Thermocouple Type Characteristics

Type T (COPPER vs. CONSTANTAN) is used for service in oxidizing, inert or reducing atmospheres or in vacuum. It is highly resistant to corrosion from atmospheric moisture and condensation and exhibits high stability at low temperatures.

Type J (IRON vs. CONSTANTAN) is used protected or unprotected in vacuum, oxidizing, inert or reducing atmospheres. Iron element oxidizes rapidly at temperatures exceeding 1000°F, and therefore heavier gauge wire is recommended for longer life at these temperatures.

Type E (CHROMEL vs. CONSTANTAN) May be used protected or unprotected in oxidizing, inert or dry reducing atmospheres, or for short periods of time under vacuum. Must be protected from sulfurous and marginally oxidizing atmospheres. Produces the highest EMF per degree of any standardized thermocouple.

Type K (CHROMEL™ vs. ALUMEL™) is used protected or exposed in oxidizing, inert or dry reducing atmospheres. Exposure to vacuum limited to short time periods. Must be protected from sulfurous and marginally oxidizing atmospheres. Reliable and accurate at high temperatures.

Type N (NICROSIL vs. NISIL) is used protected or exposed in oxidizing, inert or dry reducing atmospheres. Must be protected from sulfurous atmospheres. Very reliable and accurate at high temperatures.

Type S (PLATINUM - 10%, RHODIUM vs PLATINUM)

Type R (PLATINUM - 13%, RHODIUM vs PLATINUM)

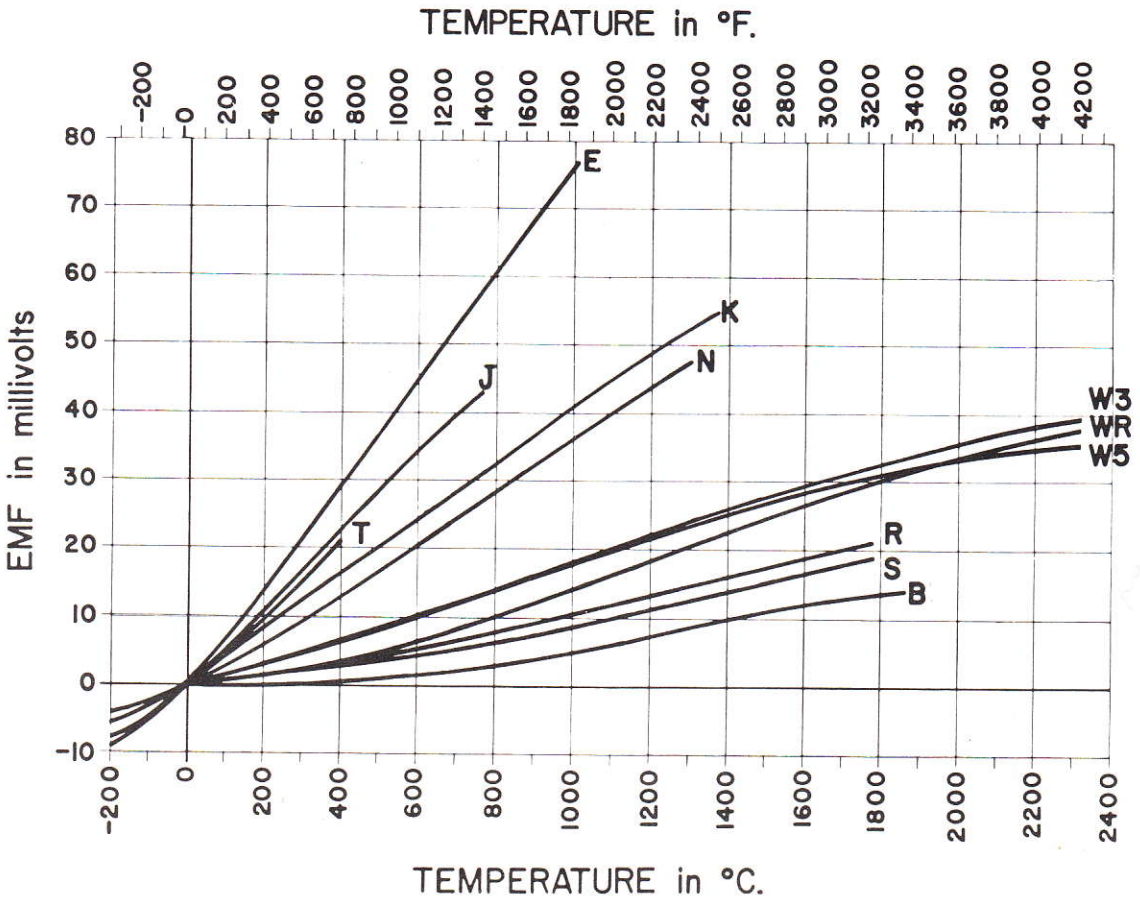
Type B (PLATINUM - 30%, RHODIUM vs Pt-6%,Rh)

