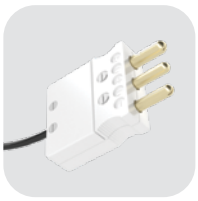
MAJOR ELEMENTS OF A SENSOR

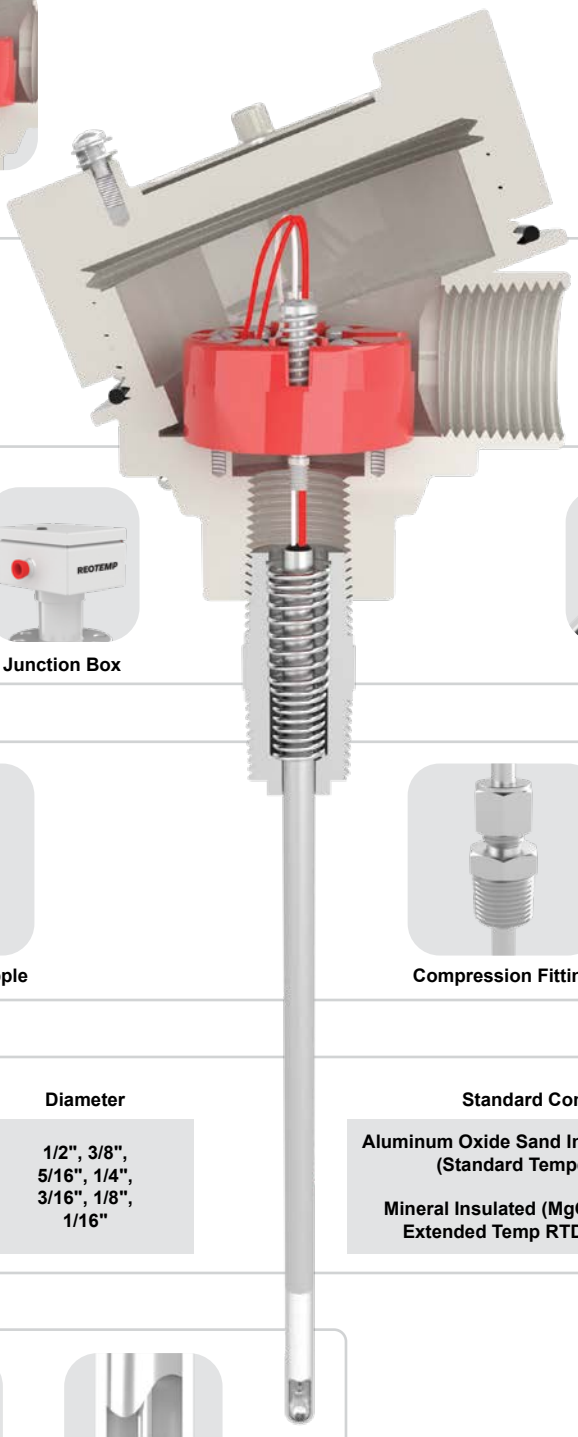
Wiring and Termination


Terminal Block


Transmitter


Plugs


M12



Head/Enclosure


Display


Head Assembly

Junction Box


Stem Only


Slimline™

Process Connection


Threaded


Nipple-Union-Nipple

Compression Fitting


Sanitary

Stem

Material	Diameter	Standard Construction
304/316/310/446 Stainless Steel Inconel Ceramics Hastelloy C	1/2", 3/8", 5/16", 1/4", 3/16", 1/8", 1/16"	Aluminum Oxide Sand Insulated Copper Wire (Standard Temperature RTD) Mineral Insulated (MgO) Cable (Reotemp Extended Temp RTD/Thermocouple)

Measuring Element


Thin Film RTD


Grounded TC

Ungrounded TC

THERMOCOUPLES

What is a thermocouple?

A thermocouple is a sensor used to measure temperature. Thermocouples consist of two wire legs made from different metals. The wire legs are welded together at one end, creating a junction. This junction is where the temperature is measured. When the junction experiences a change in temperature, a temperature dependant voltage is produced. The voltage can then be interpreted using thermocouple reference tables to calculate the temperature.

