



Thermal Manufacturing Solutions

# Section M

## Technical Information

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# THERMOCOUPLE MATERIAL SPECIFICATIONS

ANSI CALIBRATION CODE	POSITIVE LEG	NEGATIVE LEG	TEMP. RANGE °F(°C) OF PROT. TC **	APPLICATION INFORMATION
J	Iron ThermoKanthal JP *	Constantan * Cupron * Advance * ThermoKanthal KN *	32 to 1400 (0 to 760)	Suitable for vacuum, reducing or inert atmospheres, oxidising atmospheres with reduced life. Iron oxidizes rapidly above 1000°F (538°C) so only heavy gauge wire is recommended for high temperature. Bare elements should not be sulphurous atmospheres above 1000°F (538°C)
K	Chromel * Tophel * T1 * ThermoKanthal KP *	ALumel * Nial * T2 * ThermoKanthal KN *	32 to 2300 (0 to 1260)	Recommended for continuous oxidizing or neutral atmpsheres. Mostly used above 1000°C (538°C). 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 1500-1900°F (816-1038°C) range. Ventilation or inert-sealing of the protection tubes can prevent this.
T	Copper	Constantan * Cupron * Advance * ThermoKanthal KN *	-300 to 700 (-184 to 371)	Useable in oxidizing, reducing or inert atmospheres as well as vacuum. Not subject to corrosion in moist atmospheres. Limits are published for sub-zero temperature ranges.
E	Chromel * Tophel * T1 * ThermoKanthal KP *	Constantan * Cupron * Advance * ThermoKanthal KN *	32 to 1600 (0 to 871)	Recommended for continuously oxidizing or inert atmospheres. Sub-zero limits of error are not established. Highest thermoelectric output of common calibrations.
R S	Platinum 13% Rhodium  Platinum 10% Rhodium	Platinum  Platinum	100 to 3100 (538 to 1482)	Recommended for high temperature. Must be protected with a non-metallic protection tube and ceramic insulators. Continued high temperature usages cause grain which can lead to mechanical failure. Negative calibration drift causedby rhodium diffusion to pure leg as well as from rhodium volatilization. Type R is generally used in industry while Type S is general used in laboratories.
B	Platinum 30% Rhodium	Platinum 6% Rhodium	1600 to 3100 (871 to 1705)	Similar to type R & S but output is lower. Also less susceptible to grain growth and drift.
M	Nickel	18% Nickel Molybedenum	32 to 2250 (0 to 1287)	High temperature applications in inert or vacuum atmospheres. Usefull in many hydrogen applications. Continuous cycling causes excessive grain growth.
C	5% Tungsten Rhenium (W-5Re)	26% Tungsten Rhenium (W-26Re)	32 to 4200 (0 to 2315)	Very high temperature applications in inert or vacuum atmospheres. Preferred over Tungsten/26% Tungsten Rhenium because it is less brittle at low temperatures.
W	3% Tungsten Rhenium (W-3Re)	25% tungsten Rhenium (W-25Re)	32 to 4200 (0 to 2315)	The ductility of W3R3 leg is superior to pure Tugnsten, but not as good as W5Re. This combination has the highest output if the 3 common Tungsten Rhenium calibrations from 1860 to 4200°F.
N	Nicrosil *** 14.5% Chromium 1.4% Silicon 0.1% Magnesium Balance Nickel	4.2% Nisil *** 0.1% Silicon Magnesium Balance Nickel	32 to 2300 (0 to 1260)	Can be used in applications where Type K elements have shorter life and stability problems due to oxidation and the development of "green rot".
NONE	Platinel * 5355	Platinel * 7674	32 to 2300 (0 to 1260)	Noble metal combination which approximates Type K curve bus has much improved oxidation resistance. Should be treated as any noble metal calibration.

\* Trade Names. Chromel, Alumel: Hoskins Mfg. Co.; T1, T2, Advance: Driver-Harris Co.; Nial, Tophel: Wilbur B. Driver Co.; ThermoKanthal KP and KN: The Kanthal Corp.; Platinel: Engelhard Industries.

\*\* The recommended temperature range is the temperature range for which limits of error have been established.

\*\*\* Trade names: Amax Specialty Metals Corp.

