

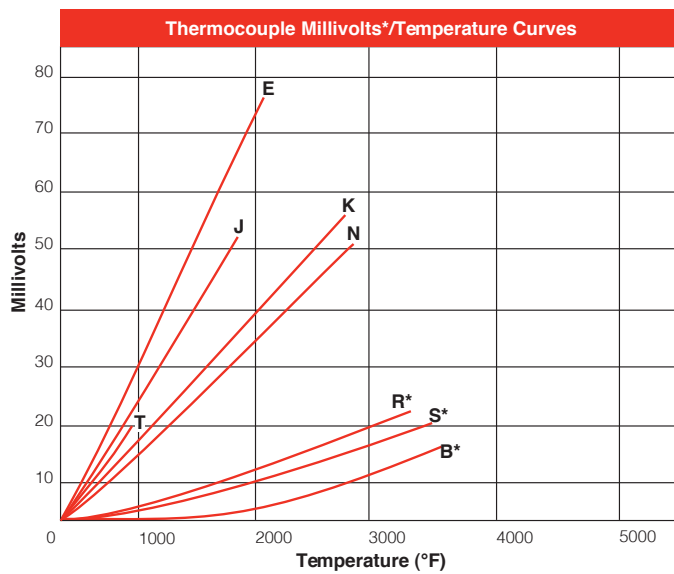
Thermocouples

General Information

Calibration Types

Thermocouples are classified by calibration type because they have varying electromotive force (EMF) versus temperature curves. Some generate considerably more voltage at lower temperatures, while others do not begin to develop a significant voltage until subjected to high temperatures. Also, calibration types are designed to deliver as close to a straight line voltage curve inside their temperature application range as possible. This makes it easier for an instrument or temperature controller to correctly correlate the received voltage to a particular temperature.

Additionally, thermocouple calibration types have different levels of compatibility with different atmospheres. Chemical reaction between certain thermocouple alloys and the application atmosphere could cause metallurgy degradation, making another calibration type more suitable for sensor life and accuracy requirements.



*Millivolt values shown for R and S calibrations pertain to thermocouple calibrations only. RX and SX constructions described in this catalog section are intended for use as **extension wire only** and will not exhibit the millivolt outputs shown.

Thermocouple Types

Calibration types have been established by the American Society for Testing and Materials (ASTM) according to their temperature versus EMF characteristics in accordance with ITS-90, in standard or special tolerances.

Additionally, there are non-ASTM calibration types. These thermocouples are made from tungsten and tungsten-rhenium alloys. Generally used for measuring higher temperatures, they are a more economical alternative to the platinum and platinum alloy based noble metal thermocouples, but limited to use in inert and non-oxidizing atmospheres.

Thermocouple Type	Useful/General Application Range
B	1600-3100°F (870-1700°C)
E*	200-1650°F (95-900°C)
J	200-1400°F (95-760°C)
K*	200-2300°F (95-1260°C)
N	200-2300°F (95-1260°C)
R	32-2700°F (0-1480°C)
S	32-2700°F (0-1480°C)
T*	32-660°F (0-350°C)

*Also suitable for cryogenic applications from -328 to 32°F (-200 to 0°C)

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Type B

Maximum recommended operating temperature for Type B is 3100°F (1700°C). Suitable for use in an oxidizing or inert atmosphere. Do not insert in metal tubes. Beware of contamination at high temperatures. Not suitable for use below 122°F (50°C).

Type E

The Type E thermocouple is suitable for use at temperatures up to 1650°F (900°C) in a vacuum, inert, mildly oxidizing or reducing atmosphere. At cryogenic temperatures, the thermocouple is not subject to corrosion. This thermocouple has the highest EMF output per degree of all the commonly used thermocouples.

Type J

Type J is the second most common calibration type and is a good choice for general purpose applications where moisture is not present.

The Type J thermocouple may be used, exposed or unexposed, where there is a deficiency of free oxygen. For cleanliness and longer life, a protection tube is recommended. Since iron (JP) wire will oxidize rapidly at temperatures over 1000°F (540°C), it is recommended that larger gauge wires be used to compensate. Maximum recommended operating temperature is 1400°F (760°C).

