Calibration Ordering Information

Our NVLAP Lab Code 200502-0 (National Voluntary Laboratory Accreditation Program) Accredited Metrology Laboratory provides comparison temperature calibrations from -196 °C to 1450 °C [-321 °F to 2642 °F] on the International Temperature Scale of 1990 (ITS-90) for temperature sensors and instruments.

Pyromation's laboratory managerial staff and technical team have documented education, training, technical knowledge and experience to precisely perform their assigned functions. The laboratory's test enviornment is constantly monitored and controlled to maintain all required conditions, while access is strictly defined and controlled.

Our Laboratory equipment includes fluidized baths and tube furnaces, standard platinum resistance thermometers, and type "B" and "S" thermocouples. All standards and calibrations are traceable to the National Institute of Standards and Technology (NIST), or have been derived from accepted values of natural physical constants, or by the ratio of self calibration. Note: Our quality system meets or exceeds the requirements for NIST Handbook 150:2006, ISO 9001:2000, ISO 10012-1:1992(E), ANSI/NCSL Z540-1-1994, and MIL-STD-45662A.

ORDER CODES

Example Order Numbers:

1	2	3		4		5
CAL	**(100, 200, 300)**	**F**	**-**	**PTD**	**-**	**TBL**

1 Standard Calibrations

CODE	DESCRIPTION
CAL	**Sensor Calibration** - All sensors of line item calibrated to specified temperatures.
LOT	**Lot Calibration - Beginning and End** - (BE) - One sample from the beginning and the end of the lot will be tested at specified temperatures.
LOP[1]	**Loop Calibration -** One instrument and one sensor will be tested together at specified temperatures.

[1] Note: Additional length may be required for loop calibrations.

2 Calibration Temperatures: Specified Required Calibration Points

3 Temperature Scale

CODE	DESCRIPTION
C	Degrees Celsius
F	Degrees Fahrenheit

4 Tagging Options

CODE	DESCRIPTION
PTD	Calibration Detail, Paper Tag
STD	Calibration Detail, Stainless Tag
ATD	Calibration Detail, Aluminum Tag
PTA	Tag all sensors with Beginning and End Calibration, Paper Tag

5 Custom Table Options

CODE	DESCRIPTION
TBL	Table in 1 degree increments
TBL (0.1)	Table in 0.1 degree increments
TBL (CVD)	Callendar Van Dusen Coefficients

1A Calibrations Per AMS 2750[2]

CODE	DESCRIPTION	ASTM E230 Tolerances
CAL-AMS-TUS	**Temperature Uniformity Survey Calibration** - All sensors of line item calibrated to specified temperatures.	± 2.2 °C [± 4 °F] or ± 0.75%
CAL-AMS-SAT	**System Accuracy Test Calibration** - All sensors of line item calibrated to specified temperatures.	(J, K, T, E, N) ± 1.1 °C [± 2 °F] or ± 0.4% (R,S) ± 0.6 °C [± 1 °F] or ± 0.1% (B) ± 0.6 °C [± 1 °F] or ± 0.25%
CAL-AMS-CRM	**Control, Recording & Monitoring Calibration -** All sensors of line item calibrated to specified temperatures.	Class 1 & 2: ± 1.1 °C [± 2 °F] or ± 0.4% Class 3 to 6: ± 2.2 °C [± 4 °F] or ± 0.75%
CAL-AMS-L	**Load Calibration** - All sensors of line item calibrated to specified temperatures.	± 2.2 °C [± 4 °F] or ± 0.75%

1B Lot Calibrations Per AMS 2750[1][2]

CODE	DESCRIPTION	Max. Lot Length		ASTM E230 Tolerances	Allowable Delta Limits
LOT-AMS-TUS	**Temperature Uniformity Survey Lot Calibration** - Beginning and End - One sample from the beginning and the end of the lot will be tested at specified temperatures.	Base	5000 ft	± 2.2 °C [± 4 °F] or ± 0.75%	± 1.1 °C [± 2 °F]
		Noble	2000 ft		
LOT-AMS-SAT	**System Accuracy Test Lot Calibration** - One sample from the beginning and the end of the lot will be tested at specified temperatures.	Base	5000 ft	(J, K, T, E, N) ± 1.1 °C [± 2 °F] or ± 0.4% (R,S) ± 0.6 °C [± 1 °F] or ± 0.1% (B) ± 0.6 °C [± 1 °F] or ± 0.25%	± 1.1 °C [± 2 °F]
		Noble	2000 ft		
LOT-AMS-CRM	**Control, Recording & Monitoring Lot Calibration -** One sample from the beginning and the end of the lot will be tested at specified temperatures.	Base	5000 ft	Class 1 & 2: ± 1.1 °C [± 2 °F] or ± 0.4% Class 3 to 6: ± 2.2 °C [± 4 °F] or ± 0.75%	± 1.1 °C [± 2 °F]
		Noble	2000 ft		
LOT-AMS-L	**Load Lot Calibration** - One sample from the beginning and the end of the lot will be tested at specified temperatures.	Base	5000 ft	± 2.2 °C [± 4 °F] or ± 0.75%	± 1.1 °C [± 2 °F]
		Noble	2000 ft		

[1] Lot AMS calibration reports contain beginning, end and average temperatures.

[2] Maximum interval between temperatures is 140 °C [250 °F]

Minimum Sensor Length Requirements for Temperature Calibrations

-196 °C	-75 °C	(-40 to 0) °C	(0 to 100) °C	(40 to 215) °C	(200 to 500) °C	(425 to 1204) °C	(800 to 1450) °C
[-321 °F]	[-103 °F]	[-40 to 32] °F	[32 to 212] °F	[104 to 420] °F	[392 to 932] °F	[800 to 2200] °F	[1472 to 2642] °F
12 Inch	12 Inch	6 Inch	6 Inch	6 Inch	18 Inch	18 Inch	30 Inch

THERMOCOUPLES - Thermocouples are the most common, convenient, and versatile devices used to measure temperature. They convert units of heat into useable engineering units that serve as input signals for process controllers and recorders.

A thermocouple consists of a welded 'hot' junction between two dissimilar metals - usually wires - and a reference junction at opposite ends of the parent materials. Heating the 'hot' junction in the working environment produces a temperature gradient which generates an Electromotive Force (EMF). The EMF appears across the free ends of the thermocouple wires where it is measured and converted into units of heat calibration. Through selection of appropriate thermocouple wires and sheath components, thermocouples are suitable to be used in temperature ranges from (-200 to 2316) °C [-328 to 4200] °F.

RESISTANCE TEMPERATURE DETECTORS - Resistance temperature detectors (RTD) accurately sense temperature with an excellent degree of repeatability and interchangeability of elements. The RTD is composed of certain metallic elements whose change in resistance is a function of temperature. In operation, a small excitation current is passed across the element, and the voltage, which is proportional to resistance, is then measured and converted to units of temperature calibration. The RTD element is manufactured by winding a wire (wire wound elements) or plating a film (thin film elements) on a ceramic or glass core and sealing the element within a ceramic or glass capsule.

Since most RTDs have a low initial resistance, often 100 ohms, and have a small change in resistance per unit of temperature range, the resistance of the lead wire is often compensated for with a three or four wire bridge configuration built into the measuring devices. By selecting the proper elements and protective sheathing, RTDs can operate in a temperature range of (-200 to 600) °C [-328 to 1112] °F.

THERMISTORS - A thermistor is an economical means of precisely sensing heat over a limited range of temperatures. A thermistor is a metal oxide whose change in resistance is typically an inverse function of the change in temperature. An excitation current is passed across the sensor and the voltage, which is proportional to the resistance, is measured and converted to units of heat calibration. Since thermistors usually have a large base resistance and a large change in resistance per unit of temperature change, compensation for lead wire length is not generally needed. Thermistors can operate across a temperature range of (-40 to 150) °C [-40 to 302] °F by selecting the proper sensor and protective materials.

ADDITIONAL REQUIREMENTS - Other components usually essential in integrating the principles of thermocouple, RTD, and thermistor sensors into a functioning system may include: (1) a protection tube or sheath of a material suitable to protect the sensing element from the environment surrounding the point of measurement; (2) a connecting head and terminal block, or possibly a temperature transmitter; (3) leadwire of the correct material and insulation to connect the temperature sensor and the process instrumentation; and (4) recording or controlling instrumentation and control devices to provide a continuous temperature history of the system and to provide constant or programmed temperature regulation.

Thermocouple Material Specifications

The thermocouple element materials listed below are those most commonly found in process applications. Selection of the proper thermocouple type for a particular application is determined by temperature expectations and by the environment in which the sensor will be placed. The following temperature and application tables are intended to aid in this selection. The thermocouples are listed by ASTM letter designations per thermocouple type.

Letter Designated Thermocouples

TYPE		TEMPERATURE RANGE	APPLICATION INFORMATION
J E230	Iron (+) Copper - 45% Nickel (Constantan) (-)	(0 to 760) °C [32 to 1400] °F	Suitable for vacuum, reducing, or inert atmospheres, oxidizing atmosphere with reduced life. Iron oxidizes rapidly above 538 °C [1000 °F] so only heavy gauge wire is recommended for high temperature. Bare elements should not be exposed to sulphurous atmospheres above 538 °C [1000 °F].
K E230	Nickel - 10% Chromium (+) Nickel - 2% Aluminum, 2% Manganese, 1% Silicon (-)	(0 to 1260) °C [32 to 2300] °F	Recommended for continuous oxidizing or neutral atmospheres. Mostly used above 538 °C [1000 °F]. Subject to failure if exposed to sulphur. Preferential oxidation of chromium in positive leg at certain low oxygen concentrations causes 'green rot' and large negative calibration drifts most serious in the (816 to 1038) °C [1500 to 1900] °F range. Ventilation or inert-sealing of the protection tube can prevent this.
N E230	Nickel - 14% Chromium, 1 1/2% Silicon (+) Nickel - 4 1/2% Silicon - 1/10% Magnesium (-)	(0 to 1260) °C [32 to 2300] °F	Can be used in applications where Type K elements have shorter life and stability problems due to oxidation and the development of 'green rot'.
T E230	Copper (+) Copper - 45% Nickel (Constantan) (-)	(-200 to 370) °C [-328 to 700] °F	Useable in oxidizing, reducing, or inert atmospheres as well as vacuum. Not subject to corrosion in moist atmospheres. Limits of error published for sub-zero temperature ranges.
E E230	Nickel - 10% Chromium (+) Copper - 45% Nickel (Constantan) (-)	(0 to 870) °C [32 to 1600] °F	Recommended for continuously oxidizing or inert atmospheres. Sub-zero limits of error not established. Highest thermoelectric output of common calibrations.
R E230	Platinum - 13% Rhodium (+) Platinum (-)	(538 to 1482) °C [1000 to 2700] °F	Recommended for high temperature. Must be protected with non-metallic protection tube and ceramic insulators. Continued high temperature usage causes grain growth which can lead to mechanical failure. Negative calibration drift caused by Rhodium diffusion to pure leg as well as from Rhodium volatilization. Type R is used in industry; Type S in the laboratory.
S E230	Platinum - 10% Rhodium (+) Platinum (-)		
B E230	Platinum - 30% Rhodium (+) Platinum - 6% Rhodium (-)	(871 to 1704) °C [1600 to 3100] °F	Same as R & S but output is lower. Also less susceptible to grain growth and drift.
C E230	95% Tungsten - 5% Rhenium (+) 74% Tungsten - 26% Rhenium (-)	(0 to 2315) °C [32 to 4200] °F	Very high temperature applications in inert or vacuum. Preferred over Tungsten/Tungsten-26% Rhenium because it is less brittle at low temperatures.

