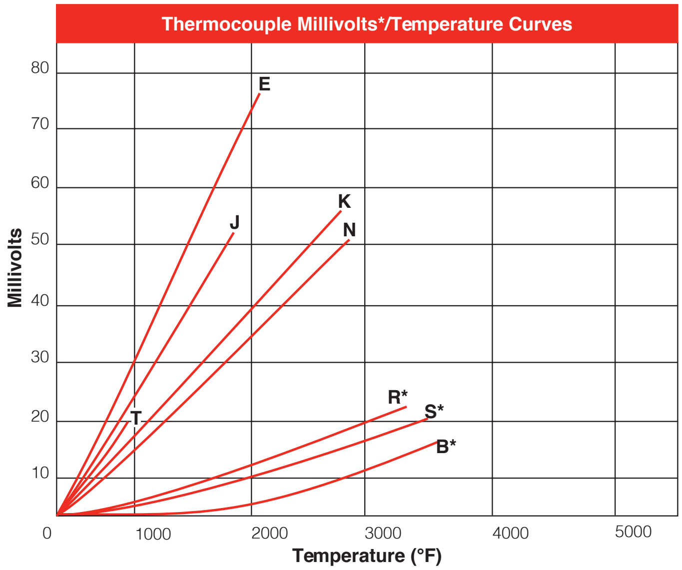
General Information

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)

General Information

Calibration Types

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.

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).

General Information

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	(980)	1800	(980)	1600	(870)	1600	(870)
R and S							2700	(1480)		
T			500	(260)	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)

General Information

Junction Types

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

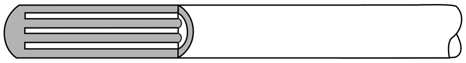
Select an **ungrounded junction** if the lead wire will be shielded and attached to the sheath. Also, select the ungrounded junction to avoid ground loops between instruments, power supplies and the sensor.

Listed below are junction styles offered by Watlow.

Exposed Junction

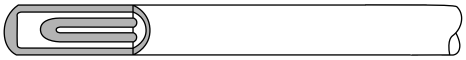
Thermocouple wires are butt welded, insulated and sealed against liquid or gas penetration. This junction style provides the fastest possible response time but leaves the thermocouple wires unprotected against corrosive or mechanical damage.

Grounded Junction



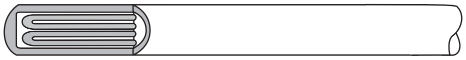
The sheath and conductors are welded together, forming a completely sealed, integral junction. The grounded junction is recommended in the presence of liquids, moisture, gas or high pressure. The wire is protected from corrosive or erosive conditions. Response time with this style approaches that of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

General Information

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.

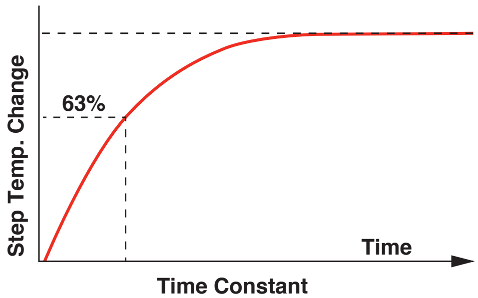
Temperature accuracy of the surrounding medium depends on the capability of the sensor to conduct heat from its outer sheath to the element wire.

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)



Mineral Insulated 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.

General Information

Thermocouple Resistance

Although resistance cannot confirm that the alloy meets the correct thermoelectric specifications, it checks for other undesirable characteristics such as opens, poor welds or wire corrosion. Always measure thermocouple resistance outside of the application to ensure that EMF output does not conflict with the resistance meter.

Ohms per Double Feet

Long lead wire runs or use of analog-based instrumentation make conductor resistance an important factor when selecting the wire gauge best suited for an application. The table below lists nominal ohms per double feet for thermocouple and thermocouple extension wire. Ohms per double feet are the total resistance, in ohms, for both conductors, per foot.