Platinum alloy thermocouples are all recommended for use in inert or oxidizing atmospheres, or for short periods of time in a vacuum. Easily contaminated, these elements must be protected from the effects of reducing atmospheres and contaminating vapors. Alumina protecting tubes are recommended for directly containing platinum elements.

Type C† (TUNGSTEN 5% RHENIUM vs TUNGSTEN 26% RHENIUM)

Tungsten Alloy are all recommended for use in vacuum, high purity hydrogen, or high purity inert atmospheres. Very poor oxidation resistance.

™ Hoskins Mfg. Co. † not ANSI symbols



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Marlin
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PHYSICAL AND MECHANICAL PROPERTIES OF THERMOELEMENTS

PROPERTIES*	TP (Copper)	TN,JN,EN (Constantan)	JP (Iron)	KP,EP (Chromel)	KN (Alumel)	NP (Nicrosil)	NN (Nisil)	RP (Pt 13% Rh)	RN,SN (Platinum)	SP (Pt 10% Rh)	BP (Pt 30% Rh)	BN (Pt 6% Rh)	CP (Tungsten 5% Re)	CN (Tungsten 26% Re)
Approx. Melting Point: °F	1981	2230	2725	2600	2552	2570	2444	3380	3214	3362	3501	3319	6062	5648
°C	1083	1221	1496	1427	1400	1410	1340	1860	1768	1850	1927	1826	3350	3120
Electrical Resistivity														
ohm-cmil/ft @ 68°F	10.37	294	75	425	177	585	215	118	63.6	115	114.5	106	70	170
microhm-cm @ 20°C	1.724	48.9	12.5	70.7	29.4	97.3	35.8	19.6	10.6	18.9	19.0	17.5	11.6	28.2
Temperature Coef. of Resistance:														
ohms/ohm/°F, 32° to 212°F	23.9×10^{-4}	0.1×10^{-4}	27×10^{-4}	1.8×10^{-4}	10.4×10^{-4}	0.6×10^{-4}	4.3×10^{-4}	8.7×10^{-4}	21.8×10^{-4}	9.2×10^{-4}	7.4×10^{-4}	11.1×10^{-4}	—	—
ohms/ohm/°C, 0° to 100°C	43.0×10^{-4}	0.18×10^{-4}	48.6×10^{-4}	3.2×10^{-4}	18.7×10^{-4}	1.1×10^{-4}	7.8×10^{-4}	15.6×10^{-4}	39.2×10^{-4}	16.6×10^{-4}	13.3×10^{-4}	20.0×10^{-4}	—	—
Thermal Coef. of Linear Expansion:														
in./in./°F, 68 to 212°F	9.2×10^{-6}	8.3×10^{-6}	6.9×10^{-6}	7.3×10^{-6}	6.7×10^{-6}	9.4×10^{-6}	9.4×10^{-6}	4.9×10^{-6}	4.9×10^{-6}	4.9×10^{-6}	—	—	—	2.9×10^{-6}
cm/cm/°C, 20 to 100°C	16.6×10^{-6}	14.9×10^{-6}	12.4×10^{-6}	13.1×10^{-6}	12.1×10^{-6}	17.0×10^{-6}	17.0×10^{-6}	8.8×10^{-6}	8.8×10^{-6}	8.8×10^{-6}	—	—	—	5.2×10^{-6}
Specific Heat: Btu/lb/°F @ 68°F	0.092	0.094	0.113	0.107	0.125	—	—	—	0.0318	—	—	—	—	—
cal./g/°C @ 20°C	0.092	0.094	0.113	0.107	0.125	—	—	—	0.0318	—	—	—	—	—
Thermal Conductivity:														
Btu/hr./ft.²/ft./°F @ 212°F	218	12.6	34.8	11.1	17.14	8.66	16.04	—	41.1	17.3	—	—	—	—
watts/cm²/cm/°C @ 199°C	3.77	0.218	0.603	0.192	0.297	0.150	0.278	—	0.71	0.30	—	—	—	—
Specific Gravity:	8.92	8.86	7.87	8.73	8.60	8.53	8.58	19.55	21.45	19.95	17.52	20.51	19.4	19.7
Density: lb./in.³	0.322	0.320	0.284	0.315	0.311	0.308	0.310	0.706	0.775	0.771	0.633	0.741	0.701	0.712
g/cm³	8.92	8.86	7.87	8.73	8.60	8.53	8.58	19.55	21.45	19.95	17.52	20.51	19.4	19.7
Tensile Strength (annealed): psi	35,000	65,000	50,000	95,000	85,000	100,000	85,000	48,000	24,000	47,000	74,000	37,000	220,000	200,000
kg/cm²	2,460	4,570	3,515	6,680	5,980	7,030	5,980	3,375	1,690	3,305	5,200	2,600	15,470	14,060
Nominal Chemical Composition %	Cu 100	Cu 55 Ni 45	Fe 100	Ni 90 Cr 10	Ni 95 Al 2 Mn 2 Si 1	Ni 84.4 Cr 14.2 Si 1.4	Ni 95.6 Si 4.4	Pt 87 Rh 13	Pt 100	Pt 90 Rh 10	Pt 70 Rh 30	Pt 94 Rh 6	W 95 Re 5	W 74 Re 26
Magnetic Response @ 68°F (20°C):	none	none	strong	none	moderate	none	none	none	none	none	none	none	none	none