Non-Letter Designated Thermocouples

TYPE		TEMPERATURE RANGE	APPLICATION INFORMATION
M E1751	Nickel - 18% Molybdenum (+) Nickel - 0.8% Cobalt (-)	(-50 to 1410) °C [-58 to 2570] °F	High temperature applications in inert or vacuum atmosphere. Useful in many hydrogen applications. Continuous cycling causes excessive grain growth.
P E1751	Platinel II® Platinel 5355 (+) Platinel 7674 (-)	(0 to 1395) °C [32 to 2543] °F	Noble metal combination which approximates Type K curve but has much improved oxidation resistance. Should be treated as any noble metal calibration.

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Thermocouple Initial Material Tolerances

The tolerances shown in the table below apply to new, essentially homogeneous thermocouple wire in the size range of 30 AWG to 8 AWG. These tolerances only apply to thermocouples used at temperatures not exceeding the recommended limits. If thermocouples are used at temperatures above the recommended limits, or in detrimental enviornments, the below stated tolerances may not apply.

Tolerances on Initial Values of EMF vs Temperature for Thermocouples

Reference Junction 0 °C [32 °F]. Published in ASTM E230

TYPE	TEMPERATURE RANGE for STANDARD TOLERANCES	STANDARD TOLERANCES	TEMPERATURE RANGE for SPECIAL TOLERANCES	SPECIAL TOLERANCES
J	(0 to 293) °C [32 to 559] °F (293 to 760) °C [559 to 1400] °F	± 2.2 °C [± 4 °F] ± 0.75%	(0 to 275) °C [32 to 527] °F (275 to 760) °C [527 to 1400] °F	± 1.1 °C [± 2 °F] ± 0.4%
K	(-200 to -110) °C [-328 to -166] °F (-110 to 0) °C [-166 to 32] °F (0 to 293) °C [32 to 559] °F (293 to 1260) °C [559 to 2300] °F	± 2% [1] ± 2.2 °C [± 4 °F][1] ± 2.2 °C [± 4 °F] ± 0.75%	[2] [2] (0 to 275) °C [32 to 527] °F (275 to 1260) °C [527 to 2300] °F	 ± 1.1 °C [± 2 °F] ± 0.4%
N	(0 to 293) °C [32 to 559] °F (293 to 1260) °C [559 to 2300] °F	± 2.2 °C [± 4 °F][1] ± 0.75%	(0 to 275) °C [32 to 527] °F (275 to 1260) °C [527 to 2300] °F	± 1.1 °C [± 2 °F] ± 0.4%
T	(-200 to -67 °C [-328 to -89] °F (-67 to 0) °C [-89 to 32] °F (0 to 133) °C [32 to 271] °F (133 to 370) °C [271 to 700] °F	± 1.5%[1] ± 1 °C [± 1.8 °F][1] ± 1 °C [± 1.8 °F] ± 0.75%	[2] [2] (0 to 125) °C [32 to 257] °F (125 to 370) °C [257 to 700] °F	 ± 0.5 °C [± 0.9 °F] ± 0.4%
E	(0 to 870) °C [32 to 1600] °F	± 1.7 °C [± 3.06 °F][3] or ± 0.5%	(0 to 870) °C [32 to 1600] °F	± 1.0 °C [± 1.8 °F][3] or ± 0.4%
R	(0 to 600) °C [32 to 1112] °F (600 to 1480) °C [1112 to 2642] °F	± 1.5 °C [± 2.7 °F] ± 0.25%	(0 to 600) °C [32 to 1112] °F (600 to 1480) °C [1112 to 2700] °F	± 0.6 °C [± 1.1 °F] ± 0.1%
S	(0 to 600) °C [32 to 1112] °F (600 to 1480) °C [1112 to 2700] °F	± 1.5 °C [± 2.7 °F] ± 0.25%	(0 to 600) °C [32 to 1112] °F (600 to 1480) °C [1112 to 2642] °F	± 0.6 °C [± 1.1 °F] ± 0.1%
B	(870 to 1700) °C [1600 to 3100] °F	± 0.5%	(870 to 1700) °C [1600 to 3100] °F	± 0.25%
C	(0 to 400) °C [32 to 752] °F (400 to 2315) °C [752 to 4200] °F	± 4.4 °C [± 8 °F] ± 1.0%	Not Available	

[1] Thermocouples and thermocouple materials are supplied to meet the tolerance specified for temperatures above 0 °C. A thermocouple material may not conform to the published sub-zero limits of error for that material when purchased, unless conformance is agreed upon by customer and Pyromation when ordering.

[2] Special tolerances for sub-zero temperatures have not yet been established. The following limits for calibrations of types E and T are useful to start discussion between customer and Pyromation.

(-200 to 0) °C Type T ± 0.5 °C or ± 0.8%, whichever is greater

[3] The standard tolerances shown do not apply to Type E mineral-insulated, metal-sheathed (MIMS) thermocouples and thermocouple cables. The standard tolerances for MIMS Type E constructions are the greater of ± 2.2 °C or ± 1.75 % from 0 to 870 °C and the greater of ± 2.2 °C or ± 2 % from -200 to 0 °C.

Initial values of tolerance for Type J and special tolerance for Type K thermocouples below 0 °C are not given due to the characteristics of the materials.

Tolerances on Initial Values of EMF vs Temperature for Thermocouples

CODE	MATERIAL	TEMPERATURE RANGE	TOLERANCE
M	Ni18Mo/Ni	(-50 to 1410) °C [-58 to 2570] °F	± 0.75%
P	Platinel® II	(0 to 1395) °C [32 to 4200] °F	± 0.10 mV

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Recommended Temperature Limits and Color Codes

Thermocouples must be selected to meet application conditions and only general recommendations of size and type can be given. Selection considerations involve useful length of service life, temperature, atmosphere, and response time. Smaller gauges provide faster response times and less service life. Larger gauges provide longer service life and reduced response times. The recommended temperature limits below are to be used as a guideline in the selection process, and the table applies only to thermocouples protected by a suitable protecting tube, sheath, or well. The color coding chart below provides ANSI/ASTM standard color codes found on thermocouple wire, extension wire, and plug and jack connectors.

Suggested Upper Temperature Limits For Protected Industrial Thermocouples

TYPE	MAXIMUM TEMPERATURE						
	8 GAUGE	11 GAUGE	14 GAUGE	20 GAUGE	24 GAUGE	28 GAUGE	30 GAUGE
	°C [°F]	°C [°F]	°C [°F]	°C [°F]	°C [°F]	°C [°F]	°C [°F]
T			370 [700]	260 [500]	200 [400]	200 [400]	150 [300]
J	760 [1400]		590 [1100]	480 [900]	370 [700]	370 [700]	320 [600]
E	870 [1600]		650 [1200]	540 [1000]	430 [800]	430 [800]	370 [700]
K, N	1260 [2300]		1090 [2000]	980 [1800]	870 [1600]	870 [1600]	760 [1400]
M		1287 [2250]	1287 [2250]				
R, S					1480 [2700]		
B					1700 [3100]		
C					2330 [4200]		

THERMO-COUPLE TYPE	U.S. & CANADIAN (ANSI/ASTM E230, ANSI/MC96.1)			
	ALLOY COMBINATION	THERMOCOUPLE GRADE	EXTENSION GRADE	PLUG & JACK
T	Copper / Constantan (Copper-Nickel)	Brown, Blue (+), Red (-)	Blue (+), Blue, Red (-)	Blue
J	Iron *(magnetic)* / Constantan (Copper-Nickel)	Brown, White (+), Red (-)	White (+), Black, Red (-)	Black
E	Nickel - Chromium / Constantan (Copper- Nickel)	Brown, Purple (+), Red (-)	Purple (+), Purple, Red (-)	Purple
K	Nickel - Chromium / Nickel - Aluminium *(magnetic)*	Brown, Yellow (+), Red (-)	Yellow (+), Yellow, Red (-)	Yellow
N	Nicrosil (Nickel-Chromium- Silicon) / Nisil (Nickel-Silicon-Magnesium)	Brown, Orange (+), Red (-)	Orange (+), Orange, Red (-)	Orange
S	Platinum Rhodium -10% / Platinum	None Established	Black (+), Green, Red (-)	Green
R	Platinum Rhodium -13% / Platinum	None Established	Black (+), Green, Red (-)	Green
B	Platinum Rhodium - 30% / Platinum Rhodium - 6%	None Established	Gray (+), Gray, Red (-) (Compensated Cable)	White (Uncom-pensated)
C	Tungsten Rhenium - 5% / Tungsten Rhenium - 26%	None Established	Green (+), Red, Red (-)	Red

Tubing, Sheath, Protection Tube, and Well Materials

Pyromation provides a variety of common tubing, MgO sheath, protection tube, and drilled-well materials to protect temperature sensing elements from the environmental conditions typically found in industrial process applications. The following tables are intended as guidelines to aid in the selection of the proper materials for sensors used in different environments. Consult the factory for the availability of other protective materials for specialty applications. NOTE: All chemical compositions and temperature ratings are nominal and are stated as received from suppliers.

Material Code Index

METALS						CERAMICS and COMPOSITE MATERIALS	
CODE	MATERIAL	CODE	MATERIAL	CODE	MATERIAL	CODE	MATERIAL
2	Molybdenum	25	Tantalum	37	Alloy 800	12	Metal Ceramic LT-1
3	Alloy 600	26	Titanium	38	Alloy 20	13	Vesuvius
4	310 S.S.	27	Alloy 400	41	HR - 160®	14	Cerite® - II
5	446 S.S.	28	Alloy B	50	Zirconium	15	Cerite® - III
6	Carbon Steel	29	Alloy C -276	59	F22-1	16	Mullite
7	Alloy 601	31	Nickel 200	60	F11-2	17	Alumina
8	316 S.S.	32	304 LC S.S.	61	A105	18	Silicon Carbide
9[2]	304 S.S.	33	316 LC S.S.	91	F91	19	Hexoloy® SA
11	Cast Iron	35	321 S.S.			71	Recrystallized Silicon Carbide
22	Brass	36	347 S.S.				
23	Copper						
24	Platinum						

