



Duro-Sense Corporation

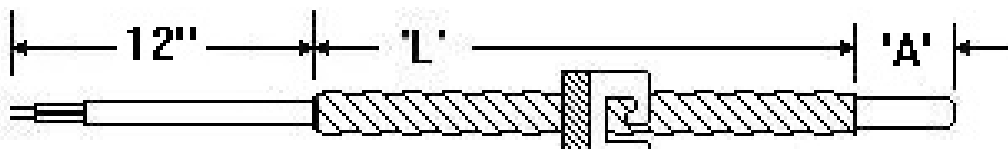


PLASTICS INDUSTRY THERMOCOUPLES

PLASTICS INDUSTRY THERMOCOUPLES

Thermocouple Ordering Information

Armor Adjustable Design (AA)



Part #: AA- - - - - - - 						
Sheath Diameter (Table 1)	Calibration (Table 2)	Lead Protection (Table 3)	Junction (Table 4)	'A' Length (inches)	'L' Length (inches)	Cold End Termination (Table 5)

NOTE: For any additional modifications to this assembly, add "-MOD" to the end of the part number and provide a physical description of the modification.

Table 1
Sheath Diameter

P/N	Description
1	.125 inches
2	.188 inches
X	Special

Table 2
Calibration

P/N	Description
1	Type 'J'
2	Type 'K'
3	Type 'T'
4	Type 'E'
5	Type 'N'
X	Special

Table 3
Lead Protection

P/N	Description
A	Fiberglass
B	Fiberglass w/ SS Overbraid
C	Teflon
D	Teflon w/ SS Overbraid
X	Special

Table 4
Junction

P/N	Description
G	Grounded
U	Ungrounded
E	Exposed
X	Special

Table 5
Cold End Termination

P/N	Description
A	Standard Plug
B	Hi-Temp Plug
C	Standard Jack
D	Hi-Temp Jack
E	Miniature Plug
F	Miniature Hi-Temp Plug
G	Miniature Jack
H	Miniature Hi-Temp Jack
J	Spade Lugs
K	Ring Lugs
L	Stripped Leads
X	Special

Example:

AA-2-1-B-G-1-12-L

Armor Adjustable Design, .188" ϕ , Type 'J', Fiberglass Leads w/ SS Overbraid, Grounded junction, 1" active length, 12" Lead length, standard stripped leads

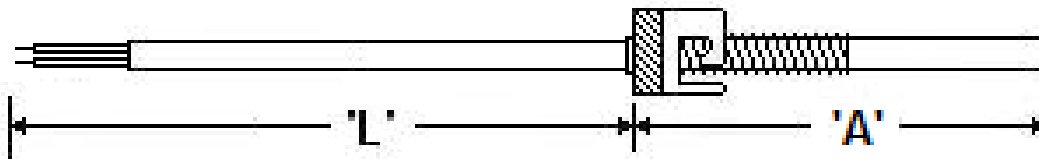
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PLASTICS INDUSTRY THERMOCOUPLES

Thermocouple Ordering Information

Bayonet Straight Design (BS)



Part #: BS- - - - - - - - - -									
Sheath Diameter (Table 1)	Calibration (Table 2)	Lead (Table 3)	Junction (Table 4)	'A' Length (inches)	'L' Length (inches)	Cold End Termination (Table 5)			

NOTE: For any additional modifications to this assembly, add "-MOD" to the end of the part number and provide a physical description of the modification.

