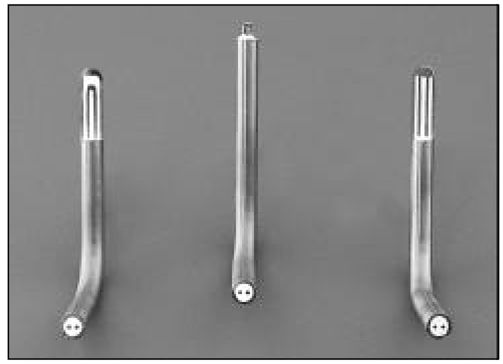
Thermocouple Specification Criteria

Now that you know how they work, it's time to get right down to specifying a thermocouple. There are a gazzilion parameters you could consider, however, 99.9999% of the time if you keep the following in mind your thermocouple will keep its little millivolt heart pumping away forever or until the next maintenance shutdown *whichever* occurs first.

Operating Environment: What is the operating temperature that the thermocouple will be used in? (Select from the tables provided in this section.) What is in the process that will affect the life or performance of the thermocouple?
Cost/Performance Ratio: How accurate do I want to be? Do I need Special Limits? How will the dynamics of the process affect the accuracy? Can I afford the accuracy want?
Environment: Do we protect the thermocouple by installing it in a well? What sheath material do we use on the thermocouple that will make it compatible with the environment?
Calibration: Since the ranges for calibrations tend to overlap there are other considerations in the selection criteria. The table below should help. *See pages 17-68 for the most common thermocouple and RTD reference tables or visit our web site www.smartsensors.com for all reference tables.*
Response Time: Typical response time for thermocouples range from a tenth of a second all the way up to 5 seconds, depending on the size of the thermocouple and the junction employed.
Longevity: Typically the larger the OD of the thermocouple the longer it will last. This criteria can be tricky. Take the cement contractor who wanted to measure the temperature of poured cement. The best thermocouple for him was a bare wire thermocouple where the junction was twisted together. He could care less what the temperature was or if the thermocouple was working once the cement became concrete. We don't do business with a lot of cement contractors. The data below may help you decide which size thermocouple is best. Response time is in seconds and measures a 63.2% step change in temperature from ambient to boiling water.



Shown is Smart Sensors' Mineral Oxide insulated thermocouple cable with a cut away of the three most common junctions, (from left) ungrounded, exposed, and grounded.

Measuring Junction Typical Response Time

Sheath OD	Measuring Junction	Response Time*
. 063 (1/16")	Grounded	.09
	Ungrounded	.28
.125 (1/8")	Grounded	.34
	Ungrounded	1.6
.188 (3/16")	Grounded	.7
	Ungrounded	2.6
.250 (1/4")	Grounded	1.7
	Ungrounded	4.5
	Exposed loop	.09

*Sensors not in thermowell or protection tubes

Calibration Selection Guide

Calibration Type	Conductors Positive	Conductors Negative	Temperature Range °C	Limits of Error Standard	Limits of Error Special	Extension Wire Jacket Color	Color Coding
J	Iron (Magnetic)	Constantan (Non-magnetic)	0°C to 750°C	±2.2°C or ±0.75%	±1.1°C or ±0.4%	Black	White+ Red-
K	Chromel (Non-magnetic)	Alumel (Magnetic)	-200°C to 0°C	±2.2°C or ±2%	- -	Yellow	Yellow+ Red-
			0°C to 1250°C	±2.2°C or ±0.75%	±1.1°C or ±0.4%		
T	Copper (Non-Magnetic)	Constantan (Non-magnetic)	-200°C to 0°C	±1°C or ±.1.5%	- -	Blue	Blue+ Red-
			0°C to 350°C	±1°C or ±0.75%	±0.5°C or ±0.4%		
E	Chromel (Non-magnetic)	Constantan (Non-magnetic)	-200°C to 0°C	±1.7°C or ±1%	- -	Purple	Purple+ Red-
			0°C to 900°C	±1.7°C or ±0.5%	±1°C or ±0.4%		
N	Nicrosil (Non-magnetic)	Nisil (Non-magnetic)	0°C to 1260°C	±3/4%	±3/8%	Orange	Orange+ Red-
R	Platinum 13% Rhodium (Non-magnetic)	Pure Platinum (Non-magnetic)	0°C to 1450°C	±1.5°C or ±0.25%	N/A N/A	Green	Black+ Red-
S	Platinum 10% Rhodium (Non-magnetic)	Pure Platinum (Non-magnetic)	0°C to 1450°C	±1.5°C or ±0.25%	N/A N/A	Green	Black+ Red-
B	Platinum 30% Rhodium (Non-magnetic)	Platinum 6% Rhodium (Non-magnetic)	870°C to 1700°C	±0.5%	N/A N/A	Gray	Black+ Red-