Metals

CATALOG MATERIAL CODE	MATERIAL/COMPOSITION	TYPICAL AREAS OF USE				APPLICATION GUIDELINE INFORMATION
		TUBING	MGO SHEATHS	PROT. TUBES	DRILLED WELLS	
2	**MOLYBDENUM** 99.9% min. Molybdenum, 0.03% Tungsten	X	X			Up to 1926 °C [3500 °F] in inert atmospheres, to 1871 °C [3400 °F] in vacuum at 10-4 torr. Has poor mechanical shock resistance after heated to 1038 °C [1900 °F]. Oxidizes in air above 427 °C [800 °F].
3	**ALLOY 600 (UNS N06600)** 72% Nickel, 15% Chromium, 8% Iron	X	X	X	X	Up to 1149 °C [2100 °F] under oxidizing conditions. Reducing conditions reduce maximum temperature to 1038 °C [1900 °F]. Must not be placed in sulfurous atmospheres above 538 °C [1000 °F]. Main areas of application for thermocouple protection are carburizing, annealing and hardening furnaces, Cyanide saltbaths, blast furnace downcomers, open hearth flue stacks, steel soaking pits, waste heat boilers, ore roasters, cement exit flues, incinerators, and glass tank flues. (INCONEL® 600)
4	**310 STAINLESS STEEL (UNS S31000)** 25% Chromium, 20% Nickel	X	X	X	X	Up to 1038 °C [1900 °F] continuous, 1149 °C [2100 °F] intermittent. Mechanical and corrosion resistance similar to and better than 304 stainless steel.
5	**446 STAINLESS STEEL (UNS S44600)** 27% Chromium		X	X	X	Up to 1093 °C [2000 °F] under oxidizing conditions. Excellent high temperature corrosion and oxidizing resistance. Main areas of application are hardening, nitriding, and annealing furnaces, salt baths, molten lead, tin and babbitt metal, sulfurous atmospheres. Not for carburizing atmospheres. Other areas of application are steel soaking pits, tinning pots, waste heat boilers, ore roasters, cement exit flues, boiler tubes to 982 °C [1800 °F], incinerators to 1093 °C [2000 °F], glass flue tanks.
6	**CARBON STEEL**[1]	X		X	X	Up to 538 °C [1000 °F] in non-oxidizing environments. Main areas of usage are galvanizing pots, tinning pots, molten babbitt metal, molten mangesium, molten zinc, Petroleum refinery applications such as dewaxing and thermal cracking.
7	**ALLOY 601 (UNS N06601)** 61% Nickel, 23% Chromium, 14% Iron, 1.35% Aluminum		X	X	X	Similar applications to Inconel® 600 but with superior resistance to sulfur, high temperature oxidation resistance to 1260 °C [2300 °F]. (INCONEL® 601)
8	**316 STAINLESS STEEL (UNS S31600)** 16% Chromium, 12% Nickel 2% Molybdenum	X	X	X	X	Up to 927 °C [1700 °F] under oxidizing conditions. Same areas of applications as 304 stainless steel. Has improved resistance to mild acid and pitting corrosion.
9[2]	**304 STAINLESS STEEL (UNS S30400)** 18% Chromium, 8% Nickel	X	X	X	X	Up to 899 °C [1650 °F] under oxidizing conditions. Has general good oxidation and corrosion resistance in a wide range of industrial environments. Subject to carbide precipitation, which can reduce corrosion resistance in the (427 to 538) °C [800 to 1000] °F range. Good mechanical properties from (-184 to 788) °C [-300 to 1450] °F. Main areas of usage for thermocouple protection is in chemicals, foods, plastics and petroleum. Generally regarded as standard protection tube material.

[1] Materials available in various alloys - consult factory
[2] Machined fittings may be supplied as 303 Series stainless steel
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INCONEL® is a registered trademark of Special Metals Corporation
HR-160® is a registered trademark of Haynes International, Inc.

Metals

CATALOG MATERIAL CODE	MATERIAL/COMPOSITION	TYPICAL AREAS OF USE				APPLICATION GUIDELINE INFORMATION
		TUBING	MGO SHEATHS	PROT. TUBES	DRILLED WELLS	
11	**CAST IRON**			X		Up to 704 °C [1300 °F] in oxidizing conditions. Main area of usage is in molten non-ferrous metals, daily whiting is recommended. Can be used to 871 °C [1600 °F] under reducing conditions.
22	**BRASS**[1]	X			X	Up to 538 °C [1000 °F] continuous. Good thermal conductivity and mechanical strength.
23	**COPPER**	X	X Limited Avail.			Up to 260 °C [500 °F] continuous. Excellent thermal conductivity. Poor mechanical strength.
24	**PLATINUM**[1]	X	X			Up to 1374 °C [2500 °F] continuous oxidizing atmospheres. Good thermal conductivity. Used in applications where high temperature, but no vacuum or inert atmosphere is available.
25	**TANTALUM**[2]	X	X		X[2]	Up to 2349 °C [4350 °F]. Good resistance to corrosion and quick heat conductivity. Good mechanical strength. Used in chemical processes and high temperatures in vacuum or inert atmosphere.
26	**TITANIUM**	X	X		X	Up to 1260 °C [2300 °F] in inert or vacuum atmosphere. Acid and chemical resistant. Oxidation resistance to 538 °C [1000 °F].
27	**ALLOY 400 (UNS N04400)** 67% Nickel 30% Copper	X	X	X	X	Up to 538 °C [1000 °F] in sulfur-free atmosphere. Excellent resistance to corrosion. Used in chemical processing and food processing equipment. MONEL® 400
28	**ALLOY B (UNS N10001)** 62% Nickel 28% Molybdenum, 5% Iron	X	X Limited Avail.	X	X	Up to 815 °C [1500 °F] in inert or vacuum atmospheres. 538 °C [1000 °F] in air. Has excellent resistance to pitting, to stress-corrosion cracking. Suitable for most chemical processes. Application excellent in hydrochloric acid. (HASTELLOY® B)
29	**ALLOY C-276 (UNS N10276)** 54% Nickel 16% Molybdenum, 15% Chromium	X	X Limited Avail.	X	X	Up to 1038 °C [1900 °F] in oxidizing atmospheres. Exceptional resistance to a wide variety of chemical environments. Withstands wet chlorine gas, hypochlorite and chlorine dioxide. (HASTELLOY® C-276)
31	**NICKEL 200 (UNS N02200)** 99% Nickel		X Limited Avail.		X	Up to 899 °C [1650 °F] in sulfur-free atmospheres. Good corrosion-resistance. Used in contact with reducing acids, foods, chemicals caustics, rayon, and plastics.
32	**304 STAINLESS STEEL LOW CARBON (UNS S30403)** 18% Chromium, 8% Nickel	X	X	X	X	Same characteristics as 304 except the low carbon allows for corrosion-resistant weld areas. Not recommended to be used above 427 °C [800 °F]. (0.03% max. carbon)
33	**316 STAINLESS STEEL LOW CARBON (UNS S31603)** 16% Chromium 12% Nickel 2% Molybdenum	X	X	X	X	Same characteristics as 316 except the low carbon allows for corrosion-resistant weld areas. Not recommended to be used above 427 °C [800 °F]. (0.03% max. carbon)
35	**321 STAINLESS STEEL (UNS S32100)** 18% Chromium 10% Nickel, Titanium	X	X	X	X	Good corrosion resistance between (482 to 871) °C [900 to 1600] °F. Used where conditions are too severe for low carbon stainless steels.
36	**347 STAINLESS STEEL (UNS S34700)** 18% Chromium, 10% Nickel, Columbium	X	X Limited Avail.		X	Good corrosion resistance between (482 to 871) °C [900 to 1600] °F. Used where conditions are too severe for low carbon stainless steels.
37	**ALLOY 800 (UNS N08800)** 33% Nickel 42% Iron 21% Chromium	X	X Limited Avail.	X	X	Strong resistance to oxidation and carburization at high temperatures. Resists sulfur attack, internal oxidation, and scaling in a wide variety of atmospheres. (INCOLOY® 800)
38	**ALLOY 20 (UNS N08020)** 35% Nickel 35% Iron 20% Chromium Columbium		X Limited Avail.	X	X	Superior resistance to stress-corrosion cracking in boiling 20-40% sulfuric acid. Also used in high octane gas, solvents, explosives, heavy chemicals and agri-chemicals. (CARPENTER 20Cb-3®)
41	**HR - 160® (UNS N12160)** 37% Nickel 30% Cobalt 28% Chromium		X	X		A premier alloy that provides excellent resistance to sulphur, vanadium, chlorines, chlorides, and other salt deposits up to 1204 °C [2200 °F]. A superior material for use in aggressive waste incineration processes.

[1] Materials available in various alloys - consult factory
[2] Generally applied as a well jacket
MONEL® and INCOLOY® are registered trademarks of Special Metals Corporation
HASTELLOY® is a registered trademark of Hayman International, Inc.
20Cb-3® is a registered trademark of Carpenter Technology Corporation
HR-160® is a registered trademark of Haynes International, Inc.

Metals

CATALOG MATERIAL CODE	MATERIAL/COMPOSITION	TYPICAL AREAS OF USE				APPLICATION GUIDELINE INFORMATION
		TUBING	MGO SHEATHS	PROT. TUBES	DRILLED WELLS	
50	**ZIRCONIUM (UNS R60702)** 99.2% Zr	X		X	X	Up to 400 °C [752 °F]. Zirconium has a high affinity to oxygen that results in the formation of a regenerative protective oxide layer in most media. This oxide layer gives the material chemical resistance and erosive resistance in high velocity applications. Zirconium is resistant to corrosion from most organic and inorganic acids and salts and it is totally resistant to alkalis.
59	**F22 (UNS K21590)** Cr 2.25%, Mo 1%			X	X	Carbon steel alloy typically used in power plant, boiler and turbine applications.
60	**F11 (UNS K11572)** Cr 1.25%, Mo .5%, Si			X	X	Carbon steel alloy typically used in power plant, boiler and turbine applications.
61	**A105** C, Si				X	Carbon steel alloy typically used in power plant, boiler and turbine applications.
91	**F91 (UNS K91560)** Cr 9%, Mo 1%, V			X	X	Chrome Moly alloy typically used in power plant, boiler and turbine applications.

Ceramics and Composite Materials

CATALOG MATERIAL CODE	MATERIAL/ COMPOSITION	TYPICAL AREAS OF USE				APPLICATION GUIDELINE INFORMATION
		TUBING	MGO SHEATHS	PROT. TUBES	DRILLED WELLS	
12	**METAL CERAMIC LT-1** (slip cast composite of chromium and aluminum oxide,) 77% chromium, 23% aluminum oxide			X		Up to 1374 °C [2500 °F] in oxidizing conditions. Main areas of usage are molten copper base alloys to 1149 °C [2100 °F], blast furnace and stack gases to 1316 °C [2400 °F], Sulfur burners to 1093 °C [2000 °F], cement kilns to 1204 °C [2200 °F], chemical process reactors to 1371 °C [2500 °F]. A ceramic primary tube is required when a noble metal thermocouple is used.
13	**VESUVIUS**			X		Up to 927 °C [1700 °F]. For use in aluminum and other non-ferrous metals. Not wetted by molten aluminum and other non-ferrous metals. No contamination. Resists thermal and mechanical shock. Brittle after heating. Handle carefully.
14	**CERITE®-II** (Cast oxide composites)			X		Up to 1093 °C [2000 °F]. For submerged use in aluminum and other non-ferrous metals. Not wetted by molten aluminum and other non-ferrous metals. No contamination. Good thermal and mechanical shock resistance.
15	**CERITE®-III** (Cast oxide composites)			X		Up to 1093 °C [2000 °F]. For submerged use in aluminum and other non-ferrous metals. Not wetted by molten aluminum and other non-ferrous metals. No contamination. Good thermal and mechanical shock resistance.
16	**MULLITE** 63% alumina			X		Up to 1510 °C [2750 °F] when supported. Has poor mechanical shock resistance, but good thermal shock resistance. For barium chloride salt baths to 1288 °C [2350 °F]. Should be vertical mounted or supported if horizontal. For high temperature applications of ceramic industry, heat treating, glass manufacture. Impervious to gases at high temperatures.
17	**ALUMINA** (Recrystallized 99.7% AL_2O_3)			X		Up to 1889 °C [3400 °F] when supported. Has only fair resistance to thermal and mechanical shock. Essentially same applications as Mullite including induction melting, vacuum furnaces. Impervious to gases at high temperatures.
18	**SILICON CARBIDE** 90% silicon carbide, 9% silicon dioxide, balance aluminum oxide			X		Up to 1650 °C [3000 °F]. For an outer protection tube with Alumina® or mullite primary tube. For brick and ceramic kilns, steel soaking pits, molten non-ferrous metals. Can withstand direct flame impingement. Fair thermal shock resistance. Approximately 14% porosity.
19	**HEXOLOY® SA** sintered alpha, silicon carbide			X		Up to 1650 °C [3000 °F] in air. High thermal conductivity, excellent wear and abrasion resistance, high thermal shock resistance, and good mechanical strength. Superior chemical resistance in both reducing and oxidizing environments. Attacked by Halides, fused caustics, and ferrous metals.
71	**RECRYSTALLIZED SILICON CARBIDE** (Halsic R) 99% silicon			X		Up to 1600 °C [2912 °F] in oxidizing atmosphere, and 2000 °C [3632 °F] in a vacuum atmosphere. Used as an outer protection tube in hot stack emissions, combustion chambers, chemical reactors, and incineration of medical, municipal, and industrial waste. Can withstand direct flame impingement, has excellent thermal shock characteristics, and excellent corrosion resistance. A ceramic inner tube is required when used with noble metal thermocouples.