# THERMOCOUPLE INITIAL MATERIAL TOLERANCES

ANSI Limits of error Thermocouples Reference Junction 0°C(32°F). Published in ANSI Circular MC 96.1-1982				
Note: 1/4 limits available on request				
TYPE	TEMPERATURE RANGE °C(°F) FOR STANDARD LIMITS OF ERROR	STANDARD LIMITS OF ERROR °C(°F)	TEMPERATURE RANGE °C(°F) FOR SPECIAL LIMITS OF ERROR	SPECIAL LIMITS OF ERROR °C(°F)
J	0 to 293 (32 to 559) 293 to 760 (559 to 1400)	± 2.2 ( +4.0) ± 0.75%	0 to 275 (32 to 537) 275 to 760 (527 to 1400)	± 1.1 ( +2.0) ± 0.4%
K	-200 to -110 (-328 to -166) -110 to 0 (-166 to 32) 0 to 293 (32 to 559) 293 to 1250 (559 to 2282)	± 2% ± 2.2 ( +4.0) * ± 2.2 ( +4.0) ± 0.75%	0 to 275 (32 to 527)  275 to 1250 (527 to 2282)	** ** ± 1.1 ( +2.0) ± 0.4%
T	-200 to -67 (-328 to -89) -67 to 0 (-89 to 32) 0 to 133 (32 to 271) 133 to 350 (271 to 662)	± 1.5% ± 1 ( +1.8) * ± 1 ( +1.8) ± 0.75%	0 to 125 (32 to 257)  125 to 350 (527 to 662)	** ** ± 0.5 ( +0.9) ± 0.4%
E	-200 to -170 (-328 to -274) -170 to 0 (-274 to 32) 0 to 340 (32 to 664) 340 to 900 (664 to 1652)	± 1% ± 1.7 ( +3.1) * ± 1.7 ( +3.1) ± 0.5%	0 to 250 (32 to 482)  250 to 900 (482 to 1652)	** ** ± 1 ( +1.8) ± 0.4%
R S	0 to 600 (32 to 1112) 600 to 1450 (1112 to 2642)	± 1.5 ( +2.7) ± 0.25%	0 to 600 (32 to 1112) 600 to 1450 (1112 to 2642)	± 0.6 ( +1.1) ± 0.1%
B	800 to 1700 (1472 to 3092)	± 0.5%	800 to 1700 (1472 to 3092)	- -

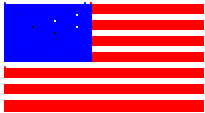
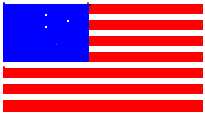


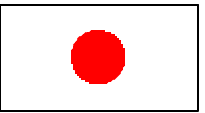
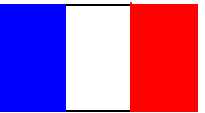
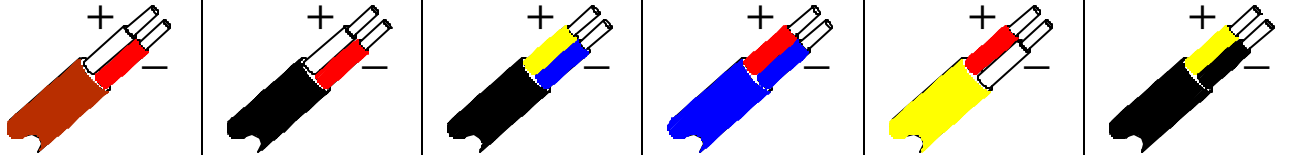
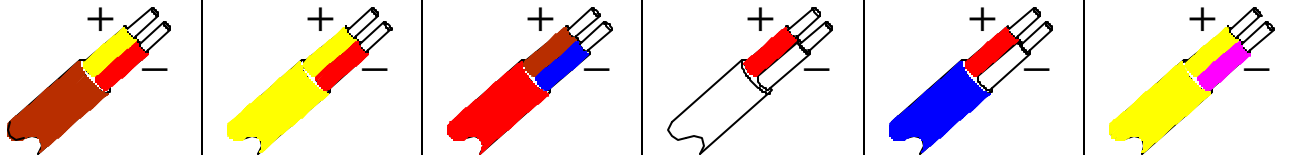
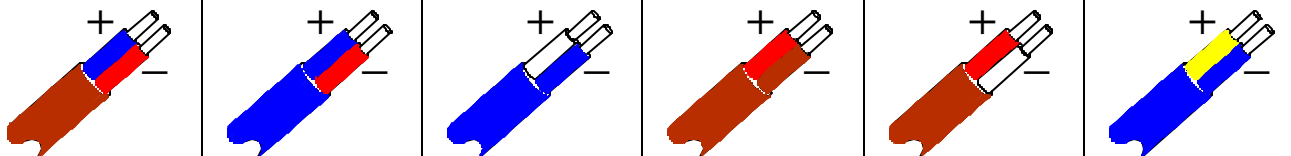
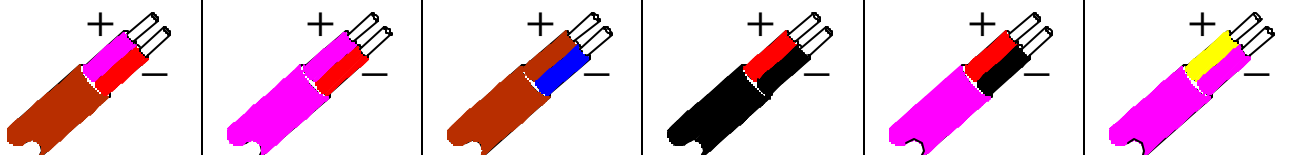
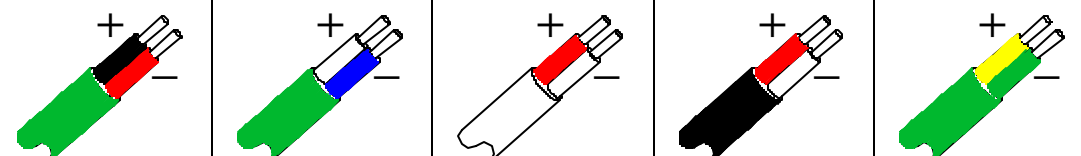
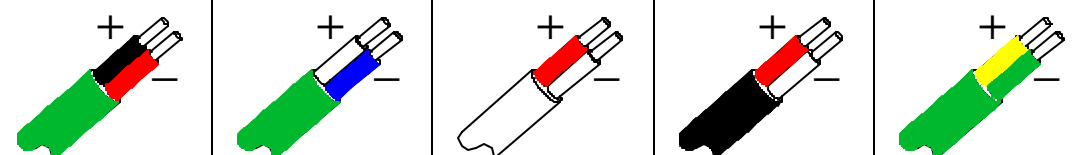
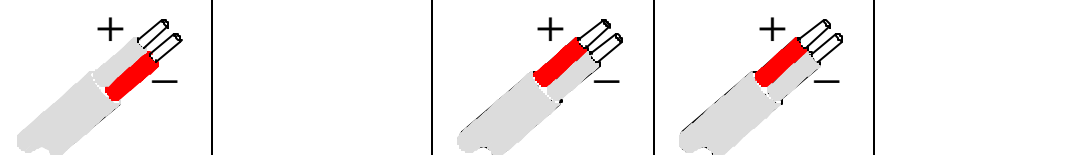
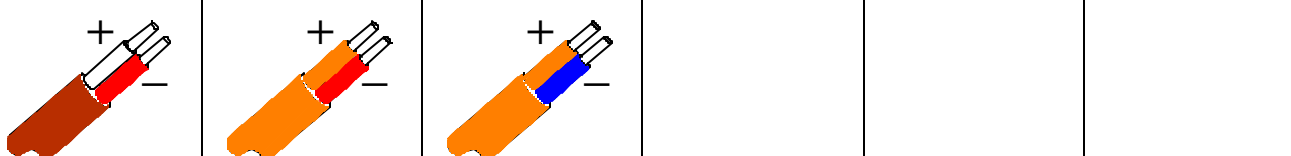
\* Thermocouples and thermocouple materials are supplied to meet limits of error specified for temperature above 0°C. A thermocouple material may not conform to the published sub-zero limits of error for that material when purchased, unless conformance is agreed to.