Nominal Resistance for Thermocouple Alloys in Ohms per Double Feet at 20°C

AUG Gauge	Calibration Type						
	Diameter in. (mm)	E	J	K	N	RX, SX	T
2	0.258 (6.543)	0.011	0.006	0.009	0.012		
4	0.204 (5.189)	0.017	0.009	0.014	0.019		
6	0.162 (4.115)	0.028	0.014	0.023	0.030		
8	0.129 (3.264)	0.044	0.023	0.036	0.048		
10	0.102 (2.588)	0.070	0.036	0.058	0.077		
12	0.081 (2.053)	0.111	0.057	0.092	0.123	0.006	0.048
14	0.064 (1.630)	0.177	0.091	0.147	0.195	0.010	0.076
16	0.051 (1.290)	0.281	0.145	0.233	0.310	0.016	0.120
18	0.040 (1.020)	0.453	0.234	0.376	0.500	0.025	0.194
20	0.032 (0.813)	0.709	0.367	0.589	0.783	0.040	0.304
22	0.025 (0.645)	1.129	0.584	0.937	1.245	0.063	0.483
24	0.020 (0.508)	1.795	0.928	1.490	1.980	0.100	0.768
26	0.016 (0.406)	2.853	1.476	2.369	3.148	0.159	1.221
28	0.013 (0.320)	4.537	2.347	3.767	5.006	0.253	1.942
30	0.010 (0.254)	7.214	3.731	5.990	7.960	0.402	3.088
32	0.008 (0.203)	11.470	5.933	9.524	12.656	0.639	4.910
34	0.006 (0.152)	18.239	9.434	15.145	20.126	1.016	7.808
36	0.005 (0.127)	29.000	15.000	24.080	32.000	1.615	12.415
14 Stranded	0.076 (1.930)	0.161	0.083	0.134	0.178	0.009	0.069
16 Stranded	0.060 (1.520)	0.408	0.133	0.213	0.283	0.014	0.110
18 Stranded	0.048 (1.220)	0.256	0.211	0.338	0.450	0.023	0.174
20 Stranded	0.038 (0.965)	0.648	0.335	0.538	0.715	0.036	0.277
22 Stranded	0.030 (0.762)	1.031	0.533	0.856	1.137	0.057	0.441
24 Stranded	0.024 (0.610)	1.639	0.848	1.361	1.808	0.091	0.701

Note: RX and SX indicate compensating thermocouple materials.

General Information

Thermocouple Resistance

Conductor Sizes

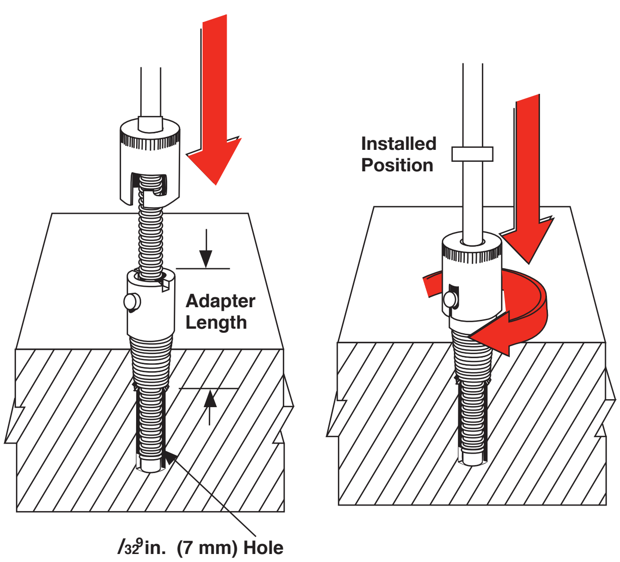
Wire Size	Solid		Stranded		Number of Strands	Strand Gauge
	Diameter in.	(mm)	Diameter in.	(mm)		
14	0.064	(1.630)	0.076	(1.930)	7	22
16	0.051	(1.290)	0.060	(1.520)	7	24
18	0.040	(1.020)	0.048	(1.220)	7	26
20	0.032	(0.813)	0.038	(0.965)	7	28
22	0.025	(0.635)	0.030	(0.762)	7	30
24	0.020	(0.508)	0.024	(0.610)	7	32
26	0.016	(0.406)				
28	0.013	(0.330)				
30	0.010	(0.254)				
32	0.008	(0.203)				
34	0.006	(0.152)				
36	0.005	(0.127)				