Hexoloy® is a registered trademark of Saint-Gobain Ceramics Corporation

General MgO Specifications

The information contained in the following pages is intended as a guideline only for general sensor usage. The specific application and the enviornmental conditions may require that other sensor sheath materials, diameters, or construction styles be used to provide optimum temperature measurement results. The dimensions, temperature ratings, and response times indicated are nominal, and they may vary in actual practice.

Thermocouple Types and Sizes

SHEATH DIAMETER (inches) - AWG WIRE SIZE									
TYPE	**MATERIAL**	0.020 O.D.	0.032 O.D.	0.040 O.D.	1/16 O.D.	1/8 O.D.	3/16 O.D.	1/4 O.D.	3/8 O.D.
E	Chromel-Constantan	38	35	32	30	24	21	19	15
J	Iron-Constantan	38	35	32	30	24	21	19	15
K	Chromel-Alumel	38	35	32	30	24	21	19	15
T	Copper-Constantan	38	35	32	30	24	21	19	15
N	Nicrosil-Nisil	38	35	34	-	29	21	19	15

Recommended Upper Temperature Limits For Protected Thermocouples
Upper Temperature Limits (F) For Various Sheath & Diameter Combinations

SHEATH TYPE	SHEATH MATERIAL	SHEATH DIAMETER (inches)					
		0.020, 0.032, 0.040	1/16	1/8	3/16	1/4	3/8
		TEMPERATURE RANGE					
J	*316 S.S.*	(0 to 260) °C [32 to 500] °F	(0 to 441) °C [32 to 825] °F	(0 to 521) °C [32 to 970] °F	(0 to 621) °C [32 to 1150] °F	(0 to 721) °C [32 to 1330] °F	(0 to 721) °C [32 to 1330] °F
K or N		(0 to 700) °C [0 to 1290] °F	(-200 to 921) °C [-328 to 1690] °F	(-200 to 927) °C [-328 to 1700] °F	(-200 to 927) °C [-328 to 1700] °F	(-200 to 927) °C [-328 to 1700] °F	(-200 to 927) °C [-328 to 1700] °F
E		(-200 to 260) °C [-328 to 570] °F	(-200 to 510) °C [-328 to 950] °F	(-200 to 649) °C [-328 to 1200] °F	(-200 to 732) °C [-328 to 1350] °F	(-200 to 821) °C [-328 to 1510] °F	(-200 to 821) °C [-328 to 1510] °F
T		(-200 to 260) °C [-324 to 500] °F	(-200 to 260) °C [-328 to 500] °F	(-200 to 371) °C [-328 to 700] °F	(-200 to 371) °C [-328 to 700] °F	(-200 to 371) °C [-328 to 700] °F	(-200 to 371) °C [-328 to 700] °F
K or N	*ALLOY 600*	(0 to 700) °C [0 to 1290] °F	(-200 to 921) °C [-328 to 1690] °F	(-200 to 1071) °C [-328 to 1960] °F	(-200 to 1149) °C [-328 to 2100] °F	(-200 to 1149) °C [-328 to 2100] °F	(-200 to 1149) °C [-328 to 2100] °F
E		(-200 to 300) °C [-328 to 570] °F	(-200 to 510) °C [-328 to 950] °F	(-200 to 649) °C [-328 to 1200] °F	(-200 to 732) °C [-328 to 1350] °F	(-200 to 821) °C [-328 to 1510] °F	(-200 to 821) °C [-328 to 1510] °F

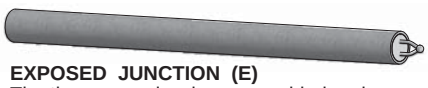
This table gives the suggested upper temperature limits for various thermocouples in several common sheath sizes. It does not address compatibility considerations between the thermoelement materials and the sheath containing them. The temperature limits given here are intended only as a guide to the purchaser and should not be taken as absolute values, nor as guarantees of satisfactory life or performance. These types and sizes are sometimes used at temperatures above the given limits, but usually at the expense of stability, life or both. In other instances, it may be necessary to reduce the given limits in order to achieve adequate service.

HOT or MEASURING JUNCTIONS and RESPONSE TIMES

UNGROUNDED JUNCTION (U)
The welded thermocouple junction is fully isolated from the welded closure of the sheath. This junction provides electrical isolation to reduce problems associated with electrical interference. Ungrounded junctions are also recommended for use in extreme positive or negative temperatures, rapid thermal cycling and for ultimate corrosion resistance of the sheath alloy. All ungrounded junctions exceed 1000 MΩ resistance @ 500 V dc at ambient room temperatures.

SHIELDED JUNCTION (S)
The thermocouple wires are welded and recessed inside the sheath with the tip of the sheath open. Insulation is not sealed against process conditions.

GROUNDED JUNCTION (G)
The thermocouple junction is welded securely into the closure end of the sheath, becoming an integral part of the weld. This is a good general purpose, low cost junction providing faster response times than an un-grounded junction of similar sheath diameter. Grounded junctions should not be used with Type T thermocouples, due to the copper wire.



EXPOSED JUNCTION (E)
The thermocouple wires are welded and exposed. The insulation is not sealed against liquid or gas penetration. Recommended where fast response is desired, and corrosive conditions are nonexistent. The exposed hot junction length for 1/8-inch diameter sheaths and above is typically 3/16" past sheath. The exposed junctions for sheath diameters less than 1/8-inch diameter are supplied as shielded junctions.

Typical Junction Response Times (63.2% of a (25 to 100) ºC Step Change)

SHEATH O.D. (inches)	"E" JUNCTION (seconds)	"G" JUNCTION (seconds)	"U" JUNCTION (seconds)
0.020	0.02 s	0.03 s	0.24 s
0.032	0.03 s	0.05 s	0.26 s
0.040	0.03 s	0.06 s	0.28 s
1/16	0.01 s	0.3 s	0.4 s
1/8	0.1 s	0.6 s	1.6 s
3/16	0.2 s	0.9 s	2.4 s
1/4	0.3 s	1.3 s	2.9 s
3/8	0.4 s	3.5 s	7.2 s

Elements of several different materials, base resistances, temperature coefficients, accuracies, and construction styles are available for installation into final RTD temperature sensor assemblies to meet customer specifications. Pyromation's standard RTD constructions utilize both thin film and wire wound elements as specified by the part number. The temperature ranges are either dictated by the construction style or element type whichever is lower. These construction styles are listed below.

LOW RANGE - THIN-FILM CONSTRUCTION (L) (-50 to 200) °C [-58 to 392] °F
The element is welded to Fluoropolymer-insulated, silver-plated copper leads, and then placed inside a specially-cleaned stainless steel sheath. The space surrounding the element and leads is filled and loosely packed with alumina oxide powder to provide good heat transfer times, and to provide a damping cushion against vibration and mechanical shock. The filled sheath is then sealed with low temperature epoxies to prevent moisture penetration.

LOW RANGE - WIRE-WOUND CONSTRUCTION (L) (-200 to 200) °C [-328 to 392] °F
The element is welded to Fluoropolymer-insulated, silver-plated copper leads, and then placed inside a specially-cleaned stainless steel sheath. The space surrounding the element and leads is filled and loosely packed with alumina oxide powder to provide good heat transfer times, and to provide a damping cushion against vibration and mechanical shock. The filled sheath is then sealed with low temperature epoxies to prevent moisture penetration.

MEDIUM RANGE - THIN-FILM CONSTRUCTION (M) (-50 to 480) °C [-58 to 896] °F
The element is welded to fiberglass-insulated, nickel-plated copper leads, and then placed inside a specially-cleaned stainless steel sheath. The space surrounding the element and leads is filled and loosely packed with alumina oxide powder to provide good heat transfer times, and to provide a damping cushion against vibration and mechanical shock. The filled sheath is then sealed with low-temperature epoxies to prevent moisture penetration.

MEDIUM RANGE - THIN-FILM CONSTRUCTION (K) (-50 to 315) °C [-58 to 599] °F
The element is welded to Polyimide-insulated, nickel-plated copper leads, and then placed inside a specially-cleaned stainless steel sheath. The space surrounding the element and leads is filled and loosely packed with alumina oxide powder to provide good heat transfer times, and to provide a damping cushion against vibration and mechanical shock. The filled sheath is then sealed with low-temperature epoxies to prevent moisture penetration.

HIGH RANGE - WIRE-WOUND CONSTRUCTION (H) (-200 to 600) °C [-328 to 1112] °F
The element is welded to nickel leads that are insulated with compacted magnesium oxide (MgO) powder inside the stainless steel sheath. The void surrounding the element is packed with MgO powder and the sheath tip is welded closed with a stainless steel cap. The leads and sheath are sealed with low-temperature epoxies to prevent moisture penetration.

HIGH RANGE - THIN-FILM CONSTRUCTION (H) (-50 to 500) °C [-58 to 932] °F
The element is welded to nickel leads that are insulated with compacted magnesium oxide (MgO) powder inside the 316 stainless steel sheath. The void surrounding the element is packed with MgO powder and the sheath tip is welded closed with a 316 stainless steel cap. The leads and sheath are sealed with low-temperature epoxies to prevent moisture penetration.

RTD Element Terminology

TEMPERATURE COEFFICIENT OF RESISTANCE: The fractional change in element resistance per change of 1 °C , is expressed as Ω/Ω/ °C or $\Omega \cdot \Omega^{-1} \cdot °C^{-1}$ or $°C^{-1}$

TOLERANCE: Initial maximum allowable deviation expressed as $\Delta t(t)$ in °C from nominal temperature/resistance relationship R(t).

SELF-HEATING: Self-heating is the rise in the measured temperature caused by the power dissipated in the element. Self-heating error is affected by the thermal conductivity and velocity of the process being measured and is negligible for most applications.

