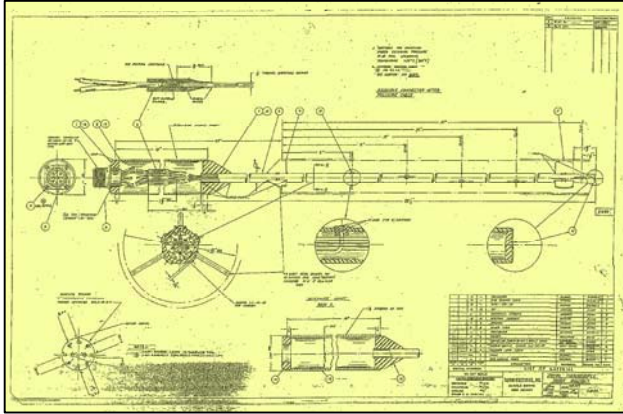




THERMO ELECTRIC

TECHNICAL REFERENCE

Section TECH



This technical reference guide is designed to provide at-your fingertips access to the technical information you need to help meet your measurement and control requirements.

The information, tables and charts found in these fifty plus pages can be used to help guide the user through the decision making process of selecting the proper temperature measuring equipment for the particular application.

TITLE	DOCUMENT NUMBER
THERMOCOUPLE CONCEPT	TE-CO010109-TECH-010
THERMOCOUPLE CALIBRATION	TE-CO010109-TECH-020
STANDARD THERMOCOUPLES	TE-CO010109-TECH-030
NON-STANDARD THERMOCOUPLES	TE-CO010109-TECH-040
THERMOCOUPLE MEASURING JUNCTIONS	TE-CO010109-TECH-050/060
THERMOCOUPLE SHEATH MATERIALS	TE-CO010109-TECH-070
CERAMO ® (MINERAL INSULATED CABLE)	TE-CO010109-TECH-080/090
LEADWIRE for TEMPERATURE SENSORS	TE-CO010109-TECH-100/110
RTD CIRCUITRY	TE-CO010109-TECH-130/150
METALLIC THERMOWELLS & PROTECTION TUBES	TE-CO010109-TECH-160/170
CERAMIC PROTECTION TUBES	TE-CO010109-TECH-180
HOW TO SELECT THERMOWELLS	TE-CO010109-TECH-190
PROTECTIVE COATINGS	TE-CO010109-TECH-200
THERMOWELL MATERIAL SELECTION GUIDE	TE-CO010109-TECH-210/220
THERMOCOUPLE SERIES & PARALLEL MEASUREMENTS	TE-CO010109-TECH-230
NOISE INTERFERENCE	TE-CO010109-TECH-240
THERMOCOUPLE TEMPERATURE/mV TABLES	TE-CO010109-TECH-250/310
RTD TEMPERATURE/RESISTANCE TABLES	TE-CO010109-TECH-330/370
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PIPE SIZES - WALL THICKNESS	TE-CO010109-TECH-400
PIPE SIZES - INSIDE DIAMETER	TE-CO010109-TECH-410
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FLANGED THERMOWELLS	TE-CO010109-TECH-430/440
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CLASSIFIED HAZARDOUS AREAS	TE-CO010109-TECH-470/480
THERMOCOUPLE COLOR CODE CHART	TE-CO010109-TECH-490
CONVERSION TABLES	TE-CO010109-TECH-500

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BASIC THERMOCOUPLE CONCEPT

Of all the primary measuring sensors, the thermocouple is perhaps the easiest to visualize. A thermocouple consists essentially of a pair of dissimilar conductors welded or fused together at one end to form the "hot" or measuring junction with the free ends available for connection to the "cold" or reference junction.

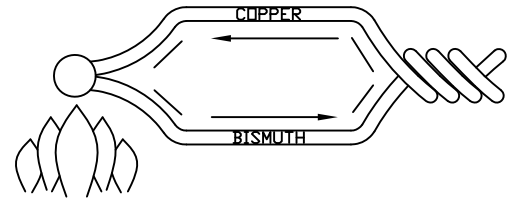
A temperature difference between the measuring and reference junctions must exist for this device to function as a thermocouple. When this occurs, small electromotive forces (emf's) are generated. These emf's originate at the "hot" junction as well as whenever there is a temperature gradient between parts of the same wire.

DISCOVERY OF THE THERMOCOUPLE

In early 1820, Thomas Seebeck searched experimentally for a relation between electricity and heat. In 1821, he joined two wires of dissimilar metals to form a loop or circuit. Connecting the ends of the wires to each other formed two junctions. He then accidentally discovered that if he heated one junction to a high temperature, and the other junction remained at a cooler temperature a magnetic field was observed around the circuit of different temperatures. This became known as the Seebeck Effect. It remains true of any pair of metals.

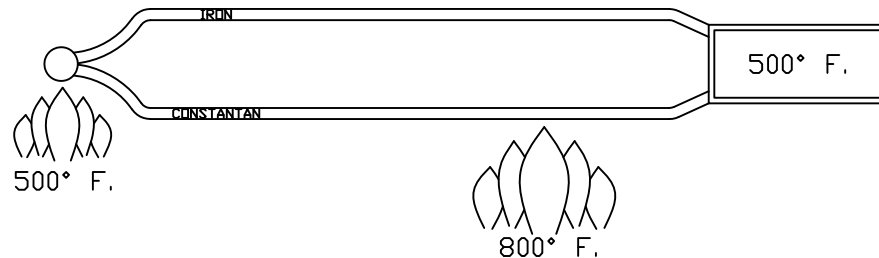
In 1834, French physicist Jean Peltier discovered that when electrical current is sent through a circuit made of dissimilar conducting materials that heat is absorbed at one junction and given up at the other, known as the Peltier Effect.

In 1851 W. Thompson (later Lord Kelvin) succeeded in showing that in certain homogeneous materials heat is absorbed when an electric current flows from colder to hotter parts of the metal and that the reverse is true when the current flows in the opposite direction. This is called the Thompson effect.



STATEMENT of LAWS

Many investigations of thermoelectric circuits have been made and have resulted in the establishment of several basic precepts. These precepts, while stated in many different ways, can be reduced to three fundamental laws.



LAW OF HOMOGENEOUS METALS

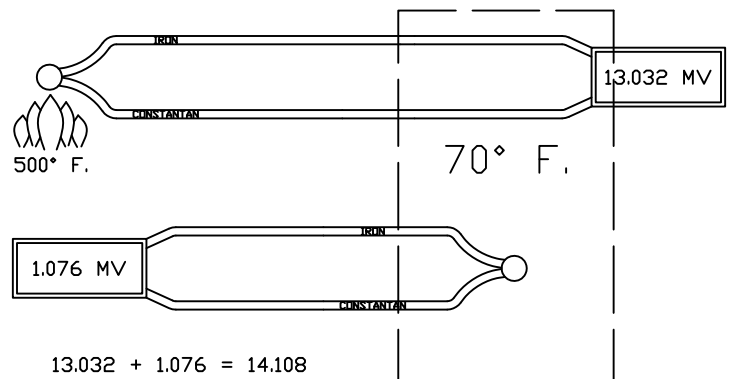
A thermoelectric current cannot be sustained in a circuit of a single homogeneous material, however varying in cross-section, by the application of heat alone.

What it means: use thermocouple extension wire and connectors.

LAW OF INTERMEDIATE TEMPERATURES

The law states that the sum of the EMF's generated by two thermocouples, one with its junction at 32° F. and some reference temperature and the other with its junction at the same reference temperature and the measured temperature is equivalent to that EMF produced by a single thermocouple with its junction at 32° F.

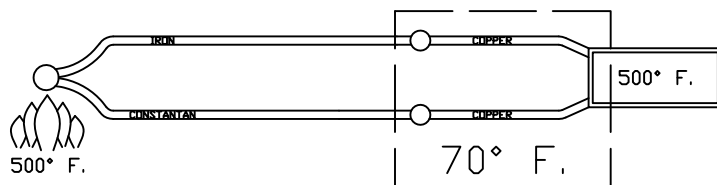
What it means: cold junction compensation is easily controlled by instrumentation



LAW OF INTERMEDIATE METALS

Insertion of an intermediate metal into a thermocouple circuit will not affect the EMF voltage output as long as the two junctions are at the same temperatures.

What it means: standard copper or brass terminal blocks inside connection heads and junction boxes will have no adverse effect on accuracy.



The three fundamental laws combined and stated as follows: the algebraic sum of the thermoelectric EMF's generate in any given circuit containing any number of dissimilar homogeneous metals is a function only of the temperature of the junction. If all but one of the junctions in such a circuit are maintained at some reference temperature, the EMF generated depends only on the temperature of that one junction and can be used as a measure of its temperature.



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SECTION TECH THERMOCOUPLE CONCEPT

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INITIAL CALIBRATION TOLERANCE Per ANSI MC96.1-1982 and ASTM E230
Reference Junction 0° C (32°F)

Thermocouple Type		Temperature Range		Standard Tolerance		Special Tolerance	
Standard	Special	°C	°F	°C (whichever is greater)	°F (whichever is greater)	°C (whichever is greater)	°F (whichever is greater)
J	JJ	0 to 760	32 to 1400	±2.2°C or ±0.75%	±4.0°F or ±0.75%	±1.1°C or ±0.4%	±2.0°F or ±0.4%
K and N	KK and NN	-200 to 0	-328 to 32	±2.2°C or ±2.0%	±4.0°F or ±2.0%		
		0 to 1260	32 to 2300	±2.2°C or ±0.75%	±4.0°F or ±0.75%	±1.1°C or ±0.4%	±2.0°F or ±0.4%
E	EE	-200 to 0	-328 to 32	±1.7°C or ±1.0%	±3.0°F or ±1.0%	±1.0°C or ±0.5%	±1.8°F or ±0.5%
		0 to 870	32 to 1600	±1.7°C or ±0.5%	±3.0°F or ±0.5%	±1.0°C or ±0.4%	±1.8°F or ±0.4%
T	TT	-200 to 0	-328 to 32	±1.0°C or ±1.5%	±1.8°F or ±1.5%	±0.5°C or ±0.8%	±0.9°F or ±0.8%
		0 to 370	32 to 700	±1.0°C or ±0.75%	±1.8°F or ±0.75%	±0.5°C or ±0.4%	±0.9°F or ±0.4%
R and S	RR and SS	0 to 1400	32 to 2700	±1.5°C or ±0.25%	±2.7°F or ±0.25%	±0.6°C or ±0.1%	±1.1°F or ±0.1%
B	BB	870 to 1700	1600 to 3100	±0.5%	0.5%	±0.25%	0.25%

Tolerances shown do not include system or installation error. Certain characteristics of thermocouple materials, including the EMF versus temperature relationship may change with time in use; consequently results and performance obtained at time of manufacture may not necessarily apply throughout an extended period of use. The magnitude of such changes will depend on such factors as size, temperature, temperature time of exposure and environment. Tolerances for temperatures below 0° C (32° F) may not fall within tolerance above zero. Temperature range should be specified when requesting thermocouples for sub zero applications.

PROPERTIES of THERMOCOUPLES

Type	Conductor		Composition	Conductor Identification	Melting Point	Recommended Service	Maximum Temperature
J	JP	Iron	Fe	Magnetic, May Have Copper Coating	2725° F (1496° C)	Oxidizing or Reducing	1400° F (760° C)
	JN	Constantan	55%CU, 44%Ni, 1%Mn	Non-Magnetic	2336° F (1280° C)		
K	KP	Chromel*	89.1%Ni, 10%Cr, 0.5%Si, 0.4%Fe	Non-Magnetic	2606° F (1430° C)	Oxidizing	2300° F (1260° C)
	KN	Alumel*	95%Ni, 5%MnAlSi	Magnetic	2552° F (1400° C)		
T	TP	Copper	Cu	Non-Magnetic, Copper Color	1981° F (1083° C)	Oxidizing or Reducing	700° F (370° C)
	TN	Constantan	55%CU, 44%Ni, 1%Mn	Non-Magnetic, Silver in Color	2336° F (1280° C)		
E	EP	Chromel*	89.1%Ni, 10%Cr, 0.5%Si, 0.4%Fe	Non-Magnetic	2606° F (1430° C)	Oxidizing	1600° F (870° C)
	EN	Constantan	55%CU, 44%Ni, 1%Mn	Non-Magnetic, Slightly Softer	2336° F (1280° C)		
N	NP	Nicrosil	84.6%Ni, 14%Cr, 1.4%Si	Non-Magnetic	2541° F (1394° C)	Oxidizing	2300° F (1260° C)
	NN	Nisil	95.6%Ni, 4.4%Si	Slightly Magnetic	2446° F (1341° C)		
R	RP	Platinum 13%Rhodium	87%Platinum 13%Rhodium		3380° F (1860° C)	Oxidizing or Inert	2700° F (1480° C)
	RN	Platinum	Platinum	Slightly Softer than the Positive Leg	3216° F (1769° C)		
S	SP	Platinum 10%Rhodium	90%Platinum 10%Rhodium		3362° F (1850° C)	Oxidizing or Inert	2700° F (1480° C)
	SN	Platinum	Platinum	Slightly Softer than the Positive Leg	3216° F (1769° C)		
B	BP	Platinum 30%Rhodium	70%Platinum 30%Rhodium		3501° F (1927° C)	Oxidizing Vacuum or Inert	3100° F (1700° C)
	BN	Platinum 6%Rhodium	94%Platinum 6%Rhodium	Slightly Softer than the Positive Leg	3319° F (1826° C)		

*Trademark of now defunct Hoskins Manufacturing Co.

REFRACTORY THERMOCOUPLES (Tungsten-Rhenium)

Type	Conductor	Temperature Range	Initial Calibration Tolerance	Melting Point	Operating Conditions
W	+	Tungsten	0 to 426°C (32 to 800°F)	±4.4°C or ±8.0°F	3410° C (6170° F)
	—	Tungsten 26% Rhenium	426 to 2315°C (800 to 4200°F)	±1% of actual temperature	3120° C (5648° F)
W ₃	+	Tungsten 3% Rhenium	0 to 426°C (32 to 800°F)	±4.4°C or ±8.0°F	3360° C (6080° F)
	—	Tungsten 25% Rhenium	426 to 2315°C (800 to 4200°F)	±1% of actual temperature	3120° C (5648° F)
W ₅	+	Tungsten 5% Rhenium	0 to 426°C (32 to 800°F)	±4.4°C or ±8.0°F	3350° C (6062° F)
	—	Tungsten 26% Rhenium	426 to 2315°C (800 to 4200°F)	±1% of actual temperature	3120° C (5648° F)

Trademark of now defunct Hoskins Manufacturing Co.