*Derived from data of various manufacturers

SOME REFERENCE POINTS FOR THERMOMETRY ON THE ITS-90

	Kelvins (K)	Degrees Celsius (°C)	Degrees Fahrenheit (°F)
*Triple point of e-hydrogen	13.8033	-259.3467	-434.8241
*Triple point of neon	24.5561	-248.5939	-415.4690
*Triple point of oxygen	54.3584	-218.7916	-361.8249
Triple point of nitrogen	63.1504	-209.9996	-345.9993
*Triple point of argon	83.8058	-189.3442	-308.8196
Triple point of krypton	115.776	-157.374	-251.273
Triple point of xenon	161.404	-111.746	-169.143
Sublimation of carbon dioxide	194.685	-78.465	-109.237
Triple point of carbon dioxide	216.589	-56.561	-69.810
*Triple point of mercury	234.3156	-38.8344	-37.9019
Freezing point of mercury	234.3216	-38.8284	-37.8911
Melting point of ice	273.15	0.0	32.0
*Triple point of water	273.16	0.01	32.018
*Melting point of gallium	302.9146	29.7646	85.5763
Triple point of gallium	302.9165	29.7665	85.5797
*Freezing point of indium	429.7485	156.5985	313.8773
*Freezing point of tin	505.078	231.928	449.472
Freezing point of cadmium	594.219	321.069	609.924
Freezing point of lead	600.612	327.462	621.432
*Freezing point of zinc	692.677	419.527	787.149
Freezing point of antimony	903.78	630.63	1167.13
*Freezing point of aluminum	933.473	660.323	1220.581
*Freezing point of silver	1234.93	961.78	1763.20
*Freezing point of gold	1337.33	1064.18	1947.52
*Freezing point of copper	1357.77	1084.62	1984.32
Freezing point of palladium	1828.0	1554.8	2830.6
Freezing point of platinum	2041.3	1768.1	3214.6
Freezing point of rhodium	2235.5	1962.3	3564.1
Freezing point of iridium	2719.	2446.	4435.
Freezing point of molybdenum	2896.	2623.	4753.