There are many types of thermocouples, each with their own unique characteristics in terms of temperature range, chemical resistance, and application compatibility. Type J, K, T, & E are “Base Metal” thermocouples, the most common type of thermocouple. Type R, S, and B thermocouples are “Noble Metal” thermocouples (due to high platinum content), which are used in high temperature applications (see thermocouple temperature ranges for more details).

Thermocouples are used in many industrial, scientific, and OEM applications. They can be found in nearly all industrial markets: Power Generation, Oil/Gas, Pharmaceutical, Biotech, Cement, Paper & Pulp, etc. Thermocouples are also used in everyday appliances like stoves, furnaces, and toasters.

Thermocouples are typically selected because of their low cost, high temperature limits, wide temperature ranges, and durable nature.

Thermocouple Types

There are multiple types and grades of thermocouple. Each type of thermocouple wire has a specific combination of metal alloys. This combination is what defines the type of thermocouple. For example, a type K thermocouple is made when a wire of Nickel-Chromium is welded to a wire of Nickel-Aluminium. The grade of the thermocouple is dependent not only on the combination of alloys used, but also on the purity of those alloys.

REFERENCE INFORMATION

Thermocouple Junctions

Grounded

Grounded: A thermocouple is grounded when both thermocouple wires and the sheath are all welded together to form one junction at the probe tip. Grounded thermocouples have a very good response time because the thermocouple is making direct contact with the sheath, allowing heat to transfer easily. A drawback of the grounded thermocouple is that the thermocouple is more susceptible to electrical interference. This is because the sheath often comes into contact with the surrounding area, providing a path for interference.

Ungrounded

Ungrounded: A thermocouple is ungrounded when the thermocouple wires are welded together but they are insulated from the sheath.

Exposed: A thermocouple is exposed when the thermocouple wires are welded together and are sticking out of an open probe tip. The response time is very quick, but exposed thermocouple wires are more prone to corrosion and degradation. Unless your application requires exposed junctions, this style is not recommended.

Ungrounded Uncommon: An ungrounded uncommon thermocouple consists of a dual thermocouple that is insulated from the sheath and each of the elements are insulated from one another.

Mineral Insulated Cable

Mineral insulated (M.I.) cable is used to create thermocouple probes. M.I. cable insulates thermocouple wires from one another and provides the metal sheath that surrounds them. M.I. cable has two (or four when duplex) thermocouple wires running down the middle of the sheath. The sheath contains highly compacted magnesium oxide to ensure the wires are properly insulated and separated. M.I. cable helps to protect the thermocouple wire from corrosion and electrical interference and provides probes with the greatest durability and service life.

Thermocouple Grade Wire vs. Extension Grade Wire

Thermocouple grade wire is used to manufacture thermocouple probes. Thermocouple grade wire is normally used for the junction and inside the stem sheath.

Extension grade wire is used to extend from the thermocouple probe to the control system or digital display. Extension grade wire is more economical due to lesser grade alloys being used.

Extension grade wire is also not generally within the process and does not play as critical of a role as the thermocouple grade wire. It also does not experience the temperature extremes and cycling of the sensor itself.

In many industrial applications, a sensor is located in a process pipe far away from the control room. This means that wire must be run a considerable distance back to the control room to get the temperature reading. Using more expensive thermocouple grade wire to accomplish this is unnecessary. Extension grade wire will do the job.

Common Thermocouple Sheath Materials

304 Stainless Steel: 1650°F maximum operating temperature. Good heat and corrosion resistance.

316/316L Stainless Steel: 1650°F maximum operating temperature. Good heat resistance. Best corrosion resistance of the 300 series stainless steels.

310 Stainless Steel: 2000°F maximum operating temperature Better heat resistance than 304/316. Good corrosion resistance.

Inconel 600: 2150°F maximum operating temperature. Better heat resistance compared to stainless steel due to much higher nickel content. Good corrosion resistance. Not used in sulfur-bearing applications.

Inconel 601: 2150°F maximum operating temperature. Similar to Inconel 600 but better oxidation resistance, holding up longer at elevated temperatures.

446 Stainless Steel: 2100°F maximum operating temperature. Highest heat resistance of all ferritic stainless steels. Used in sulfur bearing applications due to extremely low nickel content.

