Selections From Omega Engineering Inc

Thermocouples and Thermocouple Assemblies
Introduction to Thermocouples

What is a thermocouple?

A thermocouple is a sensor for measuring temperature. It consists of two dissimilar metals, joined together at one end, which produce a small unique voltage at a given temperature. This voltage is measured and interpreted by a thermocouple thermometer.

What are the different thermocouple types?

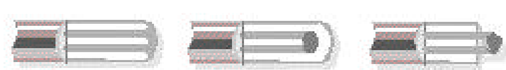
Thermocouples are available in different combinations of metals or calibrations. The four most common calibrations are J, K, T and E. Each calibration has a different temperature range and environment, although the maximum temperature varies with the diameter of the wire used in the thermocouple.

How do I choose a thermocouple type?

Because thermocouples measure in wide temperature ranges and can be relatively rugged, they are very often used in industry. The following criteria are used in selecting a thermocouple:

- Temperature range
- Chemical resistance of the thermocouple or sheath material
- Abrasion and vibration resistance
- Installation requirements (may need to be compatible with existing equipment; existing holes may determine probe diameter).

How do I know which junction type to choose?



Grounded Ungrounded Exposed

Sheathed thermocouple probes are available with one of three junction types: grounded, ungrounded or exposed. At the tip of a grounded junction probe, the thermocouple wires are physically attached to the inside of the probe wall. This results in good heat transfer from the outside, through the probe wall to the thermocouple junction. In an underground probe, the thermocouple junction is detached from the probe wall. Response time is slowed down from the grounded style, but the ungrounded offers electrical isolation of 1.5 M1/2 at 500 Vdc in all diameters. The thermocouple in the exposed junction style protrudes out of the tip of the sheath and is exposed to the surrounding environment. This type offers the best response time, but is limited in use to noncorrosive and nonpressurized applications. See the illustrations at the right for a full discussion of junction types.

What is response time?

A time constant has been defined as the time required by a sensor to reach 63.2% of a step change in temperature under a specified set of conditions. Five time constants are required for the sensor to stabilize at 600 of the step change value. Exposed junction thermocouples are the fastest responding. Also, the smaller the probe sheath diameter, the faster the response, but the maximum temperature may be lower. Be aware, however, that sometimes the probe sheath cannot withstand the full temperature range of the thermocouple type.

Diameters:
Standard diameters: 0.010", 0.020", 0.032", 0.040", 1/16", 1/8", 3/16", and 1/4" with two wires.

Length:
Standard OMEGA thermocouples have 12 inch immersion lengths. Other lengths available.

Sheaths:
304 stainless steel and Inconel are standard. Other sheath materials available; call for price and availability.

Insulation:
Magnesium Oxide is standard. Minimum insulation resistance wire to wire or wire to sheath is 1.5 megohms at 500 volts dc in all diameters.

Calibration:
Iron-Constantan (J), Chromega®-Alomega® (K),
Copper-Constantan (T), and Chromega-Constantan (E) are standard calibrations.

Bending:
Easily bent and formed. Bend radius should be not less than twice the diameter of the sheath.

Delivery:
Off-the-Shelf, other sheaths available; call for price and delivery. Dual Elements: Thermocouples with a sheath diameter of 0.040" (1.0 mm) thru 1/4" (6.3mm) are available in dual element.

Accuracy:
The wires used in OMEGA thermocouples are selected and matched to meet ANSI Limits of

Error. Special limits of error thermocouples can be made from all 1/16" (1.5 mm) O.D. or larger OMEGACLAD® Thermocouple wire.

Polarity:
In the thermocouple industry, standard practice is to color the negative lead red. Other standards that OMEGA uses are: the negative lead of bare wire thermocouple is approximately 1/4" shorter than the positive lead, and the large pin on a thermocouple connector is always the negative conductor.

Extension Wire:
Thermocouple alloy wire must always be used to connect a thermocouple sensor to the instrumentation to assure accurate measurements.

Thermocouple Junctions:
The grounded junction is recommended for the measurement of static or flowing corrosive gas and liquid temperatures and for high pressure applications. The junction of a grounded thermocouple is welded to the protective sheath giving faster response than the ungrounded junction type.

An ungrounded junction is recommended for measurements in corrosive environments where it is desirable to have the thermocouple electronically isolated from and shielded by the sheath. The welded wire thermocouple is physically insulated from the thermocouple sheath by MgO powder (soft).

An exposed junction is recommended for the measurement of static or flowing non-corrosive gas temperatures where fast response time is required. The junction extends beyond the protective metallic sheath to give accurate fast response. The sheath insulation is sealed where the junction extends to prevent penetration of moisture or gas which could cause errors.