\*\* Special limits of error for sub-zero temperatures have not yet been established. The following limits for calibrations E and T are useful to start discussion.  
-200 to 0°C  
Type E: ±1°C or ±0.5%, whichever is greater  
Type T: ±5°C or ±0.8%, whichever is greater

Sub-zero limits of error for type J and sub-zero special limits of error for type K are not considered because of the characteristics of the materials.

Non ANSI limits of error thermocouples		
TYPE	TEMPERATURE RANGE °C(°F)	LIMITS OF ERROR °C(°F)
C	0 to 427 (32 to 800) 427 to 2316 (800 to 4200)	± 4.4 ( +8.0) ± 1%
M	0 to 1287 (32 to 2349)	± 0.75%
N	0 to 1250 (32 to 2282)	± 2.2 ( +4.0) ± 0.75%

# THERMOCOUPLE COLOUR CODES

TYPE	AMERICAN TO ANSI T/C 	AMERICAN TO ANSI EXTENSION 	BRITISH TO BS 1843 	GERMAN TO DIN 43714 	JAPANESE TO JIS C 1610-1981 	FRENCH TO NF C 43-323 
J						
K						
T						
E						
R						
S						
B						
N						

# RESISTANCE TEMPERATURE DETECTOR (RTD) SPECIFICATIONS

## Standard Assemblies

ACROLAB RTD Assemblies utilize wire wound platinum elements with a reference resistance of 100 Ohms at 0°C and a temperature coefficient of 0.00385 Ohms/Ohm/°C. ALL ACROLAB RTD probes are of the "filled tube" or "MgO" construction, providing long operating life in high vibration and/or temperature applications.

TYPICAL 100 OHM PLATINUM ELEMENT TOLERANCES											
TEMPERATURE		CLASS B (0.12%) TOLERANCE ± [0.30 + 0.0050  t ]°C		BAND 1 (0.1%) TOLERANCE ± [0.26 + 0.0042  t ]°C		CLASS A (0.06%) TOLERANCE ± [0.15 + 0.0020  t ]°C		BAND 3 (0.03%) TOLERANCE ± [0.08 + 0.0017  t ]°C		BAND 5 (0.01%) TOLERANCE ± [0.03 + 0.0017  t ]°C	
°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
-200	-328	1.30	2.34	1.10	1.98	0.55	0.99	0.42	0.76	0.37	0.67
-100	-148	0.80	1.44	0.68	1.22	0.35	0.63	0.25	0.45	0.20	0.36
0	32	0.30	0.54	0.26	0.47	0.15	0.27	0.08	0.14	0.03	0.05
100	212	0.80	1.44	0.68	1.22	0.35	0.63	0.25	0.45	0.20	0.36
200	392	1.30	2.34	1.10	1.98	0.55	0.99	0.42	0.76	0.37	0.67
300	572	1.80	3.24	1.52	2.74	0.75	1.35	0.59	1.06	0.54	0.97
400	752	2.30	4.14	1.94	3.49	0.95	1.71	0.76	1.37	0.71	1.28
500	932	2.80	5.04	2.36	4.25	1.15	2.07	0.93	1.67	0.88	1.58
600	1112	3.30	5.94	2.78	5.00	1.35	2.43	1.10	1.98	1.05	1.89