W₃ & W₅ reference tables per ASTM E 988. Type letter symbols not assigned by ASTM.

NON-STANDARD THERMOCOUPLES

Type	Conductor	Temperature Range	Recommended Service	Development
19/20	20 (+) 82%Ni - 18%Mo	32 to 2300° F (0 to 1260° C)	Hydrogen or Reducing	The type 19/20 sometimes referred to as Nickel/Nickel Moly, was developed by General Electric Research Lab for special high temperature applications.
	19 (-) 99%Ni - 1%Co			
Platinel I	+	83%Pd-14%Pt-3%Au	Hydrogen, Inert or Oxidizing	Trademark of Engelhard Corporation, an all-noble metal combination demonstrates good corrosion resistance and stability at high temperatures with platinel II offering better fatigue properties. Platinel thermocouples EMF characteristics allows matching to type K extension leadwire and connectors.
	—	65%Au - 35%Pd		
Platinel II	+	55%Pd-31%Pt-14%Au	Hydrogen, Inert or Oxidizing	Generally used as for service at temperatures above the type R, S and B range. Iridium TC's also available in 50%Ir - 50%Rh. vs Ir, and 40%Ir-60%Rh. vs Ir.
	—	65%Au - 35%Pd		
Iridium/Rh. vs Iridium	+	60%Iridium-40%Rh.	Hydrogen or Vacuum	
	—	Iridium		



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THERMOCOUPLE CALIBRATION

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BASE METAL THERMOCOUPLES

Type J: Iron (+) vs Constantan (-), is the most commonly used calibration. It is suitable for use in a vacuum, inert, oxidizing with the iron leg protected or reducing atmosphere. If unprotected the iron wire may be attacked by ammonia, nitrogen and hydrogen atmospheres. In sub zero temperatures the iron wire may rust or become brittle. Type J should not be used in sulfurous atmospheres above 540°C.

Type T: Copper (+) vs Constantan (-), is commonly used for sub-zero to 700°F temperature. Preferred to Type J for sub-zero applications because of Copper's higher moisture resistance, as compared to iron. If unprotected, it will still function in a vacuum, inert, oxidizing or reducing atmosphere.

Type K: Chromel (+) vs Alumel (-) is generally used to measure high temperature to 2300°F. It should not be used for accurate temperature measurements below 900°F or after prolonged exposure above 1400°F. If unprotected it can be used only in inert or oxidizing atmospheres. It has a short life in alternately oxidizing and reducing atmospheres and in reducing atmospheres, particularly in the 1500 to 1850°F range.

Type E: CHROMEL (+) vs Constantan (-) has the highest EMF output of any standardized metallic thermocouple. If used unprotected, Type E wires are NOT subject to corrosion at sub-zero temperatures. They can be used in inert, oxidizing or reducing atmospheres. Because they cover a wide range with a single calibration curve, Type E thermocouples are preferred for computer applications.

Type N: Nicrosil (+) vs Nilil(-), was developed for oxidation resistance and EMF stability superior to those of Type K thermocouples at elevated temperatures. These couples have been shown to have a longer life, than Type K thermocouples, in both laboratories and industrial applications.

19/20 Alloy: Nickel/Nickel Moly. 19/20 Alloy thermocouples provide a very stable reading in reducing atmospheres at elevated temperatures. Can be used in an oxidizing atmosphere with proper protection.

NOBLE METAL THERMOCOUPLES

Type S: Platinum-10% Rhodium (+) vs. Platinum (-). The Type S thermocouple is widely used in industrial laboratories as a standard for calibration of base metal thermocouples and other temperature sensing instruments.

Type R: Platinum-13% Rhodium (+) vs. Platinum (-). These thermoelements should always be protected from contamination by reduced oxides, metallic vapors or other oxides at high temperatures. Platinum protective sheaths are used at temperatures which preclude the use of base metal sheaths. Insulation should be silica free to prevent contamination. Type S is frequently used for calibration and checking. Type R has a slightly greater sensitivity and consequently is used more frequently in industrial applications.

Type B: Platinum-30% Rhodium (+) vs. Platinum-6% Rhodium (-). For use between 1000 and 3175°F. Intended to prevent the problems experienced with Types S and R such as: (1) weakening of the pure platinum leg due to excessive grain growth and (2) calibration shift due to the pure platinum wire picking up rhodium volatilized from the alloy wire at 1500°C. The flatness of the temperature-millivolt curve at normal reference junction ambient temperature permits the use of copper extension wire.

REFRACTORY THERMOCOUPLES

These thermoelements possesses excellent stability at temperatures in the 3000°F to 4000°F range. For use at high temperatures a protective atmosphere must be provided such as hydrogen, inert gas or vacuum. They are extremely sensitive to mechanical damage and should be handled carefully to prevent breakage.

Type W: Tungsten (+) vs. Tungsten-26% Rhenium (-). Also identified as letter code type G. This was an early stage thermocouple capable of measuring high temperature with reasonable accuracy. However, one serious drawback was the positive leg became embrittled. Extension lead wire used is an alloy type 200/226.

Type W5: Tungsten-5% Rhenium (+) vs. Tungsten-26% Rhenium (-). Also identified as letter code type C. Adding 5 % rhenium to the positive leg improved the ductility and produces a higher EMF output. Extension lead wire used is an alloy type 405/426.

Type W3: Tungsten-3% Rhenium (+) vs. Tungsten-25% Rhenium (-). Also identified as letter code type D. The W3 provides the same ductility as the W5 with the highest EMF output of all three. Extension lead wire used is an alloy type 203/225.



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STANDARD THERMOCOUPLES

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TECHNICAL REFERENCE

Type M Thermocouples

Type M, Nickel Alloy 19 / Nickel-Molybdenum Alloy 20

This type is used in vacuum furnaces for the same reasons as refractory thermocouples. Upper temperature is limited to 2500 °F (1371 °C). Though it is a less common type of thermocouple. EMF tables for type M can be found in ASTM E 1751 for non-letter designated thermocouple combinations.

Platinel Thermocouples

This noble metal thermocouple combination was designed for high temperature indication and control in turbo - prop engines. This type approximates within reasonable tolerances to the type K thermocouple. The actual two types have been produced, they are called Platinel I and Platinel II. The negative thermoelement in both thermocouples is a 65 percent gold - 35 percent palladium alloy (Platinel 1503), but the positive one in Platinel I is composed of 83 percent palladium, 14 percent platinum, and 3 percent gold (Platinel 1786), while that used in Platinel II contains 55 percent palladium, 31 percent platinum, and 14 percent gold (Platinel 1813). Platinel II is the preferred type and has better mechanical fatigue properties. The EMF output of these combinations differ very little.

Platinum 15 Percent Iridium - Versus - Palladium Thermocouples

The platinum 15 percent iridium versus palladium was developed for high EMF output. This combination combines the desirable characteristics of noble metals with a higher output signal.

Platinum 5 Percent Molybdenum - Versus - Platinum .1 Percent Molybdenum Thermocouples

Platinum alloys containing rhodium are not suitable for use under neutron irradiation since the rhodium changes slowly to palladium. This causes a drift in the calibration of thermocouples containing rhodium. However, this thermocouple is suitable in the helium atmosphere of gas cooled atomic reactors. It offers good stability at temperatures up to 2552°F (1400°C). The EMF output of the thermocouple is high and increases in a fairly uniform manner with increasing temperature.

Iridium Rhodium - Versus - Iridium Thermocouples

Iridium rhodium - versus - iridium thermocouples are suitable for measuring temperature to approximately 3632°F (2000°C), and generally are used above the range of platinum rhodium - versus - platinum thermocouples. They can be used in inert and vacuum atmospheres and in vacuum, but not in reducing, and they may be used in oxidizing atmospheres with shortened life span.

Iridium Rhodium - Versus - Platinum Rhodium Thermocouples

Platinum - 40 percent rhodium alloy has been chosen by Lewis Research Center NASA as a substitute for an iridium thermoelement in combustor gas streams at pressures above 20 atmospheres and temperatures nearing 2912°F (1600°C). The thermocouple, consisting of a positive element of iridium 40 percent rhodium and a negative element of platinum 40 percent rhodium, showed reasonable oxidation resistance under these conditions.

Geminol Thermocouples*

The Geminol thermocouple was developed primarily for improved resistance to deterioration in reducing atmospheres. The positive thermoelement has been adjusted specifically to combat in reducing atmospheres the destructive corrosion known as "Green Rot." The substitution of an 80 percent nickel - 20 percent chromium type alloy for conventional (Type KP) 90 percent nickel - 10 percent chromium alloy positive thermoelement, and a 3 percent silicon in nickel alloy for the conventional (Type KN) manganese - aluminum - silicon in nickel alloy negative thermoelement, results in a more oxidation resistant thermocouple.

* Trademark of the Driver - Harris Company



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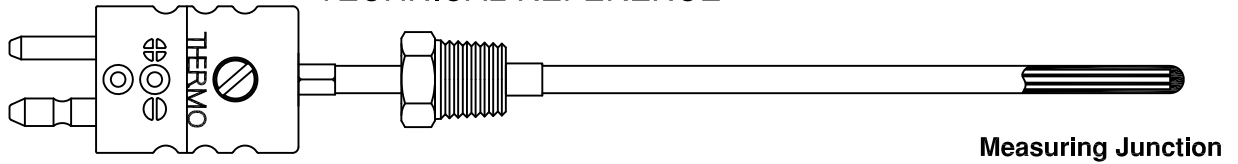
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NON-STANDARD
THERMOCOUPLES

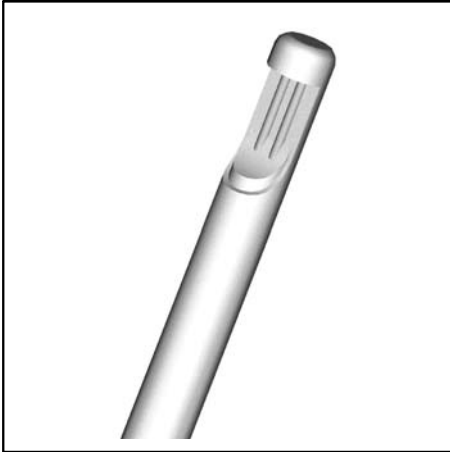
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Grounded Measuring Junction - Ordering Code G

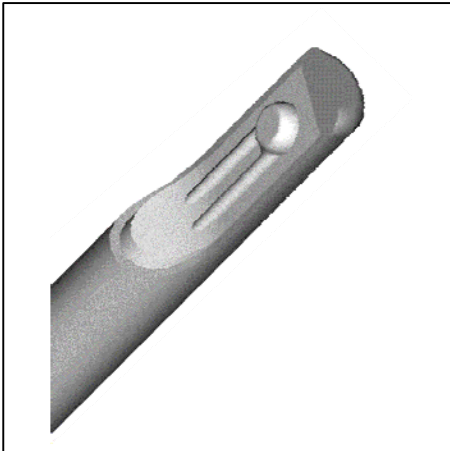


In this construction, the measuring junction is completely sealed from contaminants and becomes an integral part of sheath at the tip of the thermocouple. Response time approaches that of an exposed loop thermocouple and in addition, the junction conductors are completely protected in a pressure tight seal protecting it from harsh environmental conditions and mechanical damage. Grounded junctions should not be used when ground loops or other electrical interference is likely.

Dual Grounded Junction - Ordering Code DG (NOT SHOWN)

Dual grounded junction thermocouples furnish two measuring circuits for simultaneous control and indication (or recording) of a single point with two instruments. Thus prevents the signal loading effect common to instrumentation of low or combination low and high impedance.

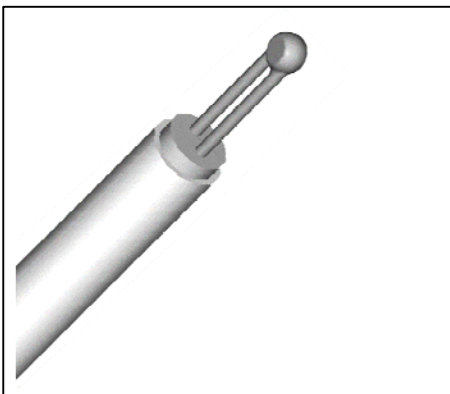
Ungrounded Measuring Junction - Ordering Code U



In this construction, the thermocouple conductors are welded together to form the junction, which is insulated from the external sheath with magnesium oxide. The response time for an insulated junction is slightly longer than for a grounded junction thermocouple of the same outside diameter. This feature is advantageous in applications where thermocouples are used in conductive solutions, or when used for differential, averaging (parallel) or additive (series) applications, or wherever isolation of the measuring circuitry is required. The strain due to differential expansion between wires and sheath may be reduced.

Dual Ungrounded Junction - Ordering Code DU (NOT SHOWN)

Same as the single ungrounded junction the dual ungrounded junction thermocouples furnish two measuring circuits for simultaneous control and indication (or recording) of a single point with two instruments. Thus preventing the signal loading effect common to instrumentation of low or combination low and high impedance.



Exposed Loop Measuring Junction - Ordering Code E

The exposed loop junction offers a faster thermal response time than the other junctions described here, while the sheath material protects the remainder of the thermocouple length. This type junction is limited to mild environmental conditions or one time usage under more severe conditions. Care must be taken not to allow the exposed insulation to become contaminated with conductive substances, especially moisture. For low temperature applications, the insulation may be sealed with one of many available sealing compounds. In most applications the disadvantages of the exposed loop junction can be overcome and response time preserved by using a smaller diameter grounded junction or with reduced diameter tip construction.



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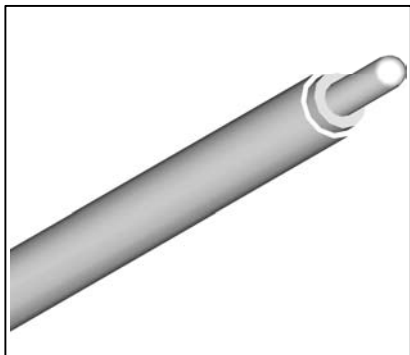
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THERMOCOUPLE MEASURING JUNCTIONS

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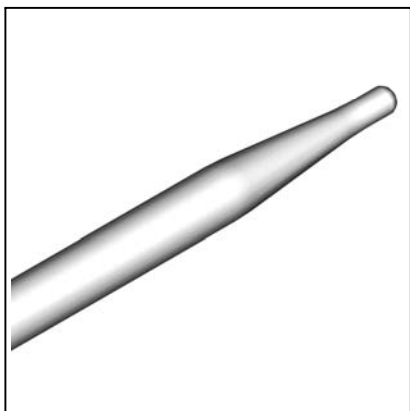
TECHNICAL REFERENCE



Coaxial Tip - Ordering Code C

A coaxial sheath thermocouple is a double sheath with the inner sheath containing the conductors insulated from a second, larger diameter outer sheath by hard packed ceramic insulation. A short section of the inner thermocouple is exposed at the measuring junction. Coax provides extra strength and rigidity because of its heavier construction without sacrificing response time.