Table 1

P/N	Description
1	.125 inches
2	.188 inches
X	Special

Table 2

P/N	Description
1	Type 'J'
2	Type 'K'
3	Type 'T'
4	Type 'E'
5	Type 'N'
X	Special

Table 3

P/N	Description
A	Fiberglass
B	Fiberglass w/ SS Overbraid
C	Fiberglass w/ SS Flex Armor
D	Teflon
E	Teflon w/ SS Overbraid
F	Teflon w/ SS Flex Armor
X	Special

Table 4

P/N	Description
G	Grounded
U	Ungrounded
E	Exposed
X	Special

Table 5

P/N	Description
A	Standard Plug
B	Hi-Temp Plug
C	Standard Jack
D	Hi-Temp Jack
E	Miniature Plug
F	Miniature Hi-Temp Plug
G	Miniature Jack
H	Miniature Hi-Temp Jack
J	Spade Lugs
K	Ring Lugs
L	Stripped Leads
X	Special

Example:

BS-2-1-B-G-6-12-L

Bayonet Straight Design, .188" ϕ , Type 'J', Fiberglass Leads w/ SS Overbraid, Grounded junction, 6" active length, 12" Lead length, standard stripped leads

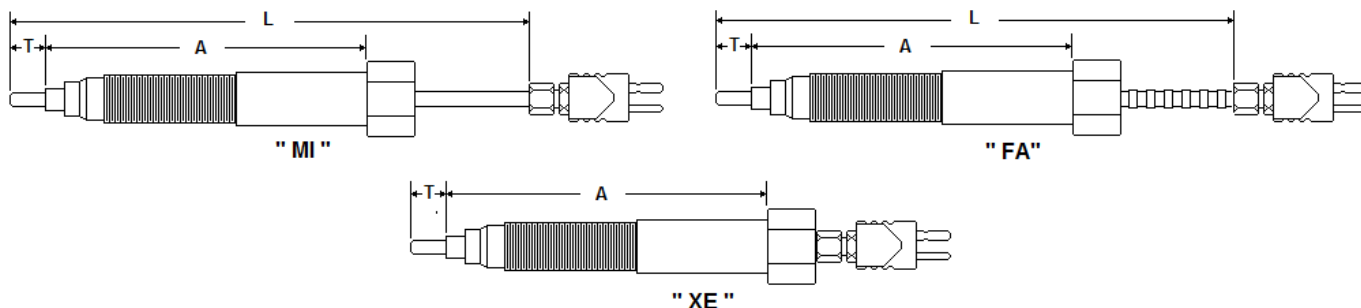
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PLASTICS INDUSTRY THERMOCOUPLES

Thermocouple Ordering Information

Melt Bolt Assembly



Part #:	PIT-MB-									
	Calibration (Table 1)	Design (Table 2)	'A' (inches)	'L' (inches)	'T' (inches)	Cold End Termination (Table 3)	*SP = Special Limits of Error If standard limits of error is desired, omit this field.			

NOTE: For any additional modifications to this assembly, add "-MOD" to the end of the part number and provide a physical description of the modification.

Table 1
Calibration

P/N	Description
J	Type 'J'
K	Type 'K'
T	Type 'T'
E	Type 'E'
N	Type 'N'
X	Special

Table 2
Design

P/N	Description
FA	Flex Armor Extension
MI	M.I. Cable Extension
XE	No Extension

Table 3
Cold End Termination

P/N	Description
A	Stripped Leads Only
B	Ceramic Terminal Block
C	Standard Plug
D	Hi-Temp Plug
E	Ceramic Plug
F	Standard Jack
G	Hi-Temp Jack
H	Ceramic Jack
J	Spade Lug
K	Ring Lug
X	Special

Example:

BMT-MB-K-MI-6-6-F-C

Melt Bolt Style, Type 'K', M.I. cable extension, A = 6, L = 6", T = flush, standard male connector.



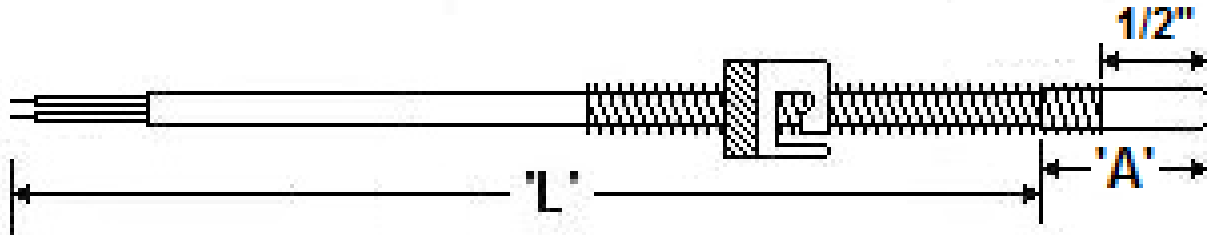
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PLASTICS INDUSTRY THERMOCOUPLES