## Element Types

Single platinum elements of 100 Ohms at 0°C and duplex elements of two 100-Ohm elements inside the same sheath are both available as standard. Elements of other resistive materials such as copper and nickel are available upon request.

## Element Types

Excitation current and voltage 2mA @24 VDC

## Time Constant

The time required to sense 63 % of a step temperature change from 25°C to 80°C in water flowing at 3 ft/sec. "The time constant for a 3/16" OD SS sheath diameter is 2.0 seconds typical."

## Temperature Range

The standard temperature range is -100°C to 260°C (-148°F to 500°F). Higher ranges available (up to 550°C) on request.

# RESISTANCE TEMPERATURE DETECTOR (RTD) SPECIFICATIONS

## Element Leads

Lead wire is stranded, silver plated copper with teflon insulation for low range units, and stranded, silver plated copper with fiberglass insulation for high range units. Three lead wires are recommended to compensate for lead wire resistance in industrial applications.

## Leadwire Insulation

Max. Temp. rating: 260°C (500°F) teflon  
550°C (1022°F) fiberglass

## WIRE CONFIGURATIONS

### 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.

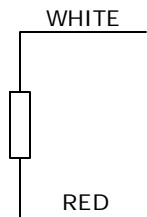
### Three-Wire

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.

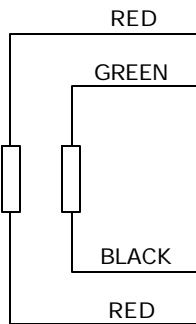
### Four-Wire

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

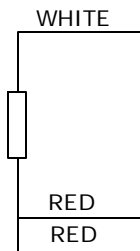
2 WIRE SINGLE



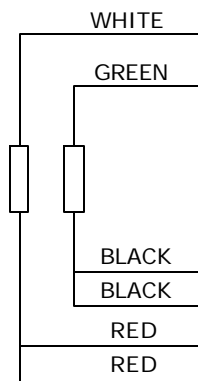
2 WIRE DUPLEX



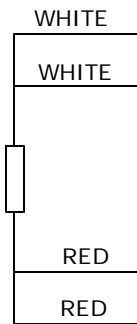
3 WIRE SINGLE



3 WIRE DUPLEX



4 WIRE DUPLEX



# TUBING, MgO SHEATH, PROTECTION TUBE, AND DRILLED WELL MATERIALS

METALS					
MATERIAL / COMPOSITION	TYPICAL AREAS OF USE				APPLICATION GUIDELINE INFORMATION
	TUBING	MgO SHEATHS	PROTECT. TUBES	DRILLED WELLS	
304 Stainless Steel (UNS S30400) 18% Chromium 8% Nickel	✓	✓	✓	✓	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 47 to 538°C corrosion resistance in the 47 to 538°C (800 to 1000°F) range. Good mechanical properties from -184 to 788°C (-300 to 1450°F) range. Main areas of usage for thermocouple protection is in areas of usage for thermocouple protection is in chemicals, foods, plastics and petroleum. Generally regarded as standard protection tube material.
304 Stainless Steel Low Carbon (UNS S30403) 18% Chromium 8% Nickel	✓	✓	✓	✓	Same characteristics as for 304 Stainless Steel except that low carbon allows corrosion resistant weld areas. Not recommended for use above 472°C (800°F). (0.03% maximum carbon)
310 Stainless Steel (UNS S31000) 25% Chromium 20% Nickel	✓	✓	✓	✓	Up to 1038°C (1900°F) continuous, 1140°C (2100°F) intermittent. Mechanical and corrosion resistant similar to and better than 304 Stainless Steel.
316 Stainless Steel (UNS S31600) 16% Chromium, 12% Nickel, 2% Molybdenum	✓	✓	✓	✓	Up to 927°C (1700°F) under oxidizing conditions. Same areas of applications as for 304 Stainless Steel. Has improved resistance to mild acid and pitting corrosion.
316 Stainless Steel Low Carbon (UNS S31603) 16% Chromium, 12% Nickel, 2% Molybdenum	✓	✓	✓	✓	Same characteristics as for 316 Stainless Steel except that low carbon allows corrosion resistant weld areas. Not recommended for use above 472°C (800°F). (0.03% maximum carbon)
446 Stainless Steel (UNS S44600) 27% Chromium	✓	✓	✓	✓	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 and sulfurous atmospheres. Not for carburizing atmospheres. Other areas 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) and gass flue tanks.
Alloy 600 (UNS N06600) (Inconel 600) 72% Nickel, 15% Chromium, 8% Iron	✓	✓	✓	✓	Up to 1149°C (2100°F) under oxidizing conditions. Reducing conditions reduce temperature to 1038°C (1900°F). Must not be placed in sulfurous atmospheres above 538°C (1000°F). Main areas of applications 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 exitflues, incinerators and glass tank flues.
Alloy 601 (UNS N06601) (Inconel 601) 61% Nickel, 23% Chromium, 1.35% Aluminum	✓	✓	✓	✓	Similar applications to Inconel 600 but with superior resistance to sulphur, high temperature oxidation resistance to 1260°C (2300°F)
Brass	✓			✓	Up to 538°C (1000°F) continuous. Good thermal conductivity and mechanical strength.
Carbon Steel	✓		✓	✓	Up to 538°C (1000°F) in non-oxidizing environments. Main areas of usage are galvanizing pots, tinning pots, molten babbitt metal, molten magnesium, molten zinc, petroleum refinery applications such as dew axing and thermal cracking.
Cast Iron			✓		Up to 704°C (1300°F) in oxidizing conditions. Main areas of usage is in molten non-ferrous metals, daily whitening is recommended. Can be used to 871°C (1600°F) under reducing conditions.
Copper	✓				Up to 260°C (500°F) continuous. Excellent thermal conductivity and mechanical strength.
Tantalum	✓	✓		✓	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 atmospheres.
Titanium	✓	✓		✓	Up to 1260°C (2300°F) in inert or vacuum atmospheres. Acid and chemical resistant. Oxidization resistance to 538°C (1000°F).