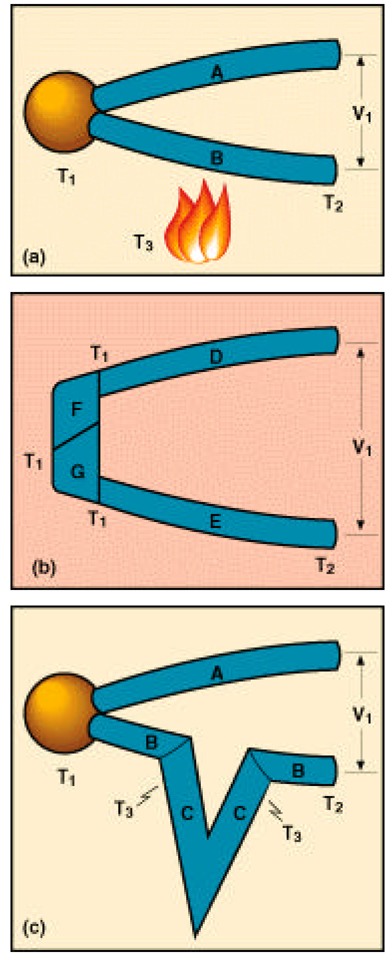
Thermocouples: Consider first the thermocouple, probably the most-often-used and least-understood of the three. Essentially, a thermocouple consists of two alloys joined together at one end and open at the other. The emf at the output end (the open end; V1 in Figure 1a) is a function of the temperature T1 at the closed end. As the temperature rises, the emf goes up.

Often the thermocouple is located inside a metal or ceramic shield that protects it from a variety of environments. Metal-sheathed thermocouples are also available with many types of outer coatings, such as polytetrafluoroethylene, for trouble-free use in corrosive solutions.

The open-end emf is a function of not only the closed-end temperature (i.e., the temperature at the point of measurement) but also the temperature at the open end (T2 in Figure 1a). Only by holding T2 at a standard temperature can the measured emf be considered a direct function of the change in T1. The industrially accepted standard for T2 is 0°C; therefore, most tables and charts make the assumption that T2 is at that level. In industrial instrumentation, the difference between the actual temperature at T2 and 0°C is usually corrected for electronically, within the instrumentation. This emf adjustment is referred to as the cold-junction, or CJ, correction.

Temperature changes in the wiring between the input and output ends do not affect the output voltage, provided that the wiring is of thermocouple alloy or a thermoelectric equivalent (Figure 1a). For example, if a thermocouple is measuring temperature in a furnace and the instrument that shows the reading is some distance away, the wiring between the two could pass near another furnace and not be affected by its temperature, unless it becomes hot enough to melt the wire or permanently change its electrothermal behavior.

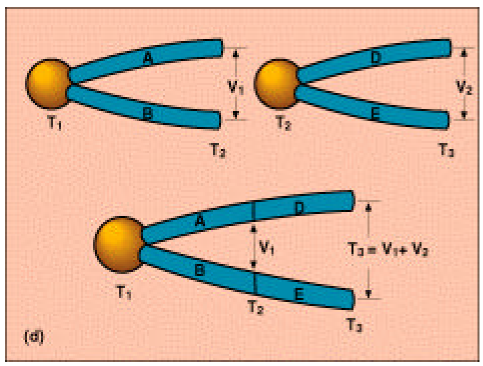
The composition of the junction itself does not affect the thermocouple action in any way, so long as the temperature, T1, is kept constant throughout the junction and the junction material is electrically conductive (Figure 1b). Similarly, the reading is not affected by insertion of non-thermocouple alloys in either or both leads, provided that the temperature at the ends of the "spurious" material is the same (Figure 1c).



(Figure 1)

This ability of the thermocouple to work with a spurious metal in the transmission path enables the use of a number of specialized devices, such as thermocouple switches. Whereas the transmission wiring itself is normally the thermoelectrical equivalent of the thermocouple alloy, properly operating thermocouple switches must be made of gold-plated or silver-plated copper alloy elements with appropriate steel springs to ensure good contact. So long as the temperature at the input and output junctions of the switch are equal, this change in composition makes no difference.

It is important to be aware of what might be called the Law of Successive Thermocouples. Of the two elements that are shown in the upper portion of Figure 1d, one thermocouple has T1 at the hot end and T2 at the open end. The second thermocouple has its hot end at T2 and its open end at T3. The emf level for the thermocouple that is measuring T1 is V1; that for the other thermocouple is V2. The sum of the two emfs, V1 plus V2, equals the emf V3 that would be generated by the combined thermocouple operating between T1 and T3. By virtue of this law, a thermocouple designated for one open-end reference temperature can be used with a different open-end temperature.



Thermocouple Reference Junction Principles

THEORY: When accurate thermocouple measurements are required, it is common practice to reference both legs to copper lead wire at the ice point so that copper leads may be connected to the emf readout instrument. This procedure avoids the generation of thermal emfs at the terminals of the readout instrument. Changes in reference junction temperature influence the output signal and practical instruments must be provided with a means to cancel this potential source of error. The EMF generated is dependent on a difference in temperature, so in order to make a measurement the reference must be known. This is shown schematically in Fig. #1 and can be accomplished by placing the reference junction in an ice water bath at a constant 0°C (32°F). Because ice baths are often inconvenient to maintain and not always practical, several alternate methods are often employed.