Thermocouple Ordering Information

Spring Adjustable Design (SA)



Part #: SA- - - - - - - - - - -

Sheath Diameter (Table 1)
Calibration (Table 2)
Lead Protection (Table 3)
Junction (Table 4)
'A' Length (inches)
'L' Length (inches)
Cold End Termination (Table 5)

NOTE: For any additional modifications to this assembly, add "-MOD" to the end of the part number and provide a physical description of the modification.

Table 1
Sheath Diameter

P/N	Description
1	.125 inches
2	.188 inches
X	Special

Table 2
Calibration

P/N	Description
1	Type 'J'
2	Type 'K'
3	Type 'T'
4	Type 'E'
5	Type 'N'
X	Special

Table 3
Lead Protection

P/N	Description
A	Fiberglass
B	Fiberglass w/ SS Overbraid
C	Teflon
D	Teflon w/ SS Overbraid
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Table 4
Junction

P/N	Description
G	Grounded
U	Ungrounded
E	Exposed
X	Special

Table 5
Cold End Termination

P/N	Description
A	Standard Plug
B	Hi-Temp Plug
C	Standard Jack
D	Hi-Temp Jack
E	Miniature Plug
F	Miniature Hi-Temp Plug
G	Miniature Jack
H	Miniature Hi-Temp Jack
J	Spade Lugs
K	Ring Lugs
L	Stripped Leads
X	Special

Example:

SA-2-1-B-G-1-12-L

Spring Adjustable Design, .188" ϕ , Type 'J', Fiberglass Leads w/ SS Overbraid, Grounded junction, 1" active length, 12" Lead length, standard stripped leads



Duro-Sense Corporation

TECHNICAL REFERENCE GUIDE

THERMOCOUPLE TECHNICAL REFERENCE

Thermocouple Types

Thermocouple Type (ANSI Code)	Positive Leg	Negative Leg	Recommended/General Temperature Range	Notes
J	Iron	Constantan	32°F-1400°F (0°C-760°C)	Suitable for vacuum, reducing, or inert atmospheres and oxidizing atmospheres with reduced life. Since oxidation of the iron leg occurs rapidly at temperatures above 1000°F(538°C), heavier gauge wire should be used at those temperatures. Iron may be attacked by ammonia, hydrogen, and nitrogen if not protected. Bare elements should not be exposed to sulphurous atmospheres above 1000°F(538°C)
K	Chromel**	Alumel**	32°F-2300°F (0°C-1260°C)	Suitable for oxidizing or inert atmospheres. Recommended for use above 1000°F(538°C). Accuracy below 900°F(482°C) is greatly reduced after prolonged use above 1400°F(760°C). Should not be used in reducing atmosphere if unprotected.
T	Copper	Constantan	-300°F-700°F (-184°C-371°C)	Suitable for oxidizing, inert, or reducing atmospheres. Has a high corrosive resistance to moisture. Is excellent for very low temperature applications.
E	Chromel**	Constantan	32°F-1600°F (0°C-871°C)	Recommended for use in oxidizing or inert atmospheres. Exhibits good resistance to corrosion at low temperatures. Greatest EMF output of standard calibrations.
N	Nicrosil***	Nisil***	32°F-2300°F (0°C-1260°C)	Suitable for use in applications where Type 'K' elements have shorter life and stability problems due to oxidation.
R	Platinum/13% Rhodium	Platinum	1000°F-2700°F (538°C-1482°C)	Recommended for high temperature applications. Protection from all atmospheres must be provided, as it is subject to contamination and drift. Prolonged use at high temperature can cause grain growth which can lead to mechanical failure. Rhodium diffusion and volatilization can lead to calibration drift. Primarily used in industrial applications.
S	Platinum/10% Rhodium	Platinum	1000°F-2700°F (538°C-1482°C)	Recommended for high temperature applications. Protection from all atmospheres must be provided, as it is subject to contamination and drift. Prolonged use at high temperature can cause grain growth which can lead to mechanical failure. Rhodium diffusion and volatilization can lead to calibration drift. Primarily used in laboratory applications.
B	Platinum/30% Rhodium	Platinum	1600°F-3100°F (871°C-1705°C)	Similar applications as Type 'R' and type 'S', but with better stability and higher temperature range. It is also less susceptible to grain growth and drift.
C*	Tungsten/5% Rhenium	Tungsten/26% Rhenium	1000°F-4200°F (538°C-2315°C)	Recommended for very high temperature applications in vacuum or inert atmospheres. No oxidation resistance.