Note: the above information is a generalized overview for comparison purposes. Other factors, such as thermocouple type, operating range, and sheath diameter are outside the scope of this overview. For example, a type K Inconel 600 3/8" diameter probe operating at 2150°F may last 6 months in an application where a 1/16" diameter probe in the same application may last a few days.

Special Limits of Error (SLE) vs. Standard Limits of Error

Standard limits of Error: These thermocouples use standard “thermocouple grade” wire and make up the great majority of sensors.

Special Limits of Error: These thermocouples are made with a higher grade of thermocouple wire that is purer than standard

wire, which increases their accuracy. They are more expensive than standard thermocouples. SLE thermocouples have twice the accuracy of standard limits.

What is System Error?

System error is calculated by adding the accuracy of the temperature sensor (thermocouple) and the accuracy of the meter used to read the voltage signal together. For example, a Type K thermocouple has an accuracy of +/- 2.2°C at 50°C. The meter has an accuracy of +/- 1.0°C. That means the total system error is +/- 3.2°C at 50°C.

Thermocouple vs. RTD

Temperature Range: First, consider the difference in temperature ranges. Base metal thermocouples can reach 2,300°F and noble metal thermocouples can reach 3,100°F. Compare this to RTDs which have a standard maximum range of 400°F and an extended maximum range of 1,100°F.

Cost: A thermocouple has lower initial cost compared to an equivalent RTD unit.

Accuracy, Linearity, & Stability: As a general rule, RTDs are more accurate than thermocouples. This is especially true at lower temperature ranges. RTDs are also more stable and have better linearity than thermocouples. If accuracy, linearity, and stability are your primary concerns and your application is within an RTD's temperature limits, go with the RTD.

Durability: In the sensors industry, RTDs are widely regarded as a less durable sensor when compared to thermocouples. However, Reotemp has developed manufacturing techniques that have greatly improved the durability of our RTD sensors. These techniques make Reotemp's RTDs nearly equivalent to thermocouples in terms of durability.

Response Time: RTDs cannot be grounded. For this reason, they have a slower response time than grounded thermocouples. Also, thermocouples can be placed inside a smaller diameter sheath than RTDs. A smaller sheath diameter will reduce response time. For example, a grounded thermocouple inside a 1/16" diameter sheath will have a faster response time than a RTD inside a ¼" diameter sheath. The effect of sheath diameter on thermocouple response time, for both grounded and ungrounded, is shown in the chart on page 6.

Hazardous Locations or Applications

Safety is a primary concern when instruments are used in hazardous locations, especially in applications where the potential for explosion is involved due to a concentration of flammable gases, vapors or dust. When specifying a sensor or any instrumentation circuit for use in a hazardous location, the user needs to exercise caution in complying with local and/or national electrical codes and safety regulations.

It is important to consider the failure modes of the instrumentation and any catastrophic effects these modes could have based on the environment they are used in. The integrity and suitability of any instrumentation for use in hazardous locations is ultimately the responsibility of the end user and/or of those making the specification decisions.

Generally, when instrumentation is to be used in a hazardous location, two commonly used methods to minimize the risk of ignitions and explosions are intrinsically safe and explosion-proof systems. Intrinsically safe systems are centered around prevention whereas explosion proof systems are focused on containment.

Intrinsically safe systems operate on low power and are designed to limit the thermal and electrical energy of the instrument and associated connections to a level where ignition is not possible. Also, the devices cannot store enough energy to cause a spark when energy is released.

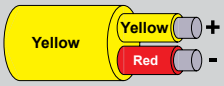
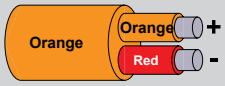
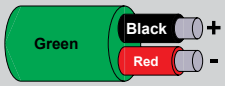
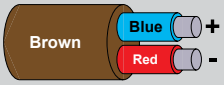
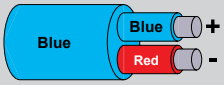
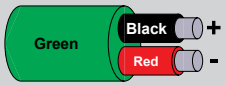
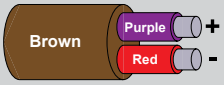
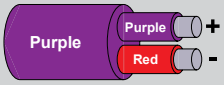
Explosion proof systems are based on the principle of containment. In other words, an explosion proof enclosure prevents any generated flames, sparks or hot gases from escaping. These devices are designed to contain, control, cool, and/or vent any possible ignition due to a failure mode, without igniting the surrounding atmosphere.