Type K

Type K thermocouples usually work in most applications as they are nickel based and exhibit good corrosion resistance. It is the most common sensor calibration type providing the widest operating temperature range.

Due to its reliability and accuracy the Type K thermocouple is used extensively at temperatures up to 2300°F (1260°C). This type of thermocouple should be protected with a suitable metal or ceramic protection tube, especially in reducing atmospheres. In oxidizing atmospheres, such as electric furnaces, tube protection is not always necessary when other conditions are suitable; however, it is recommended for cleanliness and general mechanical protection. Type K will generally outlast Type J because the JP wire rapidly oxidizes, especially at higher temperatures.

Type N

This nickel-based thermocouple alloy is used primarily at high temperatures up to 2300°F (1260°C). While not a direct replacement for Type K, Type N provides better resistance to oxidation at high temperatures and longer life in applications where sulfur is present. It also outperforms Type K in K's aging range.

Types S and R

Maximum recommended operating temperature for Type S or R is 2700°F (1480°C). These thermocouples are easily contaminated. Reducing atmospheres are particularly damaging to the calibration. Noble metal thermocouples should always be protected with a gas-tight ceramic tube, a secondary tube of porcelain, and a silicon carbide or metal outer tube as conditions require.

Type T

This thermocouple can be used in either oxidizing or reducing atmospheres, though for longer life, a protecting tube is recommended. Because of its stability at lower temperatures, this is a superior thermocouple for a wide variety of applications in low and cryogenic temperatures. Its recommended operating range is -330° to 660°F (-200° to 350°C), but it can be used up to -452°F (-269°C) (boiling helium).

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Maximum Temperatures

The diameter of the sensor wires determines the upper most operating temperature. The larger the diameter, the higher the temperature rating.

Choose alloy 600 over 304 stainless steel (SS) or 316 SS when higher temperatures are expected.

The environment is also a critical factor when determining the best material to use. Consult the manual on **The Use of Thermocouples in Temperature Measurement**, published by ASTM for further details.

Recommended Upper Temperature Limit for Protected Thermocouple Wire

Thermocouple Type	No. 8 Gauge °F (°C)	No. 14 Gauge °F (°C)	No. 20 Gauge °F (°C)	No. 24 Gauge °F (°C)	No. 28 Gauge °F (°C)
E	1600 (870)	1200 (650)	1000 (540)	800 (430)	800 (430)
J	1400 (760)	1100 (590)	900 (480)	700 (370)	700 (370)
K and N	2300 (1260)	2000 (1190)	1800 (980)	1600 (870)	1600 (870)
R and S				2700 (1480)	
T		700 (370)	500 (260)	400 (200)	400 (200)

This table gives the recommended upper temperature limits for the various thermocouples and wire sizes. These limits apply to protected thermocouples in conventional closed-end protecting tubes. They do not apply to sheathed thermocouples with compacted mineral oxide insulation.

The temperature limits shown here are intended only as a guide and should not be taken as absolute values nor as guarantees of satisfactory life or performance. These types and sizes are sometimes used at temperatures above the given limits, but usually at the expense of stability, life or both. In other instances, it may be necessary to reduce the above limits to achieve adequate service.

Mineral Insulated Sensors by Diameter and Sheath

Sheath Diameter in.	Calibration	Sheath Material	Maximum Recommended Operating Temperature	
			°F	(°C)
0.032	K	304 SS/Alloy 600	1600	(871)
0.032	J	304 SS	1500	(816)
0.040	K	304 SS/316 SS/Alloy 600	1600	(871)
0.040	J	304 SS	1500	(816)
0.040	T	304 SS	662	(350)
0.040	E	304 SS	1600	(871)
0.063	K or N	Alloy 600	2000	(1093)
0.063	S	Alloy 600	2000	(1093)
0.063	J	304 SS/316 SS	1500	(816)
0.063	E	304 SS	1600	(871)
0.063	K	304 SS/316 SS	1600	(871)
0.063	K	Hastelloy® X	2200	(1204)
0.125	K or N	Alloy 600	2150	(1177)
0.125	T	304 SS/316 SS/Alloy 600	662	(350)
0.125	E	Alloy 600	1600	(871)
0.125	S	Alloy 600	2150	(1177)
0.125	J	304 SS/316 SS	1500	(816)
0.125	K	304 SS	1600	(871)
0.250	K or N	Alloy 600	2150	(1177)
0.250	J	304 SS/310 SS/316 SS	1500	(816)
0.250	K	304 SS	1600	(871)
0.250	T	304 SS	662	(350)
0.250	E	304 SS/316 SS	1600	(871)
0.250	K	310 SS	2000	(1093)
0.250	K	316 SS	1600	(871)
0.250	T	316 SS	662	(350)
0.250	K	446 SS	2100	(1149)

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Junction Types

Generally, the **grounded junction** offers the best compromise between performance and reliability. It is the best choice for general purpose measurements.