# TUBING, MgO SHEATH, PROTECTION TUBE, AND DRILLED WELL MATERIALS

CERAMICS AND COMPOSITE MATERIALS					
MATERIAL / COMPOSITION	TYPICAL AREAS OF USE				APPLICATION GUIDELINE INFORMATION
	TUBING	MgO SHEATHS	PROTECT. TUBES	DRILLED WELLS	
Alumina <sup>■</sup> (Recrystallized 99.7% AL <sub>2</sub> O <sub>3</sub> )			✓		Up to 1889°C (3400°F) when supported. Has only fair resistance to thermal and mechanical shock. Essentially same areas as Mullite including induction melting and vacuum furnaces. Impervious to gases at high temperatures.
Cerite <sup>■</sup> II (Cast oxide composites)			✓		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.
Cerite <sup>■</sup> II (Cast oxide composites)			✓		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.
Hexaloy <sup>SA</sup> sintered alpha, silicon carbide			✓		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.
Metal Ceramic LT-1 (slip cast composite of chromium and aluminum oxide) 77% chromium 2% aluminum oxide			✓		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), Sulfer burners to 1093°C (2000°F), cement kilns to 1024°C (2200°F), chemical process reactors to 1371°C (2500°F). A ceramic primary tube is required when a noble metal thermocouple is used.
Mullite 63% alumina			✓		Up to 1510°C (2750°F) when supported. Has poor mechanical shock resistance, 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 and glass manufacturing. Impervious to gases at high temperature.
Refractory Coated (Series 1100)			✓		Up to 745°C (1400°F). Refractory laminated coating resists erosion from molten aluminum, zinc or galvanizing baths. Special protective bulb at tip for fast response and thermal expansion.
Silicon Carbide 99% silicon carbide, 9% silicone 9% silicon dioxide balance aluminum oxide			✓		Up to 1650°C (3000°F). For an outer protection tube with Alumina <sup>■</sup> or mullite primary tube. For brick and ceramic kilns, steel soaking pits and molten non-ferrous metals. Can withstand direct flame impingement. Fair thermal shock resistance. Approximately 14% porosity.
Silicon Nitride			✓		Up to 927°C (1700°F). For use in aluminum and other non-ferrous metal foundries. Not wetted by molten aluminum and other non-ferrous metals. No contamination. Resists thermal and mechanical shock.
Vesuvius			✓		Up to 927°C (1700°F). For use in aluminum and other non-ferrous metal foundries. Not wetted by molten aluminum and other non-ferrous metals. No contamination. Resists thermal and mechanical shock. Handle carefully.

## THERMOCOUPLE SELECTION

Selecting the proper thermocouple and installing it correctly will provide you with more accurate results and give the device a longer life time. The following are some helpful tips for selecting and maintaining thermocouples.

### **A. Thermocouples should be protected.**

Many external factors can affect the composition of the thermocouple materials causing skewed readings and shortened lifetime. Evaporation, oxidation, contamination, corrosion, diffusion, and induced EMF must all be considered when a thermocouple is being put into service. Protective sheaths can be used in the construction to protect the device. If the thermocouple contains a bare wire, it is important that the protection tubes are clean and have the proper diameter and length to allow proper ventilation inside.