SPECIFY LENGTH OF INNER SHEATH TO BE EXPOSED WHEN ORDERING



Reduced Diameter Tip, Grounded Junction - Ordering Code RG

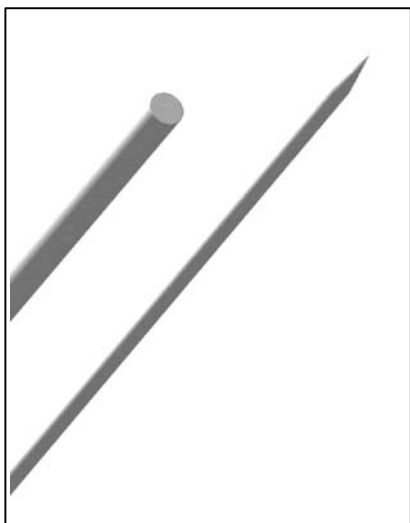
Reduced Diameter Tip, Ungrounded Junction - Ordering Code RU

Reduced Diameter Tip, Duplex Grounded Junction - Ordering Code RDG

Reduced Diameter Tip, Duplex Ungrounded Junction - Ordering Code RDU

Larger size thermocouples may have the temperature sensitive portion of the thermocouple probe swaged down in diameter to increase the thermal response time of the junction. This construction is especially valuable in applications where the strength of a large diameter is required along with the response time of a small diameter thermocouple. Other special reductions available on request.

THERMOCOUPLE DIAMETER	TIP DIAMETER AFTER REDUCTION
7/16", 3/8" or 5/16"	to 1/4"
1/4" or 3/16"	to 1/8"
1/8"	to 1/16"
1/16"	to 1/25"



Flat and Pointed Tip Grounded Junctions

In place of the common radius shaped grounded junction thermocouples can be machined or ground flat for improved surface contact thereby decreasing the temperature response time. Tips can also be machined into a point for penetrating gel like substances or semi-solids.

Values listed to the right are the average of several MgO insulated thermocouples checked in each category. They show the time required to indicate 63.2% of a temperature change. The tests were performed during a step change from room temperature to boiling water. Per ASTM STP 470 (Full Response is approximated five time constants).

TYPICAL RESPONSE TIME ON THERMOCOUPLES

THERMOCOUPLE DIAMETER	TYPE OF MEASURING JUNCTION	RESPONSE TIME IN SECONDS
1/100 (0.010")	Grounded	0.02
1/50 (0.020")	Grounded	0.05
1/50 (0.020")	Ungrounded	0.15
1/25 (0.040")	Grounded	0.1
1/25 (0.040")	Ungrounded	0.3
1/16 (0.063")	Grounded	0.2
1/16 (0.063")	Ungrounded	0.5
1/8 (0.125")	Grounded	0.7
1/8 (0.125")	Ungrounded	1.3
3/16 (0.187")	Grounded	1.1
3/16 (0.187")	Ungrounded	2.2
1/4 (0.25")	Grounded	2.0
1/4 (0.25")	Ungrounded	4.5
1/4 (0.25")	Exposed Loop	0.1



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SECTION - TECH

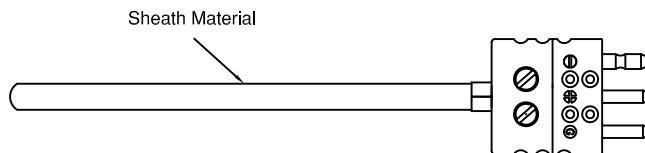
THERMOCOUPLE MEASURING JUNCTIONS

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Doc. No.: TE-CO010109-TECH-060

TECHNICAL REFERENCE

The metal sheath protects the insulation and wires from physical damage, contamination and the environment, all of which affect the service life. Depending on the conditions a number of sheaths are available for prolong service life and reliability.



Ordering Code	Sheath Material	Maximum Temperature (continuous service in air)	Recommended Atmospheres	Melting Range	Application Notes
304	Austenitic Stainless Steel Grade 304	1650°F	Oxidizing, Reducing, Inert, Vacuum	2550 - 2650°F	Resistant to a wide range of corrosive media. Subject to carbide precipitation in the 900 to 1600°F range.
310	Austenitic Stainless Steel Grade 310	2100°F	Oxidizing, Reducing, Inert, Vacuum	2550 - 2650°F	Very high elevated temperature strength and scale resistance. Good resistance to carbonizing and reducing environments.
316	Austenitic Stainless Steel Grade 316	1650°F	Oxidizing, Reducing, Inert, Vacuum	2500 - 2550°F	Higher corrosion resistance than type 304. High creep strength. Withstands sulfuric acid compounds,
321	Austenitic Stainless Steel Grade 321	1500°F	Oxidizing, Reducing, Inert, Vacuum	2550 - 2600°F	Excellent resistance to intergranular corrosion. Stabilized against chromium carbide with the addition of titanium.
347	Austenitic Stainless Steel Grade 347	1500°F	Oxidizing, Reducing, Inert, Vacuum	2550 - 2600°F	Excellent resistance to intergranular corrosion. Stabilized by the addition of columbium and tantalum.
446	Ferritic Stainless Steel Grade 446	1600°F	Oxidizing, Reducing, Inert, Vacuum	2750°F	Excellent resistance to sulfurous atmospheres at high temperature. Good corrosion resistance to nitric acid.
1600	INCONEL®* 600	2100°F	Oxidizing, Inert, Vacuum	2500 - 2600°F	High hot-strength and resistance to progressive oxidation and fatigue. Use in sulfur free atmosphere.
1601	INCONEL®* 601	2100°F	Oxidizing, Inert, Vacuum	2374 - 2494°F	Excellent resistance to high temperature oxidation and corrosive environments. Good resistance to aqueous corrosion.
800	INCOLOY®* 800	2100°F	Oxidizing, Reducing, Inert, Vacuum	2475 - 2525°F	Good resistance to oxidation, carbonization and other harmful effects of high temperature exposure.
400	Monel 400	1000°F	Oxidizing, Reducing, Inert, Vacuum	2370 - 2460°F	Good resistance to oxidation, carbonization and other harmful effects of high temperature exposure.
HC	HASTELLOY® C276	2200°F	Oxidizing, Reducing, Inert, Vacuum	2350°F	Excellent corrosion resistance to salt water hydrofluoric, sulfuric and hydrochloric acid.
P10RH	Platinum 10% Rhodium	2500°F	Oxidizing, Reducing, Inert, Vacuum	3370°F approx.	Used usually with type R, S and B TC's. Sheath provides service temperatures above the melting range of most metals.
MOLY	Molybdenum	Not Recommended	Reducing, Inert, Vacuum	5425°F	Used mostly with refractory TC's Molybdenum is inert to carbon dioxide, ammonia, and nitrogen to 2000° F.
TA	Tantalum	Not Recommended	Vacuum	5425°F	Used mostly with refractory TC's tantalum is almost completely immune to attack by acids and liquid metals.
TI	Titanium	2300°F	Inert, Vacuum	2585°F	Titanium is immune to corrosive attack by salt water or marine atmospheres, Offers superior resistance to erosion.



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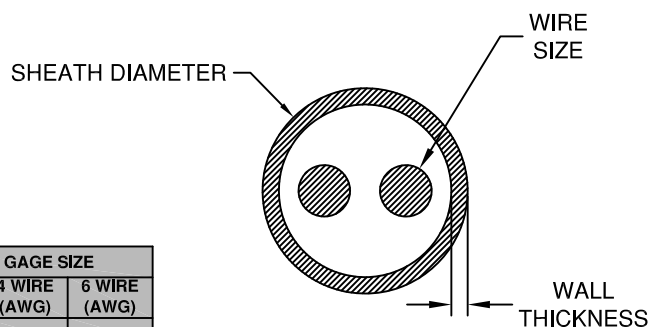
THERMOCOUPLE SHEATH MATERIALS

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Doc. No.: TE-CO010109-TECH-070

TECHNICAL REFERENCE

CERAMO® is the registered trademark for Thermo Electric's metal sheathed mineral insulated thermocouple cable. As in the case with all conductors of electricity, high quality insulation is the key to a superior product. One of the many CERAMO® advantages is the protection of the thermoelements afforded by the metal sheath. For long service life, only contaminant free sheathing of known chemical and physical composition is used. All finished CERAMO® is single strand annealed in a protective atmosphere to improve flexibility and restore EMF properties after cold working. Finished product meets applicable ASTM, ANSI MC96.1 requirements for thermocouple wires. The standard CERAMO® insulation material is magnesium oxide (MgO). It is highly compacted to prevent powdering and reduce moisture absorption. Minimum insulation resistance is 100 megohms with an applied measuring voltage of 50 VDC for sheath diameters of 1/16" and smaller, and 500 VDC for larger diameters, when measured at room temperature (measured between conductors and between conductors and sheath). Other CERAMO® constructions are available, contact your nearest Thermo Electric representative for assistance.



CODE	SHEATH MATERIAL
304	304 Stainless Steel
310	310 Stainless Steel
316	316 Stainless Steel
347	347 Stainless Steel
446	446 Stainless Steel
1600	Inconel 600
1601	Inconel 601
400	Monel 400
HC	Hastelloy C

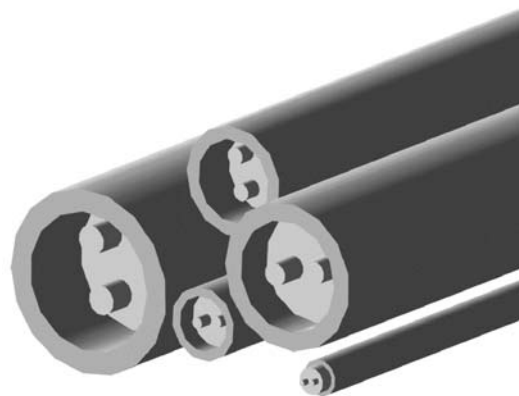
CODE	SHEATH DIAMETER			WIRE GAGE SIZE		
	O.D. Fraction	O.D. Decimal	O.D. Metric	2 WIRE (AWG)	4 WIRE (AWG)	6 WIRE (AWG)
.040	1/25"	.040"	1 mm	33		
.059		.059"	1.5 mm	30		
.062	1/16"	.062"	1.6 mm	30	31	
.118		.118"	3.0 mm	25	25	
.125	1/8"	.125"	3.2 mm	24	24	30
.158		.158"	4.0 mm	22	22	28
.187	3/16"	.187"	4.7 mm	20	20	26
.236		.236"	6.0 mm	19	19	24
.250	1/4"	.250"	6.4 mm	18	18	23
.312	5/16"	.313"	7.9 mm	16	16	21
.375	3/8"	.375"	9.5 mm	15	15	20
.500	1/2"	.500"	12.7 mm	11	12	16

Code	MgO Insulation
M	Standard Purity
H	High Purity

CE	SHEATH MAT'L 316	SHEATH DIAM. .250	NO. of WIRES 2	MgO M	CALIBR. JJ	WIRE GAGE 24
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CODE	NUMBER of WIRES
2	Single Construction
4	Duplex Construction
6	Triplex Construction

CODE		CALIBRATION
STD.	SPECIAL	
J	JJ	Iron vs Constantan
K	KK	Chromel vs Alumel
T	TT	Copper vs Constantan
E	EE	Chromel vs Constantan
N	NN	Nicrosil vs Nisil
19/20	N/A	Nickel Alloy 19 vs Nickel Moly 20
S	SS	Platinum 10% Rhodium vs Platinum
R	RR	Platinum 13% Rhodium vs Platinum
B	BB	Platinum 30% Rhodium vs Platinum 6% Rhodium



Example: CE316-.125-2-M-JJ-24



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SECTION TECH

CERAMO®
(MINERAL INSULATED CABLE)

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Doc. No.: TE-CO010109-TECH-080

TECHNICAL REFERENCE

Single 2 Wire	Sheath Diameter	Tol.	Wall Thickness	Tol.	Wire Size (gauge)	Tol.
	.500	±.002"	.064	±.002"	.093 (13)	±.002"
	.375	±.002"	.047	±.002"	.060 (15)	±.002"
	.312	±.002"	.039	±.002"	.050 (16)	±.002"
	.250	±.002"	.031	±.002"	.040 (18)	±.002"
	.236 (6 mm)	±.002"	.030	±.002"	.038 (19)	±.002"
	.187	±.002"	.023	±.002"	.030 (20)	±.002"
	.157 (4 mm)	±.002"	.018	±.002"	.025 (22)	±.002"
	.125	±.002"	.016	±.002"	.020 (24)	±.002"
	.118 (3 mm)	±.002"	.015	±.002"	.019 (25)	±.002"
	.093	±.002"	.011	±.002"	.015 (26)	±.002"
	.062	±.002"	.009	±.002"	.010 (30)	±.002"
	.059 (1.5 mm)	±.001"	.008	±.001"	.010 (30)	±.001"
	.040	±.001"	.006	±.001"	.007 (33)	±.001"
	.020	±.001"	.003	±.001"	.004 (37)	±.001"
	.010	±.0005"	.0015	±.0015"	.0015 (46)	±.0005"
Duplex 4 Wire	Sheath Diameter	Tol.	Wall Thickness	Tol.	Wire Size (gauge)	Tol.
	.500	±.002"	.064	±.002"	.080 (12)	±.002"
	.375	±.002"	.047	±.002"	.058 (15)	±.002"
	.312	±.002"	.039	±.002"	.048 (16)	±.002"
	.250	±.002"	.031	±.002"	.038 (18)	±.002"
	.236 (6 mm)	±.002"	.030	±.002"	.036 (19)	±.002"
	.187	±.002"	.023	±.002"	.029 (20)	±.002"
	.157 (4 mm)	±.002"	.018	±.002"	.024 (22)	±.002"
	.125	±.002"	.016	±.002"	.019 (24)	±.002"
	.118 (3 mm)	±.002"	.015	±.002"	.018 (25)	±.002"
	.093	±.002"	.011	±.002"	.014 (27)	±.002"
	.062	±.002"	.009	±.002"	.009 (31)	±.002"
Triplex 6 Wire	Sheath Diameter	Tol.	Wall Thickness	Tol.	Wire Size (gauge)	Tol.
	.500	±.002"	.064	±.002"	.051 (16)	±.002"
	.375	±.002"	.047	±.002"	.031 (20)	±.002"
	.312	±.002"	.039	±.002"	.027 (21)	±.002"
	.250	±.002"	.031	±.002"	.022 (23)	±.002"
	.236 (6 mm)	±.002"	.030	±.002"	.021 (24)	±.002"
	.187	±.002"	.023	±.002"	.016 (26)	±.002"
	.157 (4 mm)	±.002"	.018	±.002"	.013 (28)	±.002"
	.125	±.002"	.016	±.002"	.010 (30)	±.002"

