

## Thermocouples

Tech Tip #28 ©2000

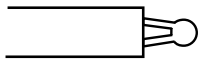
### Definitions

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.

### 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 below 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 TEFLON® PFA with grounded junction is ideal with corrosive liquids and atmospheres. Longer response time. Temperatures to 500° F (260°C).





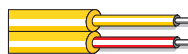




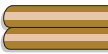
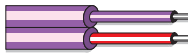


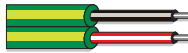


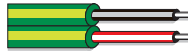

## Considerations

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  $\pm 0.7^{\circ}\text{F}$ ; from the probe-error limits table below, type T probes with metal sheaths, straight cables, and stripped ends have an error limit of  $\pm 1.8^{\circ}\text{F}$  at  $400^{\circ}\text{F}$ . Therefore, the probe-meter system accuracy will be  $(\pm 0.7) + (\pm 1.8) = \pm 2.5^{\circ}\text{F}$  at  $400^{\circ}\text{F}$ .

NIST Traceability is required for many applications. See page 1042 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 certificate. When taking future readings with the item, the value on the certificate must be added or subtracted from the measured value.

## Physical Characteristics of Thermocouples

| Type | Outer Insulation  |   | Wire insulation color   | Polarity | Wire material of construction | Properties for identification | Atmosphere for exposed junction   |
|------|---|---|---|----------|-------------------------------|-------------------------------|---|
|      | Thermocouple grade  | Extension grade   |   |          |                               |                               |   |
| 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<br>13% Rhodium   | Greater stiffness             | Resists oxidation and corrosion, but contaminated by hydrogen, carbon, and metal vapors |
|      |   |   |   |          | Platinum                      | —                             |   |
| S    |  |  |  | +        | 90% Platinum<br>10% Rhodium   | Greater stiffness             | Resists oxidation and corrosion, but contaminated by hydrogen, carbon, and metal vapors |
|      |   |   |   |          | Platinum                      | —                             |   |

## Maximum Thermocouple Probe Error Limits

Tolerances apply only to new thermocouples from  $-200^{\circ}\text{C}$  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   | $\pm 4.0^{\circ}\text{F}$ ( $\pm 2.2^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 2.0\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| T  | $\pm 1.8^{\circ}\text{F}$ ( $\pm 1.0^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 0.8\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| E  | $\pm 3.6^{\circ}\text{F}$ ( $\pm 2.0^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 0.5\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| Probes with metal sheath, coiled cord, and connector           |  |
| J, K   | $\pm 7.9^{\circ}\text{F}$ ( $\pm 4.4^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 2.0\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| T  | $\pm 3.6^{\circ}\text{F}$ ( $\pm 2.0^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 0.8\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| E  | $\pm 6.7^{\circ}\text{F}$ ( $\pm 3.7^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 0.5\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| Probes with metal sheath, straight cable, and connector        |  |
| J, K   | $\pm 5.9^{\circ}\text{F}$ ( $\pm 3.3^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 2.0\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| T  | $\pm 2.7^{\circ}\text{F}$ ( $\pm 1.5^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 0.8\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| E  | $\pm 5.4^{\circ}\text{F}$ ( $\pm 3.0^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 0.5\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| Probes with metal sheath, straight cable, and stripped ends    |  |
| J, K   | $\pm 4.0^{\circ}\text{F}$ ( $\pm 2.2^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 2.0\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| T  | $\pm 1.8^{\circ}\text{F}$ ( $\pm 1.0^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 0.8\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| E  | $\pm 3.6^{\circ}\text{F}$ ( $\pm 2.0^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 0.5\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| Probes made of one piece of thermocouple wire with a connector |  |
| J, K   | $\pm 4.0^{\circ}\text{F}$ ( $\pm 2.2^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 2.0\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| T  | $\pm 1.8^{\circ}\text{F}$ ( $\pm 1.0^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 0.8\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| E  | $\pm 3.6^{\circ}\text{F}$ ( $\pm 2.0^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 0.5\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| Thermocouple wire only, no connector                           |  |
| J, K   | $\pm 2.0^{\circ}\text{F}$ ( $\pm 1.1^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 2.0\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| T  | $\pm 0.9^{\circ}\text{F}$ ( $\pm 0.5^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 0.8\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |
| E  | $\pm 1.8^{\circ}\text{F}$ ( $\pm 1.0^{\circ}\text{C}$ ), or $\pm 0.4\%$ of reading above $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ); $\pm 0.5\%$ of reading below $32^{\circ}\text{F}$ ( $0^{\circ}\text{C}$ ) |

**NOVA-TECH**  
**INTERNATIONAL**  
 800 Rockmead Dr Ste 102 • Houston, TX 77339-2112  
 Tel: (281) 359-8538 • Toll Free Tel: (866) 433-6682  
 Fax: (281) 359-0084 • Toll Free Fax: (866) 433-6684  
 sales@novatech-usa.com • www.novatech-usa.com

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