Tech Insights

What types of temperature probes are there?

Temperature is one of the most commonly measured variables and it is therefore not surprising that there are many ways of sensing it. To measure temperature, heat is transferred by three methods: convection, conduction, and radiation. Temperature sensing can be done either through direct contact with the heating source, or remotely, without direct contact with the source using radiated energy instead. Contact sensors use conduction or convection, while remote sensing uses radiation as the primary method of heat transfer.

Today, there are three types of temperature sensors that are most commonly used: thermocouple, RTD, and thermistor. Thermocouples are the most versatile temperature transducers, RTDs the most stable, and thermistors the most sensitive.

Thermocouple Probes operate on the principle that an electromagnetic force (emf) is generated when heat is applied to the junction of two dissimilar metals (sensing junction). At the other end of the wires, usually as part of the input instrument, is another junction called the reference junction. The temperature is inferred based on the emf difference between the sensing junction and the reference junction, which is at a known temperature.

RTD Probes operate on the principle that the electrical resistance of a metal increases as its temperature increases. The RTD sensing element consists of pure metal (frequently platinum) and shows a small positive, linear change in resistance per degree of temperature change.

Thermistor Probes have a thermally active resistor composed of metal oxides normally encapsulated in epoxy or glass. A typical thermistor shows a large negative, nonlinear change in resistance per degree of temperature change.

The principal factors to determine what sensor probe to use are temperature range, accuracy, and the speed of response. Size and cost will usually be secondary factors.

Temperature Range

Thermocouples are suitable for use from –200 to 2000°C, depending on type. Linearity varies according to type and temperature range. Generally thermocouple linearity falls between thermistor and RTD characteristics.

Platinum RTDs are suitable for use from –50 to 550°C when long-term stability and repeatability is required. They offer virtually linear response over this range and are interchangeable to DIN specifications.

Thermistors are suitable for use from –40 to 200°C when accuracy and high sensitivity are required. Their response is nonlinear but can be linearized over short ranges (50°C or less) or computed by microprocessor.

Accuracy

Thermocouples offer the greatest temperature range and are more cost effective but are the least sensitive and accurate of these sensor types. Typical sensitivity is 50 μV/°C and accuracy in the range of ±2°C unless specially manufactured.

Thermistors have less stability and repeatability, but are more sensitive tha n RTDs. They are typically more expensive compared to RTDs.

RTDs offer the best stability and repeatability, but are less sensitive than thermistors. They usually can be purchased to higher calibrated accuracy than thermistors for equivalent cost.

Speed of Response

Sensor response time depends strongly on the mounting enclosure. A bare, unenclosed sensor will always respond faster than one in a tube or probe assembly, but is also more susceptible to damage.

Considerations

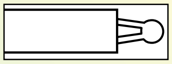
Extend Your Thermocouples up to 2000 feet without signal loss. Extension wire must be the same type as the thermocouple.

System Error becomes important when you select a probe and meter to make a complete temperature measurement system. For example: a meter has an accuracy of ±0.7°F; from the probe-error limits table below, type T probes with metal sheaths, straight cables, and stripped ends have an error limit of ±1.8°F at 400°F. Therefore, the probe-meter system accuracy will be (±0.7) + (±1.8) = ±2.5°F at 400°F.

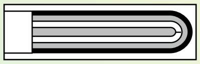
NIST Traceability is required for many applications. See pages 254–260 for our calibration services. In order to make an item traceable to NIST standards, the item and the standard are exposed to the same conditions, the readings are noted, and the difference between the readings is recorded on a NIST calibration report. When taking future readings with the item, the value on the calibration report must be added or subtracted from the measured value.

Thermocouple Probe Junction Types

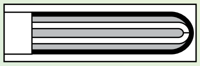
Sheaths with small diameters have faster response times; sheaths with larger diameters have longer life and are better for measuring higher temperatures.



Exposed Junction has the fastest response time—ideal for measuring rapid temperature changes. Clear coating on most models provides a humidity barrier for the thermocouple. Do not use with corrosive fluids or atmospheres. See table at right for recommended atmosphere type for exposed-junction probes.



Ungrounded Junction has a welded junction insulated from the protective sheath and is electrically isolated. Longer response time; use for conductive solutions or where isolation of the measuring circuitry is required.



Grounded Junction has a junction welded to tip of sheath. Wires are completely sealed from contaminants. Good response time.

Probe Sheath Materials

Inconel® 600 Sheath are ideal for severely corrosive environments and at elevated temperatures. Resists progressive oxidation. Maximum operating temperatures: continuous— 2100°F, intermittent—2500°F.

304 SS Sheath are for general purpose use, are corrosion-resistant, and good for food service and biological applications. Maximum operating temperatures: continuous—1650°F, intermittent—2550°F.

316 SS Sheath have higher corrosion resistance than 304 SS. Withstands some strong acids. Maximum operating temperatures: continuous— 1650°F, intermittent—2500°F.

SS Sheath with coating of PFA with grounded junction is ideal with corrosive liquids and atmospheres. Longer response time. Temperatures to 500° F (260°C).