### **B. Select practical and large wire.**

Wire that contains heavier wire is often more stable in a high temperature environment when compared with a lighter gauge. However, fine gauge wire provides rapid response and flexibility. A compromise must be made using these factors to determine the largest wire possible to meet the specifications.

### **C. Select proper location for installation.**

Thermocouple must be installed in an area that properly represents the temperature of the equipment or substance that is being measured.

### **D. Ensure proper thermocouple depth.**

Since heat can be transferred away from the thermocouple sensor, it is important to ensure the thermocouple has sufficient depth to gain an accurate reading.

### **E. Maintain a constant immersion depth.**

Imperfections in the thermocouple wires can result from factors such as oxidation, corrosion, and evaporation. These imperfections can cause inaccurate readings if the depth of the thermocouple is altered.

### **F. Heating cycles can affect accuracy.**

It is recommended that the thermocouples be used at a single temperature or increasingly higher temperatures to maintain high accuracy. However, this is not always the case. It must be accounted for that there will be some error when cyclic heating occurs. The error can be reduced by using thermocouples which are still in good condition.

### **G. Check equipment regularly.**

It is important to check and repair the thermocouples, protection tubes, and extension wires for any damage. Checks should occur as frequent as necessary, however, once a month is usually sufficient. Check to see if the protection tubes are burnt out or damaged to prevent harm to the thermocouple. Check thermocouples in place if possible. If not, they should be reinserted to at least the same depth to avoid error. Make sure the external wire reaches the resistance equipment.

## TROUBLE-SHOOTING

If a thermocouple is giving erroneous readings, the following steps should be taken to spot the error.

### **A. Check Circuit**

Check the polarity of the thermocouple at each connection. They can often be identified by magnetism or colour coding. The negative thermocouple wire should connect to the negative extension wire, and in turn, to the negative side of the meter. This should also be true for the positive connections.

### **B. Check Instrumentation**

After checking the circuit, turn your attention to control meter or recording instrument. Make sure the instrument is set to the proper thermocouple type. Check the room temperature setting (cold junction compensation). Do this by removing the extension wires and placing a jumper wire across the meter connection terminals. The reading should coincide with the room temperature. If problems still arise, compare the reading of a test thermocouple with known accuracy (also connected to a meter of known accuracy) with the thermocouple in question. Make sure the test thermocouple is placed as close to the original as possible to ensure they are measuring the same temperature.

### **C. Check Thermocouple**

Thermocouples are always susceptible to a change in composition which could cause faulty readings. This could be due to many factors such as oxidation, corrosion, or contamination that often come from such things as brazing alloys and fluxes. Check the working thermocouple by hooking it up to a test meter of known accuracy. If the working meter reading is the same as the previous test reading of known accuracy, then the working thermocouple is not the problem.

### **D. Test Meter and Extension Wires**

Connect the extension wires to a test thermocouple of known accuracy and observe the reading. If the reading is different than obtained with the test meter, then the fault lays in either the working meter or extension wires.

Checking all of these components of the system can often result in diagnosing the problem and finding a solution. If the error is directly due to a faulty thermocouple, then it should be removed and inspected. If the thermocouple is severely corroded or oxidized then it should be replaced. It is often better to replace an inaccurate thermocouple than to risk a loss of product or time due to temperature problems.

## CAUSES OF AGING (DRIFT)

Aging refers to a positive EMF shift (more output) of nickel thermocouple alloys resulting from a temperature gradient along the thermocouple elements. The temperature that aging occurs is estimated to be around 370° to 540°C (700° to 1000°F). There are a few things that can increase the amount of EMF shift:

- The temperature that is being measured or the previous thermal history of the thermocouple.
- The thermocouple composition.
- Duration of aging temperature.
- Amount of thermocouple exposed to the aging temperatures.

It must be recognized that aging depends on the application for which the thermocouple is being used and the temperature gradient it experiences. The operating temperature of the thermocouple should be checked. If the thermocouple has never been exposed to aging temperatures, it should never have errors due to aging.

To reduce the inaccuracy of reading temperatures in the aging range, a pre-aged thermocouple may be used. Pre-aged thermocouples are heat treated and have special compositions to minimize errors caused by aging. However, if these are heated above the aging range then the effect of the pre-aging can be removed. For applications where the temperature is above the aging range, it is important to keep as little length of thermocouple as possible in the aging range. This will help to minimize the aging effects.

The effects of the aging process can actually be removed. This is done by heating the entire thermocouple above 870°C (1600°F) for at least 5 minutes. Then the thermocouple should be rapidly cooled to below the aging temperatures. This should restore the wire to its original calibration.

# HOT OR MEASURING JUNCTIONS

## 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 100 megaohms resistance @ 100V dc at ambient room temperatures.

## 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 equal to the outside diameter of the sheath. The exposed junctions for sheath diameters less than 1/8-inch diameter are supplied as shielded junctions.