*Not an ANSI symbol

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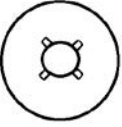
Initial Calibration Tolerances

Thermocouple Type ANSI Symbol	°C			°F		
	Temperature Range	Standard Limits	Special Limits	Temperature Range	Standard Limits	Special Limits
T	-200 to -65 -65 to 130 130 to 350	±1.5% ±1° ±0.75%	±0.8% ±0.5° ±0.4%	-330 to -85 -85 to 270 270 to 660	±1.5% ±1.8° ±0.75%	±0.8% ±0.9° ±0.4%
J	0 to 285 285 to 750	±2.2° ±0.75%	±1.1° ±0.4%	32 to 545 545 to 1400	±4° ±0.75%	±2° ±0.4%
E	-200 to -170 -170 to 250 250 to 340 340 to 900	±1% ±1.7° ±1.7° ±0.5%	±1° ±1° ±0.4% ±0.4%	-330 to -270 -270 to 480 480 to 640 640 to 1600	±1% ±3° ±3° ±0.5%	±1.8° ±1.8° ±0.4% ±0.4%
K	-200 to -110 -110 to 0 0 to 285 285 to 1250	±2% ±2.2° ±2.2° ±0.75%	-- -- ±1.1° ±0.4%	-330 to -165 -165 to 32 32 to 545 545 to 2300	±2% ±4° ±4° ±0.75%	-- -- ±2° ±0.4%
N	0 to 285 285 to 1250	±2.2° ±0.75%	±1.1° ±0.4%	32 to 545 545 to 2300	±4° ±0.75%	±2° ±0.4%
S	0 to 600 600 to 1450	±1.5° ±0.25%	±0.6° ±0.1%	32 to 1110 1110 to 2650	±2.7° ±0.25%	±1.1° ±0.1%
R	0 to 600 600 to 1450	±1.5° ±0.25%	±0.6° ±0.1%	32 to 1110 1110 to 2650	±2.7° ±0.25%	±1.1° ±0.1%
B	870 to 1700	±0.5%	±0.25%	1600 to 3100	±0.5%	±0.25%
C*	400 to 2300	±1%	--	800 to 4200	±1%	--

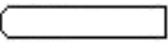
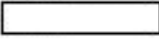
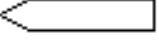
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THERMOCOUPLE TECHNICAL REFERENCE

Hot Tip Junction Types

Description	Illustration
Exposed Junction: Thermocouple conductors are welded to form a junction that extends beyond the sheath for a distance equal to the diameter. This style is used where fast response is required and contamination is not a factor.	
Grounded Junction: Thermocouple conductors are welded directly to the sheath. Provides good protection against pressure, moisture and mechanical damage, yet retains good response characteristics.	
Ungrounded Junction: Thermocouple conductors are welded together but remain electrically and mechanically isolated from the sheath. This provides long life characteristics under maximum corrosion, thermal shock, and vibration conditions.	
Dual Element Junction: This version provides two circuits for simultaneous response from individual thermal points. Exposed, grounded or ungrounded junctions are available. Two versions of dual junctions are available; <u>Uncommon</u> and <u>Common</u> . In the Uncommon version, the junctions are isolated from the sheath <i>and</i> from each other. In the common version the junctions are isolated from the sheath but <i>not</i> from each other.	  Uncommon Common
Weld Pad Junction: This type of junction is used as a means of attaching thermocouples to surfaces such as boiler tubes and pipes to provide efficient surface temperature measurement. Standard weld pad design uses an alloy pad (1"x1"x1/8") of the same composition as the sheath. Tube skin perpendicular and parallel pad arrangements are available.	  Flat or Formed Pad 0° to 90°