Upper Temperature Limit for Various Sheath Diameters °C (°F)					
Nominal Sheath Diameter		Thermocouple Type			
mm	in.	T	J	E	K, N
0.5	0.020	260 (500)	260 (500)	300 (570)	700 (1290)
...	0.032	260 (500)	260 (500)	300 (570)	700 (1290)
1.0	0.040	260 (500)	260 (500)	300 (570)	700 (1290)
1.5	0.062	260 (500)	440 (825)	510 (950)	920 (1690)
2.0	...	260 (500)	440 (825)	510 (950)	920 (1690)
...	0.093	260 (500)	480 (900)	580 (1075)	1000 (1830)
3.0	0.125	315 (600)	520 (970)	650 (1200)	1070 (1960)
4.5	0.188	370 (700)	620 (1150)	730 (1350)	1150 (2100)
6.0	0.250	370 (700)	720 (1330)	820 (1510)	1150 (2100)
8.0	0.375	370 (700)	720 (1330)	820 (1510)	1150 (2100)



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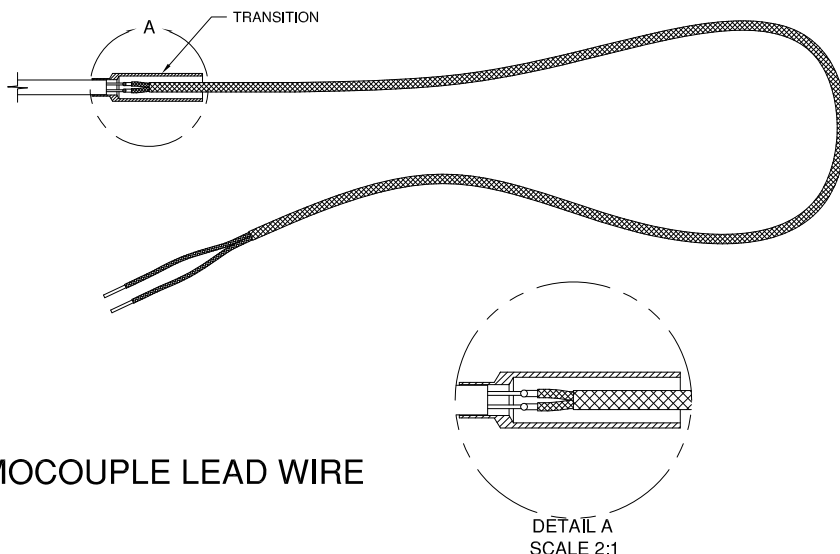
CERAMO®
(Mineral Insulated Cable)

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Doc. No.: TE-CO010109-TECH-090

TECHNICAL REFERENCE

Thermo Electric stocks a variety of insulated thermocouple and RTD lead wire for termination from the sheath solid wire to flexible lead wire. This is accomplished by attaching the lead wires by welding or soldering to the solid wires inside the sheath and encasing the area inside a sealed transition. For flexibility lead wires are mostly supplied with stranded conductors in 20 or 24 gauge. Thermocouple lead wires utilize the same alloys as the the sensor. Thermocouple lead wire is calibrated and traceable to the National Institute for Standards and Technology (NIST) for conformance to ISA and ANSI standards. RTD lead wires are mostly 24 gauge nickel plated copper. Insulation can be selected for such requirements as high abrasion , moisture and chemical resistance. Metal coverings are available for increased resistance to mechanical stress and abrasion. Twisted shielded wires for electrical interference rejection are also available.



THERMOCOUPLE LEAD WIRE

Fiberglass Insulation - Ordering Code 1

Standard 20 gauge stranded wires, fiberglass braided insulation over each wire, parallel with a fiberglass jacket. Fiberglass is saturated with a polyester silicone enamel coating for improved durability and handling. Suitable for continuous temperature rating of 950°F (510°C) and intermitting to 1200°F (649°C). Fiberglass provides high tensile strength, excellent dielectric constant and resistance to most oils and acids.

Fiberglass Insulation with Stainless Steel Armor - Ordering Code 2

Same as code 1 with additional protection of an interlocking or square lock stainless steel flexible armor. Armor provides protection from physical abuse and is ideal for connection to junction boxes or control cabinets by means of BX connectors or cable glands.

Fiberglass Insulation with Stainless Steel Overbraid - Ordering Code 3

Same as code 1 with additional protection of a stainless steel braided outer jacket. Braid provides higher resistance to abrasion and mechanical damage maintaining approximately the same diameter.

PVC Insulation - Ordering Code 4

Standard 20 gauge stranded wires, flame retardent PVC insulation over each wire, parallel with a flame retardent PVC jacket. PVC provides excellent resistance to moisture, chemical and solvents. Suitable for continuous temperature rating of 221°F (105°C). Excellent dielectric strength.

TEFLON® Insulation - Ordering Code 5

Standard 20 gauge stranded wires, extruded Teflon (FEP) insulation over each wire, parallel with extruded Teflon (FEP) jacket. Teflon insulation is chemically inert and thermally stable, low coefficient of friction and has excellent electrical properties. Teflon is highly flexible has excellent mechanical strength and is unaffected by most chemicals. Suitable for continuous temperature rating of 400°F (205°C). Teflon is FDA approved for use in the pharmaceutical, food and beverage industry.

PVC Insulation with Stainless Steel Armor - Ordering Code 8

Same as code 4 with additional protection of an interlocking or square lock stainless steel flexible armor. Armor provides protection from physical abuse and is ideal for connection to junction boxes or control cabinets by means of BX connectors or cable glands. Armor available with a PVC outer jacket for additional moisture protection.

Transitions

Manufactured from 300 series stainless steel and filled with an epoxy potting compound. Potting compound seals the sheath from moisture and other contaminants. The transition is hex crimped or silver soldered to the sheath. Lead wires with shielding can be supplied with the drain wire attached to the inside of the transition.

Potting Compounds

Potting compounds fill the transition providing a durable water seal. Standard potting is suitable for temperature up to 350°F (177°C). Other higher temperature potting compounds are available on request.



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SECTION TECH

LEADWIRE for TEMPERATURE SENSORS

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Doc. No.: TE-CO010109-TECH-100

TECHNICAL REFERENCE

THERMOCOUPLE LEAD WIRE- Continued

Ordering Code 9

Other lead wire gauge size, insulation materials and construction are available. For any alternatives specify "9" in the ordering code and the description desired. Below are a few of the more widely used specials.

Ordering Code 9, Coil Cord

Coil cord, PVC insulation with a standard retracted length of 10 1/2" and extended length of approximately 39". The continuous retraction of the cord prevents lead wire interference with movable equipment. Longer coil cords are available.

Ordering Code 9, P/ALPTW-20

Standard 20 gauge solid or stranded wires, flame retardent PVC insulation over each wire, twisted with a polyester backed aluminum tape shield with copper drain wire then jacketed with a flame retardent PVC. This construction can be supplied with the drain wire left floating or grounded and sealed inside the transition.

Ordering Code 9, K/K-20

Standard 20 gauge solid or stranded wires, fused Kapton tape insulation over each wire, parallel fused Kapton tape jacket. Suitable for continuous temperature rating of 500°F (260°C), intermittent usage as high as 800°F (427°C). No known organic solvents to deteriorate insulation, resistant to nuclear radiation, will not support combustion, self extinguishing, high abrasion and cut-thru resistance. Unaffected by extreme or rapid variations in temperature.

Ordering Code 9, CF/CF-20

Standard 20 gauge solid or stranded wires, ceramic fiber insulation over each wire, parallel ceramic fiber jacket. Designed for extreme temperature applications. Low elongation and shrinkage provides flexibility throughout extended temperature ranges. Minimal moisture absorption and resistant to most industrial chemicals. Suitable for continuous temperature rating of 2200°F (1204°C), intermittent usage as high as 2600°F (1427°C).

RTD LEAD WIRE

Fiberglass Insulation - Ordering Code 1

Standard 24 gauge stranded nickel clad copper wires, Fiberglass braided insulation over each wire. Fiberglass is saturated with a polyester silicone enamel coating for improved durability and handling.. Suitable for continuous temperature rating of 950°F (510°C) and intermitting to 1200°F (649°C). Fiberglass provides high tensile strength, excellent dielectric constant and resistance to most oils and acids.

TEFLON® Insulation with Stainless Steel Armor - Ordering Code 2

Same as code 5 with additional protection of an interlocking or square lock stainless steel flexible armor. Armor provides protection from physical abuse and is ideal for connection to junction boxes or control cabinets by means of BX connectors or cable glands.

TEFLON® Insulation - Ordering Code 5

Standard 24 gauge stranded wires, extruded Teflon (FEP) insulation over each wire. Teflon insulation is chemically inert and thermally stable, low coefficient of friction and has excellent electrical properties. Teflon is highly flexible has excellent mechanical strength and unaffected by most chemicals. Suitable for continuous temperature rating of 400°F (205°C). Teflon is FDA approved for use in the pharmaceutical, food and beverage industry.

TEFLON® Insulation with Stainless Steel Armor - Ordering Code 8

Same as code 5 with additional protection of interlocking or square lock stainless steel flexible armor. Armor provides protection from physical abuse and is ideal for connection to junction boxes or control cabinets by means of BX connectors or cable glands. Armor available with a TEFLON outer jacket for additional moisture protection.

Ordering Code 9, TEX/TEXTW-24F

Same as code 5 with the insulated conductors twisted and jacketed with extruded Teflon (FEP). Jacketed wire provides additional abrasion protection and easier installation for long runs.



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SECTION TECH

LEADWIRE for TEMPERATURE SENSORS

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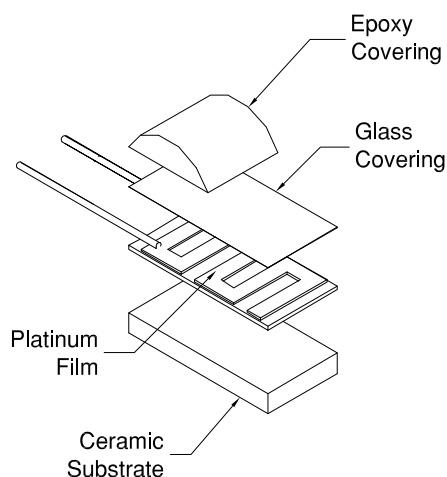
Doc. No.: TE-CO010109-TECH-110

TECHNICAL REFERENCE

Resistance Temperature Detector (RTD) elements are normally constructed of platinum, copper, nickel or nickel/iron. They operate as a positive temperature coefficient device when an excitation voltage is applied to convert changes in temperature to voltage signals by the measurement of resistance. The metals have the properties necessary for use in RTD elements due to their resistance to temperature characteristics that increase in resistance as temperature increases and, conversely, decrease in resistance as temperature decreases. These metals are best suited for RTD applications because of their linear resistance-temperature characteristics, their high coefficient of resistance, and their ability to withstand repeated temperature cycles. The change in electrical resistance to temperature for a material is termed the "temperature coefficient of resistance".

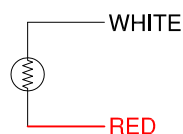
Thermo Electric uses two types of RTD, the wire wound and the thin film.

Wire wound design uses helical coil of very small platinum sensing wire of known alpha value. This coil is then slid into a ceramic insulator. Larger extension leads are spot welded to the ends of the platinum wire and cemented in place. Another construction is an outer winding of the platinum around a center mandrel usually made of ceramic. This winding is then coated with glass as a means of securing the windings. Wire wound elements are available in a number of materials and suitable for a wider temperature range.

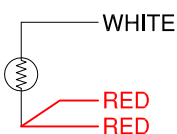


Thin film sensing elements are manufactured with a thin layer of platinum deposited on to a ceramic substrate. The platinum film is laser cut or chemical etched to achieve the desired resistance path. The element is then coated with a thin layer of glass for protection. Lead wires are welded to the platinum with epoxy applied to hold the lead wires in place. Thin film elements are lower in cost than wire wound and faster in response time.

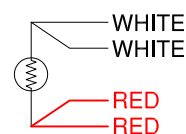
RTD's are available in two, three and four wire configuration. Selection of the lead wire configuration is usually based on the instrumentation, desired accuracy and stability.



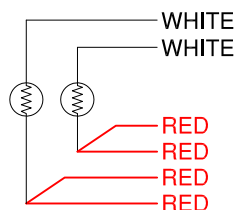
Two wire RTD: One lead wire is attached to each side of the element. This is the least accurate due to the inability to compensate for lead length resistance.



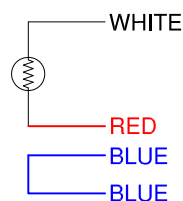
Three wire RTD: This is the most commonly used configuration. By adding a third lead to one end of the sensing element instrumentation can detect and compensate for lead resistance.



Four wire RTD: Four wire provide for the most accurate method of RTD measurement. A constant current is carried through two leads with the remaining two used to measure the voltage drop.



Duplex RTD: RTD's are available in duplex construction in any of the wire configurations. With wire wound bulbs two sets of windings are used. In thin film, two elements are set in place side-by-side. The second element may be used as a spare, testing purposes or connection to a second instrument. In most of Thermo Electric ordering codes a "D" is added to the prefix to denote duplex construction.



Compensating Loop RTD: A compensating loop is an extra pair of lead wires that have the same resistance as the actual lead wires but which are not connected to the RTD element. Its purpose is to correct for lead wire resistance errors when making temperature measurement.