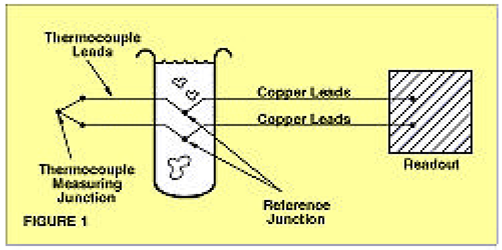


FIGURE 1

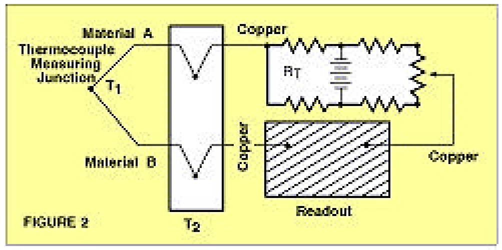


FIGURE 2

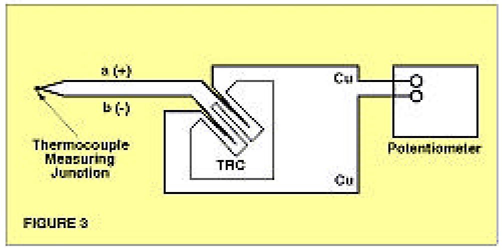


FIGURE 3

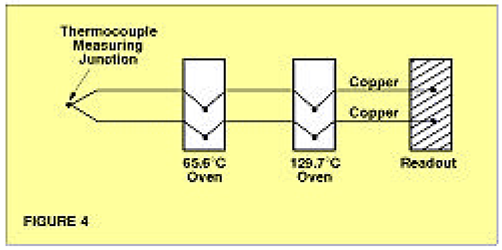


FIGURE 4

ELECTRICAL BRIDGE METHOD: This method usually employs a self-compensating electrical bridge network as shown in Figure 2. This system incorporates a temperature sensitive resistance element (RT), which is in one leg of the bridge network and thermally integrated with the cold junction (T2). The bridge is usually energized from a mercury battery or stable d.c. power source. The output voltage is proportional to the unbalance created between the pre-set equivalent reference temperature at (T2) and the hot junction (T1). In this system, the reference temperature of 0° or 32°F may be chosen.

As the ambient temperature surrounding the cold junction (T2) varies, a thermally generated voltage appears and produces an error in the output. However, an automatic equal and opposite voltage is introduced in series with the thermal error. This cancels the error and maintains the equivalent reference junction temperature over a wide ambient temperature range with a high degree of accuracy. By integrating copper leads with the cold junction, the thermocouple material itself is not connected to the output terminal of the measurement device, thereby eliminating secondary errors.

THERMOELECTRIC REFRIGERATION METHOD: The Omega¨ TRC Thermoelectric ice pointTM Reference Chamber relies on the actual equilibrium of ice and distilled, deionized water and atmospheric pressure to maintain several reference wells at precisely 0°C. The wells are extended into a sealed cylindrical chamber containing pure distilled, deionized water. The chamber outer walls are cooled by thermoelectric cooling elements to cause freezing of the water in the cell. The increase in volume produced by freezing an ice shell on the cell wall is sensed by the expansion of a bellows which operates a microswitch, de-energizing the cooling element. The alternate freezing and thawing of the ice shell accurately maintains a 0°C environment around the reference wells. An application schematic is shown in Fig. #3.

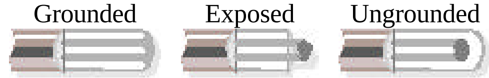
Completely automatic operation eliminates the need for frequent attention required of common ice baths. Thermocouple readings may be made directly from ice point reference tables, such as those listed in the technical section, without making corrections for reference junction temperature. Any combination of thermocouples may be used with this instrument by simply inserting the reference junctions in the reference wells. Calibration of other type temperature sensors at 0°C may be performed as well. Heated oven references: The double-oven type employs two temperature-controlled ovens to simulate ice-point reference temperatures as shown in Fig. 4. Two ovens are used at different temperatures to give the equivalent of a low reference temperature differing from the temperature of either oven. For example, leads from a type K thermocouple probe are connected with a 150° oven to produce a Chromega¨-Alomega¨ and an Alomega-Chromega junction at 150°F (2.66 mV each).

The voltage between the output wires of the first oven will be twice 2.66 mV or 5.32 mV. To compensate for this voltage level, the output leads (Chromega and Alomega) are connected to copper leads within a second oven maintained at 265.5°F. This is the precise temperature at which Chromega-Copper and Alomega-Copper produce a bucking voltage of differential of 5.32 mV. Thus, this voltage cancels out the 5.32 mV differential from the first oven leaving 0 mV at the Copper output terminals. This is the voltage equivalent of 32°F (0°C).

Thermocouple Technical Data

Junction Types

Grounded Exposed Ungrounded



Measuring Junctions

An **exposed junction** is recommended for the measurement of static or flowing non-corrosive gas temperatures where fast response time is required. The junction extends beyond the protective metallic sheath to give accurate fast response. The sheath insulation is sealed where the junction extends to prevent penetration of moisture or gas which could cause errors.
An **ungrounded junction** is recommended for measurements in corrosive environments where it is desirable to have the thermocouple electronically isolated from and shielded by the sheath. The welded wire thermocouple is physically insulated from the thermocouple sheath by MgO powder (soft).
The **grounded junction** is recommended for the measurement of static or flowing corrosive gas and liquid temperatures and for high pressure applications. The junction of a grounded thermocouple is welded to the protective sheath giving faster response than the ungrounded junction type.