When it comes to RTDs and thermocouples, it is important to note that these temperature measurement sensors are defined as simple apparatus by the National Fire Protection Association (NFPA). This means that they simply operate on, store and/or generate too low level an energy, i.e. low amperage and low voltage, to cause an ignition. This status can change, however, depending on what the sensor is connected to or how hot the surface of the sensor assembly may get outside of the process. The required method of protection can vary depending on many different factors and the entire instrumentation system must be examined before use in hazardous locations.

In summary, RTD and thermocouple sensors are considered a simple apparatus as defined in the National Electric Code NFPA 70 Article 100 (Rev. 2020). By definition, these sensors generate too low an energy to be an ignition source. For use in hazardous environments, the sensor is typically connected to an intrinsically safe or explosion proof apparatus. Final application suitability and compliance with regional standards are to be determined and approved by the end user.

REFERENCE INFORMATION

THERMOCOUPLE WIRE COLOR CODES (U.S.A. ANSI)

	Thermocouple Grade	Extension Grade	Plug/Jack		Thermocouple Grade	Extension Grade	Plug/Jack
K			Yellow	N			Orange
J			Black	S	None Established		Green
T			Blue	R	None Established		Green
E			Purple	B	None Established		White

THERMOCOUPLE & RTD ACCURACIES

	Type K	Type J	Type T	Type E	Type N	Type S	Type R	Type B	RTD Class B	RTD Class A
-328°F	*	–	*	*	–	–	–	–	± 2.34°F	± 2.34°F
-148°F	*	–	*	*	–	–	–	–	± 1.44°F	± 1.44°F
32°F	± 3.96°F	± 3.96°F	± 1.8°F	± 3.06°F	± 3.96°F	± 2.7°F	± 2.7°F	–	± 0.54°F	± 0.27°F
392°F	± 3.96°F	± 3.96°F	± 2.7°F	± 3.06°F	± 3.96°F	± 2.7°F	± 2.7°F	–	± 2.34°F	± 0.99°F
752°F	± 5.4°F	± 5.4°F	–	± 3.6°F	± 5.4°F	± 2.7°F	± 2.7°F	–	± 4.14°F	± 4.14°F
1112°F	± 8.1°F	± 8.1°F	–	± 5.4°F	± 8.1°F	± 2.7°F	± 2.7°F	–	± 5.94°F	± 5.94°F
1472°F	± 10.8°F	–	–	± 7.2°F	± 10.8°F	± 3.6°F	± 3.6°F	–	–	–
1832°F	± 13.5°F	–	–	–	± 13.5°F	± 4.5°F	± 4.5°F	± 9°F	–	–
2192°F	± 16.2°F	–	–	–	± 16.2°F	± 5.4°F	± 5.4°F	± 10.8°F	–	–
2552°F	–	–	–	–	–	± 6.3°F	± 6.3°F	± 12.6°F	–	–
2912°F	–	–	–	–	–	–	–	± 14.4°F	–	–

Note: The accuracies in the above table are estimates given at fixed points, they do not apply to temperature ranges and are intended only as examples to give a general idea of what can be expected. Consult Reotemp if a specific accuracy is required or to confirm accuracies at any points not listed in the above table.
*Thermocouples are normally supplied to meet the tolerances specified in the table for temperatures above 32°F. The same materials, however, may not fall within the tolerances for temperatures below 32°F. If materials are required to meet the tolerances stated for temperatures below 32°F, contact Reotemp sales.

Looking for better accuracy?

Hi-Accuracy™

Reotemp offers **RTDs** up to 5x more accurate than Class B RTDs with the Hi-Accuracy™ option.

Thermocouples up to 2x more accurate with the Special Limits of Error option.