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RTD CIRCUITRY

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Doc. No.: TE-CO010109-TECH-120

TECHNICAL REFERENCE

Temperature Coefficient and Sensitivity of RTD's

The best RTD for a given application meets the temperature range required and delivers the performance and cost requirements expected. All RTDs are specified by both a base resistance and the Temperature Coefficient of Resistance (TCR) or Alpha, expressed as $\Omega/\Omega/^{\circ}\text{C}$. The base resistance is usually the ice point, the most common exception is Copper which is specified as 10 Ω at 25 $^{\circ}\text{C}$. The TCR is the RTD's Resistance change from 0 to 100 $^{\circ}\text{C}$, divided by the resistance at 0 $^{\circ}\text{C}$, divided by 100 $^{\circ}\text{C}$. The following is the formula used to calculate TCR.

$$\text{TCR } (\Omega/\Omega/^{\circ}\text{C}) = \frac{R_{100^{\circ}\text{C}} - R_{0^{\circ}\text{C}}}{R_{0^{\circ}\text{C}} \times 100^{\circ}\text{C}}$$

$$R = 200 \text{ ft.} \times 0.0103 \Omega/\text{ft.} = 2.06\Omega$$

$$\text{Approximate Error} \\ E = \frac{2.06\Omega}{0.385 \Omega/^{\circ}\text{C}} = 5.35^{\circ}\text{C}$$

The most common and important use of TCR is in specifying the curves for Platinum RTDs. It is important that the TCR be matched properly when replacing RTDs or connecting them to instrumentation or erroneous readings will result. The most popular RTD used in most applications is a 100 U+03A9 with a TCR of 0.00385. Sensitivity of an RTD is the value of the TCR multiplied by $R_{0^{\circ}\text{C}}$ and is therefore a function of the base resistance and TCR. Sensitivity is expressed as $\Omega/^{\circ}\text{C}$. Since an RTD is a resistance type sensor any variable that can alter the resistance between the RTD and the control instrument will add to the reading. Therefore, the length of the lead wires can alter the readings. Since, the copper in lead wire changes resistance with changing ambient temperatures, the resistance is not constant. Lead wire error can be calculated by multiplying the total length of the lead wire, in feet, by the resistance value per foot of the wire gauge used at a given temperature. This figure is then divided by the sensitivity value to obtain an error figure. Lead wire errors can be significant when using small gauge wires or elements with low sensitivity. Example: A two wire 100 Ω Platinum RTD has a sensitivity value of 0.385 $\Omega/^{\circ}\text{C}$. Leadwires are 100 feet, 20 gauge copper wire with a resistance value of 0.0103

Available RTD Elements

The most commonly used element material is the standard platinum with a resistance of 100 ohms at 0 $^{\circ}\text{C}$ and a temperature coefficient of resistance of 0.00385 ohms/ohms/ $^{\circ}\text{C}$. Other types of RTDs are available from Thermo Electric. Below is a listing for some of the other element types that we supply.

ELEMENT MATERIAL	NOMINAL RESISTANCE	TEMPERATURE COEFFICIENT OHMS/OHM/ $^{\circ}\text{C}$	RELATED STANDARDS
PLATINUM	50 Ohms @ 0 $^{\circ}\text{C}$	0.003916	JIS C1604-1997, US STANDARD*
PLATINUM	98.129 Ohms @ 0 $^{\circ}\text{C}$	0.003923	SAMA RC21-4-1966
PLATINUM	100 Ohms @ 0 $^{\circ}\text{C}$	0.00385	ASTM-1137, IEC-60751, DIN 43760, ITS-90 BS EN 60751:1998(Replaces BS 1904:1984)
PLATINUM	100 Ohms @ 0 $^{\circ}\text{C}$	0.003916	JIS C1604-1997, US STANDARD*
PLATINUM	100 Ohms @ 0 $^{\circ}\text{C}$	0.003902	US STANDARD*
PLATINUM	130 Ohms @ 0 $^{\circ}\text{C}$	0.003900	BS 2G 148 (British Aircraft Industry)
PLATINUM	200 Ohms @ 0 $^{\circ}\text{C}$	0.00385	DIN 43760
PLATINUM	500 Ohms @ 0 $^{\circ}\text{C}$	0.00385	DIN 43760
PLATINUM	1000 Ohms @ 0 $^{\circ}\text{C}$	0.00385	DIN 43760
NICKEL	100 Ohms @ 0 $^{\circ}\text{C}$	0.00617	DIN 43760
NICKEL	120 Ohms @ 0 $^{\circ}\text{C}$	0.00672	Edison No. 7
NICKEL/IRON	604 Ohms @ 0 $^{\circ}\text{C}$	0.00518	N/A
COPPER	10 Ohms @ 25 $^{\circ}\text{C}$	0.00427	Edison No. 15

*No document exists for US Standard.



THERMO ELECTRIC

SECTION TECH

RTD CIRCUITRY

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TECHNICAL REFERENCE

RTD Stability: Stability is a RTD ability to maintain its specified resistance to temperature characteristic over long periods of time while being operated within its specified temperature limits. Often referred to as long term stability is the ability of the element to maintain its initial accuracy over an extended period of time. Most RTD's are stable to less than 0.05°C per year. However, stability is also affected by the environment, vibration, thermal shock and mechanical abuse it may be subject to.

RTD Interchangeability: Interchangeability is the measure of the variable based on tolerance and temperature coefficient from element to element. RTD's allow for easier interchangeability since their original variation is much lower than that of thermocouples.

Insulation Resistance: RTD's are insulated with MgO or insulated lead wire which is then sealed in a stainless steel tube. To prevent a shunting effect between the sensing element and the tube, care must be taken to assure no contamination or moisture absorption is present to cause any potential problems.

Repeatability: Repeatability of the element is defined as the relationship of the original resistance at 0°C and any different resistance at 0°C after being subjected to the following test. The sensor shall be brought slowly to the upper limits of its temperature range and then exposed to air at room temperature. It shall then be brought slowly to its lower limit, and exposed to air at room temperature. This procedure is repeated ten times. The resistance of 0°C is then measured and the difference from the pretesting resistance at 0°C is noted. For a typical platinum probe, the resistance should not change more than 0.3°C for a 0.12 % sensor or 0.15°C for a 0.06% sensor. The 0.12% and 0.06% are original resistance tolerances at 0°C of the element.

Self Heating: To measure resistance, it is necessary to pass a current through the element. The voltage drop across fine wire of a wire wound or thin coating of a thin film will tend to heat the element, this is known as Joule heating. To prevent this self heating RTD's are specified to have a current applied of 1 mA or less.
(Self Heating: 0.01 °C/mW in still liquid)

Vibration: Damage to the weld joints caused by excessive vibration can cause erratic readings or complete failure. All styles of Thermo Electric RTD's were tested and passed in accordance with IEC 60751 over a frequency range of 10 to 500Hz with a forcing acceleration of 20m/s² to 30m/s² peak-to-peak.

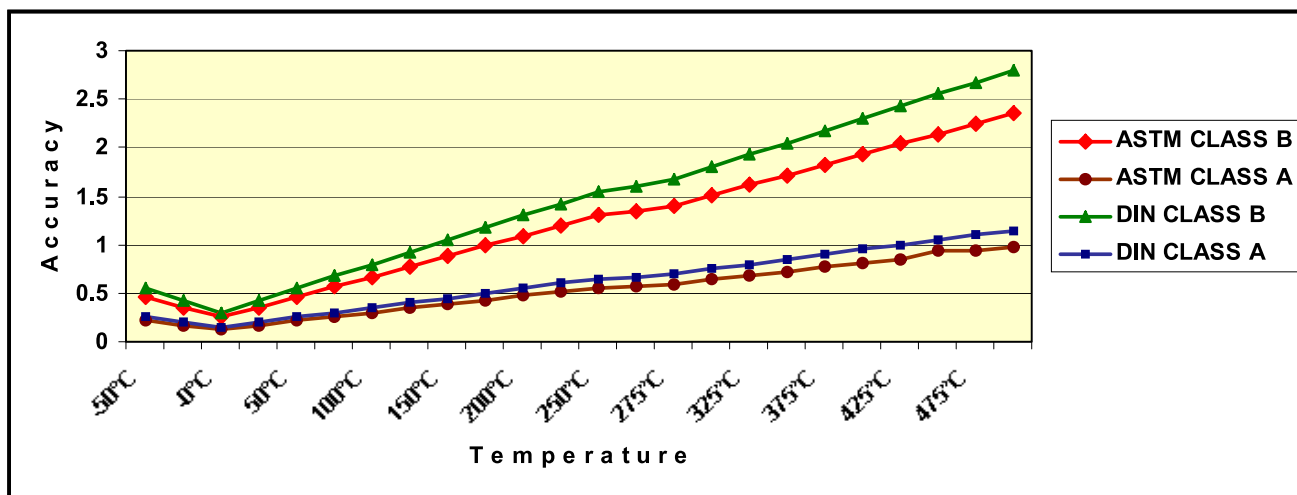
Response Time: Thermal response time is the time necessary for an RTD to reach 63.2 % step change of temperature and reach the resistance corresponding to some specified fraction of the total temperature change. Table to the right shows typical performance of the time constant in moving water at 3FT/sec.

SHEATH DIAMETER	TIME
.125" (3.2mm)	1.5 seconds
.188" (4.8mm)	3.0 seconds
.25" (6.4mm)	3.0 seconds

Callendar Van Dusen: Founded by British physicist Hugh Longbourne Callendar, and refined by M. S. Van Dusen. The Callendar-Van Dusen equation is an equation that describes the relationship between resistance (R) and temperature (t) of platinum. The Callendar Van Dusen equation analytically addresses the tolerance and accuracy of a platinum RTD at any point within its operation temperature range independent of alpha and ice point resistance.

Accuracy: Platinum RTD's typically are provided in grades (or class) of tolerance. Grade A has an ice point tolerance of ±0.06 % at ice point and grade B ±0.12 % at ice point. The ASTM standard is slightly better than the DIN at ±0.05 % and 0.10%. The accuracy will decrease with temperature. Thermo Electric RTD's conform to standard ASTM grade B accuracy and ASTM grade A accuracy when selected in ordering code.

ACCURACY	ASTM E1137	DIN EN 60751
CLASS B	± .10% @ 0°C (32°F)	± .12% @ 0°C (32°F)
CLASS A	± .05% @ 0°C (32°F)	± .06% @ 0°C (32°F)



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TECHNICAL REFERENCE

TEMPERATURE	ASTM E1137 °C (°F)		DIN EN 60751 °C (°F)	
	CLASS B	CLASS A	CLASS B	CLASS A
-175°C (-292°F)	±1.006 (1.811)	±0.436 (0.785)	±1.200 (2.160)	±0.510 (0.918)
-175°C (-283°F)	±0.985 (1.773)	±0.428 (0.770)	±1.175 (2.115)	±0.500 (0.900)
-150°C (-238°F)	±0.880 (1.584)	±0.385 (0.693)	±1.050 (1.890)	±0.450 (0.810)
-125°C (-193°F)	±0.775 (1.395)	±0.343 (0.617)	±0.925 (1.665)	±0.400 (0.720)
-100°C (-148°F)	±0.670 (1.206)	±0.300 (0.540)	±0.800 (1.440)	±0.350 (0.630)
-75°C (-103°F)	±0.565 (1.017)	±0.258 (0.464)	±0.675 (1.215)	±0.300 (0.540)
-50°C (-58°F)	±0.460 (0.828)	±0.215 (0.387)	±0.550 (0.990)	±0.250 (0.450)
-25°C (-13°F)	±0.355 (0.693)	±0.173 (0.311)	±0.425 (0.765)	±0.200 (0.360)
0°C (32°F)	±0.250 (0.450)	±0.130 (0.234)	±0.300 (0.540)	±0.150 (0.270)
25°C (77°F)	±0.355 (0.639)	±0.173 (0.311)	±0.425 (0.765)	±0.200 (0.360)
50°C (122°F)	±0.460 (0.828)	±0.215 (0.387)	±0.550 (0.990)	±0.250 (0.450)
75°C (167°F)	±0.565 (1.017)	±0.258 (0.464)	±0.675 (1.215)	±0.300 (0.540)
100°C (212°F)	±0.670 (1.206)	±0.300 (0.540)	±0.800 (1.440)	±0.350 (0.630)
125°C (257°F)	±0.775 (1.395)	±0.343 (0.617)	±0.925 (1.665)	±0.400 (0.720)
150°C (302°F)	±0.880 (1.564)	±0.385 (0.693)	±1.050 (1.890)	±0.450 (0.810)
175°C (347°F)	±0.985 (1.773)	±0.428 (0.770)	±1.175 (2.115)	±0.500 (0.900)
200°C (392°F)	±1.090 (1.962)	±0.470 (0.846)	±1.300 (2.340)	±0.550 (0.990)
225°C (437°F)	±1.195 (2.151)	±0.513 (0.923)	±1.425 (2.565)	±0.600 (1.080)
250°C (482°F)	±1.300 (2.430)	±0.555 (0.999)	±1.550 (2.790)	±0.650 (1.170)
260°C (500°F)	±1.342 (2.416)	±0.572 (1.030)	±1.600 (2.880)	±0.670 (1.206)
275°C (527°F)	±1.405 (2.529)	±0.598 (1.076)	±1.675 (3.015)	±0.700 (1.260)
300°C (572°F)	±1.510 (2.718)	±0.640 (1.152)	±1.800 (3.240)	±0.750 (1.350)
325°C (617°F)	±1.615 (2.907)	±0.683 (1.229)	±1.925 (3.465)	±0.800 (1.440)
350°C (662°F)	±1.720 (3.069)	±0.725 (1.305)	±2.050 (3.690)	±0.850 (1.530)
375°C (707°F)	±1.825 (3.285)	±0.768 (1.382)	±2.175 (3.915)	±0.900 (1.620)
400°C (752°F)	±1.930 (3.474)	±0.810 (1.458)	±2.300 (4.140)	±0.950 (1.710)
425°C (797°F)	±2.035 (3.663)	±0.853 (1.535)	±2.425 (4.365)	±1.000 (1.800)
450°C (842°F)	±2.140 (3.852)	±0.895 (1.611)	±2.550 (4.590)	±1.050 (1.890)
475°C (887°F)	±2.245 (4.041)	±0.938 (1.688)	±2.675 (4.815)	±1.100 (1.980)
500°C (932°F)	±2.350 (4.230)	±0.980 (1.764)	±2.800 (5.040)	±1.150 (2.070)
525°C (977°F)	±2.455 (4.419)	±1.023 (1.841)	±2.925 (5.265)	±1.200 (2.160)
550°C (1,022°F)	±2.560 (4.608)	±1.065 (1.917)	±3.050 (5.490)	±1.250 (2.250)
575°C (1,067°F)	±2.665 (4.797)	±1.108 (1.994)	±3.175 (5.715)	±1.300 (2.340)
600°C (1,112°F)	±2.770 (4.986)	±1.150 (2.070)	±3.300 (5.940)	±1.350 (2.430)
625°C (1,157°F)	±2.875 (5.175)	±1.193 (2.147)	±3.425 (6.165)	±1.400 (2.520)
650°C (1,202°F)	±2.980 (5.364)	±1.235 (2.223)	±3.550 (6.390)	±1.450 (2.610)

LT - Low Temperature

Recommended for uses up to 260°C (500°F).

The Standard RTD employs either film or wire wound element and is suitable for uses from -50°C to 260°C. The element is calibrated to ASTM E1 137 Grade B. The probe is available in lengths up to 28 inches. Internal lead wires are nickel clad copper, insulated with Teflon. Available in either three wire or four wire design. Film elements are sometimes better suited for high vibration applications.