<table>
<tr><th rowspan="2">Symbol</th><th colspan="4">Recommended Thermocouples</th></tr>
<tr><th>Calibration and Use</th><th>Positive (+)</th><th>Negative (-)</th><th>Color Code—ANSI</th></tr>
<tr><td rowspan="2">T</td><td>Copper-Constantan
(very low temperature)</td><td>Copper
(yellow metal)</td><td>Constantan
(silver metal)</td><td>Blue</td></tr>
<tr><td colspan="4">Suitable for subzero temperatures. Can be used in oxidizing, reducing, inert or vacuum atmospheres up to 350°C (662°F).</td></tr>
<tr><td rowspan="2">K</td><td>CHROMEGA-ALOMEGA
(Oxidizing atmosphere)</td><td>CHROMEGA
(Non-magnetic)</td><td>ALOMEGA
(Magnetic)</td><td>Yellow</td></tr>
<tr><td colspan="4">Recommended temperature range is -200 to 1250°C (-328 to 2282°F). Should not be used in reducing or sulfurous atmospheres. Can only be used in vacuum for short time until calibration shifts.</td></tr>
<tr><td rowspan="2">J</td><td>Iron-Constantan
(reducing atmosphere)</td><td>Iron
(Magnetic)</td><td>Constantan
(Non-magnetic)</td><td>Black</td></tr>
<tr><td colspan="4">Recommended temperature range is 0 to 750°C (32 to 1382°F). Can be used in oxidizing, reducing, inert or vacuum atmospheres.</td></tr>
<tr><td rowspan="2">E</td><td>CHROMEGA-Constantan
(High output)</td><td>CHROMEGA
(Non-magnetic)</td><td>Constantan
(Non-magnetic)</td><td>Purple</td></tr>
<tr><td colspan="4">Recommended temperature range is -200 to 900°C (-330 to 1600°F). Can be used in oxidizing or inert atmospheres. Should not be used in reducing or vacuum atmospheres.</td></tr>
</table>

Reference Guide

Temperature Dependent Data

Mineral insulated wire is a 3-part system composed of compacted ceramic insulation, thermocouple wire and metal sheath. Therefore, three factors determine the useful service temperature for mineral insulated wire.

- Range for the thermocouple wire (see table - limits of error)
- Maximum service temperature of insulation. In the case of MgO, this is in excess of **1650°C** (3000°F).
- Properties of the sheath material

Material	Melting Point	Continuous Max. Temp.	Tensile (PSI) Strength	
			at 93°C (200°F)	at 538°C (1000°F)
304 SS	**1400°C** (2560°F)	**900°C** (1650°F)	68,000	15,000
316 SS	**1370°C** (2500°F)	**900°C** (1650°F)	75,000	23,000
Inconel*	**1400°C** (2550°F)	**1150°C** (2100°F)	93,000	5,000

**Vacuum or Inert atmosphere only.*

Maximum Long-Term Service Temperature for Protected Bare Wire Thermocouples of Various Wire Diameters

Symbol	0.127 mm (0.005")	0.381 mm (0.015")	0.508 mm (0.020")	0.813 mm (0.032")
T		**200°C** (393°F)	**200°C** (393°F)	**260°C** (500°F)
J	**315°C** (599°F)	**370°C** (698°F)	**370°C** (698°F)	**480°C** (898°F)
E	**370°C** (698°F)	**425°C** (797°F)	**425°C** (797°F)	**535°C** (995°F)
K	**590°C** (1094°F)	**870°C** (1598°F)	**870°C** (1598°F)	**980°C** (1796°F)
R, S			**1480°C** (2696°F)	
B			**1700°C** (3092°F)	
C, G, D†	**1980°C** (3596°F)	**2315°C** (4199°F)	**2315°C** (4199°F)	