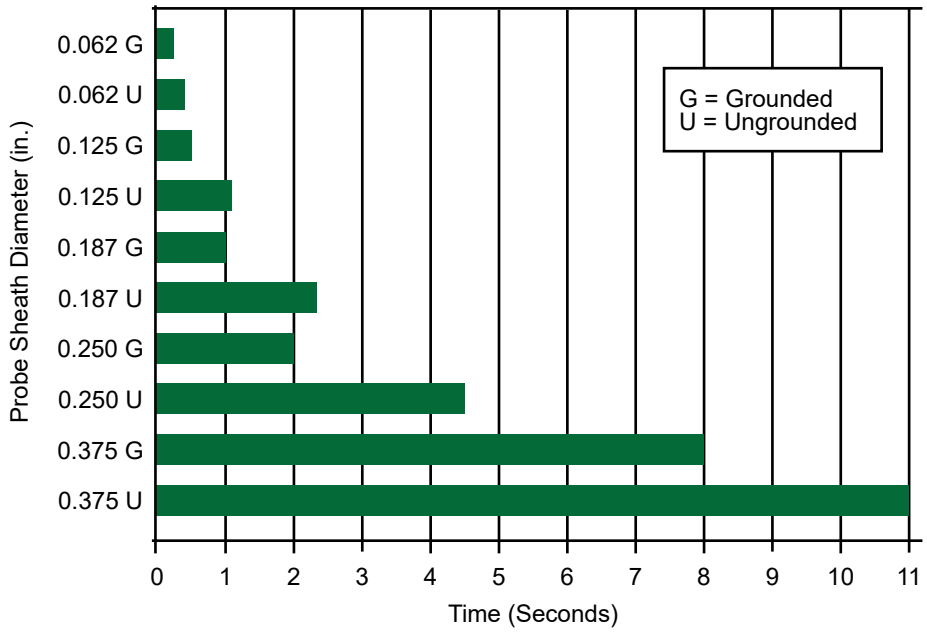
REFERENCE INFORMATION

THERMOCOUPLE TEMPERATURE OPERATING RANGES

Type	Minimum Temp. °F	Maximum Temp. °F
K	-328	2300
J	32	1400
T	-328	700
E	-328	1600
N	32	2300
S	32	2700
R	32	2700
B	1600	3100

THERMOCOUPLE TYPICAL RESPONSE TIMES

63.2% Temperature Change in an Agitated Water Bath



TEMP. LIMITS OF WIRE JACKETS

Jacket	Temp. Limit
PVC	221°F
Teflon	400°F
Std. Fiberglass	900°F
High Temp Fiberglass	1,300°F
Ceramic Fiberglass	2,200°F

WIRE LENGTH GUIDE

Actual maximum lead wire length is dictated by total loop resistance and the presence of electrical noise. Allowable loop resistance is dictated by the equipment used to measure the sensor's signal. The tables below have been generated using assumptions of allowable loop resistance. Final determination of suitability rests with the customer. Green zones indicate estimated lead wire lengths that will allow the temperature sensor to still function properly with limited accuracy loss. The exact accuracy loss is dependent on a number of application specific factors.

	Assembly is expected to function properly with limited accuracy loss. The exact accuracy loss is dependent on a number of application specific factors.
SL	Assembly is likely to have significant accuracy loss and may not function properly.
X	Assembly is not recommended. Consider a 4-20mA transmitter or thicker wire gauge.

Sensor Type	Wire Size (AWG)	0-50 ft.	51-100 ft.	101-150 ft.	151-200 ft.	200-300 ft.	300-500 ft.	500-1000 ft.	1000 ft. +
3 or 4 Wire RTD*	18							SL	X
	20						SL	X	X
	22					SL	X	X	X
	24				SL	X	X	X	X
	26			SL	X	X	X	X	X
	28		SL	X	X	X	X	X	X
	30	SL	X	X	X	X	X	X	X
		0-50 ft.	51-100 ft.	101-150 ft.	151-200 ft.	200-300 ft.	300-500 ft.	500-1000 ft.	1000 ft. +
Type K	18					SL	X	X	X
	20				SL	X	X	X	X
	24		SL	X	X	X	X	X	X
	26	SL	X	X	X	X	X	X	X
	30	SL	X	X	X	X	X	X	X
		0-50 ft.	51-100 ft.	101-150 ft.	151-200 ft.	200-300 ft.	300-500 ft.	500-1000 ft.	1000 ft. +
Type J	18						SL		
	20					SL	X		
	24			SL	X	X	X		
	26		SL	X	X	X	X		
	30	SL	X	X	X	X	X		
		0-50 ft.	51-100 ft.	101-150 ft.	151-200 ft.	200-300 ft.	300-500 ft.	500-1000 ft.	1000 ft. +
Type T	18							SL	
	20						SL	X	
	24			SL	X	X	X	X	
	26		SL	X	X	X	X	X	
	30	SL	X	X	X	X	X	X	
		0-50 ft.	51-100 ft.	101-150 ft.	151-200 ft.	200-300 ft.	300-500 ft.	500-1000 ft.	1000 ft. +
Type E	18					SL			
	20			SL	X	X			
	24		SL	X	X	X			
	26	SL	X	X	X	X			
	30	SL	X	X	X	X			
		0-50 ft.	51-100 ft.	101-150 ft.	151-200 ft.	200-300 ft.	300-500 ft.	500-1000 ft	1000 ft. +
4-20 mA Transmitters	18								
	20								
	22								
	24								
	26								
	28								
	30							SL	X