MT - Medium Temperature

The medium temperature RTD is designed for use in the -50 to 400°C range. It uses a sheath construction of 316 Stainless Steel and fiberglass insulation then packed with MgO powder. The element is calibrated to ASTM E1 137 Grade A or B. Calibration to the IEC standard is also available. Higher accuracy specifications can be met on application. Three wire and four wire designs are available.

Industrial RTD

CE- Rugged RTD

Recommended for rugged industrial applications and for applications requiring higher accuracy up to 500°C(932°F). The CERAMO® design RTD is available in lengths up to 20 feet. It is made utilizing CERAMO (MgO insulated, metal sheathed cable). It is bendable from 3 inches from tip, internal lead wires are made from a nickel plated copper wires. This provides the minimum lead wire resistance change with temperature. CERAMO® RTD's employ a Ceramic wire wound element that can be calibrated to ASTM E1 137 Grade A or B. Calibration to the IEC standard is also available. Higher accuracy specifications can be met on application. Three wire and four wire designs are available. The temperature range for CERAMO® RTD's is -180 to 500°C. (-266°F to 932°F)

HT - High Temperature

These are custom design RTD's that are suitable for uses up to 650°C. Sheath material is an Alloy 600 and the bulb is a specially selected wire wound encapsulated ceramic or glass.



SECTION TECH

RTD CIRCUITRY

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TECHNICAL REFERENCE

A wide variety of steels and nickel-based alloys are used to make thermowells. This is because there is no one material which will stand up to all of the many service conditions which can be found across the industry. It is important that the proper metal be used in the fabrication of a thermowell. Obviously an improper choice will lead to premature failure while over-specifying leads to a higher cost than is necessary to do a given job.

The primary metals used in the fabrication of thermowells are: Carbon Steel, Chrome Molybdenum Steels, Stainless Steels (304, 310, 316, 321, 347, 304L, 316L, 446), Nickel-Based Alloys, (Inconels, Incolloys, Hastelloys).

The main responsibility of a thermowell is to protect the temperature sensor from corrosion or oxidation conditions found in the process, as well as mechanical stresses. More important: the thermowell allows removal of the sensor without compromising the integrity of the mother vessel or interruption of the process. Each of the previously mentioned materials provide different degrees of protection under various service conditions. The following is a discussion of the above materials with some recommendations for their use.

As a general guide, a high chromium content is desirable for high temperature resistance to oxidation and sulfur attack. The presence of aluminum (1-2%) is also useful as a very resistant surface film of mixed chromium oxide/aluminum oxide is formed.

Carbon Steels

Usually supplied in grade C1018 this is a general purpose low carbon steel with a medium range manganese content. C1018 is easily welded and cold formed, it also possesses good carburizing properties. C1018 is a relatively low strength steel and is suitable for low stress applications that do not require the greater strength of higher carbon or alloy steels.

Chrome-Moly Steels

Chromium-molybdenum (chrome-moly) steels have become a standard in the power generation industry because of its corrosion resistance and low-temperature strength. Chrome-molys are available in several grades of forged bars for machining into any style of thermowell in any of the following grades.

ALLOY	NOMINAL COMPOSITION							
	C	Mn	Cr	Mo	Cb	N	Al	V
F5	.15MAX	.30-.60	4.0-6.0	.44-.65				
F9	.15MAX	.30-.60	8.0-10.0	.9-1.10				
F11	.10-.20	.30-.80	1.0-1.5	.44-.65				
F22	.05-.15	.30-.60	2.0-2.5	.87-1.13				
F91	.08-.12	.30-.60	8-9.5	.85-1.05	.06-.10	.03-.07	.04MAX	.18-.25

Stainless Steels

This group of metals form an invisible chromium oxide film which serves to resist oxidation and corrosive attack by chemicals and acids. To be effective they need to have a minimum of 14 % chromium. 300 series Stainless Steels are known as "austenitic" while the 400 series are known as "ferritic". Austenitic Stainless Steels do not become brittle at low temperature as do ferritic steels.

304SS - Also known as "18-8" (nominally 18% chromium, 8% nickel) is the most through commonly specified austenitic Stainless Steel. 304SS like other 300 series Stainless Steels, is subject to "carbide precipitation" in the area of 700-1650 °F. This means that chromium carbides form when 304SS is held in or is cooled slowly through the above temperature range. The net effect is a localized depletion of chromium around the carbides, which can lead to intergranular corrosion from acids or other corrosives. This condition is especially apparent where parts are welded (leading to "weld decay") in air. Care must be taken, however, as the strength falls off considerably at elevated temperature applications across industry since it is not affected by most organic and inorganic chemicals.

310SS - Has higher chromium and nickel (nominally 25% chromium and 20% nickel) improved high temperature characteristics. 310SS is subject to carbide precipitation in the 800° to 1600°F range. Maximum continuous service temperature in air is 2100 °F. 310SS is used where good high temperature strength is needed or in carburizing or reducing atmospheres.

316SS - Another very popular all purpose austenitic Stainless Steel. 316SS has nominally 18 % chromium and 12% nickel, but is modified with 2-3% molybdenum which improves its resistance to chlorides. 316SS is subject to carbide precipitation in the 800-1600 °F range. Maximum continuous service temperature in air is 1650 °F. Because of its increased corrosive resistance, 316SS is used where improved corrosion resistance is required, especially in chlorides.

304 L and 316 L - Low carbon versions of 304SS and 316SS. These alloys solve the problem of carbide precipitation since they have a very low carbon content (0.03% maximum instead of 0.08% maximum).

446SS - A ferritic Stainless Steel containing about 26% chromium and no nickel. The 26% chromium gives improved high temperature oxidation resistance. However, this material becomes very brittle if held in, or slowly cooled through the range 750 -1050°F.



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SECTION TECH

METALLIC THERMOWELLS & PROTECTION TUBES

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TECHNICAL REFERENCE

Special Stainless Steels

Carpenter 20-Cb3 - A Stainless Steel having 20% chromium, 34% nickel, 2.5% copper and columbium and tantalum equal to 8 times the carbon content for carbide stabilization. This alloy has excellent resistance to corrosive conditions, and especially to sulfuric acid.

Nickel based Alloys

Incolloys, Inconels, Monel:

A very important group of alloys are the nickel-based Inconels and Incolloys. These alloys have excellent resistance to corrosive attack by many aggressive chemicals. They also have excellent resistance to oxidation at high temperatures and have good high temperature strength. They typically contain 15-23% chromium to provide a protective oxide film. The inconels contain 30-73 % nickel, while the incolloys have from 32-42% and 30-36% iron. Some grades contain a small amount of titanium or tantalum for improved high temperature strength; and aluminum to improve the protective characteristics of the oxide film at elevated temperatures (a mixed chromium oxide/aluminum film).

Inconel 600 - High nickel, 76%, high chromium, 15.5% for resistance to oxidizing and reducing atmospheres. I600 is used for severely corrosive environments at high temperature.

Inconel 601 - High nickel, 60.5%, high chromium, 23.0% plus 1.5% aluminum. Good high temperature properties. I601 provides outstanding resistance to oxidation, and good resistance to carburizing and sulfur containing atmospheres.

Incoloy 800 - 32.5% nickel, 46.0% iron, 21% chromium. Resistance to oxidation and carburization at high temperatures. Resists sulfur attack and corrosion in many environments.

Incoloy 800H - A special version of the above alloy with a small controlled amount of carbon for improved high temperature strength.

Monel 400 - High nickel, 66% high copper, 31%. Monel provides good resistance to corrosion in salt water. Not subject to chloride stress cracking. Monel is used for heat exchangers and for sulfuric acid applications.

Hastelloys:

These nickel-based alloys are used for their excellent corrosion resistance under many severe conditions due to their high molybdenum content.

Hastelloy B - 61% nickel, 28% molybdenum. Excellent corrosion resistance to hydrochloric acid and to sulfuric, phosphoric and acetic acids and hydrogen chloride gas.

Hastelloy C - 54% nickel, 16% molybdenum, 15.5% chromium, 4% tungsten. Excellent corrosion resistance to many chemical environments, including ferric acid and cupric chlorides, contaminated mineral acids, and wet chlorine gas. Oxidation resistant to 1900°F

Hastelloy X - 47% nickel, 9% molybdenum, 22% chromium, 0.5% tungsten. Good high temperature strength and resistance to oxidation to 2200°F. Also good for reducing conditions.

HAYNES® Alloys:

HAYNES® HR-160® alloy - HAYNES HR-160 alloy with outstanding resistance to most forms of high temperature corrosion. Its high levels of chromium and silicon provide for the formation of a highly protective surface oxide scale which resists attack from sulfur, chloride, vanadium and other salt deposits.

HAYNES® 214® alloy - HAYNES 214 alloy is a nickel-base superalloy with outstanding oxidation resistance at temperatures up to about 2300°F(1260°C). Although it can be age-hardened by thermal treatment at temperatures below about 1700°F (925°C), 214 alloy is principally intended for use in the solution-treated condition at temperatures of about 1800°F (980°C) or above.

HAYNES® 230® alloy - HAYNES 230 alloy is a nickel-chromium-tungsten-molybdenum alloy that combines excellent high-temperature strength, outstanding resistance to oxidizing environments up to 2100°F(1149°C) for prolonged exposures, premier resistance to nitriding environments, and excellent long-term thermal stability.

HAYNES® 556® alloy - HAYNES 556 alloy is a solid-solution-strengthened superalloy that combines excellent resistance to sulfidizing carburizing and most other high-temperature corrosive environments with good oxidation resistance, excellent fabricability and high elevated temperature strength up to 2000°F (1095°C).

Haynes: Trademark of Haynes International Inc.



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SECTION TECH

METALLIC THERMOWELLS & PROTECTION TUBES

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TECHNICAL REFERENCE

Thermo Electric ceramic protecting tubes are used in many different industries including iron and steel, glass, cement and lime processing. Their principal advantages include resistance to high temperatures and thermal shock, chemical inertness, good abrasion resistance and high dielectric strength. Our high purity alumina tubes are primarily used to protect noble metal thermocouples such as the platinum - rhodium types. Alumina and mullite protecting tubes are the most widely used, and are available in a wide variety of sizes. They are supplied with stainless steel bushings so that you can order them as part of a thermocouple assembly, and without bushings for replacement purposes. A cermet (metal - ceramic) tube is also offered for high temperature applications where extra high tube strength and abrasion resistance is required.

Mullite

Vitreous refractory mullite (silica - alumina) protection tubes can be used to 3000°F. They are impervious to air to 3000°F, to dry hydrogen and carbon monoxide to 2550°F, and will maintain 10 - 5 millimeters of mercury to 2600°F. Low rate of thermal expansion imparts good thermal shock resistance. Acid slag resistance is good, basic slag resistance is fair. Low sag. Recommended for use with J, K, and T thermocouples.

Fired Properties

Water absorption: impervious

Flexural Strength: 20,000 PSI

Coefficient of Linear Thermal Expansion: $2.8 \times 10^{-6}/^{\circ}\text{F}$

Hardness (Moh's scale): 7.5 - 8

High Purity Alumina

Sintered alumina oxide (over 99.5% Alumina Oxide) tubes have a maximum working temperature of 3450°F. They have the highest bending and breaking strength of any of our ceramic tubes above 2200°F. The high thermal conductivity of 99.5% alumina oxide guarantees quick temperature response. It is highly resistant to reducing, oxidizing, and high vacuum atmospheres, corrosive alkaline vapors and aluminum chloride vapors. Stable to acids, alkalis, metal melts, most glass fluxes, salt melts and slags. Dense structure prevents penetration of melts providing longer life in environments which normally react within 96% alumina. These tubes are impermeable to most gases under the conditions found in industrial furnaces. They are highly recommended for use with thermocouples containing platinum, iridium, and rhodium because of their relative freedom from Silicon dioxide and Iron oxide contaminants which can affect the thermocouple calibration and lifespan at high temperatures. Especially recommended for the glass industry where 99.5% alumina tubes are used in the furnace roof as well as in the melt.

Properties

Water Absorption: impervious

Flexural Strength: 55,000 PSI

Thermal Expansion: 32 to 1832°F: $4.5 \times 10^{-6}/^{\circ}\text{F}$ (approx)

Hardness (Moh's scale): 9

Cermet

Cermet metal - ceramic is a combination of chromium and aluminum oxide stable in oxidizing atmospheres to 2500°F. Cermet tubes are stronger and more resistant to repeated thermal and mechanical shock than ceramic materials, but are relatively brittle as compared to metals. Abrasive conditions at temperatures to 2300°F have little effect on cermet tubes, and chemicals such as sulphur dioxide, sulphur trioxide and concentrated sulphuric acid have a low rate of attack on the material. Ferrous alloys, copper, brass, zinc, lead and many other metals do not wet cermet. Thermal conductivity approximates that of cast iron for fast temperature response. Typical applications include open hearth furnace checkers, copper and brass melting pots, and abrasive conditions where gas - borne particles rapidly erode metal tubes operating near their softening point. Not recommended for use in molten aluminum, acid or carbide slags, nitriding carburizing atmospheres.

Properties

Flexural Strength at 68°F: 45,000 PSI

Coefficient of Thermal Expansion: 75 to 1830°F: $5 \times 10^{-6}/^{\circ}\text{F}$

Hardness (Rockwell): C - 34

Silicon Carbide

Silicon carbide protection tubes can be used in temperatures up to 3000°F where an extremely hard and chemically inert material is required. It resists most acids, molten salts and acid slags making it ideal for use with molten metals such as aluminum, copper, brass, cadmium, lead and zinc. This resistance to corrosive attack and abrasion are maintained at temperatures above the range of commonly used nickel-chromium alloys such as INCONELS, INCOLOYS, HASTELLOYS etc. Other useful properties include a high heat-shock resistance and thermal conductivity. Silicon carbide protection tubes are often used in conjunction with alumina inner tubes.



SECTION TECH

CERAMIC PROTECTION TUBES

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TECHNICAL REFERENCE

Thermowells are critical accessories for the successful operation of temperature sensors in industrial processes. They protect the sensing element and insure that the temperature of the process is passed to the sensor. Unfortunately, many users look at thermowells as a commodity product and do not realize the wide range of performance they supply. An improperly specified thermowell could result in:

1. A catastrophic failure due to poor welding practices that compromises the process.
2. Poor compatibility with the temperature and media of the process leading to premature failure.
3. Inadequate temperature transfer to the sensor, thus providing an inaccurate signal.
4. Incompatibility with the process velocity leading to catastrophic failure due to vibration.

