in the microvolt range and care must be taken to obtain a usable measurement. Although very little current flows, power can be generated by a single thermocouple junction.

Thermocouples are ideal for the following applications:

- Need for highly accurate temperature reading.
- Need for a failsafe sensor.
- Need for a sensor to work in high temperatures, pressure and vibrations.

Thermocouple Working Principle

The basic design of a thermocouple involves two dissimilar metal wires, each with different electrical properties at different temperatures. The two metals are in contact – touching, twisted, or welded – at one end; this is the **measuring point**. At the other end is the **connection point**, so called because it connects to the voltage reader. When the temperature changes at the measuring point, so does the electron density of each metal wire. This varying electron density is the **voltage**, which is measured at the connection point.

Note that thermocouples do not actually measure the absolute temperature. Instead, they measure the **differential temperature** between the measuring point and the connection point. That's why thermocouples also need a **cold junction compensation**, which ensures that the ambient temperature at the connection terminals of the cold junction does not alter the measuring result, thus allowing for more accurate readings.

Requirement for a reference junction

To obtain the desired measurement of, it is not sufficient to just measure. The temperature at the reference junctions must be already known. Two strategies are often used here:

- "Ice bath" method: The reference junction block is immersed in a semi-frozen bath of distilled water at atmospheric pressure. The precise temperature of the melting point phase transition acts as a natural thermostat, fixing to 0 °C.
- Reference junction sensor (known as "cold junction compensation"): The reference junction block is allowed to vary in temperature, but the temperature is measured at this block using a separate temperature sensor. This secondary measurement is used to compensate for temperature variation at the junction block. The thermocouple junction is often exposed to extreme environments, while the reference junction is often mounted near the instrument's location. Semiconductor thermometer devices are often used in modern thermocouple instruments.

For a thermocouple to work well, its two wires should offer as much contrast as possible in individual electronegativities. This is so that the voltage reader can detect the greatest thermoelectric voltage difference.

Base metal thermocouples, known as Types J, T, K, E, and N, produce higher thermoelectric voltages than more expensive noble metals, known as Types R, S, and B. The latter type, however, can withstand temperatures up to 3,092°F (1,700°C) or even higher. Some of the common metal pairings are iron and copper–nickel (type J), copper and copper–nickel (type T), and nickel–chromium and nickel-aluminum (type K).

Noble metal thermocouples are typically made of platinum and rhodium (types S, R, and B).

Aging of thermocouples

Thermocouples are often used at high temperatures and in reactive furnace atmospheres. In this case, the practical lifetime is limited by thermocouple aging. The thermoelectric coefficients of the wires in a thermocouple that is used to measure very high temperatures may change with time, and the measurement voltage accordingly drops. The simple relationship between the temperature difference of the junctions and the measurement voltage is only correct if each wire is homogeneous (uniform in composition). As thermocouples age in a process, their conductors can lose homogeneity due to chemical and metallurgical changes caused by extreme or prolonged exposure to high temperatures. If the aged section of the thermocouple circuit is exposed to a temperature gradient, the measured voltage will differ, resulting in error.

Aged thermocouples are only partly modified; for example, being unaffected in the parts outside the furnace. For this reason, aged thermocouples cannot be taken out of their installed location and recalibrated in a bath or test furnace to determine error. This also explains why error can sometimes be observed when an aged thermocouple is pulled partly out of a furnace—as the sensor is pulled back, aged sections may see exposure to increased temperature gradients from hot too cold as the aged section now passes through the cooler refractory area, contributing significant error to the measurement. Likewise, an aged thermocouple that is pushed deeper into the furnace might sometimes provide a more accurate reading if being pushed further into the furnace causes the temperature gradient to occur only in a fresh section.

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Comparison of types

The table below describes properties of several different thermocouple types. Within the tolerance columns, *T* represents the temperature of the hot junction, in degrees Celsius. For example, a thermocouple with a tolerance of ±0.0025×*T* would have a tolerance of ±2.5 °C at 1000 °C.

T/C Type	Conductor +	Conductor −	T/C Junction Continuous Temperature range °C	INTERNATIONAL IEC 584-3:1989 BS 4937 P:00:1993	(FORMER) UNITED KINGDOM BS 1843:1952	FRANCE NFE-18001	GERMANY DIN43714	JAPAN JIS C 1610-1981	USA ANSI MC 96.1	Cable Code
E	Ni-CR	Cu-Ni Constantan	0 to +800							EX
J	Fe	Cu-Ni Constantan	0 to +750							JX
K	Ni-Cr	Ni-Al	0 to +1100							KX
N	Ni-Cr-Si Nicrosil	Ni-Si-Mg Nisil	0 to +1100							NX NC
R	Pt-13Rh	Pt	0 to +1600							RCA
S	Pt-10Rh	Pt	0 to +1600							SCA
T	Cu	Cu-Ni Constantan	-185 to +300							TX
B	Pt-30Rh	Pt-6Rh	+200 to +1700							BX

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