*A defining point of the ITS-90

MATERIAL	Melting Point °F	Recommended Operating Atmosphere	Maximum Operating Temp. in Atmosphere
STAINLESS STEELS			
304	2560	ORNV	1650
310	2560	ORNV	2100
316	2500	ORNV	1700
321	2550	ORNV	1600
347	2600	ORNV	1600
446	2700	ORNV	2000
Carbon Steel	2500	ON	1300
Inconel	2550	ONV	2100
Inconel X	2620	ONV	2200
Incoloy	2500	ON	1600
Hastelloy X	2350	O	2200
Hastelloy C	2310	O	1800
Hastelloy B	2375	OR	1400
Monel	2460	OR	1000
Brass	1850	O	650
Aluminum	1220	O	700
Nickel	2647	O	1400
Tantalum	5425	V	5000
Titanium	3035	VN	2000

O = Oxidizing R = Reducing N = Neutral V = Vacuum

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REFERENCE DATA
THERMOCOUPLE WIRE SPECIFICATIONS

ANSI COLOR CODE FOR THERMOCOUPLE AND THERMOCOUPLE EXTENSION WIRE

ANSI TYPE	WIRE ALLOYS	POLARITY	THERMOCOUPLE WIRE COLOR		ANSI TYPE	T/C EXTENSION WIRE COLOR	
			INDIVIDUAL	OVERALL		INDIVIDUAL	OVERALL
T	COPPER CONSTANTAN	+TP -TN	BLUE RED	BROWN	TX	BLUE RED	BLUE
J	IRON CONSTANTAN	+JP -JN	WHITE RED	BROWN	JX	WHITE RED	BLACK
E	CHROMEL™ CONSTANTAN	+EP -EN	PURPLE RED	BROWN	EX	PURPLE RED	PURPLE
K	CHROMEL™ ALUMEL™	+KP -KN	YELLOW RED	BROWN	KX	YELLOW RED	YELLOW
N	NICROSIL NISIL	+NP -NN	ORANGE RED	BROWN	NX	ORANGE RED	ORANGE
R	PLATINUM 13% RHODIUM PLATINUM	+RP -RN			RX	BLACK RED	GREEN
S	PLATINUM 10% RHODIUM PLATINUM	+SP -SN			SX	BLACK RED	GREEN
B	PLATINUM 30% RHODIUM PLATINUM 6% RHODIUM	+BP -BN			BX	GREY RED	GREY

NOMINAL THERMOCOUPLE RESISTANCE Ohms per Double Foot @ 68°F (20°C)

Wire Ga B & S	Wire Size DIA.	ANSI TYPES						
		J	K	T	E	S	R	B
6	.162	.014	.023	.012	.027	.007	.007	.008
*7	.144	.021						
8	.128	.022	.036	.019	.044	.010	.010	.013
14	.064	.089	.147	.074	.176	.044	.044	.054
16	.050	.141	.232	.117	.277	.069	.069	.086
18	.040	.229	.377	.190	.450	.112	.113	.139
20	.032	.357	.588	.297	.702	.175	.178	.218
24	.020	.905	1.488	.745	1.778	.449	.453	.550
26	.015	1.441	2.45	1.20	2.84	.701	.708	.875
28	.012	2.297	3.59	1.92	4.33	1.062	1.073	1.392
30	.010	3.65	6.02	2.94	7.19	1.794	1.813	2.213
36	.005	14.66	24.08	12.22	28.80	7.150	7.226	8.897

*Double feet 7 Ga Type J=7 Ga Iron/8 Ga Constantan

BARE THERMOCOUPLE WIRE APPROXIMATE WEIGHT FEET/LB.

Wire Ga B & S	Wire Size DIA.	TYPE J		TYPE K		TYPE T		TYPE E	
		Iron + JP	Constantan— JN	Chromel + KP	Alumel— KN	Copper + TP	Constantan— TN	Chromel + EP	Constantan— EN
6	.162	14.2	12.6	13	13	12.6	12.6	13	12.6
7	.144	18.0							
8	.128	22.8	20.2	21	21	19.8	20.2	21	20.2
14	.064	91.2	80.9	83	83	80.5	80.9	83	80.9
16	.050	144	127	130	130	128	127	130	127
18	.040	233	207	212	212	203	207	212	207
20	.32	365	324	331	331	324	324	331	324
24	.020	925	821	838	838	820	821	838	821
26	.015	1478	1312	1340	1340	1299	1312	1340	1312
28	.012	2353	2089	2130	2130	2062	2089	2130	2089
30	.010	3736	3316	3370	3370	3294	3316	3370	3316
36	.005	14940	13260	13500	13500	13250	13260	13500	13260

