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# Thermocouples - An Introduction

**What is a thermocouple sensor?**

A thermocouple is a sensor for measuring temperature. It consists of two dissimilar metals, joined together at one end. When the junction of the two metals is heated or cooled a voltage is produced that can be correlated back to the temperature. The thermocouple alloys are commonly available as wire.

**What are the different thermocouple types?**

A thermocouple is available in different combinations of metals or calibrations. The four most common calibrations are J, K, T and E. There are high temperature calibrations R, S, C and GB. Each calibration has a different temperature range and environment, although the maximum temperature varies with the diameter of the wire used in the thermocouple. Although the thermocouple calibration dictates the temperature range, the maximum range is also limited by the diameter of the thermocouple wire. That is, a very thin thermocouple may not reach the full temperature range.

**How do I choose a thermocouple type?**

Because a thermocouple measures in wide temperature ranges and can be relatively rugged, thermocouples are very often used in industry. The following criteria are used in selecting a thermocouple:

- Temperature range
- Chemical resistance of the thermocouple or sheath material
- Abrasion and vibration resistance
- Installation requirements (may need to be compatible with existing equipment; existing holes may determine probe diameter)

**How do I know which junction type to choose?**

Sheathed thermocouple probes are available with one of three junction types: grounded, ungrounded or exposed . At the tip of a grounded junction probe, the thermocouple wires are physically attached to the inside of the probe wall. This results in good heat transfer from the outside, through the probe wall to the thermocouple junction. In an ungrounded probe, the thermocouple junction is detached from the probe wall. Response time is slower than the grounded style, but the ungrounded offers electrical isolation (see table below).

| Room-Temperature Insulation Resistance Ungrounded Thermocouple | | |
|---|---|---|
| **Nominal Sheath Diameter** | **Applied dc Voltage min.** | **Insulation Resistance min.** |
| Less than 0.90mm (0.03in.) | 50V | 100M Ohms |
| 0.80-1.5mm (0.030 to 0.059in.) | 50V | 500M Ohms |
| Greater than 1.5mm (0.059in.) | 500V | 1000M Ohms |

The thermocouple in the exposed junction style protrudes out of the tip of the sheath and is exposed to the surrounding environment. This type offers the best response time, but is limited in use to dry, noncorrosive and nonpressurized applications.

**What is response time?**

A time constant has been defined as the time required by a sensor to reach 63.2% of a step change in temperature under a specified set of conditions. Five time constants are required for the sensor to approach 100% of the step change value. An exposed junction thermocouple is the fastest responding. Also, the smaller the probe sheath diameter, the faster the response, but the maximum temperature may be lower. Be aware, however, that sometimes the probe sheath cannot withstand the full temperature range of the thermocouple type.

| **Material** | **Maximum Temperature** | **Application Atmosphere** | | | |
|---|---|---|---|---|---|
| | | **Oxidizing** | **Hydrogen** | **Vacuum** | **Inert** |
| 304 SS | 900°C (1650°F) | Very Good | Good | Very Good | Very Good |
| Inconel 600 | 1148°C (2100°F) | Very Good | Good | Very Good | Very Good |

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**Thermocouple Ranges and Limits of Error**

The table below shows temperature ranges and accuracy for J, K, E and T thermocouples. Additional thermocouple types, you can ask us.

**Common Thermocouple Temperature Ranges**

| Calibration | Temp Range | Std. Limits of Error | Spec. Limits of Error |
|---|---|---|---|
| J | 0°C to 750°C (32°F to 1382°F) | Greater of 2.2°C or 0.75% | Greater of 1.1°C or 0.4% |
| K | –200°C to 1250°C (–328°F to 2282°F) | Greater of 2.2°C or 0.75% | Greater of 1.1°C or 0.4% |
| E | –200°C to 900°C (–328°F to 1652°F) | Greater of 1.7°C or 0.5% | Greater of 1.0°C or 0.4% |
| T | –250°C to 350°C (–328°F to 662°F) | Greater of 1.0°C or 0.75% | Greater of 0.5°C or 0.4% |

**Thermocouple Reference Tables**

Thermocouples produce a voltage output that can be correlated to the temperature that the thermocouple is measuring. The documents in the table below provide the thermoelectric voltage and corresponding temperature for a given thermocouple type. Most of the documents also provide the thermocouple temperature range, limits of error and environmental considerations.