## 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.

# WATT DENSITY CALCULATION

The durability and performance of a heater depends on selecting the appropriate wattage. Exceeding the maximum allowable watt density for the specified heater size will result in premature heater failure. While calculating watt densities, we should remove the area of the cold section from the overall calculated surface area of the heater.

$$\text{Watt Density (W/in}^2\text{)} = \frac{\text{Wattage}}{(3.14 \times \text{ID} \times \text{Width}) - (\text{Cold Section})}$$

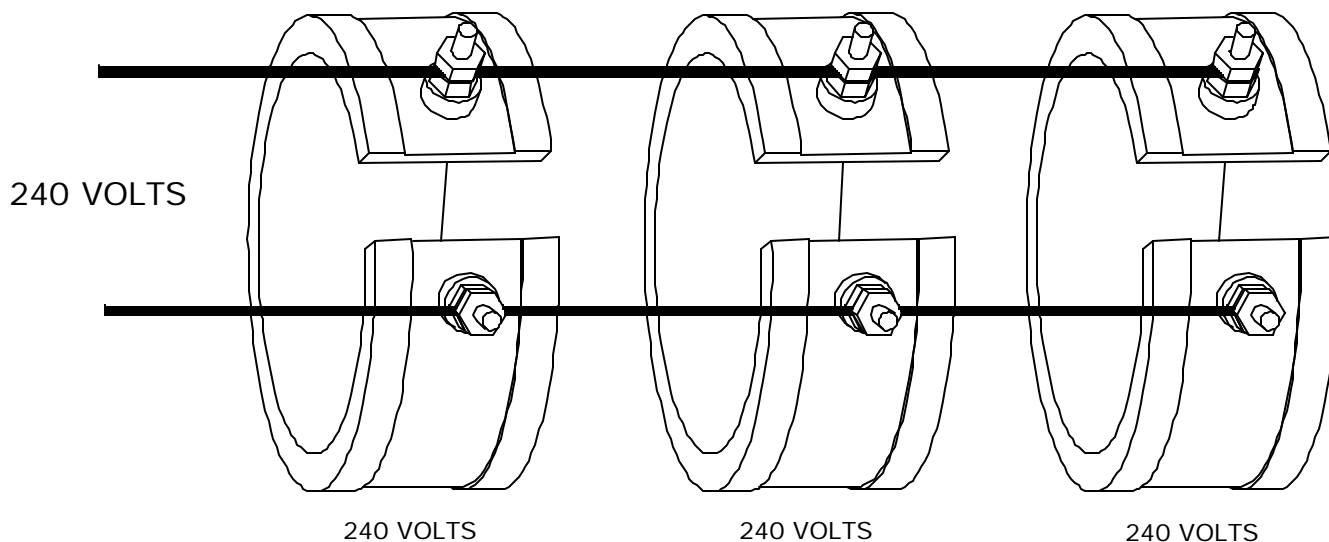
COLD SECTION	
CONSTRUCTION	DESCRIPTION
One piece	1" x width
Two piece	2" x width
Holes, Cutout	(Size + 1/2") x width

## Points to Consider while Selecting Watt Density

- Select narrower heaters where possible, as their heat transfer is superior to wide heaters. 1" to 2.5" wide heaters are ideal.
- The watt density should be selected in accordance with the operating temperature. A table that shows the maximum allowable watt density is provided as a guideline.
- To avoid short cycling and inefficient operation, select a wattage as close to the needed capacity as possible.
- The wattage should be in accordance with the voltage and current rating of the controls.
- The safe heating pattern of the material heated, thermal conductivity and coefficient of expansion of the cylinder are other factors that should be taken into consideration while deciding wattage.