American Wire Gauge (AWG)	Size DIA. Inches
7/0	—
6/0	0.5800
5/0	0.5165
4/0	0.4600
3/0	0.4096
2/0	0.3648
1/0	0.3249
1	0.2893
2	0.2576
3	0.2294
4	0.2043
5	0.1819
6	0.1620
7	0.1443
8	0.1285
9	0.1144
10	0.1019
11	0.0907
12	0.0808
13	0.0720
14	0.0641
15	0.0571
16	0.0508
17	0.0453
18	0.0403
19	0.0359
20	0.0320
21	0.0285
22	0.0253
23	0.0226
24	0.0201
25	0.0179
26	0.0159
27	0.0142
28	0.0126
29	0.0113
30	0.0100
31	0.00893
32	0.00795
33	0.00708
34	0.00630
35	0.00561
36	0.00500
37	0.00445
38	0.00396
39	0.00353
40	0.00314
41	0.00280
42	0.00249
43	0.00222
44	0.00198
45	0.00176
46	0.00157
47	0.00140
48	0.00124
49	0.00111
50	0.00099

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Selection and Use of Thermocouple and Thermocouple Extension Wire

Thermocouple wire can be fabricated into accurate and dependable thermocouples by joining the thermoelements at the sensing end. Thermocouple wire or thermocouple extension wire must be used to extend thermocouples to indicating or control instruments. The conditions of measurement determine the type of thermocouple wire and insulation to be used. Temperature range, environment, protection, insulation requirements, response and service life should be considered. The following parameters serve as a guide to the selection of wire. For a basic application study refer to Marlin literature "Thermocouple Fundamentals."

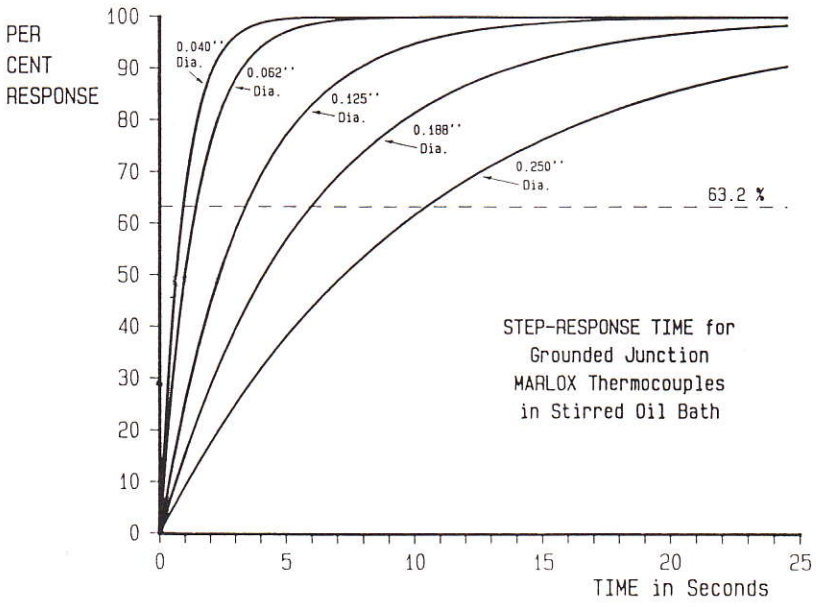
Temperature Limits for Thermocouple Wire

Temperature limits for standard thermocouples that are protected with a closed end protecting tube are shown. These limits are suggested for continuous temperature sensing where thermal limitation of the insulation is not a factor. For unprotected thermocouples these limits should be reduced for equivalent service life.

UPPER TEMPERATURE LIMITS FOR THERMOCOUPLES

THERMOCOUPLE TYPE	ANSI TYPE SYMBOL	WIRE GAUGE (AWG)				
		8 ga.	14 ga.	20 ga.	24 ga.	30 ga.
Copper-Constantan	T		370°C (700°F)	260°C (500°F)	200°C (400°F)	150°C (300°F)
*Iron-Constantan	J	760°C (1400°F)	600°C (1100°F)	500°C (900°F)	370°C (700°F)	320°C (600°F)
Chromel™ - Constantan	E	870°C (1600°F)	650°C (1200°F)	550°C (1000°F)	430°C (800°F)	430°C (800°F)
Chromel™ - *Alumel™	K	1260°C (2300°F)	1100°C (2000°F)	1000°C (1800°F)	870°C (1600°F)	760°C (1400°F)
Nicrosil - Nisil	N	1260°C (2300°F)	1100°C (2000°F)	1000°C (1800°F)	870°C (1600°F)	760°C (1400°F)
Platinum - 10% Rhodium	S				1480°C (2700°F)	
Platinum - 13% Rhodium	R				1480°C (2700°F)	
Platinum - 30% vs 6% Rhodium	B				1700°C (3100°F)	
Tungsten - 5% vs 26% Rhenium	C†				2300°C (4200°F)	

*Magnetic ™Trade Mark Hoskins Mfg. Co. † Not ANSI symbol



Accuracy of Marlin Wire

Marlin insulated and bare thermocouple wire is matched to meet standard initial calibration tolerances for temperatures above 0°C. as given in ANSI MC96.1 and shown in the table below.