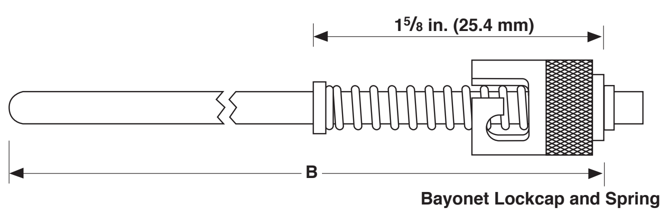
General Information

How Do I Install a Sensor with Spring Loaded Bayonet Cap?

The bayonet adapter is used in conjunction with the spring loaded bayonet cap attached to the sensor sheath. The part to be measured is drilled and tapped for the installation of the bayonet adapter. After placing the sensor through the adapter, the spring is compressed and locked with the bayonet cap. This allows the sensing zone to be pushed tightly against the surface for increased accuracy and faster response time.

"B" Dimension	Adapter Length				
	0.875	1	1.5	2	2.5
2.0	0.500	0.375	2	–	–
2.5	0.875	0.750	0.375	–	–
3.0	1.375	1.250	0.750	0.375	–
3.5	1.875	1.750	1.250	0.750	0.375
4.0	2.375	2.250	1.750	1.250	0.750
4.5	2.875	2.750	0.250	1.750	1.250
5.0	3.375	3.250	2.750	2.250	1.750
5.5	3.875	3.750	3.250	2.750	2.250
6.0	4.375	4.250	3.750	3.250	2.750
6.5	4.875	4.750	4.250	3.750	3.250
7.0	5.375	5.250	4.750	4.250	3.750
7.5	5.875	5.750	5.250	4.750	4.250
8.0	6.375	6.250	5.750	5.250	4.750
8.5	6.875	6.750	6.250	5.750	5.250
9.0	7.375	7.250	6.750	6.250	5.750
9.5	7.875	7.750	7.250	6.750	6.250
10.0	8.375	8.250	7.750	7.250	6.750
10.5	8.875	8.750	8.250	7.750	7.250
11.0	9.375	9.250	8.750	8.250	7.750
11.5	9.875	9.750	9.250	8.750	8.250
12.1	10.375	10.250	9.750	9.250	8.750





General Applications Tube and Wire

Watlow® is a world class supplier of temperature measurement products, with more than 90 years of manufacturing, research and design expertise.

Companies engaged in critical process control of food and metals rely on Watlow thermocouples. Watlow designs and manufactures sensors to meet customers' industrial and commercial equipment needs.

Watlow has developed an extensive line of thermocouples to meet a broad range of sensing needs.

Performance Capabilities

- Fiberglass insulated thermocouples can reach temperatures up to 900°F (480°C) for continuous operation