Conductor Size Equivalents

Gauge No.	AWG		SWG		Gauge No.	AWG		SWG	
	inches	mm	inches	mm		inches	mm	inches	mm
0	0.3249	8.25	0.324	8.23	23	0.0226	0.574	0.024	0.610
1	0.2893	7.35	0.300	7.62	24	0.0201	0.511	0.022	0.559
2	0.2576	6.54	0.276	7.01	25	0.0179	0.455	0.020	0.508
3	0.2294	5.83	0.252	6.40	26	0.0159	0.404	0.0180	0.457
4	0.2043	5.19	0.232	5.89	27	0.0142	0.361	0.0164	0.417
5	0.1819	4.62	0.212	5.38	28	0.0126	0.320	0.0148	0.376
6	0.1620	4.11	0.192	4.88	29	0.0113	0.287	0.0136	0.345
7	0.1443	3.67	0.176	4.47	30	0.0100	0.254	0.0124	0.315
8	0.1285	3.26	0.160	4.06	31	0.0089	0.226	0.0116	0.295
9	0.1144	2.91	0.144	3.66	32	0.0080	0.203	0.0108	0.274
10	0.1019	2.59	0.128	3.25	33	0.0071	0.180	0.0100	0.254
11	0.0907	2.30	0.116	2.95	34	0.0063	0.160	0.0092	0.234
12	0.0808	2.05	0.104	2.64	35	0.0056	0.142	0.0084	0.213
13	0.0720	1.83	0.092	2.34	36	0.0050	0.127	0.0076	0.193
14	0.0641	1.63	0.080	2.03	37	0.0045	0.114	0.0068	0.173
15	0.0571	1.45	0.072	1.83	38	0.0040	0.102	0.0060	0.152
16	0.0508	1.29	0.064	1.63	39	0.0035	0.089	0.0052	0.132
17	0.0453	1.15	0.056	1.42	40	0.0031	0.079	0.0048	0.122
18	0.0403	1.02	0.048	1.22	41	0.0028	0.071	0.0044	0.112
19	0.0359	0.912	0.040	1.02	42	0.0025	0.064	0.0040	0.102
20	0.0320	0.813	0.036	0.914	43	0.0022	0.056	0.0036	0.091
21	0.0285	0.724	0.032	0.813	44	0.0020	0.051	0.0032	0.081
22	0.0253	0.643	0.028	0.711	45	0.0018	0.046	0.0028	0.071

Maximum Temperature Ratings of Thermocouples

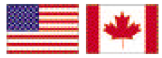
Thermocouple Type	8 AWG 3.25 mm	14 AWG 1.63 mm	20 AWG 0.81 mm	24 AWG 0.51 mm	28 AWG 0.32 mm	30 AWG 0.25 mm
J	**760°C** (1400°F)	**590°C** (1100°F)	**480°C** (900°F)	**370°C** (700°F)	**370°C** (700°F)	**320°C** (600°F)
K	**1260°C** (2300°F)	**1090°C** (2000°F)	**980°C** (1800°F)	**870°C** (1600°F)	**870°C** (1600°F)	**760°C** (1400°F)
E	**870°C** (1600°F)	**650°C** (1600°F)	**540°C** (1000°F)	**430°C** (800°F)	**430°C** (800°F)	**370°C** (400°F)
T		**370°C** (700°F)	**260°C** (500°F)	**200°C** (400°F)	**200°C** (400°F)	**150°C** (300°F)
RX, SX			**200°C** (400°F)	**200°C** (400°F)	**200°C** (400°F)	**150°C** (300°F)
N	**1260°C** (2300°F)	**1090°C** (2000°F)	**980°C** (1800°F)	**980°C** (1800°F)	**980°C** (1800°F)	**870°C** (1600°F)

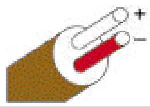
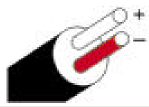
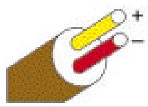
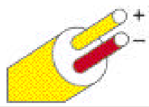
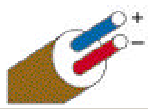
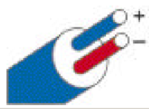
Resistance vs. Wire Diameter — Resistance in Ohms per DOUBLE FOOT (30 cm) Length at **20°C** (68°F)