THERMAL RESPONSE: The time a thermometer takes to respond at a specified percentage to a step change in temperature. To specify response time, it is necessary to declare the percentage of response, usually $\tau_{0.9}$, $\tau_{0.5}$, or $\tau_{0.1}$, which gives 90%, 50% or 10% of the response. The test medium and its flow conditions have to be specified (usually flowing water or flowing air).

MINIMUM IMMERSION DEPTH: Immersion depth at which the change from calibration at full immersion does not exceed 0.1 °C.

REPEATABILITY-STABILITY: The ability of an element to reproduce the same resistance or temperature reading each time it is at equilibrium at a given repeated temperature. Expressed as a ± resistance or temperature value over a given temperature range. This may also be expressed as the stability of its resistance. Typically platinum elements will not change more than 0.04% at 0 °C [32 °F] after receiving ten consecutive shocks from (-200 to 600) °C [-328 to 1112] °F.

VIBRATION: Pyromation's fully assembled sheathed RTD sensors are designed to withstand an average vibration level of 30 G's using random vibrating frequencies from (20 to 2,000) Hz at ambient temperature. Supporting test results indicate that initial RTD tolerances remain as specified when tested at these vibration levels.

HUMIDITY LIMITS: Sheaths, transition fittings, and lead seals capable of withstanding 100% humidity at normal atmospheric pressure, and at normal ambient temperatures.

INTERCHANGEABILITY: The amount of allowable difference in readings between two RTD's when placed side by side in a process at the same temperature. This is determined by the allowable RTD tolerance at that particular temperature.

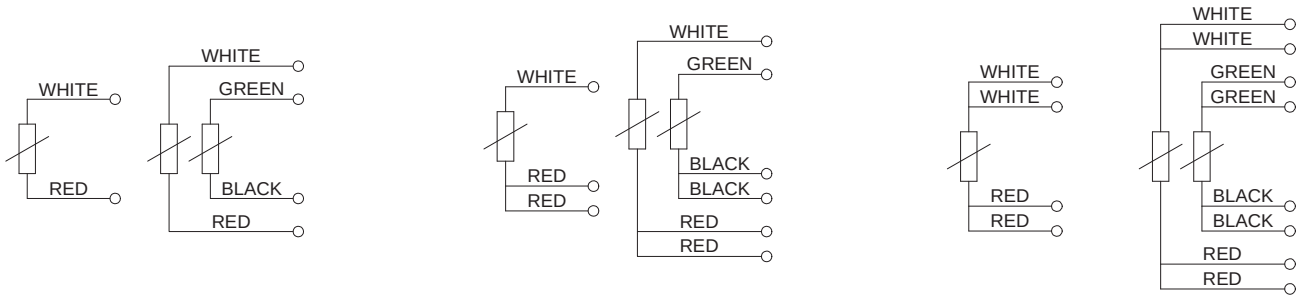
Element Connections

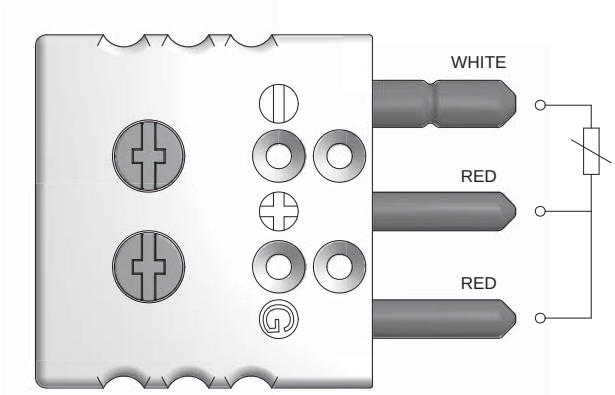
Two-Wire: Provides one connection to each end of the element. This construction is suitable where the resistance of the lead wire may be considered as an additive constant in the circuit, and particularly where the changes in lead resistance due to ambient temperature changes may be ignored.

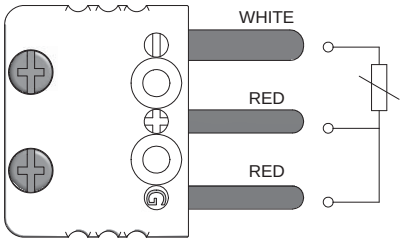
Three-Wire: Provides one connection to one end of the element and two to the other end of the element. Connected to an instrument designed to accept three wire input, sufficient compensation is usually achieved for leadwire resistance and temperature change in leadwire resistance. This is the most commonly used configuration.

Four-Wire: Provides two connections to each end of the element to completely compensate for leadwire resistance and temperature change in leadwire. This configuration is used where highly accurate temperature measurement is vital.

2-WIRE SINGLE **2-WIRE DUPLEX** **3-WIRE SINGLE** **3-WIRE DUPLEX** **4-WIRE SINGLE** **4-WIRE DUPLEX**







Lead resistance has a large effect on RTD temperature measurement accuracy. A 2-wire circuit provides no compensation and can provide large measurement errors. The following table shows the effects of leadwire resistance on temperature measurements using low-temperature RTD assemblies with copper leadwire.

Leadwire Resistance

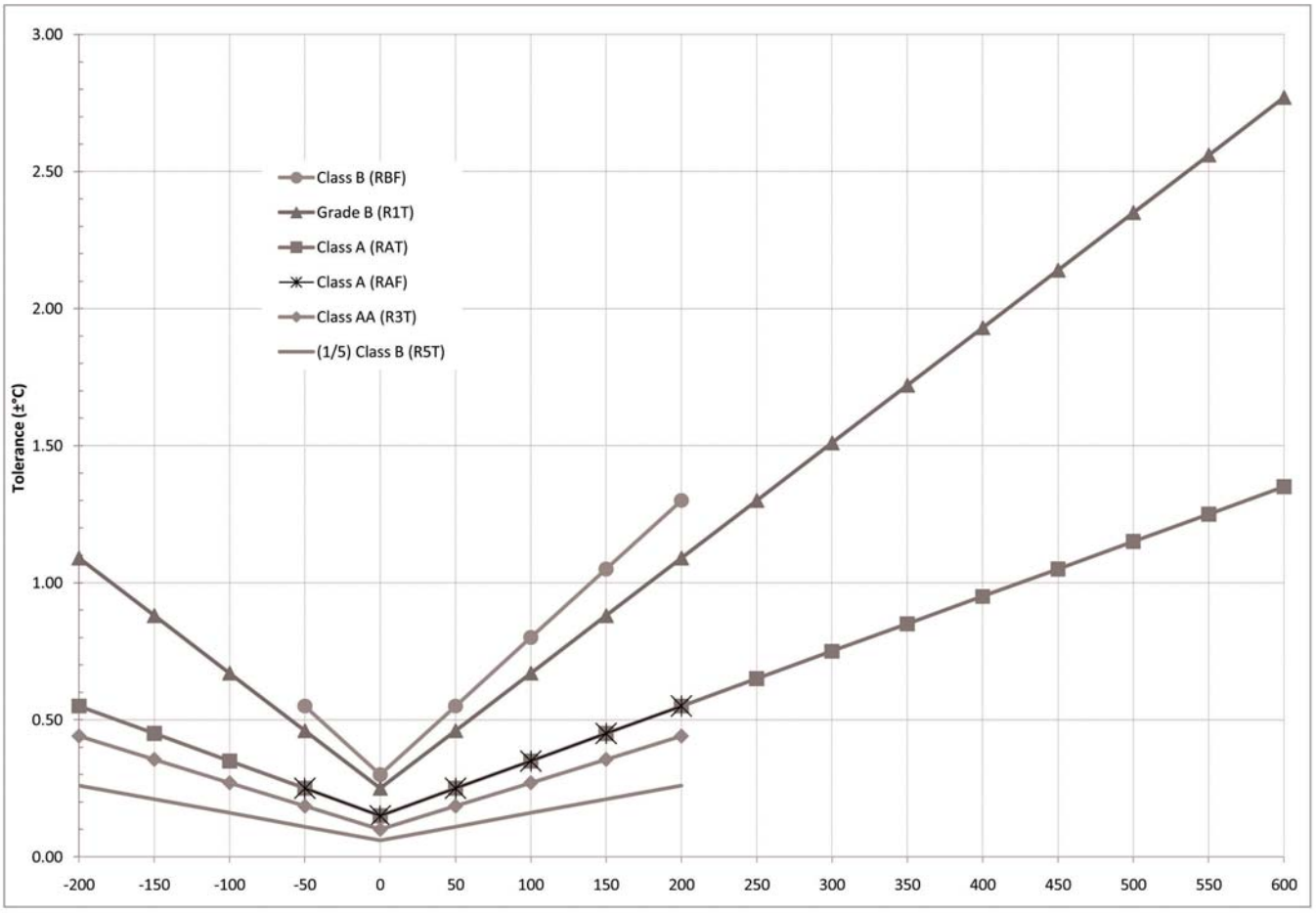
LEADWIRE-WIRE GAUGE	RESISTANCE-OHMS PER FOOT	UNCOMPENSATED 2-WIRE CIRCUITS	
		MAX. LENGTH FOR 1 °F ERROR @ 20 °C [68 °F]	ERROR IN °F PER DOUBLE FT.
30	0.133	0.81 ft	1.24 °F
28	0.0851	1.26 ft	0.79 °F
24	0.0333	3.2 ft	0.31 °F
22	0.0213	5.1 ft	0.198 °F
20	0.0148	7.27 ft	0.14 °F
18	0.0083	13.0 ft	0.077 °F
16	0.0052	20.7 ft	0.048 °F

STANDARD PLATINUM RTD ASSEMBLIES - Pyromation standard RTD assemblies are constructed using either wire-wound platinum elements or thin-film elements with a reference resistance of 100 ohms at 0 °C, a temperature coefficient 0.003 85 $°C^{-1}$ and which are in accordance with the following standards:

1. International Standard, IEC 60751 2. American Standard, ASTM E1137

TEMPERATURE		IEC CLASS B [1] ± (0.12% × R_O) Ω		ASTM GRADE B [1] ± (0.1% × R_O) Ω		IEC CLASS A [1] ± (0.06% × R_O) Ω		IEC CLASS AA [1] ± (0.04% × R_O) Ω		(1/5) IEC CLASS B [2] ± (0.02% × R_O) Ω	
		± (0.3 + 0.005 |t|) °C		± (0.25 + 0.0042 |t|) °C		± (0.15 + 0.002 |t|) °C		± (0.1 + 0.0017 |t|) °C		± (0.06 + 0.001 |t|) °C	
°C	[°F]	°C	[°F]	°C	[°F]	°C	[°F]	°C	[°F]	°C	[°F]
-200	[-328]			1.09	[1.96]	0.55	[0.99]	0.44	[0.79]	0.26	[0.47]
-100	[-148]			0.67	[1.21]	0.35	[0.63]	0.27	[0.49]	0.16	[0.29]
-50	[-58]	.55	[0.99]	0.46	[0.83]	0.25	[0.45]	0.19	[0.34]	0.11	[0.20]
0	[32]	.30	[0.54]	0.25	[0.45]	0.15	[0.27]	0.10	[0.18]	0.06	[0.11]
100	[212]	.80	[1.44]	0.67	[1.21]	0.35	[0.63]	0.27	[0.49]	0.16	[0.29]
200	[392]	1.3	[2.34]	1.09	[1.96]	0.55	[0.99]	0.44	[0.79]	0.26	[0.47]
300	[572]	1.8	[3.24]	1.51	[2.72]	0.75	[1.35]				
400	[752]	2.3	[4.14]	1.93	[3.47]	0.95	[1.71]				
500	[932]	2.8	[5.04]	2.35	[4.23]	1.15	[2.07]				
600	[1112]			2.77	[4.99]	1.35	[2.43]				

Where: |t| = value of temperature without regard to sign, °C
[1] The equations represent values for 3- and 4-wire PRTs. Caution must be exercised with 2-wire PRTs due to lead resistance.
[2] This tolerance can only be met with a 4-wire PRT.