Junction Tip Styles

Rounded	
Flat	
Pointed	
Half-Shield	
Aspirated	
Recessed Exposed	

THERMOCOUPLE TECHNICAL REFERENCE

Thermocouple Type Color Codes

Thermocouple Type (ANSI Code)	Symbol	Trade Name	Magnetic		Color Coding			
			Yes	No	Conductors	Overall T/C Wire	Overall Extension Wire	Connector
J	JP	Iron	X		White	Brown	Black	Black
	JN	Constantan		X	Red			
K	KP	Chromel**		X	Yellow	Brown	Yellow	Yellow
	KN	Alumel**	X		Red			
T	TP	Copper		X	Blue	Brown	Blue	Blue
	TN	Constantan		X	Red			
E	EP	Chromel**		X	Purple	Brown	Purple	Purple
	EN	Constantan	X		Red			
N	NP	Nicrosil***		X	Orange	Brown	Orange	Orange
	NN	Nisil***		X	Red			
R	RP	Platinum 13% Rhodium		X	Black	-----	Green	Green
	RN	Pure Platinum		X	Red			
S	SP	Platinum 10% Rhodium		X	Black	-----	Green	Green
	SN	Pure Platinum		X	Red			
B	BP	Platinum 30% Rhodium		X	Gray	-----	Gray	White (Uncompensated)
	BN	Platinum 6% Rhodium		X	Red			
C*	CP*	Tungsten 5% Rhenium		X	White/Red Trace	-----	White/Red Trace	Brown
	CN*	Tungsten 26% Rhenium		X	Red			

*Not an ANSI symbol

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Upper Temperature Limits for Thermocouples

Thermocouple Type	ANSI Code	Wire Gauge (AWG)				
		8 gauge	14 gauge	20 gauge	24 gauge	30 gauge
Iron-Constantan	J	760°C 1400°F	600°C 1100°F	500°C 900°F	370°C 700°F	320°C 600°F
Chromel**-Alumel**	K	1260°C 2300°F	1100°C 2000°F	1000°C 1800°F	870°C 1600°F	760°C 1400°F
Copper-Constantan	T	-----	370°C 700°F	260°C 500°F	200°C 400°F	150°C 300°F
Chromel**-Constantan	E	870°C 1600°F	650°C 1200°F	550°C 1000°F	430°C 800°F	430°C 800°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	R	-----	-----	-----	1480°C 2700°F	-----
Platinum-13% Rhodium	S	-----	-----	-----	1480°C 2700°F	-----
Platinum-30% vs 6% Rhodium	B	-----	-----	-----	1700°C 3100°F	-----
Tungsten-5% vs 26% Rhenium	C*	-----	-----	-----	2300°C 4200°F	-----

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GENERAL TECHNICAL REFERENCE

General Thermometry Reference Points

	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 pint 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	1828.00	1554.8	2830.60
Freezing point of platinum	2041.30	1768.10	3214.60
Freezing point of rhodium	2235.50	1962.30	3564.10
Freezing point of iridium	2719.00	2446.00	4435.00
Freezing point of molybdenum	2896.00	2623.00	4753.00

Physical Properties of Materials

Material	Melting Point (°F)	Recommended Operating Atmosphere	Maximum Operating Temp. in Atmosphere (°F)
304 SS	2560	ORNV	1650
310 SS	2560	ORNV	2100
316 SS	2500	ORNV	1700
321 SS	2550	ORNV	1600
347 SS	2600	ORNV	1600
446 SS	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

GENERAL TECHNICAL REFERENCE

Nominal Thermocouple Resistance – Ohms per Double Foot @ 68°F (20°C)

Wire Gauge	Wire Size Diameter	ANSI Types						
		J	K	T	E	S	R	B
6	.162	.014	.023	.012	.027	.007	.007	.008
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	7.15	7.226	8.897

Bare Thermocouple Wire Approximate Weight Feet/Lb.