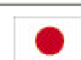
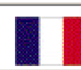
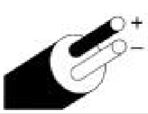
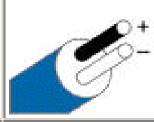
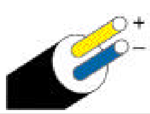
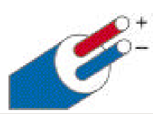
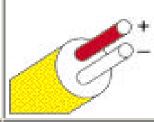
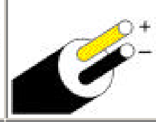
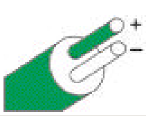
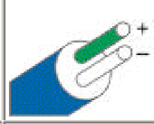
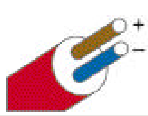
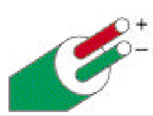
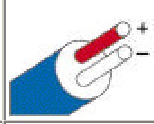
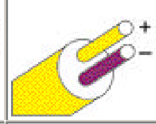
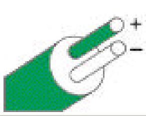
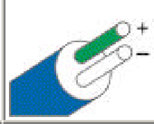
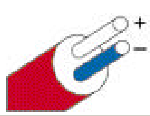
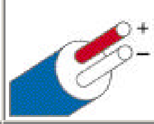
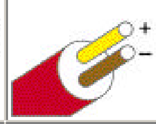
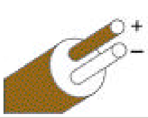
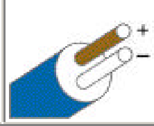
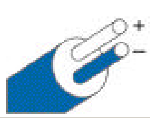
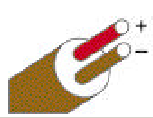
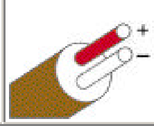
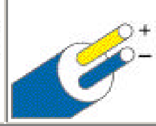
SWG No.	Diameter mm (inches)	Type K CHROMEGA ALOMEGA	Type J Iron/ Constantan	Type T Copper/ Constantan	Type E CHROMEGA/ Constantan	Type S Pt10% Rh/Pt	Type R Pt13% Rh/Pt	Type C* W5% Re/ W26% Re	Type G* W/ W26% Re	Type D* W3% Re/ W25% Re
7-8	4.11 (0.162)	0.023	0.014	0.012	0.027	0.007	0.007	0.009	0.008	0.009
10	3.25 (0.128)	0.037	0.022	0.019	0.044	0.011	0.011	0.015	0.012	0.015
12-13	2.59 (0.102)	0.058	0.034	0.029	0.069	0.018	0.018	0.023	0.020	0.022
14	2.06 (0.081)	0.091	0.054	0.046	0.109	0.028	0.029	0.037	0.031	0.035
16	1.63 (0.064)	0.146	0.087	0.074	0.175	0.045	0.047	0.058	0.049	0.055
17-18	1.30 (0.051)	0.230	0.137	0.117	0.276	0.071	0.073	0.092	0.078	0.088
19	1.02 (0.040)	0.374	0.222	0.19	0.448	0.116	0.119	0.148	0.126	0.138
21	0.81 (0.032)	0.586	0.357	0.298	0.707	0.185	0.190	0.235	0.20	0.220
25	0.51 (0.0201)	1.490	0.878	0.7526	1.78	0.464	0.478	0.594	0.560	0.560
27-28	0.40 (0.0159)	2.381	1.405	1.204	2.836	0.740	0.760	0.945	0.803	0.890
33	0.25 (0.0100)	5.984	3.551	3.043	7.169	1.85	1.91	2.38	2.03	2.26
35-36	0.20 (0.0080)	9.524	5.599	4.758	11.31	1.96	3.04	3.8	3.22	3.60
37-38	0.16 (0.0063)	15.17	8.946	7.66	18.09	4.66	4.82	6.04	5.10	5.70
39	0.13 (0.0050)	24.08	14.20	12.17	28.76	7.40	7.64	9.6	8.16	9.10
43	0.09 (0.0039)	38.20	23.35	19.99	45.41	11.6	11.95	15.3	12.9	15.3
44	0.08 (0.00315)	60.88	37.01	31.64	73.57	18.6	19.3	24.4	20.6	23.0
—	0.05 (0.0020)	149.6	88.78	76.09	179.2	74	76.5	60.2	51.1	56.9
—	0.03 (0.0010)	598.4	355.1	304.3	716.9	185	191	240	204	227
—	0.01 (0.00049)	2408	1420	1217	2816	740	764	1000	850	945

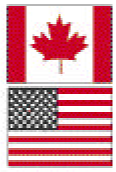
Material	Maximum Temperature	Application Atmosphere				Applications
		Oxidizing	Hydrogen	Vacuum	Inert	
304 SS	**900°C**(1652°F)	Very Good	Good	Very Good	Very Good	Recommended for general chemical applications, food applications, oil refinery use, and steam lines.
Inconel 600	**1150°C** (2102°F)	Very Good	Good	Very Good	Very Good	Recommended for gas furnaces, lead baths, and bath mixtures containing cyanide. Do not use in salt baths contaminated by sulphur.