Leadwire Transition Fitting Dimensions

CODE	SHEATH DIAMETERS (inches)	FITTING O.D. (inches)	FITTING LENGTH	
			W/SPRING (inches)	W/O SPRING (inches)
15,16,19	0.020	3/8	2 (5/8)	1 (3/16)
15,16,19	0.032	3/8	2 (5/8)	1 (3/16)
15,16,19	0.040	3/8	2 (5/8)	1 (3/16)
15,16,19	1/16	1/4	2 (5/8)	1 (3/16)
15,16,19	1/16[1]	3/8	2 (5/8)	1 (3/16)
15,16,19	1/8	1/4	2 (5/8)	1 (3/16)
15,16,19	1/8[1]	3/8	2 (5/8)	1 (3/16)
15,16,19	3/16	3/8	2 (5/8)	1 (3/16)
15,16,19	1/4	3/8	2 (5/8)	1 (3/16)
15,16,19	3/8	7/16	2 (5/8)	1 (3/16)

[1] Used with flexible armor tubing, duplex T/C's, and wire codes P3, P1, and F3

Compression Fitting Pressure Rating Table

CODE	05A	05A, 05B, 05C	05A, 05B	05A, 05B, 05C	05B, 05C
Sheath O.D. & Wall Thickness	1/6" O.D. x 0.0077"	1/8" O.D. x 0.012"	3/16" O.D. x 0.020"	1/4" O.D. x 0.028"	3/8" O.D. x 0.049"
TEMPERATURE	MAXIMUM ALLOWANCE WORKING PRESSURE (PSIG)				
(-29 to 149) ºC [-20 to 300] ºF	3300	2850	3150	3350	3900
204 ºC [400 ºF]	3200	2750	3050	3250	3800
260 ºC [500 ºF]	3000	2550	2850	3000	3500
316 ºC [600 ºF]	2800	2400	2700	2850	3300
371 ºC [700 ºF]	2700	2350	2600	2750	3200
427 ºC [800 ºF]	2650	2300	2550	2650	3100
482 ºC [900 ºF]	2600	2200	2450	2600	3050
538 ºC [1000 ºF]	2400	2100	2300	2450	2850

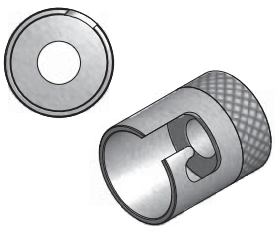
Calculations are based on the following criteria: 316 stainless steel sheath, ultimate tensil stress of 75,000 PSI for seamless tube, Conservative Barlow Formula and safety factor of 4.0.

Sheath Mounting Fitting Dimensions

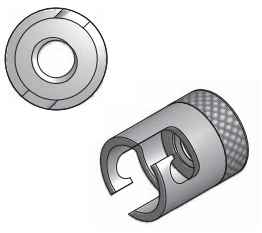
CODE	STYLE	SHEATH O.D. (inches)	NPT SIZE (inches)	LENGTH (inches)
01A	303 SS one-time adjustable	1/16, 1/8, 3/16, 1/4	1/8	1 5/16
05A	316 SS one-time adjustable	1/16, 1/8, 3/16, 1/4	1/8	1 1/4
05B	316 SS one-time adjustable	1/8, 3/16, 1/4, 3/8	1/4	1 7/8
05C	316 SS one-time adjustable	1/8, 1/4, 3/8	1/2	1 13/16
15A	Brass one-time adjustable	1/8, 3/16, 1/4	1/8	1 1/4
15B	Brass one-time adjustable	3/16, 1/4, 3/8	1/4	1 3/8
15C	Brass one-time adjustable	1/4, 3/8	1/2	1 1/2
10A	303 SS re-adjustable	1/16, 1/8, 3/16	1/8	1 1/4
10B	303 SS re-adjustable	1/4, 3/8	1/4	2 7/16
10C	303 SS re-adjustable	1/4, 3/8	1/2	2 7/16
12A	316 SS re-adjustable	1/16, 1/8, 3/16, 1/4	1/8	1 1/4
12B	316 SS re-adjustable	1/8, 3/16, 1/4, 3/8	1/4	1 1/2
12C	316 SS re-adjustable	1/8, 1/4, 3/8	1/2	1 3/4
11A	Brass re-adjustable	1/16, 1/8, 3/16, 1/4	1/8	1 19/64
11B	Brass re-adjustable	1/8, 3/16, 1/4, 3/8	1/4	1 9/16
11C	Brass re-adjustable	1/4, 3/8	1/2	1 13/16
19C	303 SS spring-loaded well ftg.	3/16, 1/4	1/2	2 1/4
8A	316 SS fixed bushing	All sizes	1/8	5/8
8B	316 SS fixed bushing	All sizes	1/4	11/16
8C	316 SS fixed bushing	All sizes	1/2	15/16
8D	316 SS fixed bushing	All sizes	3/4	1
6HN	Steel hex fitting	1/8, 3/16, 1/4, 3/8	1/2	2
8HN	316 SS hex fitting	1/8, 3/16, 1/4, 3/8	1/2	2
8RNDC	316 SS reducing hex fitting	1/8, 3/16, 1/4, 3/8	3/4 x 1/2	2
9HNB	303 SS hex fitting	1/8, 3/16, 1/4, 3/8	1/4	1 3/16
13A	Fixed bayonet fitting	1/8, 3/16	N/A	1 5/8
14	Adjustable flange	1/8, 3/16, 1/4, 3/8	N/A	1 1/2
16A	Adustable bayonet fitting	1/8	N/A	1 5/8

Bayonet Caps

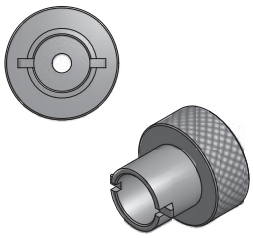
7/16" I.D. single slot
Order code: A



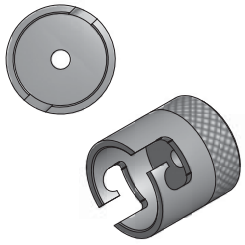
12 mm I.D. double slot
Order code: B



12 mm O.D. dual pin
Order code: C



15 mm I.D. double slot
Order code: E



Corrosive Service Guide to Materials for Sheaths and Thermowells
Refer to A.S.M.E. Boiler Code, Section VIII for allowable stress levels
(Fluoropolymer coated thermowells and/or Fluoropolymer sheaths may be substituted for all corrosive agents listed)

CORROSIVE AGENT	TEMP. ºC	TEMP. °F	CONC. %	RECOM. MATERIAL	CORROSIVE AGENT	TEMP. ºC	TEMP. °F	CONC. %	RECOM. MATERIAL
Acetic Acid (Glacial)	199	[390]	ALL	316 SS	Chlorine (Gas)	93	[200]	ALL	Monel®
Acetic Acid	143	[290]	80%	Hast. C		199	[390]	ALL	316 SS[1]
	199	[390]	50%	316 SS	Chlorine (Gas - Moist)	66	[150]	ALL	Hast C
	143	[290]	80%	Carp. 20[1]	Chloroacetic Acid	182	[360]	ALL	Hast. B
Acetic Anhydride	132	[270]	ALL	Hast. C	Chloroform	93	[200]	ALL	Nickel
	199	[390]	ALL	316 SS[1]		93	[200]	ALL	Carp. 20[1]
Acetone	199	[390]	ALL	316 SS	Chromic Acid	93	[200]	50%	Titanium
Acetylene	199	[390]	ALL	304 SS		93	[200]	50%	Hast. C[1]
Alcohol, Ethyl	93	[200]	ALL	Hast. C	Citric Acid	127	[260]	ALL	Hast. C
	199	[390]	ALL	316 SS[1]		93	[200]	ALL	Carp. 20[1]
Aluminum Chloride (Aqueous)	143	[290]	ALL	Hast. B	Copper Chloride	88	[190]	ALL	Titanium
	143	[290]	ALL	Nickel[1]		88	[190]	ALL	Hast. C[1]
Aluminum Nitrate (Saturated)	93	[200]	ALL	446 SS	Copper Nitrate	149	[300]	ALL	304 SS
	88	[190]	ALL	316 SS[1]	Copper Sulfate	93	[200]	ALL	Hast. C
Aluminum Sulfate (Saturated)	93	[200]	ALL	Titanium		199	[390]	ALL	316 SS[1]
	93	[200]	ALL	316 SS[1]	Corn Oil	238	[460]	ALL	TFE
Ammonia (Anhydrous)	293	[560]	ALL	316 SS		193	[380]	ALL	FEP
Ammonia (Gas)	93	[200]	ALL	304 SS		171	[340]	ALL	316 SS[1]
Ammonium Chloride	88	[190]	ALL	Titanium	Crude Oil	93	[200]	ALL	304 SS
	293	[560]	ALL	Nickel[1]	Cyanogen Gas	238	[460]	ALL	TFE
	71	[160]	50%	Nickel		193	[380]	ALL	FEP
Ammonium Hydroxide	27	[80]	ALL	Steel		171	[340]	ALL	316 SS[1]
	82	[180]	ALL	Steel[1]	Ether	88	[190]	ALL	304 SS
Ammonium Nitrate	93	[200]	ALL	Carp. 20	Ethyl Acetate	93	[200]	ALL	Titanium
Ammonium Sulfate	93	[200]	SAT.	Hast. B		199	[390]	ALL	316 SS[1]
	143	[290]	SAT.	304 SS[1]	Ethyl Chloride (Dry)	293	[560]	ALL	316 SS
	93	[200]	10 - 40%	Titanium	Ethylene Glycol	93	[200]	ALL	Carp. 20
	199	[390]	10 - 40%	316 SS[1]		93	[200]	ALL	304 SS[1]
Amyl Acetate	143	[290]	ALL	304 SS	Ethylene Oxide	21	[70]	ALL	Hast. C
Aniline	254	[490]	ALL	304 SS		199	[390]	ALL	316 SS[1]
Barium Chloride (Saturated)	93	[200]	ALL	Hast. C	Fatty Acids	199	[390]	ALL	316 SS
	293	[560]	ALL	Inconel®[1]	Ferric Chloride	143	[290]	ALL	Titanium
Barium Hydroxide (Saturated)	104	[220]	50%	Carp. 20		27	[80]	ALL	Hast. C[1]
	199	[390]	ALL	316 SS[1]	Ferric Sulfate	49	[120]	ALL	Carp. 20
Beer	88	[190]		304 SS		88	[190]	10%	316 SS
Benzene (Benzol)	104	[220]	ALL	Carp. 20	Ferrous Sulfate	27	[80]		Titanium
	104	[220]	ALL	304 SS[1]		93	[200]	ALL	304 SS[1]
Benzoic Acid	199	[390]	ALL	Titanium	Formaldehyde	49	[120]	ALL	304 SS
	199	[390]	ALL	304 SS[1]		49-293	[120-560]	50%	304 SS[1]
Black Liquor	238	[460]	ALL	TFE	Formic Acid (Anhydrous)	93	[200]	50%	Carp. 20
	193	[380]	ALL	FEP	Freon (F-11)	204	[400]	ALL	Monel®
	93	[200]	ALL	Carp. 20[1]		204	[400]	ALL	316 SS[1]
Bleach (Active Chlorine)	60	[140]	12.5%	Hast. C	Furfural	199	[390]	ALL	Nickel
Borax	199	[390]	ALL	316 SS		199	[390]	ALL	304 SS[1]
Boric Acid	293	[560]	ALL	Hast. C	Gallic Acid	238	[460]	ALL	TFE
	93	[200]	ALL	Nickel[1]		193	[380]	ALL	FEP
Brine Acid	60	[140]	ALL	Hast. C		199	[390]	ALL	316 SS[1]
	27	[80]	ALL	Brass[1]	Gasoline (Unleaded)	154	[310]	ALL	Hast. C
Bromine (Liquid)	293	[560]	ALL	Tantalum		16	[60]		446 SS
	93	[200]	ALL	Aluminum[1]		171	[340]		Steel[1]
Butane	171	[340]	ALL	Steel		238	[460]		TFE
Butyl Acetate	93	[200]	ALL	Titanium	Gasoline (Refined)	193	[380]		FEP
	188	[370]	ALL	316 SS[1]		88	[190]		Steel[1]
Butyl Alcohol	199	[390]	ALL	316 SS		27	[80]	ALL	Nickel
Butyric Acid	143	[290]	ALL	Carp. 20	Glucose	193	[380]	ALL	316 SS[1]
	199	[390]	ALL	316 SS[1]		27	[80]	ALL	Hast. B
Calcium Bisulfite	93	[200]	ALL	TFE	Glue	60	[140]	ALL	Steel[1]
	193	[380]	ALL	FEP		127	[260]	ALL	304 SS
	171	[340]	ALL	316 SS[1]	Glycerine	88	[190]	50%	Titanium
Calcium Chlorate	238	[460]	ALL	TFE	Hydrobromic Acid	121	[250]	50%	Hast. B[1]
	193	[380]	ALL	FEP		60	[140]	38%	Hast. B
	93	[200]	ALL	316 SS[1]	Hydrochloric Acid	238	[460]	ALL	TFE
Calcium Chloride (Saturated)	171	[340]	ALL	Hast. C	Hydrocyanic Acid	193	[380]	ALL	FEP
	93	[200]	ALL	Carp. 20[1]		171	[340]	ALL	316 SS[1]
Calcium Hydroxide	93	[200]	50%	Hast. C		238	[460]	ALL	TFE
	88	[190]	SAT.	304 SS[1]	Hydroflouric Acid	193	[380]	ALL	FEP
Carbonic Acid	293	[560]	ALL	Carp. 20		93	[200]	ALL	Hast. C[1]
	171	[340]	ALL	316 SS[1]		293	[560]	ALL	Carp. 20
Carbon Dioxide (Dry)	427	[800]	ALL	Brass	Hydrogen Chloride (Gas, Dry)	38	[100]	ALL	304 SS
Carbonated Beverages	100	[212]	ALL	304 SS	Hydrogen Flouride (Dry)	199	[390]	ALL	304 SS[1]
Carbon Disulfide	93	[200]	ALL	Titanium		88	[190]	90%	Hast. C
	199	[390]	ALL	316 SS[1]	Hydrogen Peroxide	71	[160]	ALL	316 SS
Carbon Tetrachloride	93	[200]	ALL	304 SS	Hydrogen Sulfide (Dry)	293	[560]	ALL	316 SS

