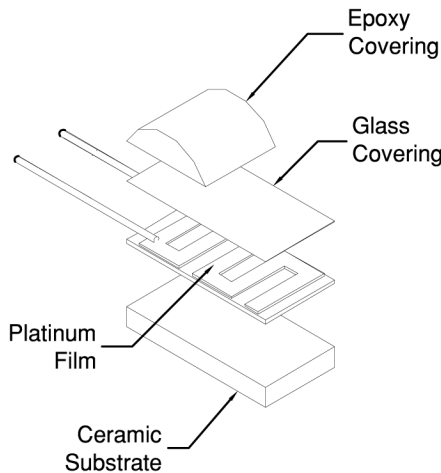


Resistance Temperature Detector (RTD) elements are normally constructed of platinum, copper, nickel or nickel/iron. They operate as a positive temperature coefficient device when an excitation voltage is applied to convert changes in temperature to voltage signals by the measurement of resistance. The 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".

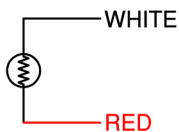
Thermo Electric uses two types of RTD, the wire wound and the thin film.

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.

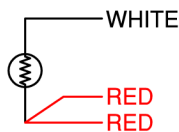


Thin film sensing elements are manufactured with a thin layer of platinum deposited on to a ceramic substrate. The platinum film is laser cut or chemical etched to achieve the desired resistance path. The element is then coated with a thin layer of glass for protection. Lead wires are welded to the platinum 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.

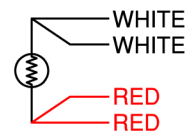
RTD's are available in two, three and four wire configuration. Selection of the lead wire configuration is usually based on the instrumentation, desired accuracy and stability.



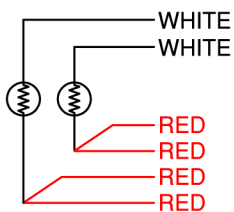
Two wire RTD: One lead wire is attached to each side of the element. This is the least accurate due to the inability to compensate for lead length resistance.



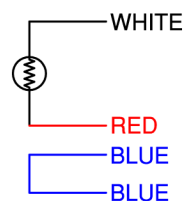
Three wire RTD: This is the most commonly used configuration. By adding a third lead to one end of the sensing element instrumentation can detect and compensate for lead resistance.



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.

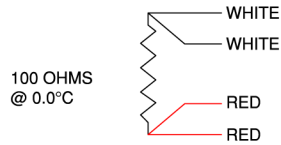


Compensating Loop RTD: A compensating loop is an extra pair of lead wires that have the same resistance as the actual lead wires but which are not connected to the RTD element. Its purpose is to correct for lead wire resistance errors when making temperature measurement.

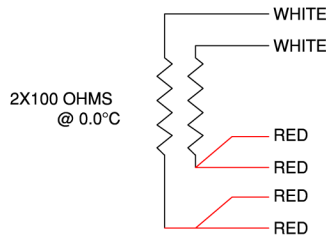
WIRING DIAGRAM



SINGLE 3 WIRE CONSTRUCTION



SINGLE 4 WIRE CONSTRUCTION



DUPLEX 4 WIRE CONSTRUCTION

Bulb Construction

Platinum thin film on a ceramic substrate, glass sealed. Lead wires of nickel platinum-clad
Connection protected by temperature stable enamel.

Tolerance Compliance

ASTM E1137, IEC 751, DIN 60751(Formerly DIN 43760)

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)

Temperature Coefficient of Resistance (TCR): 0.00385 Ohms/Ohm/°C
Resistance at 0°C: 100 Ohms

Long Term Stability: Max. Ro drift 0.04% after 1000 H @ 500° C
Time Constant in Water Moving at 3 fps, 25" Diameter: 5.0 seconds

Self Heating: Less than 0.20° C

Vibration Resistance: 10 to 500Hz @ 1 octave/minute acceleration of
20 to 30m/s² peak-to-peak

TEMPERATURE	ASTM E1137 °C (°F)		DIN EN 60751 °C (°F)	
	CLASS B	CLASS A	CLASS B	CLASS A
-50°C (-58°F)	±0.460 (0.828)	±0.215 (0.387)	±0.550 (0.990)	±0.250 (0.450)
-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)
260°C (500°F)	±1.342 (2.416)	±0.572 (1.030)	±1.600 (2.880)	±0.670 (1.206)

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°C. The TCR is the RTD's Resistance change from 0 to 100°C, divided by the resistance at 0°C, divided by 100°C. The following is the formula used to calculate TCR.