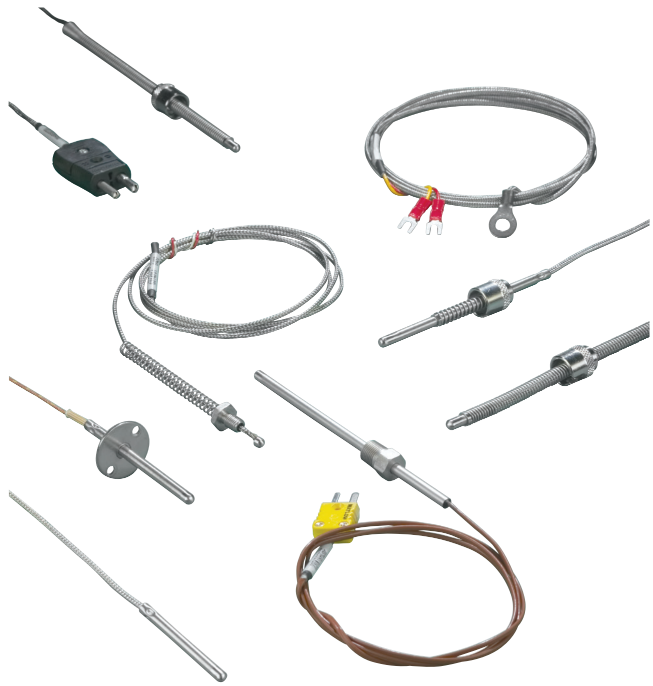
Features and Benefits

Standard products including:

- 32 standard sheath lengths
- Lead lengths from six to 360 inches
- Stainless steel braid or hose protection
- J, K, T and E calibrations
- Grounded, ungrounded and exposed junctions
- Flat and drill point
- Epoxy sealed cold ends
- Adjustable depths
- Flexible extensions
- Washers, nozzles and clamp bands
- PFA coated and stainless steel sheaths
- Straight, 45° bend or 90° bend
- Locking bayonet caps in standard
- 300 series stainless tubing

Typical Applications

- Food processing equipment
- De-icing
- Plating baths
- Industrial processing
- Medical equipment
- Pipe tracing control
- Industrial heat treating
- Packaging equipment
- Liquid temperature measurement
- Refrigerator temperature control
- Oven temperature control



Construction and Tolerances

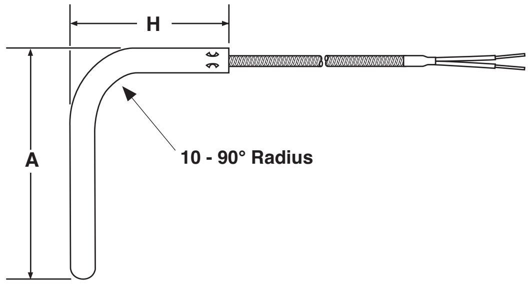
Thermocouples feature flexible SERV-RITE® wire insulated with woven fiberglass or high temperature engineered resins. For added protection against abrasion, products can be provided with stainless steel wire braid and flexible armor. ASTM E230 color-coding identifies standard catalog thermocouple types.

The addition of a metal sheath over the thermocouple provides rigidity for accurate placement and added protection of the sensing junction. Mounting options include springs, ring terminals, specialized bolts, pipe style clamps and shims.

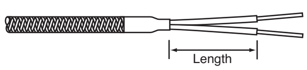
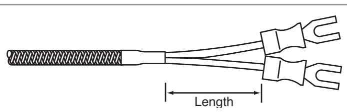
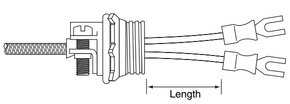
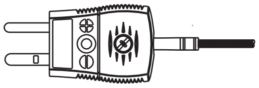
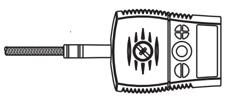
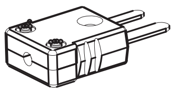
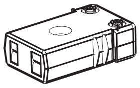
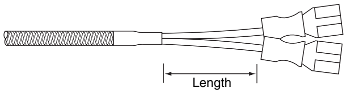
General Applications Tube and Wire

Bends

Diameter in.	Standard Bend Radius in.	Minimum "A" Dimension in.	Minimum "H" Dimension in.
0.125	3/8	1	2
0.188	3/8	1	2
0.250	1/2	2	2
0.375	3/4	3	2



Lead Terminations

Terminations	Code	Length
 Split Leads	A	2 1/2
 #6 Spade Lugs	B	2 1/2
 #6 Spade Lugs and BX Connector	C	2 1/2
 Standard Male Plug	D	—
 Standard Female Jack	E	—
 Miniature Male Plug	F	—
 Miniature Female Jack	G	—
 ¼ inch Push-on Connectors	H	2 1/2