All materials listed are rated < 2 Mils penetration/year except as noted: [1] = < 20 Mils penetration/year

Monel® and Inconel® are registered trademarks of Special Metals Corporation.

Corrosive Service Guide to Materials for Sheaths and Thermowells

Refer to A.S.M.E. Boiler Code, Section VIII for allowable stress levels
(Fluoropolymer coated thermowells and/or Fluoropolymer sheaths may be substituted for all corrosive agents listed)

CORROSIVE AGENT	TEMP. °C	TEMP. °F	CONC. %	RECOM. MATERIAL
Iodine	83	[190]	ALL	Hast. C
	21	[70]	ALL	Nickel
Kerosene	238	[460]	ALL	TFE
	193	[380]	ALL	FEP
	171	[340]		Steel[1]
Ketones	32	[90]	ALL	Hast. C
	127	[260]	ALL	316 SS[1]
Lactic Acid	154	[310]	ALL	Titanium
	116	[240]	ALL	Hast. B[1]
Lime (Sulfur)	238	[460]	ALL	TFE
	193	[380]	ALL	FEP
	154	[310]	ALL	316 SS[1]
Linseed Oil	60	[140]	ALL	Carp. 20
	27	[80]	ALL	Steel[1]
Magnesium Chloride	143	[290]	ALL	Nickel
	88	[190]	50%	Carp. 20[1]
Magnesium Hydroxide	93	[200]	ALL	304 SS
Magnesium Sulfate	93	[200]	60%	Nickel
	171	[340]	ALL	316 SS[1]
Mercuric Chloride	143	[290]	ALL	Tantalum
	77	[170]	10%	Hast. C[1]
Mercury	293	[560]	ALL	304 SS
Methyl Chloride (Dry)	171	[340]	ALL	316 SS
Methylene Chloride	93	[200]	ALL	Carp. 20
Milk	93	[200]		304 SS
Naphtha	16	[60]	ALL	446 SS
	116	[240]	ALL	304 SS[1]
Natural Gas	238	[460]		TFE
	193	[380]		FEP
	43	[110]		Steel[1]
Nickel Chloride	93	[200]	80%	Hast. C
Nickel Sulfate	82	[180]	10%	Tantalum
	93	[200]	ALL	304 SS[1]
Nitric Acid	21	[70]	ALL	304 SS
	93	[200]	40%	304 SS
Nitrobenzene	143	[290]	ALL	Carp. 20
	171	[340]	ALL	316 SS[1]
Oleic Acid	138	[280]	ALL	316 SS
Oleum	49	[120]	40%	Hast. C
	116	[240]	ALL	316 SS[1]
Oxalic Acid	93	[200]	ALL	Tantalum
	93	[200]	ALL	Carp. 20[1]
Oxygen	271	[520]	ALL	Tantalum
	16	[60]	ALL	446 SS
	171	[340]	ALL	316 SS[1]
Palmitic Acid	238	[460]	ALL	TFE
	193	[380]	ALL	FEP
	199	[390]	ALL	304 SS[1]
Phenol (Carbolic Acid)	293	[560]	ALL	316 SS
Phosphoric Acid	93	[200]	50-85%	Hast. C
Phosphoric	43	[110]	50-85%	Carp. 20
	171	[340]	ALL	316 SS
Phosphoric Solutions	27	[80]	ALL	Titanium
Picric Acid	21	[70]	ALL	Aluminum
	199	[390]	ALL	316 SS[1]
Potassium Bromide	93	[200]	30%	Titanium
	93	[200]	30%	446 SS
Potassium Carbonate	93	[200]	50%	304 SS
Potassium Chlorate	171	[340]	30%	316 SS
Potassium Hydroxide	93	[200]	50%	Nickel
Potassium Nitrate	171	[340]	80%	Aluminum
	277	[530]	80%	446 SS[1]
Potassium Permanganate	21	[70]	20%	Hast C.
	171	[340]	20%	316 SS[1]
Potassium Sulfate	171	[340]	10%	316 SS
Propane	60	[140]	ALL	446 SS
	27	[80]	ALL	Brass
Pyrogallic Acid	27	[80]	ALL	Copper
	171	[340]	ALL	316 SS[1]
Salicylic Acid	116	[240]	ALL	Hast. C
	171	[340]	ALL	316 SS[1]
Sea Water (Stagnant)				Monel®
Sea Water (Cavitation)				316 SS
Soap Solutions	16	[60]	ALL	446 SS
	54	[130]	ALL	Nickel[1]
Sodium Bicarbonate	171	[340]	20%	316 SS
Sodium Bisulfite	71	[160]	10%	316 SS
	93	[200]	10 - 40%	Carp. 20
Sodium Carbonate	93	[200]	30%	Carp. 20
	293	[560]	10-100%	Hast. B[1]
Sodium Chloride	27	[80]	30%	Nickel
Sodium Flouride	71	[160]	ALL	Monel®
	77	[170]	ALL	Carp. 20[1]
Sodium Hydroxide	104	[220]	ALL	Monel®
	71	[160]	ALL	316 SS[1]
Sodium Nitrate	171	[340]	60%	316 SS
Sodium Nitrite	93	[200]	Saturated	Titanium
	93	[200]	40%	304 SS[1]
Sodium Peroxide	16	[60]	10%	446 SS
	171	[340]	10%	316 SS[1]
Sodium Phosphate Acid	93	[200]	ALL	Titanium
	93	[200]	ALL	304 SS[1]
Sodium Silicate	27	[80]	ALL	446 SS[1]
	166	[330]	ALL	316 SS[1]
Sodium Sulfate	199	[390]	ALL	316 SS
Sodium Sulfide	238	[460]	50%	TFE
	193	[380]	50%	FEP
	93	[200]	50%	316 SS[1]
Sodium Sulfite	93	[200]	10%	304 SS
Sodium Thiosulfate	16	[60]	25%	446 SS
	116	[240]	ALL	316 SS[1]
Steam (Low Pressure)				Inconel
				304 SS[1]
(Medium Pressure)				Nickel
				304 SS[1]
(High Pressure)				316 SS[1]
Sulfur	293	[560]	ALL	304 SS
	871	[1600]	ALL	Alloy 556
Sulfur Chloride (Dry)	32	[90]	ALL	Tantalum
	293	[560]	ALL	Nickel[1]
Sulfur Dioxide (Dry)	49	[120]	ALL	Steel
	293	[560]	ALL	316 SS[1]
Sulfur Trioxide (Dry)	238	[460]	ALL	TFE
	193	[380]	ALL	FEP
	293	[560]	ALL	304 SS[1]
Sulfuric Acid	38	[100]	100%	Carp. 20
	121	[250]	60%	Hast. B
Sulfurous Acid	71	[160]	ALL	Titanium
	177	[350]	ALL	Carp. 20[1]
Tannic Acid	93	[200]	10 - 20%	Titanium
	93	[200]	ALL	304 SS[1]
Tartaric Acid	199	[390]	ALL	304 SS
Titanium Tetrachloride	27	[80]	ALL	Carp. 20
	138	[280]	ALL	Titanium
Toluene (Toluol)	171	[340]	ALL	Steel
	93	[200]	ALL	304 SS
Trichloroacetic Acid	238	[460]	ALL	TFE
	193	[380]	ALL	FEP
	93	[200]	ALL	Hast. C[1]
Trichloroethylene	71	[160]	ALL	Inconel®
Turpentine	88	[190]	ALL	304 SS
Whiskey and Wine			ALL	304 SS
Xylene (Xylol)	88	[190]	ALL	446 SS
Zinc Chloride	82	[180]	to 70%	Titanium
	293	[560]	ALL	Hast. B[1]
Zinc Sulfate	93	[200]	SAT.	316 SS

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All materials listed are rated < 2 Mils penetration/year except as noted: [1] = < 20 Mils penetration/year

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Fahrenheit and Celsius Conversion Chart

Read known temperature in bold face type. Corresponding temperature in degrees Fahrenheit will be found in column to the right. Corresponding temperature in degrees Celsius will be found in column to the left.