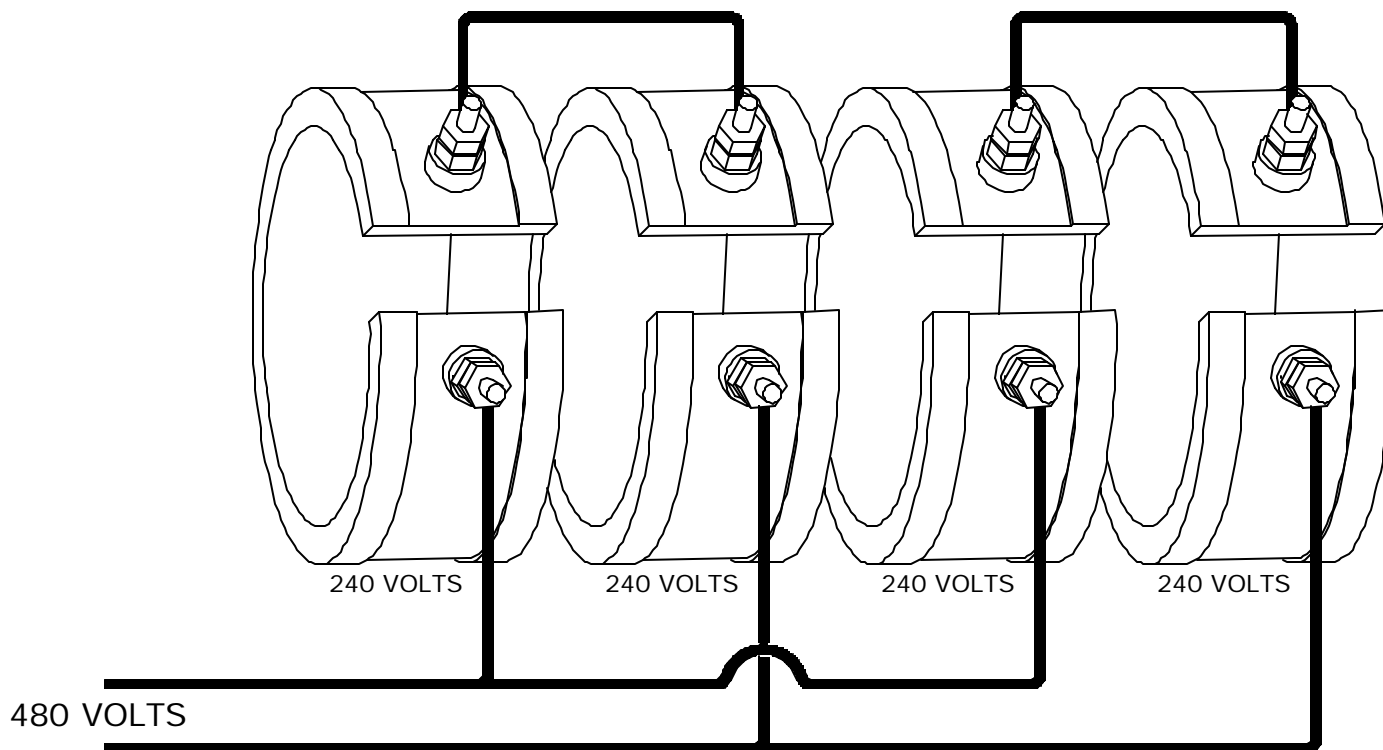
# BAND HEATER WIRING DIAGRAMS

## PARALLEL WIRING



HEATERS ARE NORMALLY WIRED IN PARRALEL BY ZONES

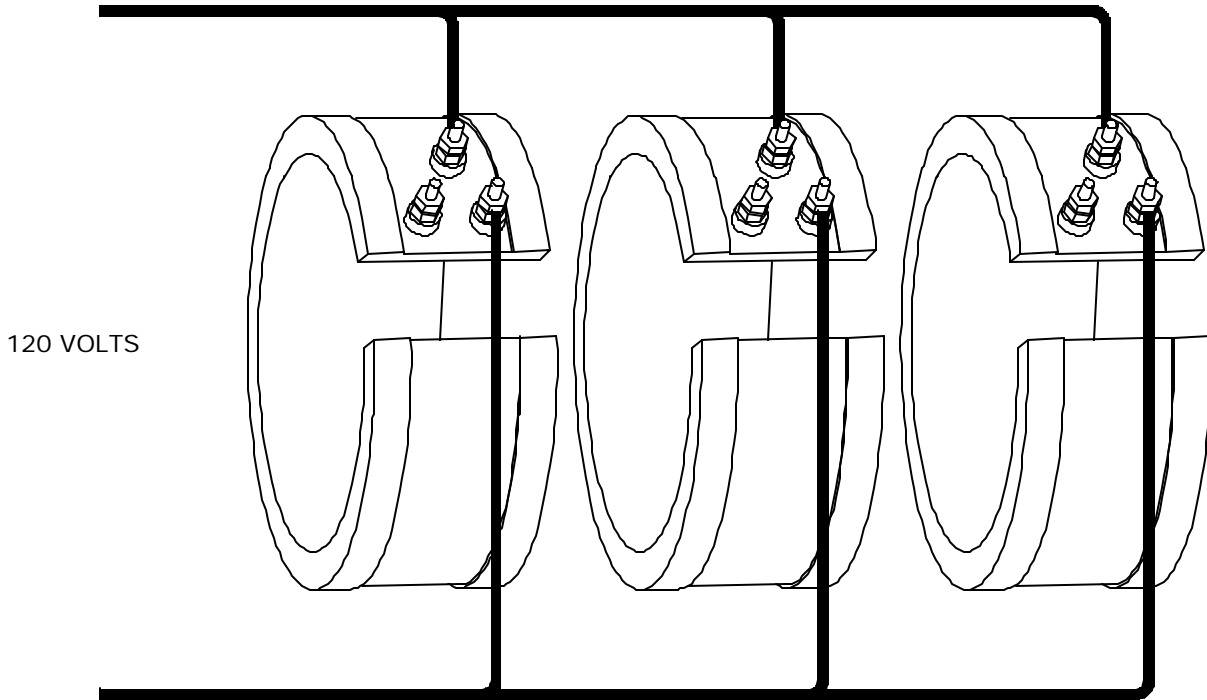
## SERIES WIRING



THIS ILLUSTRATION INDICATES FOUR 240V BAND HEATERS WIRED TO ACCEPT 480V. THE BANDS MUST ALL BE OF THE SAME WATTAGE AND WIRE IN PAIRS IN SERIES

# DUAL VOLTAGE BAND HEATERS

120/240V



DO NOT USE