Calibration Notes
J- Iron Constantan - *Reducing atmosphere recommended. Iron oxidizes rapidly at elevated temperatures. A larger gage size will extend the life of the iron wire.*
T- Copper Constantan - *Can be used in oxidizing or reducing atmospheres. Rust and corrosion resistant. Best for sub-zero temperatures.*
K- Chromel Alumel - *Oxidizing atmosphere recommended. Most commonly used base metal thermocouple. Cycling at high temperatures can cause calibration drift. Not recommended in sulfur environments.*
E- Chromel Constantan - *Oxidizing atmosphere recommended. Highest emf output of thermocouples commonly used. Good corrosion resistance*
S, R- *Use in oxidizing or inert atmospheres. Not recommended for reducing atmospheres. Granular precipitation from metal protection tubes can cause failure or calibration drift.*
N- *Use in oxidizing, reducing and inert atmospheres. Not recommended in sulfur environments. Improved resistance to drift and better stability over K and E at elevated temperatures.*

Thermocouple Construction Materials

The most basic thermocouple construction is the wire type consisting of two dissimilar metals homogeneously joined at one end to form the measuring junction. All wire-type thermocouples have an exposed junction. While wire-type thermocouples offer good response time, ruggedness, and high temperature use, they are susceptible to environmental conditions and therefore must be protected.

Mineral insulated thermocouples overcome the disadvantages of wire type construction by imbedding the thermocouple wires in ceramic insulation and protecting them with a metallic sheath. The mineral insulated cable (MI cable) design is based on small mass and high thermal conductivity which in turn promotes rapid heat transfer from the heat source to the measuring junction.

The sheaths are impervious to most liquids and gases and withstand high external pressures. The seamless design protects against moisture or other contaminants attacking the thermocouple elements. Since the only materials used to make the MI cable are the thermocouple conductors, the mineral oxide insulation and the metallic sheath, the cables are inherently fireproof thus providing the safest temperature measuring system.

Mineral Insulated Cable

M.I. cable is designed to meet the following specifications:

Sheath OD & Wall Thickness: Per ASTME-585
Accuracy: Per ASTME-230 (1993) & ANSI MC96.1 (1988)
Insulation Resistance @ Room Temperature: Per ASTME-585 (Table 2)
Formability: Per ASTME-585 (Can be formed around a mandrel equal to twice the outside diameter without sheath rupture or loss of IR.)
Fabrication: The cable can be welded, brazed or soldered without changing IR. (Care should be taken with smaller diameter sheaths)

See MI Cable Specification Tables on page 9.

Sheath Material

The table below shows just some of the many different materials which can be used to protect the mineral insulated thermocouple. Sheath materials used vary from standard stainless alloys like 304, 310, 316, 321, 347, 446 to the slightly more exotic alloy 600 or Hasteloy®.

These sheaths are selected based on the rigors of the application with corrosion and temperature being the leading factors in sheath selection. The atmospheric environmental parameters are oxidizing, reducing, neutral, and vacuum. For example, 304 Stainless Steel can be used in each type of atmosphere with a maximum operating temperature of 1650°F.

Sheath Material

Material	Melting Point °F	Max. Temp. in Air	Recommended OPR ATM *	Recommended Continuous Max. Temp. °F
304SS	2560	1920	ORNV	1650
310 SS	2560	1960	ORNV	2100
316SS	2280	1760	ORNV	1650
321 SS	2580	1500	ORNV	1600
347SS	2600	1680	ORNV	1600
Inconel Alloy 600	2550	2000	ONV(c)	2100
Copper	1980	600	ORNV (b)	600
Aluminum	1220	800	ORNV	700
Platinum	3216	3000	ON(c)	3050
Molybdenum	4750	1000	VNR	4000
Tantalum	5440	750	V	4500
Titanium	3300	600	VN	2000

Key: O — Oxidizing
R — Reducing
N — Neutral
V — Vacuum
(b)— Scales readily in oxidizing atmosphere
(c)— Sensitive to sulphur corrosion