The specifying engineer can eliminate the possibility of these problems by working with a quality manufacturer who can ensure that the thermowell is the right selection for the application.

Heat Transfer

A very important role of the thermowell is to transfer heat from the process to the sensor. For this reason, quality manufacturers follow a number of guidelines to improve the heat transfer qualities of the well. First is the bore diameter, which is the drilled out portion of the well where the sensor is inserted. For thermocouples, it is recommended to use a .385 inch diameter bore. This allows ample room for the sensing element to be inserted into the well and makes removal easy. Because thermocouples are tip sensitive, the sensor to well contact is critical in the tip of the thermowell. For this reason, most industrial thermocouple sensors are spring loaded to insure contact with the thermowell. For RTD's the recommended bore is .260 inches of diameter. This provides a closer relationship with the normally .250 inches diameter element. Because RTD's are stem sensitive, it is important that the well be close to the side of the sensing element. This improves the transfer of heat directly to the RTD element within the probe. Improved heat transfer provides better accuracy and better response time, which are normally weaknesses of RTD's. Thermowell profile is another means of insuring that the thermowell is capable of transferring the process temperature. Most thermowells have a tapered construction where the tip is of a smaller diameter than the base of the stem. This aids in the transfer of heat. A variation on the tapered well is the stepped down well, where the tip is significantly reduced in diameter for a specified length. This improves the heat transfer to the sensing element even more. It will help make the sensor more sensitive to changes in the process temperature. This is more commonly used for RTD's where stem sensitivity is important for accurate temperature measurement.

Process Connection

Generally, thermowells are either threaded into the process connection or attached using a flanged connection. The guidelines are rather simple. For smaller diameters where the well will not be required to be removed on a regular basis and corrosion is not a serious problem, threaded process connections are preferred. By threading into a welded in fitting, the well is attached directly to the vessel or pipe. To make installation easier, a 1 - 1/8 inch hex is left at the top of the well. This provides a strong place for the installer to grip the well with a wrench. The hex portion can be extended up to 3 inches for easier installation for use under insulation. For installations where the well needs to be removed more frequently due to corrosion or other requirements, a flanged connection is used. The flanged connection will bolt to a mating flange mounted to the process. Flanged connections are more appropriate for high pressure applications and larger pipe sizes. They are normally used up to 3 inches in diameter. For some applications where the process is not corrosive and access is not required, a welded connection for the thermowell may be used. These provide a high quality connection, but obviously cannot be removed without significant effort. Welded connections are also preferred for very high temperature and pressure applications, especially steam lines.

Flanged Well Construction

When a flanged thermowell is made, a blind (blank) flange is machined to provide a hole to pass the thermowell stem through. This stem must then be adequately attached to the flange to insure that it can withstand the pressure, temperature, shock and corrosion of the process. The normal method used to attach the flange to the stem is a seal weld at both the top and bottom of the flange. The seal weld requires good welding procedures to insure that the welds are strong and void free. If a seal weld should fail, it is possible for the stem to travel downstream in the process and damage any equipment in the line, such as pumps or compressors. Some users will use a lower quality material for the flange and a higher quality material for the stem. This is based on the fact that most of the flange is not normally in contact with the process. While this saves money on the initial purchase, if the welds of dissimilar metals are not done with certified welding procedures, the weld between the flange and stem may lack integrity. When high alloy wells are used on some processes, the flange may be of a lower alloy with a built up surface of the high alloy on the raised face. For example, a hastelloy well may have a hastelloy stem and a stainless flange with a hastelloy overlay on the raised face, which can be considered part of the wetted surface of the well. This again is a cost saver, but could lead to weld and well failures if not done by certified procedures. Another option is to have a flange stem connection that is both threaded and welded. This provides an additional security for the connection should the seal weld fail. One major process licensor specifies this connection for all thermowells. The most secure method of connecting the flange to the well is with a full penetration weld. In this, the flange is overbored to allow the well material to make full contact for the entire length of the connection. With a full penetration welded connection, the integrity of the connection is excellent. While this is much more costly in initial procurement cost, it can save significant long term cost in the life and performance of the thermowell. Again, proper welding procedures are critical.



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SECTION TECH

HOW TO SELECT THERMOWELLS

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Doc. No.: TE-CO010109-TECH-190

TECHNICAL REFERENCE

The weakest part of most metal components is the surface. It is here that corrosion and wear takes place, and where most metals fail. One of the most effective methods of preventing metal failure is to protect the surface with an industrial strength coating. Metal impregnation was developed to help the chemical and process industries run smoother with lower production and replacement costs. Thermo Electric can supply any number of coatings on thermowells or directly on the sensor probe itself to protect for problems arising from erosion, corrosion, abrasion, release and various problems resulting from intense temperatures.

Epoxy Coatings

Air dry epoxy coatings are self-priming, high gloss, corrosion resistant coating that are recommended for use where a high performance, chemically resistant coating is desired. These coatings offer single coat corrosion protection at 4-6 mils thickness, as well as very good abrasion resistance. It may also be used as a 2 or 3 coat system for use in industrial environments including offshore oil and gas.

PTFE (polytetrafluoro ethylene) nonstick coatings are two-coat (primer/topcoat) systems. The chemical inertness of PTFE is outstanding because of the chemical structure. These products have the highest operating temperature of any fluoropolymer, extremely low coefficient of friction, good abrasion resistance, and good chemical resistance. PTFE coatings can withstand a maximum use temperature of 600°F. This coating is typically applied to a thickness of 1-3 mils.

Tefzel coating is a melt processable fluoropolymer coating. It's a copolymer of TFE and ethylene also known by its chemical name. Tefzel coatings provide maximum continuous service temperature is 300°F, excellent chemical resistance to a wide range of chemicals, exceptionally Tough and abrasion resistant.

Metco 16C is one of several self-fluxing alloys which was designed to be remelted in a normal atmosphere after being sprayed. They then coalesce into a dense, essentially pore-free coating. Metco 16C produces coatings which resist wear by abrasive grains, hard surfaces, particle erosion, fretting, and cavitation. It is useful for nearly all hard-facing applications, especially on irregular shapes, and where heavy coatings are required. Coatings up to 1/8" (3 mm) or more in thickness may be fused without difficulty. Coatings of Metco 16C are similar in wear resistance to coatings of Metco 15E Self-Fluxing Nickel-Chromium Alloy Powder. They are easier to fuse than coatings of Metco 15E and have less tendency to crack. The fused surface of Metco 16C is not quite as smooth as that of Metco 15E. Where a very smooth as-fused surface is required, a few mils of Metco 15E can be applied over the Metco 16C before fusing. Of all of the Metco self-fluxing alloys, Metco 16C and Metco 19E are generally the most resistant to corrosion. The Metco self-fluxing alloys were designed to be sprayed with Metco ThermoSpray equipment, and subsequently fused. Metco 16C is certifiable as meeting U.S. Navy Specifications OS 12358, MPR 1031 and MPR 1032.

Stellite 6 is a cobalt based alloy coating powder designed to produce hard, dense coatings. Coatings of Stellite 6 are recommended for resistance to wear by abrasive grains and hard surfaces. They are resistant to wear, galling and corrosion and retain these properties at high temperatures. Their exceptional wear resistance is due mainly to the unique inherent characteristics of the hard carbide phase dispersed in a CoCe alloy matrix. Stellite 6 has excellent resistance to many forms of mechanical and chemical degradation over a wide temperature range, and retains an acceptable level of hardness up to 930°F(500°C).



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SECTION TECH

PROTECTIVE COATINGS

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TECHNICAL REFERENCE

Process Fluid	Concentration	Temperature	Well Material
Acetate Solvents	Pure		Monel 400 or Nickel 200
Acetic Acid	to 50%	212°F	316 Stn. Stl.
Acetic Acid	to 99%	212°F	Hastelloy C276
Acetic Anhydride	All Conc.		Hastelloy C276
Acetone	All Conc.	212°F	Hastelloy C276 or Monel 400
Acetylene			304 Stn. Stl.
Alcohol, Ethyl	All Conc.	70°F to 212°F	316 Stn. Stl.
Aluminum		Molten	Cast Iron
Aluminum Acetate	Saturated		304 Stn. Stl.
Aluminum Sulphate	to 25%	212°F	304 Stn. Stl.
Aluminum Sulphate	to 50%	212°F	Hastelloy C276
Ammonia	All Conc.	70°F	304 Stn. Stl.
Ammonium Chloride	All Conc.	70°F	316 Stn. Stl.
Ammonium Fluoride	to 25%	150°F	Hastelloy C276
Ammonium Nitrate	All Conc.	212°F	304 Stn. Stl.
Ammonium Phosphate	to 25%	212°F	304 Stn. Stl.
Ammonium Sulphate	All Conc.	212°F	Hastelloy C276
Amyl Acetate	All Conc.	300°F	Monel 400
Aniline	All Conc.	400°F	304 Stn. Stl.
Asphalt		250°F	C1018 Steel
Barium Carbonate		70°F	304 Stn. Stl.
Barium Chloride	to 25%	212°F	Hastelloy C276
Barium Hydroxide	to 50%	212°F	316 Stn. Stl.
Barium Sulphide			304 Stn. Stl.
Baroacic Acid	5%		304 Stn. Stl.
Beer		70°F	304 Stn. Stl.
Benzaldehyde			304 Stn. Stl.
Benzene, Benzol		212°F	304 Stn. Stl.
Benzoic Acid	All Conc.	212°F	316 Stn. Stl.
Black Liquor			Hastelloy C276
Bleaching Powder	15%	70°F	Monel 400
Bordeaux Mixture	All Conc.	212°F	304 Stn. Stl.
Boric Acid	All Conc.	400°F	316 Stn. Stl.
Bromine	Wet	70°F	Tantalum
Bromine	Dry	70°F	Tantalum
Butane		400°F	Carbon Steel
Butyl Alcohol			Copper
Butylacetate			Monel 400
Butylenes			Carbon Steel
Butyric Acid		70°F	304 Stn. Stl.
Butyric Acid		212°F	Hastelloy C276
Calcium Bicarbonate			304 Stn. Stl.
Calcium Chlorate	30%	212°F	304 Stn. Stl.
Calcium Fluoride			304 Stn. Stl.
Calcium Hydroxide	20%	212°F	304 Stn. Stl.
Calcium Hydroxide	50%	212°F	Hastelloy C276
Calcium Hypochlorite	15%	70°F	Monel 400
Carbolic Acid	All Conc.	212°F	316 Stn. Stl.
Carbon Dioxide	Dry		Carbon Steel
Carbon Dioxide	Wet		Carbon Steel
Carbon Tetrachloride	All Conc.	70°F	Monel 400
Carbonic Acid		212°F	304 Stn. Stl.

Process Fluid	Concentration	Temperature	Well Material
Chloracetic Acid	All Conc.	300°F	Hastelloy C276
Chlorex Caustic			316 Stn. Stl.
Chlorine Gas	Dry	70°F	C.Stl.
Chlorine Gas	Moist	70°F	Hastelloy C276
Chloroform	Dry	212°F	Monel 400
Chromic Acid	5%	70°F	304 Stn. Stl.
Chromic Acid	50%	212°F	Hastelloy C276
Cider	All Conc.	300°F	304 Stn. Stl.
Citric Acid	15%	70°F	304 Stn. Stl.
Citric Acid	All Conc.	212°F	Hastelloy C276
Coal Tar		Hot	304 Stn. Stl.
Coke Oven Gas		70°F	Alumium
Copper Nitrate	All Conc.	300°F	316 Stn. Stl.
Copper Sulphate	All Conc.	300°F	316 Stn. Stl.
Corn Oils		212°F	316 Stn. Stl.
Cottenseed Oil			Carbon Steel
Creosols		212°F	304 Stn. Stl.
Cyanogen Gas			304 Stn. Stl.
Dowtherm			Carbon Steel
Epson Salt			304 Stn. Stl.
Ether		70°F	304 Stn. Stl.
Ethyl Acetate			Monel 400
Ethyl Chloride		70°F	304 Stn. Stl.
Ethyl Sulphate		70°F	Monel 400
Ethylene Glycol	All Conc.	212°F	304 Stn. Stl.
Ethylene Oxide		70°F	Carbon Steel
Ferric Chloride	1%	70°F	316 Stn. Stl.
Ferric Chloride		212°F	Tantalum
Ferric Nitrate		212°F	Tantalum
Ferric Sulphate	All Conc.	300°F	Tantalum
Fluorine		212°F	Hastelloy C276
Fluosilicic Acid		70°F	Carp. 20
Formaldehyde	40%	212°F	316 Stn. Stl.
Formic Acid	All Conc.	300°F	316 Stn. Stl.
Furfural		400°F	316 Stn. Stl.
Galic Acid	5%	150°F	Monel 400
Gasoline		70°F	304 Stn. Stl.
Glucose		70°F	304 Stn. Stl.
Glycerine		212°F	304 Stn. Stl.
Glycerol		70°F	304 Stn. Stl.
Hydrobromic Acid	All Conc.	212°F	Hastelloy B
Hydrochloric Acid	All Conc.	212°F	Tantalum
Hydrocyanic Acid	All Conc.	212°F	304 Stn. Stl.
Hydrofluoric Acid	60%	212°F	Hastelloy C276
Hydrogen Chloride	Dry	500°F	304 Stn. Stl.
Hydrogen Peroxide		212°F	304 Stn. Stl.
Hydrogen Sulphide	Dry	212°F	316 Stn. Stl.
Iodine		70°F	Hastelloy C276
Kerosene		300°F	304 Stn. Stl.
Lacquer		212°F	316 Stn. Stl.
Lactic Acid	5%	150°F	316 Stn. Stl.
Laetic Acid	10%	212°F	Tantalum