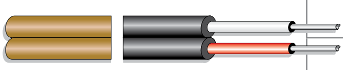
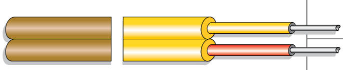
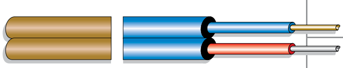
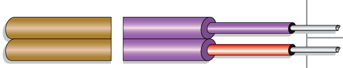
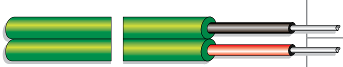
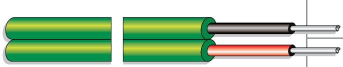
Definitions

Thermocouple Probes are composed of two dissimilar metals, joined to produce a voltage when the applied (measured) temperature differs from the reference temperature.

Thermocouple Thermometers measure, amplify, linearize, and display the proportional voltage signal generated by the thermocouple probe.

Application/Selection Guide

Physical Characteristics of Thermocouples

Type	Outer Insulation: Thermocouple grade	Outer Insulation: Extension grade	Wire insulation color	Polarity	Wire material of construction	Properties for identification	Atmosphere for exposed junction
J				+	Iron	Strongly magnetic	Reducing
				–	Constantan	—	
K				+	Chromel	Moderately magnetic	Clean oxidizing
				–	Alumel	—	
T				+	Copper	Copper color	Mildly oxidizing and reducing or with moisture
				–	Constantan	—	
E				+	Chromel	Greater stiffness	Vacuum, inert, mildly oxidizing or reducing
				–	Constantan	—	
R				+	87% Platinum 13% Rhodium	Greater stiffness	Resists oxidation and corrosion, but contaminated by hydrogen, carbon, and metal vapors
				–	Platinum	—	
S				+	90% Platinum 10% Rhodium	Greater stiffness	
				–	Platinum	—	

Maximum Thermocouple Probe Error Limits

Tolerances apply only to new thermocouples from –200°C to the recommended upper temperature limit of the probe. Tolerances change with use and it is up to the user to establish acceptable limits of error for used thermocouples. Calculated from ASTM tolerances.

Type	Maximum error limit
Probes with detachable handles	
J, K	±4.0°F (±2.2°C), or ±0.4% of reading above 32°F (0°C); ±2.0% of reading below 32°F (0°C)
T	±1.8°F (±1.0°C), or ±0.4% of reading above 32°F (0°C); ±0.8% of reading below 32°F (0°C)
E	±3.6°F (±2.0°C), or ±0.4% of reading above 32°F (0°C); ±0.5% of reading below 32°F (0°C)
Probes with metal sheath, coiled cord, and connector	
J, K	±7.9°F (±4.4°C), or ±0.4% of reading above 32°F (0°C); ±2.0% of reading below 32°F (0°C)
T	±3.6°F (±2.0°C), or ±0.4% of reading above 32°F (0°C); ±0.8% of reading below 32°F (0°C)
E	±6.7°F (±3.7°C), or ±0.4% of reading above 32°F (0°C); ±0.5% of reading below 32°F (0°C)
Probes with metal sheath, straight cable, and connector	
J, K	±5.9°F (±3.3°C), or ±0.4% of reading above 32°F (0°C); ±2.0% of reading below 32°F (0°C)
T	±2.7°F (±1.5°C), or ±0.4% of reading above 32°F (0°C); ±0.8% of reading below 32°F (0°C)
E	±5.4°F (±3.0°C), or ±0.4% of reading above 32°F (0°C); ±0.5% of reading below 32°F (0°C)
Probes with metal sheath, straight cable, and stripped ends	
J, K	±4.0°F (±2.2°C), or ±0.4% of reading above 32°F (0°C); ±2.0% of reading below 32°F (0°C)
T	±1.8°F (±1.0°C), or ±0.4% of reading above 32°F (0°C); ±0.8% of reading below 32°F (0°C)
E	±3.6°F (±2.0°C), or ±0.4% of reading above 32°F (0°C); ±0.5% of reading below 32°F (0°C)
Probes made of one piece of thermocouple wire with a connector	
J, K	±4.0°F (±2.2°C), or ±0.4% of reading above 32°F (0°C); ±2.0% of reading below 32°F (0°C)
T	±1.8°F (±1.0°C), or ±0.4% of reading above 32°F (0°C); ±0.8% of reading below 32°F (0°C)
E	±3.6°F (±2.0°C), or ±0.4% of reading above 32°F (0°C); ±0.5% of reading below 32°F (0°C)
Thermocouple wire only, no connector	
J, K	±2.0°F (±1.1°C), or ±0.4% of reading above 32°F (0°C); ±2.0% of reading below 32°F (0°C)
T	±0.9°F (±0.5°C), or ±0.4% of reading above 32°F (0°C); ±0.8% of reading below 32°F (0°C)
E	±1.8°F (±1.0°C), or ±0.4% of reading above 32°F (0°C); ±0.5% of reading below 32°F (0°C)

Selection Chart

Choose the right temperature probe for your application based on the following features:

Feature	Thermocouple	Platinum RTD	Thermistor
Temperature range	High	Medium	Low
Accuracy	Low	Medium	High
Long-term stability	Low	High	Medium
Repeatability	Low	High	Medium
Linearity	Average	Good	Poor
Size	Large	Small	Medium
Time response	2 to 5 sec	2 to 5 sec	1 to 2 sec