International Thermocouple Color Codes — Thermocouple and Extension Grade Wires

OMEGA 

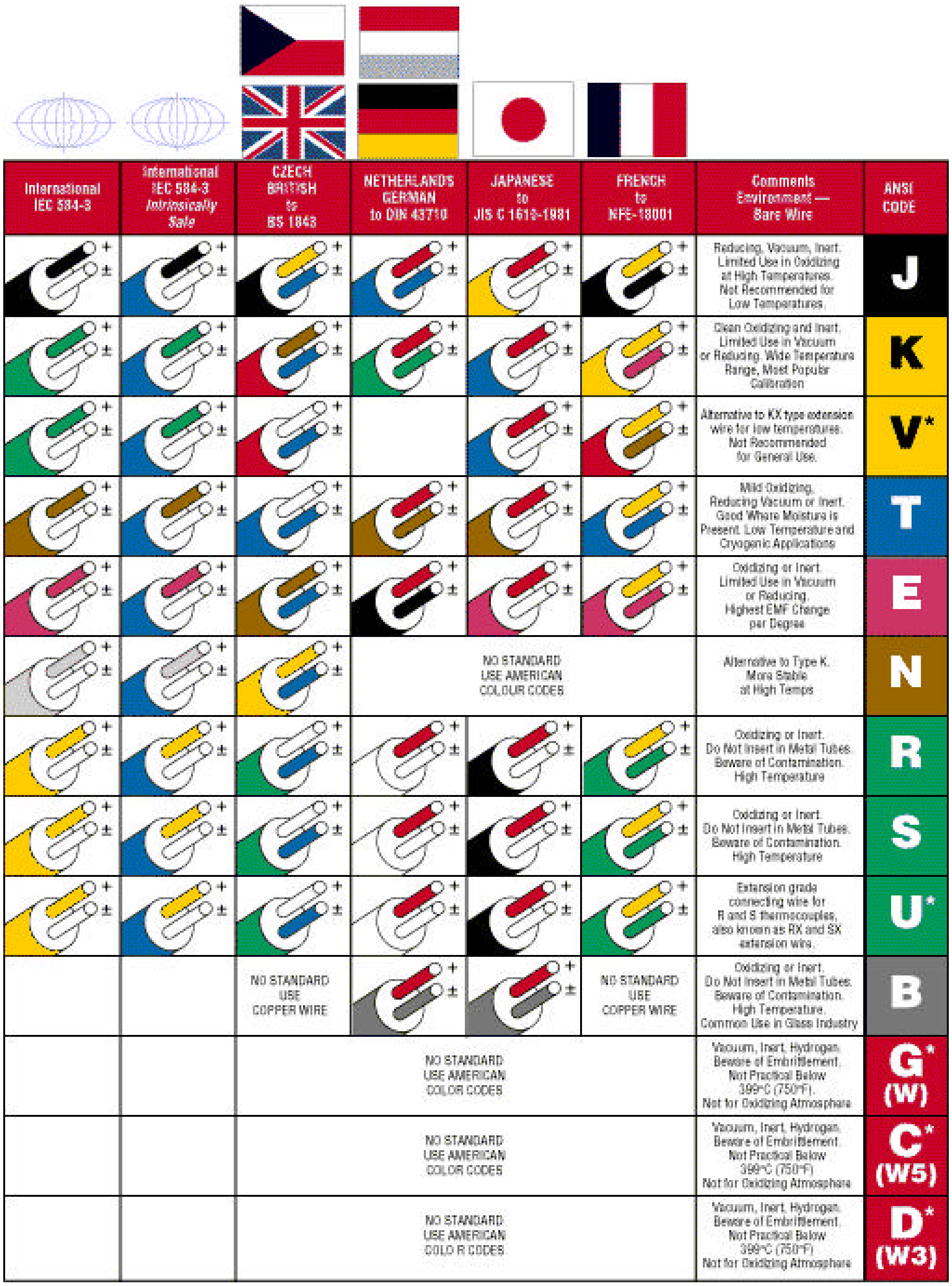
ANSI Code	Alloy Combination		Color Coding		Maximum Temperature Useful Range	EMF (mV) Over Max. Temperature Range	Limits of Error** (Whichever is Greater)	
	+Lead	-Lead	Thermocouple Grade	Extension Grade			Standard	Special
J	‡IRON Fe (magnetic)	CONSTANTAN COPPER-NICKEL Cu-Ni			**0 to 750°C** (32 to 1382°F) Therm. Grade **0 to 200°C** (32 to 392°F) Ext. Grade	-8.095 to 69.553	**0 to 750°C** (32 to 1382°F) 2.2°C or 0.75%	1.1°C or 0.4%
K	CHROMEGA NICKEL-CHROMIUM Ni-Cr	ALOMEGA NICKEL-ALUMINIUM Ni-Al (magnetic)			**-200 to 1250°C** (-328 to 2282°F) Therm. Grade **0 to 200°C** (32 to 392°F) Ext. Grade	-6.458 to 54.886	**-200 to 1250°C** (-328 to 2282°F) 2.2°C or 0.75% Above 0°C 2.2°C or 2.0% Below 0°C	1.1°C or 0.4%
V*	COPPER Cu	CONSTANTAN COPPER-NICKEL Cu-Ni	NONE ESTABLISHED	NONE ESTABLISHED	**0 to 80°C** (32 to 176°F) Ext. Grade			
T	COPPER Cu	CONSTANTAN COPPER-NICKEL Cu-Ni			**-200 to 350°C** (-328 to 662°F) Therm. Grade **-60 to 100°C** (-76 to 212°F) Ext. Grade	-6.528 to 20.872	**-200 to 350°C** (-328 to 662°F) 1.0°C or 0.75% Above 0°C 1.0°C or 1.5% Below 0°C	0.5°C or 0.4%

							
ANSI CODE	**International IEC 584-3**	**International IEC 584-3 *Intrinsically Safe***	**CZECH BRITISH to BS 1843**	**NETHERLANDS GERMAN to DIN 43710**	**JAPANESE to JIS C 1610-1981**	**FRENCH to NFC 42-324**	**Comments - Environment - Bare Wire**
J							Reducing, Vacuum, Inert. Limited Use in Oxidising at High Temperatures Not Recommended for Low Temperatures
K							Clean Oxidising and Inert. Limited Use in Vacuum or Reducing. Wide Temperature Range. Most Popular Calibration
V*							Alternative to KX Type Extension Wire for Low Temperatures; Not Recommended for General Use
T							Mild Oxidising, Reducing Vacuum or Inert. Good Where Moisture is Present, Low Temperature and Cryogenic Applications