*4 wire RTDs are recommended for minimum accuracy loss.

HEAD STYLES

All head styles are IP65 or greater. Additional head styles available, contact customer service for more information.

Head	Code	Description	NEMA Rating	IP Rating	FM APPROVED	CSA C US	Ex	Display	STD Conduit	Material
	A	Cast Iron Black	4	65					3/4"	Cast Iron
	B	Cast Aluminum	4X	68					3/4"	Cast Aluminium
	E	Explosion Proof Aluminum	4X	68	✓	✓			3/4"	Cast Aluminium
	I	Blue Epoxy Aluminum	4X	68					3/4"	Cast Aluminium
	S	Polypropylene White	4	65					3/4"	Polypropylene
	W	Explosion Proof Field HART Transmitter	4X	68	✓	✓	✓	✓	1/2"	Cast Aluminium
	Z	Z-Temp™ Explosion Proof Aluminum	4X	66	✓	✓	✓	✓	1/2"	Cast Aluminium
	C	Polypropylene Black	4	65					3/4"	Polypropylene
	G	316SS	4X	65					3/4"	316SS
	H	Aluminum Flip Top	4	65					3/4"	Cast Aluminium
	J	Explosion Proof 316SS	4X	65	✓	✓			3/4"	316SS
	T	ATEX Explosion Proof Aluminum	4X	68	✓	✓	✓		1/2"	Cast Aluminium
	L	Explosion Proof Epoxy Coated Aluminium	4X	68	✓	✓			3/4"	Cast Aluminium
	D	Mini Cast Aluminum	4	65					3/4"	Cast Aluminium
	K	Polished 316SS Knurl	4X	65					1/2"	316SS
	P	DIN Black Polypropylene	4	65					3/4"	Polypropylene
	U	Hi-dome Aluminum Fliptop	4	65					3/4"	Cast Aluminium
	V	Ball-dome Aluminum Fliptop	4	65					3/4"	Cast Aluminium

HAZARDOUS LOCATION CERTIFIED THERMOCOUPLE & RTD OPTIONS

		Thermocouple	RTD
CERTIFICATION OPTIONS			
-R1	1 Point Calibration Certification, Reotemp Chooses	✓	✓
-R3	3 Point Calibration Certification, Reotemp Chooses	✓	✓
-C1	1 Point Calibration Certification, Customer Chooses	✓	✓
-C3	3 Point Calibration Certification, Customer Chooses	✓	✓
-CC	Certificate of Conformance	✓	✓
-CS	NIST Calibration Sticker (No Logged Points)	✓	✓
OTHER OPTIONS			
-VB	Hi-Vibration	N/A	✓
-AC	Hi-Accuracy	N/A	✓
-PS	Pointed Stem	✓	✓
-HT	Heat Transfer Compound (2 oz)	✓	✓
TAG OPTION			
-TS	Stainless Steel Tag (1-10 Characters)	✓	
-TM	Stainless Steel Tag (11-80 Characters)	✓	
-TP	Paper Tag	✓	

✓	Indicates that the option is available with this model.
N/A	Indicates the option is not available with this model.
STD	Indicates standard options with no additional cost.