Select an **ungrounded junction** if the lead wire will be shielded and attached to the sheath. Also, select the ungrounded junction to avoid ground loops between instruments, power supplies and the sensor.

Listed below are junction styles offered by Watlow.

Exposed Junction



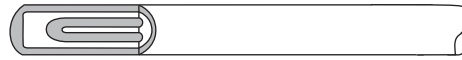
Thermocouple wires are butt welded, insulated and sealed against liquid or gas penetration. This junction style provides the fastest possible response time but leaves the thermocouple wires unprotected against corrosive or mechanical damage.

Grounded Junction



The sheath and conductors are welded together, forming a completely sealed, integral junction. The grounded junction is recommended in the presence of liquids, moisture, gas or high pressure. The wire is protected from corrosive or erosive conditions. Response time with this style approaches that of the exposed junction.

Ungrounded Junction



The thermocouple junction is fully insulated from the welded sheath end. The ungrounded junction is excellent for applications where stray EMFs would affect the reading and for frequent or rapid temperature cycling. Response time is longer than with the grounded junction.

Ungrounded Dual Isolated Junction



Two separate thermocouples are encased in a single sheath. The isolation prevents ground loop errors if wired to separate instruments. Only available as ungrounded junctions.

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Response Time

The smaller the diameter, the faster the thermocouple responds. Grounding the junction also improves response time by approximately 50 percent based on the sensor achieving 63.2 percent of the final reading or to the first time constant. It takes approximately five time constants to obtain steady state readings.

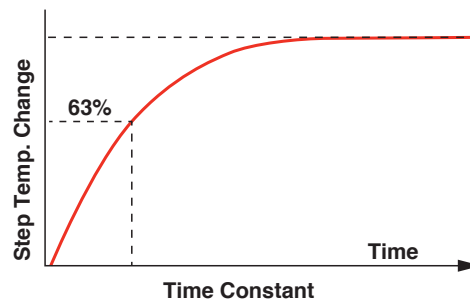
Temperature accuracy of the surrounding medium depends on the capability of the sensor to conduct heat from its outer sheath to the element wire.

Several factors come into play. Most commonly noted is "time constant" (thermal response time). Time constant, or thermal response time, is an expression of how quickly a sensor responds to temperature changes. As expressed here, time response is defined as the length of time it takes a sensor to reach 63.2 percent of a step temperature change (see graph to the right).

Response is a function of the mass of the sensor and its efficiency in transferring heat from its outer surfaces to the wire sensing element. A rapid time response is essential for accuracy in a system with sharp temperature changes. Time response varies with the probe's physical size and design.

Response times indicated represent standard industrial probes.

Time Constant (Thermal Response Time)



Thermocouple Time Response

Sheath Diameter	Average Response Time Still Water (seconds)*	
	Grounded Junction	Ungrounded Junction
0.010 in.	<0.02	<0.02
0.020 in.	<0.02	0.03
0.032 in.	0.02	0.07
0.040 in.	0.04	0.13
0.063 in.	0.22	0.40
0.090 in.	0.33	0.68
0.125 in.	0.50	1.10
0.188 in.	1.00	2.30
0.250 in.	2.20	4.10
0.313 in.	5.00	7.00
0.375 in.	8.00	11.00
0.500 in.	15.00	20.00
0.5 mm	<0.02	0.03
1.0 mm	0.04	0.13
1.5 mm	<0.15	0.35
2.0 mm	0.25	0.55
3.0 mm	0.40	0.90
4.5 mm	0.95	2.00
6.0 mm	2.00	3.50
8.0 mm	5.00	7.00

*Readings are to 63 percent of measured temperatures.