

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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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 environments, 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%	(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%	(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 2700] °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 2700] °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 ± 0.75 % 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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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	Brown Blue + Red -	+ Blue Blue - Red Red	Blue ●
	Constantan (Copper-Nickel)			
J	Iron (magnetic)	Brown White + Red -	+ White Black - Red Red	Black ●
	Constantan (Copper-Nickel)			
E	Nickel - Chromium	Brown Purple + Red -	+ Purple Purple - Red Red	Purple ●
	Constantan (Copper-Nickel)			
K	Nickel - Chromium	Brown Yellow + Red -	+ Yellow Yellow - Red Red	Yellow ○
	Nickel - Aluminium (magnetic)			
N	Nicrosil (Nickel-Chromium-Silicon)	Brown Orange + Red -	+ Orange Orange - Red Red	Orange ●
	Nisil (Nickel-Silicon-Magnesium)			
S	Platinum Rhodium -10%	None Established	+ Black Green - Red Red	Green ●
	Platinum			
R	Platinum Rhodium -13%	None Established	+ Black Green - Red Red	Green ●
	Platinum			
B	Platinum Rhodium - 30%	None Established	+ Gray Gray - Red Red (Compensated Cable)	White (Uncompensated) ○
	Platinum Rhodium - 6%			
C	Tungsten Rhenium - 5%	None Established	+ Green Red - Red Red	Red ●
	Tungsten Rhenium - 26%			

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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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 whitening 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-3 (UNS N10675) 65% Nickel 28.5% Molybdenum 1.5% Chromium 1.5% Iron	X	X Limited Avail.	X	X	Up to 600 °C [1200 °F] Exhibits extremely high resistance to pure hydrochloric, hydrobromic, and sulfuric acids. Greatly improved structural stability compared with previous B-type alloys, leading to fewer concerns during welding, fabrication, and service. Used in numerous chemical process industry applications, especially in the construction of reaction vessels for pure, reducing acid service. Poor corrosion resistance to oxidizing environments, not recommended for use in oxidizing media or in the presence of ferric or cupric salts. (HASTELLOY® B-3)
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

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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 ₂ O 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.

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The information contained in the following pages is intended as a guideline only for general sensor usage. The specific application and the environmental 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

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



UNGROUND 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. Ungrounded junctions exceed 1000 MΩ resistance @ 500 V dc at ambient room temperatures for diameters 1/16 inch and larger.



GROUND 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.



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.

Typical Junction Response Times
(63.2% of a (25 to 100) °C 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