ANSI Code	Alloy Combination + Lead	Alloy Combination – Lead	Color Coding Thermocouple Grade	Color Coding Extension Grade	Maximum Temperature Range	EMF (mV) Over Max. Temperature Range	Limits of Error (Whichever is Greater) Standard	Limits of Error (Whichever is Greater) Special
J	IRON Fe (magnetic)	CONSTANTAN COPPER-NICKEL Cu-Ni	+ ±	+ ±	–210 to 1200°C, –346 to 2193°F Thermocouple Grade 0 to 200°C, 32 to 392°F Extension Grade	–8.095 to 69.553	2.2°C or 0.75%	1.1°C or 0.4%
K	CHROMEGA NICKEL-CHROMIUM Ni-Cr	ALOMEGA NICKEL-ALUMINIUM Ni-Al (magnetic)	+ ±	+ ±	–270 to 1372°C, –454 to 2501°F Thermocouple Grade 0 to 200°C, 32 to 392°F Extension Grade	–6.458 to 54.886	2.2°C or 0.75% Above 0°C 2.2°C or 2.0% Below 0°C	1.1°C or 0.4%
V*	COPPER Cu	CONSTANTAN COPPER-NICKEL Cu-Ni	NONE ESTABLISHED	NONE ESTABLISHED	0 to 80°C 32 to 176°F Extension Grade			
T	COPPER Cu	CONSTANTAN COPPER-NICKEL Cu–Ni	+ ±	+ ±	–270 to 400°C –454 to 752°F Thermocouple Grade –60 to 100°C, –76 to 212°F Extension Grade	–6.258 to 20.872	1.0°C or 0.75% Above 0°C 1.0°C or 1.5% Below 0°C	0.5°C or 0.4%
E	CHROMEGA NICKEL-CHROMIUM Ni-Cr	CONSTANTAN COPPER-NICKEL Cu-Ni	+ ±	+ ±	–270 to 1000°C –454 to 1832°F Thermocouple Grade 0 to 200°C, 32 to 392°F Extension Grade	–9.835 to 76.373	1.7°C or 0.5% Above 0°C 1.7°C or 1.0% Below 0°C	1.0°C or 0.4%
N	OMEGA-P NICROSIL Ni-Cr-Si	OMEGA-N NISIL Ni-Si-Mg	+ ±	+ ±	–270 to 1300°C, –450 to 2372°F Thermocouple Grade 0 to 200°C, 32 to 392°F Extension Grade	–4.345 to 47.513	2.2°C or 0.75% Above 0°C 2.2°C or 2.0% Below 0°C	1.1°C or 0.4%
R	PLATINUM-13% RHODIUM Pt-13% Rh	PLATINUM Pt	NONE ESTABLISHED	+ ±	–50 to 1768°C –58 to 3214°F Thermocouple Grade 0 to 150°C, 32 to 300°F Extension Grade	–0.226 to 21.101	1.5°C or 0.25%	0.6°C or 0.1%
S	PLATINUM-10% RHODIUM Pt-10% Rh	PLATINUM Pt	NONE ESTABLISHED	+ ±	–50 to 1768°C –58 to 3214°F Thermocouple Grade 0 to 150°C, 32 to 300°F Extension Grade	–0.236 to 18.693	1.5°C or 0.25%	0.6°C or 0.1%
U*	COPPER Cu	COPPER-LOW NICKEL Cu-Ni	NONE ESTABLISHED	+ ±	0 to 50°C 32 to 122°F Extension Grade			
B	PLATINUM-30% RHODIUM Pt-30% Rh	PLATINUM-6% RHODIUM Pt-6% Rh	NONE ESTABLISHED	+ ±	0 to 1820°C 32 to 3308°F Thermocouple Grade 0 to 100°C, 32 to 212°F Extension Grade	0 to 13.820	0.5% over 800°C	NOT ESTABLISHED
G* (W)	TUNGSTEN W	TUNGSTEN-26% RHENIUM W-26% Re	NONE ESTABLISHED	+ ±	0 to 2320°C 32 to 4208°F Thermocouple Grade 0 to 260°C, 32 to 500°F Extension Grade	0 to 38.564	4.5°C to 425°C 1.0% to 2320°C	NOT ESTABLISHED
C* (W5)	TUNGSTEN-5% RHENIUM W-5% Re	TUNGSTEN-26% RHENIUM W-26% Re	NONE ESTABLISHED	+ ±	0 to 2320°C 32 to 4208°F Thermocouple Grade 0 to 870°C, 32 to 1600°F Extension Grade	0 to 37.066	4.5°C to 425°C 1.0% to 2320°C	NOT ESTABLISHED
D* (W3)	TUNGSTEN-3% RHENIUM W-3% Re	TUNGSTEN-25% RHENIUM W-25% Re	NONE ESTABLISHED	+ ±	0 to 2320°C 32 to 4208°F Thermocouple Grade 0 to 260°C, 32 to 500°F Extension Grade	0 to 39.506	4.5°C to 425°C 1.0% to 2320°C	NOT ESTABLISHED

Thermocouple and Extension Grade Wires International Thermocouple Color Codes



Thermocouple and Extension Grade Wires International Thermocouple Color Codes