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SECTION TECH

THERMOWELL MATERIAL SELECTION GUIDE

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TECHNICAL REFERENCE

Process Fluid	Concentration	Temperature	Well Material
Latex		212°F	Carbon Steel
Lime Sulphur			PVC
Linseed Oil		70°F	304 Stn. Stl.
Magnesium Carbonate		150°F	304 Stn. Stl.
Magnesium Chloride	5%	70°F	Monel 400
Magnesium Chloride	5%	212°F	Nickel 200
Magnesium Hydroxide	All Conc.	70°F	304 Stn. Stl.
Magnesium Nitrate		150°F	304 Stn. Stl.
Magnesium Oxide	All Conc.	70°F	304 Stn. Stl.
Magnesium Sulphate	40%	212°F	304 Stn. Stl.
Mallic Acid		212°F	316 Stn. Stl.
Mercuric Chloride	10%	70°F	Hastelloy C276
Mercury	100%	660°F	Carbon Steel
Methane		70°F	Carbon Steel
Methyl Chloride	Dry	70°F	Carbon Steel
Methylene Chloride	All Conc.	212°F	304 Stn. Stl.
Milk		175°F	304 Stn. Stl.
Molasses		300°F	304 Stn. Stl.
Muriatic Acid		70°F	Tantalum
Naphta		70°F	304 Stn. Stl.
Natural Gas		70°F	304 Stn. Stl.
Neon		70°F	304 Stn. Stl.
Nickel Chloride		70°F	304 Stn. Stl.
Nickel Sulphate		212°F	304 Stn. Stl.
Nitric Acid	40%	180°F	347 Stn. Stl.
Nitric Acid	All Conc.	370°F	Tantalum
Nitrobenzene		70°F	304 Stn. Stl.
Nitrous Acid		70°F	304 Stn. Stl.
Oleic Acid	All Conc.	400°F	316 Stn. Stl.
Oleum		70°F	316 Stn. Stl.
Oxalic Acid	5%	70°F	304 Stn. Stl.
Oxalic Acid	10%	212°F	Monel 400
Oxygen	Liquid		304 Stn. Stl.
Oxygen		70°F	Carbon Steel
Palmitic Acid	All Conc.	400°F	316 Stn. Stl.
Pentane			304 Stn. Stl.
Petroleum Ether			304 Stn. Stl.
Phenol	All Conc.	212°F	316 Stn. Stl.
Phosphoric Acid	10%	70°F	316 Stn. Stl.
Phosphoric Acid	85%	212°F	Hastelloy C276
Picric Acid		70°F	304 Stn. Stl.
Pot. Permanganate	5%	70°F	304 Stn. Stl.
Potassium Bromide		70°F	316 Stn. Stl.
Potassium Carbonate	20%	212°F	316 Stn. Stl.
Potassium Chlorate		70°F	304 Stn. Stl.
Potassium Chloride	20%	70°F	316 Stn. Stl.
Potassium Chloride	20%	212°F	Monel 400
Potassium Hydroxide	30%	212°F	316 Stn. Stl.
Potassium Nitrate	40%	212°F	316 Stn. Stl.
Potassium Nitrite	20%	70°F	316 Stn. Stl.
Potassium Sulphate	30%	212°F	316 Stn. Stl.
Potassium Sulphide	10%	212°F	304 Stn. Stl.

Process Fluid	Concentration	Temperature	Well Material
Potassium Sulphite	30%	212°F	304 Stn. Stl.
Propane		300°F	Carbon Steel
Pyrogalllic Acid			304 Stn. Stl.
Quinine Bisulphate	Dry		316 Stn. Stl.
Quinine Sulphate	Dry		304 Stn. Stl.
Salommoniac		70°F	Monel 400
Sea Water		70°F	Monel 400
Shellac			304 Stn. Stl.
Silver Chloride		70°F	Carp. 20
Silver Nitrate		212°F	304 Stn. Stl.
Sodium Bicarbonate	All Conc.	150°F	316 Stn. Stl.
Sodium Bisulphate	20%	212°F	Hastelloy B
Sodium Bisulphite	20%	212°F	Hastelloy C276
Sodium Carbonate	20%	212°F	316 Stn. Stl.
Sodium Chloride	30%	70°F	316 Stn. Stl.
Sodium Chloride	30%	212°F	Monel 400
Sodium Chromate	All Conc.	212°F	316 Stn. Stl.
Sodium Fluoride	5%	70°F	Hastelloy B
Sodium Hydroxide	30%	212°F	316 Stn. Stl.
Sodium Hypochlorite			Tantalum
Sodium Nitrate	40%	212°F	304 Stn. Stl.
Sodium Nitrate	20%	70°F	304 Stn. Stl.
Sodium Peroxide	Fused		304 Stn. Stl.
Sodium Phosphate	10%	212°F	Carbon Steel
Sodium Silicate	10%	212°F	Carbon Steel
Sodium Sulphate	30%	212°F	316 Stn. Stl.
Sodium Sulphide	10%	212°F	316 Stn. Stl.
Sodium Sulphite	30%	212°F	304 Stn. Stl.
Stearic Acid			316 Stn. Stl.
Sulphur		Molten	304 Stn. Stl.
Sulphur	Wet		316 Stn. Stl.
Sulphur Dioxide		500°F	316 Stn. Stl.
Sulphur Trioxide	Dry	500°F	316 Stn. Stl.
Sulphuric Acid	Fuming	365°F	Carp. 20
Sulphuric Acid	All Conc.	212°F	Hastelloy B
Sulphurous Acid	20%	70°F	316 Stn. Stl.
Tar			Carbon Steel
Tartaric Acid		70°F	304 Stn. Stl.
Tartaric Acid		150°F	316 Stn. Stl.
Tin		Molten	Cast Iron
Tinan. Tetrachloride	All Conc.	70°F	316 Stn. Stl.
Toluene			304 Stn. Stl.
Trichloroacetic Acid	All Conc.	70°F	Hastelloy B
Trichlorethylene	Dry	300°F	Monel 400
Turpentine		70°F	316 Stn. Stl.
Vegetable Oils			304 Stn. Stl.
Vinegar			304 Stn. Stl.
Whiskey, Wine			304 Stn. Stl.
Xylene			Copper
Zinc		Molten	Cast Iron
Zinc Chloride	All Conc.	212°F	Hastelloy B
Zinc Sulphate	All Conc.	212°F	316 Stn. Stl.



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SECTION TECH

THERMOWELL MATERIAL SELECTION GUIDE

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Doc. No.: TE-CO010109-TECH-220

TECHNICAL REFERENCE

Questions as to the definition and use of thermocouples in series or parallel come up on occasion. In an attempt to generally clarify most of these questions, the following information is offered.

Series - Frequently referred to as a thermopile.

Thermocouples connected in series produce an EMF signal that is additive. That is, the output from a number of thermocouples is added together to produce a total output of all the thermocouples. With reference to Sketch No.1, we will assume that A is iron and B is constantan. We will further assume the reference junctions are at 32°F and the measuring junctions are at 200°F. From our catalog thermocouple temperature millivolt tables, we see that the output of a single thermocouple at 200°F is 4.906 millivolts. With four couples in a series, as in sketch no.1, we add 4.906 millivolts four times to get a final millivolt output of 19.624 millivolts. The formula for working this out is:

$$E = ET1 + ET2 + ET3 + ET4$$

Two common applications are:

1. Measuring temperature where a very minute change is critical to the application. By enlarging the signal, these small changes can be detected more easily on simple instruments.
2. Working a voltage sensitive relay where a small change is not sufficient to trip the contact. Care must be taken in this case so that you do not exceed a workable external resistance factor.

Parallel - Frequently referred to as averaging thermocouples.

Thermocouples connected in parallel produce an EMF the same as for a single thermocouple. If all the thermocouples are of equal resistance and their measuring junctions are at various temperatures, then the EMF generated will correspond to the average of the temperatures of the individual junctions. Looking at sketch no. 2, let us again assume that A is iron and B is constantan. Let us also assume the reference temperature T1 is at 32°F. If T2 is 200°F, T3 is at 205°F, T4 is at 210°F and T5 is 215°F, and all couples are of equal resistance, we will get an output of 207 - 1/2°F which is the average temperature. The formula which applies is

$$EMF = \frac{T2+T3+T4+T5}{4}$$

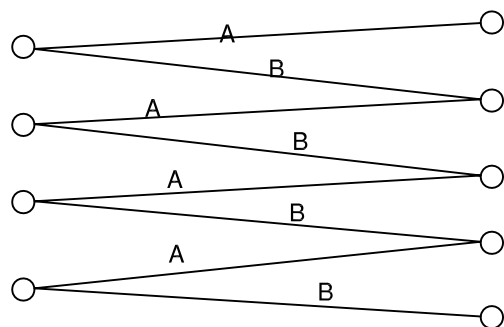
It is not always possible to make all parallel couples of equal resistance. When this presents a problem we can add swamping resistors in series with each couple. If we have four couples varying between 8 and 12 ohms and add a 200 ohm swamping resistor in series with each, we reduce the differences to insignificant fractions of the total resistance.

Two common applications are:

1. Aircraft harness assemblies where a group of couples are placed in a ring around the exhaust system and lead back to a single cockpit indicator.
2. An inexpensive method of high temperature alarm using a single instrument for alarm indication. This would be a good application for digital monitors is sensitive enough to sense small changes in EMF signals.

Grounds which introduce cross connections between either the series or parallel combination of thermocouples are not permissible.

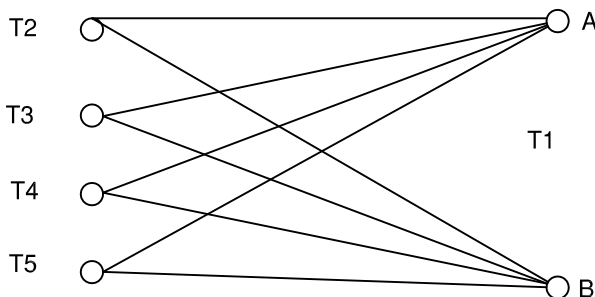
Series Wiring



Measuring
Junctions

Reference
Junctions

Parallel Wiring



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SECTION TECH

THERMOCOUPLE
SERIES & PARALLEL MEASUREMENTS

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Doc. No.: TE-CO010109-TECH-230

TECHNICAL REFERENCE

Control of "Noise" in Instrumentation Circuits.

The type of signal transmitted by the sensor is related to its sensitivity to noise. The lower the voltage level and the higher the impedance of a circuit, the greater the circuit's sensitivity to noise of all types. The following discussion describes the major types of noise and commonly accepted solutions for each.

There are four types of noise which affect process instruments:

Common Mode: Different ground potentials at each location in a process plant cause common mode noise to be a problem. Two different grounds in an instrument circuit mean a current will flow between them, causing noise to be added to the signal being transmitted. Using a receiver which has a high common mode rejection ratio will control this type of common mode interference. A second type of common mode interference will occur even when a high quality receiver is used and is a particular problem in thermocouple extension wire circuits. Most thermocouples used are the "grounded" type. That is, the couple is connected physically and electrically to the well in which it is installed. When a thermocouple circuit shield (or any nearby metallic object, such as conduit, tray, building frames, etc.) is at a different potential than the couple, charging currents flow in the extension wire, causing interference to be superimposed on the thermocouple signal. Grounding the shield circuit at the couple and only at the couple will eliminate noise problems from common mode. Multipair cables used with thermocouples must be the individually shielded, isolated pair shield type so that the shield circuit may be maintained at the individual couple ground potential all the way back to the control room.

Cross Talk: This occurs with AC instrument signals, especially pulse-type signals, where more than one circuit is carried in the same cable. It is the tendency for a signal to be coupled from one pair to another within the cable, resulting in noise being superimposed on a circuit. Cross talk noise may be eliminated by the use of cables with individually shielded, isolated pair shields. The pair shield protects against noise picked up from adjacent pairs, as well as reducing noise by the pair it surrounds.

Static: Static interference is caused by the electric field radiated by a voltage source being coupled capacitively into the instrument circuit. The best way of fighting static noise is to place the circuit inside a total coverage shield which isolates the pair of wires from outside influence. The grounded shield intercepts static interference and carries it off to ground. The shield must be grounded in order to reduce static noise; an ungrounded shield will not reduce noise.

Magnetic noise: Produced by currents flowing through conductors and pieces of electrical equipment such as motors, generators, etc. As the current flows through equipment, a magnetic field is radiated around the conductor. As this field passes through the space between the conductors in an instrument circuit, a current is set up in the instrument circuit to oppose the magnetic field (transformer action). This current causes a noise to be superimposed on the signal in the instrument circuit. The best way of fighting this type of noise is to twist the wires in the instrument circuit. Twisting causes the noise to be canceled in adjacent sections of the wire. This is the least expensive, most effective way of combating magnetic noise.

Process Instrumentation

Recently there have been many changes in recording, indicating and controlling instruments used in the process industries. For the purpose of this discussion, however, there are three general classifications of receiving instruments in which the majority of process instruments can be replaced. They are:

A to D Converters, Computers: An analog signal is conditioned, amplified and then converted to a digital signal either for input to a computer or for telemetry transmission, or the signal is amplified and fed to a recording system or time sampled.

Potentiometer and Bridge: Input signal is conditioned, sent through a chopper, either mechanical or electronic, to compare with a standard voltage or to null. The output signal is amplified and then drives a chart recorder pen or indicator to a "balance" or "null" position.

Current Elements: Current flowing in instrument loop is converted directly to a torque to move a chart recorder pen or meter pointer. No electronic circuits are involved. (This Classification includes pyrometers.)

In systems with amplifiers, excessive noise levels cause overloading of the amplifier input with a resultant shift in the operating characteristics of the amplifier. The amplifier output is then no longer proportional to the input signal and serious errors result. When A to D converters are involved or when time sampling is taking place, noise will cause significant errors in the readings.

Plant Installation Notes

Besides the electrical problems which are considered in choosing the proper wire and cable, one should also consider what a particular wire or cable installation must withstand from a mechanical standpoint. If a cable is being installed in an open tray, or underground, armor should be provided to protect against damage from crushing or the impact of falling objects. If the cable is to be pulled a great distance, suspended from two points or buried where shifting ground will cause tensile forces on the cable, an armor which acts as a strength member should be considered. Armoring should be used where crush and impact resistance is required. Where tensile strength is important, a served wire armor will provide this protection, as well as crush and impact resistance.

Precautions taken during design, engineering and installations can also reduce the effects of noise considerably. Routing of instrument cables away from noise sources such as power cables, motors, generators, and any arc-producing equipment will greatly reduce the chance of noise pickup. Putting signals of the same relative strength into the same cable and excluding any higher level signals will reduce the chances of cross talk. Shielding of data transmission circuits will reduce pickup by nearby instrument circuits. Twisting of control and power cables will reduce the magnetic noise pickup in nearby instrument circuits. Separation of instrument circuits from noise sources will reduce the noise problem considerably, as both static and magnetic fields fall off fairly rapidly as distance from the source is increased.

Where shields are employed in both the single pair wires and in multipair cables for noise protection, there are some important ground rules to follow:

1 To protect against common mode noise pickup within the wire and cable, a shield circuit should be grounded at the point which the instrument circuit is grounded and isolated from all other grounds; i.e., with a grounded couple, ground the shield on the extension wire at the couple. As the shield circuit is carried back to the control room through a junction box and a multipair cable, connect the pair shield in the cable to the single pair which leads to the couple without grounding the shield at the junction box or connecting it to any other shield (or other pairs). The shield should not be grounded in the control room.

2. Ground all shields. An ungrounded shield will not provide noise protection.

3. Ground a shield at one point only.



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