Wire conforming to special initial calibration tolerances, wire for use at sub-zero temperatures, and wire with certified traceable calibration is available on request. Designate special limit grade wire using a double ANSI symbol (e.g. KK, JJ). Sub-zero and calibration requirements should be spelled out on the Purchase Order.

INITIAL CALIBRATION TOLERANCES FOR THERMOCOUPLE WIRE

THERMOCOUPLE TYPE		°C.			°F.		
WIRE ALLOYS	ANSI TYPE SYMBOL	TEMPERATURE RANGE	STANDARD LIMITS	SPECIAL LIMITS	TEMPERATURE RANGE	STANDARD LIMITS	SPECIAL LIMITS
Copper (+) vs. Constantan (−)	T	−200° to −65° −65° to +130° +130° to +350°	±1.5% ±1° ±.75%	±.8% ±.5° ±.4%	−330° to −85° −85° to +270° +270° to +660°	±1.5% ±1.8° ±.75%	±.8% ±.9° ±.4%
*Iron (+) vs. Constantan (−)	J	0° to +285° +285° to +750°	±2.2° ±.75%	±1.1° ±.4%	+32° to +545° +545° to +1400°	±4° ±.75%	±2° ±.4%
Chromel™ (+) vs. Constantan (−)	E	−200° to −170° −170° to +250° +250° to +340° +340° to +900°	±1% ±1.7° ±1.7° ±.5%	±1° ±1° ±.4% ±.4%	−330° to −270° −270° to +480° +480° to +640° +640° to +1600°	±1% ±3° ±3° ±.5%	±1.8° ±1.8° ±.4% ±.4%
Chromel™ (+) vs. *Alumel™ (−)	K	−200° to −110° −110° to 0° 0° to +285° +285° to +1250°	±2% ±2.2° +2.2° ±.75%	±1.1° ±.4%	−330° to −165° −165° to +32° +32° to +545° +545° to +2300°	±2% ±4° ±4° ±.75%	±2° ±.4%
Nicrosil (+) vs. Nisil (−)	N	0° to +285° +285° to +1250°	±2.2° ±.75%	±1.1° ±.4%	+32° to +545° +545° to 2300°	±4° ±.75%	±2° ±.4%
Platinum −10% Rhodium (+) vs. Platinum (−)	S	0° to +600° +600° to +1450°	±1.5° ±.25%	±.6° ±.1%	+32° to +1110° +1110° to 2650°	±2.7° ±.25%	±1.1° ±.1%
Platinum −13% Rhodium (+) vs. Platinum (−)	R	0° to +600° +600° to +1450°	±1.5° ±.25%	±.6° ±.1%	+32° to +1110° +1110° to +2650°	±2.7° ±.25%	±1.1° ±.1%
Platinum −30% Rhodium (+) vs. Platinum −6% Rhodium (−)	B	+870° to +1700°	±.5%	±.25%	+1600° to +3100°	±.5%	±.25%
Tungsten −5% Rhenium (+) vs. Tungsten −26% Rhenium (−)	C†	+400° to +2300°	±1%		+800° to +4200°	±1%	

*Magnetic
™TradeMark, Hoskins Mfg. Co.
†NOT ANSI Type Symbol

NOTE — Per cent limits apply directly to temperatures in °C units, but for °F equivalents are applied to the number of °F above or below the ice point (+32°F.).
[i.e., Limit (°F) = (Temp. °F −32°F) × Percentage]

Thermocouple Extension Wire

Thermocouple extension wire has approximately the same thermoelectric characteristic as thermocouple wire but its accuracy is guaranteed over a more limited range of temperatures. Thermocouple extension wire can offer advantages in cost or mechanical properties when used for connections between thermocouples and instruments. For base metal types of thermocouples, extension wire is of substantially the same composition as the corresponding thermocouple type. For noble metal types, however, an entirely different alloy is formulated to match the noble metal characteristics over a specified temperature range. This is necessary due to the high cost of the noble metals which could otherwise be necessary for the interconnection. The "X" in the ANSI code denotes extension grade wire.