INTERPOLATION FACTORS

°C		°F	°C		°F
0.56	1	1.8	3.33	6	10.8
1.11	2	3.6	3.89	7	12.6
1.67	3	5.4	4.44	8	14.4
2.22	4	7.2	5.00	9	16.2
2.78	5	9.0	5.56	10	18.0

TEMPERATURE CONVERSION FORMULA

°C = (°F - 32) ÷ 1.8

°F = (°C x 1.8) + 32

0 to 100						100 to 1000						1000 to 2000						2000 to 3000					
°C		°F	°C		°F	°C		°F	°C		°F	°C		°F	°C		°F	°C		°F	°C		°F
-17.8	**0**	32.	10.0	**50**	122.0	38	**100**	212	260	**500**	932	538	**1000**	1832	816	**1500**	2732	1093	**2000**	3632	1371	**2500**	4532
-17.8	**1**	33.8	10.6	**51**	123.8	43	**110**	230	266	**510**	950	543	**1010**	1850	821	**1510**	2750	1099	**2010**	3650	1377	**2510**	4550
-16.7	**2**	35.6	11.1	**52**	125.6	49	**120**	248	271	**520**	968	549	**1020**	1868	827	**1520**	2768	1104	**2020**	3668	1382	**2520**	4568
-16.1	**3**	37.4	11.7	**53**	127.4	54	**130**	266	277	**530**	986	554	**1030**	1886	832	**1530**	2786	1110	**2030**	3686	1388	**2530**	4586
-15.6	**4**	39.2	12.2	**54**	129.2	60	**140**	284	282	**540**	1004	560	**1040**	1904	838	**1540**	2804	1116	**2040**	3704	1393	**2540**	4604
-15.0	**5**	41.0	12.8	**55**	131.0	66	**150**	302	288	**550**	1022	566	**1050**	1922	843	**1550**	2822	1121	**2050**	3722	1399	**2550**	4622
-14.4	**6**	42.8	13.3	**56**	132.8	71	**160**	320	293	**560**	1040	571	**1060**	1940	849	**1560**	2840	1127	**2060**	3740	1404	**2560**	4640
-13.9	**7**	44.6	13.9	**57**	134.6	77	**170**	338	299	**570**	1058	577	**1070**	1958	854	**1570**	2858	1132	**2070**	3758	1410	**2570**	4658
-13.3	**8**	46.4	14.4	**58**	136.4	82	**180**	356	304	**580**	1076	582	**1080**	1976	860	**1580**	2876	1138	**2080**	3776	1416	**2580**	4676
-12.8	**9**	48.2	15.0	**59**	138.2	88	**190**	374	310	**590**	1094	588	**1090**	1994	866	**1590**	2894	1143	**2090**	3794	1421	**2590**	4694
-12.2	**10**	50.0	15.6	**60**	140.0	93	**200**	392	316	**600**	1112	593	**1100**	2012	871	**1600**	2912	1149	**2100**	3812	1427	**2600**	4712
-11.7	**11**	51.8	16.1	**61**	141.8	99	**210**	410	321	**610**	1130	599	**1110**	2030	877	**1610**	2930	1154	**2110**	3830	1432	**2610**	4730
-11.1	**12**	53.6	16.7	**62**	143.6	100	**212**	413	327	**620**	1148	604	**1120**	2048	882	**1620**	2948	1160	**2120**	3848	1438	**2620**	4748
-10.6	**13**	55.4	17.2	**63**	145.4	104	**220**	428	332	**630**	1166	610	**1130**	2066	888	**1630**	2966	1166	**2130**	3866	1443	**2630**	4766
-10.0	**14**	57.2	17.8	**64**	147.2	110	**230**	446	338	**640**	1184	616	**1140**	2084	893	**1640**	2984	1171	**2140**	3884	1449	**2640**	4784
-9.44	**15**	59.0	18.3	**65**	149.0	116	**240**	464	343	**650**	1202	621	**1150**	2102	899	**1650**	3002	1177	**2150**	3902	1454	**2650**	4802
-8.89	**16**	60.8	18.9	**66**	150.8	121	**250**	482	349	**660**	1220	627	**1160**	2120	904	**1660**	3020	1182	**2160**	3920	1460	**2660**	4820
-8.33	**17**	62.6	19.4	**67**	152.6	127	**260**	500	354	**670**	1238	632	**1170**	2138	910	**1670**	3038	1188	**2170**	3938	1466	**2670**	4838
-7.78	**18**	64.4	20.0	**68**	154.4	132	**270**	518	360	**680**	1256	638	**1180**	2156	916	**1680**	3056	1193	**2180**	3956	1471	**2680**	4856
-7.22	**19**	66.2	20.6	**69**	156.2	138	**280**	536	366	**690**	1274	643	**1190**	2174	921	**1690**	3074	1199	**2190**	3974	1477	**2690**	4874
-6.67	**20**	68.0	21.1	**70**	158.0	143	**290**	554	371	**700**	1292	649	**1200**	2192	927	**1700**	3092	1204	**2200**	3992	1482	**2700**	4892
-6.11	**21**	69.8	21.7	**71**	159.8	149	**300**	572	377	**710**	1310	654	**1210**	2210	932	**1710**	3110	1210	**2210**	4010	1488	**2710**	4910
-5.56	**22**	71.6	22.2	**72**	161.6	154	**310**	590	382	**720**	1328	660	**1220**	2228	938	**1720**	3128	1216	**2220**	4028	1493	**2720**	4928
-5.00	**23**	73.4	22.8	**73**	163.4	160	**320**	608	388	**730**	1346	666	**1230**	2246	943	**1730**	3146	1221	**2230**	4046	1499	**2730**	4946
-4.44	**24**	75.2	23.3	**74**	165.2	166	**330**	626	393	**740**	1364	671	**1240**	2264	949	**1740**	3164	1227	**2240**	4064	1504	**2740**	4964
-3.89	**25**	77.0	23.9	**75**	167.0	171	**340**	644	399	**750**	1382	677	**1250**	2282	954	**1750**	3182	1232	**2250**	4082	1510	**2750**	4982
-3.33	**26**	78.8	24.4	**76**	168.8	177	**350**	662	404	**760**	1400	682	**1260**	2300	960	**1760**	3200	1238	**2260**	4100	1516	**2760**	5000
-2.78	**27**	80.6	25.0	**77**	170.6	182	**360**	680	410	**770**	1418	688	**1270**	2318	966	**1770**	3218	1243	**2270**	4118	1521	**2770**	5018
-2.22	**28**	82.4	25.6	**78**	172.4	188	**370**	698	416	**780**	1436	693	**1280**	2336	971	**1780**	3236	1249	**2280**	4136	1527	**2780**	5036
-1.67	**29**	84.2	26.1	**79**	174.2	193	**380**	716	421	**790**	1454	699	**1290**	2354	977	**1790**	3254	1254	**2290**	4154	1532	**2790**	5054
-1.11	**30**	86.0	26.7	**80**	176.0	199	**390**	734	427	**800**	1472	704	**1300**	2372	982	**1800**	3272	1260	**2300**	4172	1538	**2800**	5072
-0.56	**31**	87.8	27.2	**81**	177.8	204	**400**	752	432	**810**	1490	710	**1310**	2390	988	**1810**	3290	1266	**2310**	4190	1543	**2810**	5090
0	**32**	89.6	27.8	**82**	179.6	210	**410**	770	438	**820**	1508	716	**1320**	2408	993	**1820**	3308	1271	**2320**	4208	1549	**2820**	5108
0.56	**33**	91.4	28.3	**83**	181.4	216	**420**	788	443	**830**	1526	721	**1330**	2426	999	**1830**	3326	1277	**2330**	4226	1554	**2830**	5126
1.11	**34**	93.2	28.9	**84**	183.2	221	**430**	806	449	**840**	1544	727	**1340**	2444	1004	**1840**	3344	1282	**2340**	4244	1560	**2840**	5144
1.67	**35**	95.0	29.4	**85**	185.0	227	**440**	824	454	**850**	1562	732	**1350**	2462	1010	**1850**	3362	1288	**2350**	4262	1566	**2850**	5162
2.22	**36**	96.8	30.0	**86**	186.8	232	**450**	842	460	**860**	1580	738	**1360**	2480	1016	**1860**	3380	1293	**2360**	4280	1571	**2860**	5180
2.78	**37**	98.6	30.6	**87**	188.6	238	**460**	860	466	**870**	1598	743	**1370**	2498	1021	**1870**	3398	1299	**2370**	4298	1577	**2870**	5198
3.33	**38**	100.4	31.1	**88**	190.4	243	**470**	878	471	**880**	1616	749	**1380**	2516	1027	**1880**	3416	1304	**2380**	4316	1582	**2880**	5216
3.89	**39**	102.2	31.7	**89**	192.2	249	**480**	896	477	**890**	1634	754	**1390**	2534	1032	**1890**	3434	1310	**2390**	4334	1588	**2890**	5234
4.44	**40**	104.0	32.2	**90**	194.0	254	**490**	914	482	**900**	1652	760	**1400**	2552	1038	**1900**	3452	1316	**2400**	4352	1593	**2900**	5252
5.00	**41**	105.8	32.8	**91**	195.8				488	**910**	1670	766	**1410**	2570	1043	**1910**	3470	1321	**2410**	4370	1599	**2910**	5270
5.56	**42**	107.6	33.3	**92**	197.6				493	**920**	1688	771	**1420**	2588	1049	**1920**	3488	1327	**2420**	4388	1604	**2920**	5288
6.11	**43**	109.4	33.9	**93**	199.4				499	**930**	1706	777	**1430**	2606	1054	**1930**	3506	1332	**2430**	4406	1610	**2930**	5306
6.67	**44**	111.2	34.4	**94**	201.2				504	**940**	1724	782	**1440**	2624	1060	**1940**	3524	1338	**2440**	4424	1616	**2940**	5324
7.22	**45**	113.0	35.0	**95**	203.0				510	**950**	1742	788	**1450**	2642	1066	**1950**	3542	1343	**2450**	4442	1621	**2950**	5342
7.78	**46**	114.8	35.6	**96**	204.8				516	**960**	1760	793	**1460**	2660	1071	**1960**	3560	1349	**2460**	4460	1627	**2960**	5360
8.33	**47**	116.6	36.1	**97**	206.6				521	**970**	1778	799	**1470**	2678	1077	**1970**	3578	1354	**2470**	4478	1632	**2970**	5378
8.89	**48**	118.4	36.7	**98**	208.4				527	**980**	1796	804	**1480**	2696	1082	**1980**	3596	1360	**2480**	4496	1638	**2980**	5396
9.44	**49**	120.2	37.2	**99**	210.2				532	**990**	1814	810	**1490**	2714	1088	**1990**	3614	1366	**2490**	4514	1643	**2990**	5414
			37.8	**100**	212.0				538	**1000**	1832				1093	**2000**	3632				1649	**3000**	5432