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

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

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

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°C and a temperature coefficient of resistance of 0.00385 ohms/ohms/°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/° C	RELATED STANDARDS
PLATINUM	50 Ohms @ 0° C	0.003916	JIS C1604-1997, US STANDARD*
PLATINUM	98.129 Ohms @ 0° C	0.003923	SAMA RC21-4-1966
PLATINUM	100 Ohms @ 0° C	0.00385	ASTM-1137, IEC-60751, DIN 43760, ITS-90 BS EN 60751:1998(Replaces BS 1904:1984)
PLATINUM	100 Ohms @ 0° C	0.003916	JIS C1604-1997, US STANDARD*
PLATINUM	100 Ohms @ 0° C	0.003902	US STANDARD*
PLATINUM	130 Ohms @ 0° C	0.003900	BS 2G 148 (British Aircraft Industry)
PLATINUM	200 Ohms @ 0° C	0.00385	DIN 43760
PLATINUM	500 Ohms @ 0° C	0.00385	DIN 43760
PLATINUM	1000 Ohms @ 0° C	0.00385	DIN 43760
NICKEL	100 Ohms @ 0° C	0.00617	DIN 43760
NICKEL	120 Ohms @ 0° C	0.00672	Edison No. 7
NICKEL/IRON	604 Ohms @ 0° C	0.00518	N/A
COPPER	10 Ohms @ 25° C	0.00427	Edison No. 15

*No document exists for US Standard.



THERMO ELECTRIC

SECTION TECH

RTD CIRCUITRY

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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.

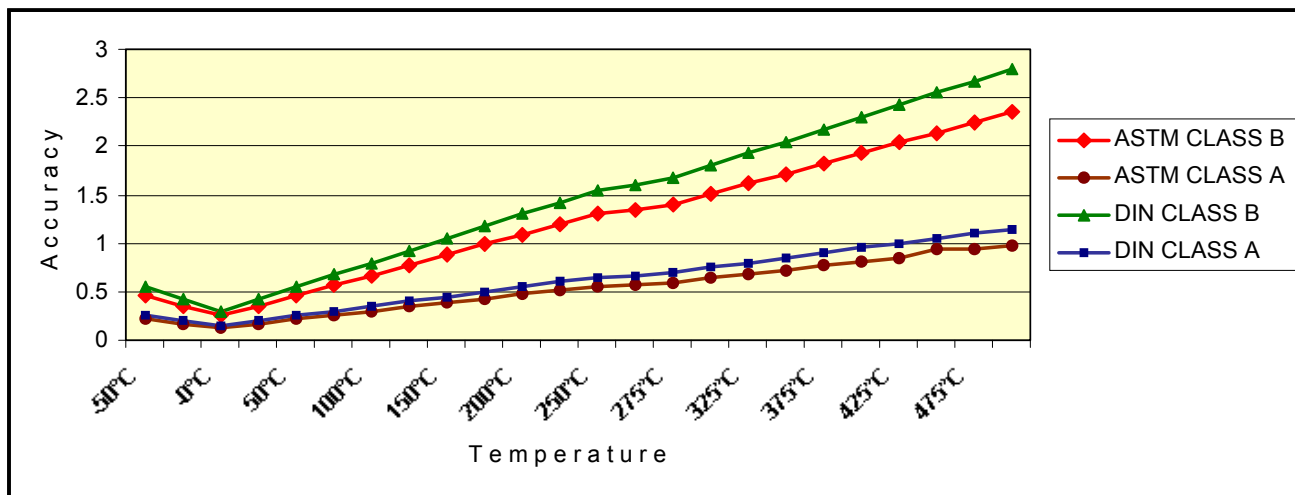
Response Time: Thermal response time is the time necessary for an RTD to reach 63.2 % step change of temperature and reach the resistance corresponding to some specified fraction of the total temperature change. Table to the right shows typical performance of the time constant in moving water at 3FT/sec.

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.



THERMO ELECTRIC

SECTION TECH

RTD CIRCUITRY

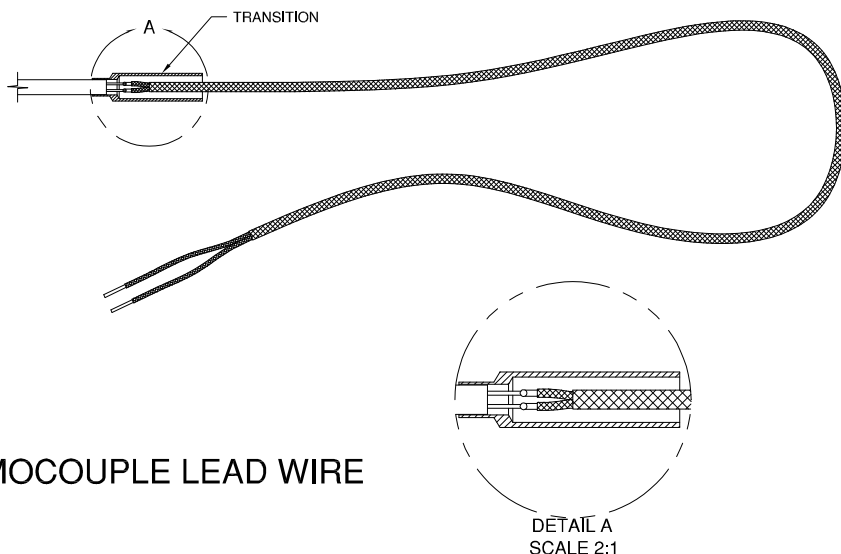
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TECHNICAL REFERENCE

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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