INITIAL CALIBRATION TOLERANCES FOR THERMOCOUPLE EXTENSION WIRE

THERMOCOUPLE TYPE		°C.			°F.		
EXTENSION WIRE ALLOY	ANSI TYPE SYMBOL	TEMPERATURE RANGE	STANDARD LIMITS	SPECIAL LIMITS	TEMPERATURE RANGE	STANDARD LIMITS	SPECIAL LIMITS
Copper vs. Constantan	TX	−60° to +100°	±1°	±5°	−75° to +210°	±2°	±1°
*Iron vs. Constantan	JX	0° to +200°	±2.2°	±1.1°	+32° to +400°	±4°	±2°
Chromel™ vs. Constantan	EX	0° to +200°	±1.7°	±1.1°	+32° to +400°	±3°	±2°
Chromel™ vs. *Alumel™	KX	0° to +200°	±2.2°	±1.1°	+32° to +400°	±4°	±2°
Nicrosil vs. Nisil	NX	0° to +200°	±2.2°	±1.1°	+32° to +400°	±4°	±2°
Copper vs. Copper Alloy	SX RX	+25° to +200°	±7°		+75° to +400°	±12°	
PCLW630 vs. Copper	BX	0° to +200°	±2.2°		+32° to +400°	±4°	
Copper vs. Copper	BX	0° to 65°	±1°		+32° to +150°	±2°	
Alloy 405 vs Alloy 426	CX†	0° to 870°	±7°		+32° to +1600°	±12°	

*Magnetic
™Trade Mark Hoskins Mfg. Co.
†NOT ANSI Symbol

Thermocouple wire is matched so that it will initially produce the emfs given in the following tables within either standard or special limits of calibration tolerance. Tolerance limits vary with thermocouple type and temperature as shown below. Limits given here are those taken from ASTM Standard E230. They are also in agreement with other internationally recognized standards.

Note that where a tolerance is given in percent, the percentage applies to the temperature of interest only when it is expressed in degrees Celsius. Tolerances in degrees Fahrenheit are obtained by multiplying the Celsius equivalent temperature tolerances by 9/5.

INITIAL CALIBRATION TOLERANCES FOR THERMOCOUPLES

Type	Alloy	Temperature	Standard Limits	Special Limits
T	Copper (+) vs. Constantan (−)	−200°C to 0°C* 0°C to 350°C	±1°C or ±1.5%* ±1°C or ±0.75%	±0.5°C or ±0.8%* ±0.5°C or ±0.4%
J	Iron (+) vs. Constantan (−)	0°C to 750°C	±2.2°C or ±0.75%	±1.1°C or ±0.4%
E	Chromel (+) vs. Constantan (−)	−200°C to 0°C* 0°C to 900°C	±1.7°C or ±1%* ±1.7°C or ±0.5%	±1°C or ±0.5%* ±1°C or ±0.4%
K	Chromel (+) vs. Alumel (−)	−200°C to 0°C* 0°C to 1250°C	±2.2°C or ±2%* ±2.2°C or ±0.75%	N.A. ±1.1°C or ±0.4%
N	Nicrosil (+) vs. Nisil (−)	0°C to 1250°C	±2.2°C or ±0.75%	±1.1°C or ±0.4%
R	Pt/13%Rh (+) vs. Pt (−)	0°C to 1450°C	±1.5°C or ±0.25%	±0.6°C or ±0.1%
S	Pt/10%Rh (+) vs. Pt (−)	0°C to 1450°C	±1.5°C or ±0.25%	±0.6°C or ±0.1%
B	Pt/30%Rh (+) vs. Pt/6%Rh (−)	870°C to 1700°C	±0.5%	±0.25%
C†	W/5%Re (+) vs. W/26%Re (−)	400°C to 2300°C	±1%	±N.A

* Thermocouple wire is normally supplied to meet tolerances for temperatures above 0°C. These same materials may not fall within the sub-zero tolerances given without special selection and testing.

† Symbol shown is not an ANSI standard type designation.