Wire Gauge	Wire Size Diameter	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
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	.032	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

Bare Wire Sizes

American Wire Gauge (AWG)	Size (Diameter) inches	American Wire Gauge (AWG)	Size (Diameter) inches
1	0.2893	21	0.0285
2	0.2576	22	0.0253
3	0.2294	23	0.0226
4	0.2043	24	0.0201
5	0.1819	25	0.0179
6	0.1620	26	0.0159
7	0.1443	27	0.0142
8	0.1285	28	0.0126
9	0.1144	29	0.0113
10	0.1019	30	0.0100
11	0.0907	31	0.00893
12	0.0808	32	0.00795
13	0.0720	33	0.00708
14	0.0641	34	0.00630
15	0.0571	35	0.00561
16	0.0508	36	0.00500
17	0.0453	37	0.00445
18	0.0403	38	0.00396
19	0.0359	39	0.00353
20	0.0320	40	0.00314

THERMOCOUPLE TECHNICAL REFERENCE

Thermocouple Science

It is commonly known that a thermocouple consists of a pair of dissimilar wires joined at one end. This connecting point is known as a measuring junction. However, the junction itself doesn't really "measure" anything. It simply joins the two wires at one place, and ensures that there can be no electrical potential difference between the wires at that point.

Therefore, the sole purpose of the "junction" is to establish a starting point from which a thermoelectric voltage can be developed. In this erroneous "model", it is imagined that the thermocouple's "hot" (measuring) junction somehow functions as an electrical source, and that the junction itself produces the thermocouple's small signal voltage. This concept is simply not true.

The actual thermoelectric effect is an extended and continuous one that is distributed along the entire length of the thermocouple conductors. The process is driven by the temperature differences, or gradients, through which these conductors pass. The key point here is that a thermocouple electromotive force (emf), or voltage, is developed from the measuring junction rather than by that junction. It follows that throughout the circuit beyond this starting point or junction, the thermocouple conductors must be electrically insulated from each other, and must remain so under all operating conditions, so that a useful output signal may be realized.

One helpful way of visualizing a thermocouple is to consider a hypothetical and greatly idealized application in which there are three temperature zones.

One zone, where the temperature is being measured, is uniformly hot. Another, containing the reference junction and instrument connections, is taken to be at a cooler, and likewise uniform, ambient temperature. And in between is a zone within which the temperature is assumed to vary in a linear manner with distance, decreasing smoothly from the hotter to the cooler temperature section.

Because of the connection at the measuring junction, there is no electrical potential difference between the wires at that point. In fact, no emf difference between the wires can exist anywhere within the uniform hot zone because, under the assumed temperature conditions, there is no thermal gradient there that could produce one. For the same reason, no additional change in emf difference between wires will occur within the uniformly cool, ambient temperature zone.

All thermoelectric activity therefore takes place in the center zone of decreasing temperature. The two thermocouple wires, or thermo elements, are dissimilar by design. That is to say, each conductor is made up of chemical elements that essentially differ from those of the other wire, and the presence of these dissimilarities will cause each element to respond to external stimuli (in this case, a temperature change) in a different way.

The electrical potential emf along any wire will change as the local temperature changes. Thus, a diminishing temperature will result in a reduced emf for both thermo elements, but the amount of this reduction in one wire will not be the same as for the other because of their different compositions. The small net difference in emf change between two dissimilar wires constitutes a thermocouple output signal. For an appropriately chosen thermocouple pair, this emf output can be a dependable and repeatable function of the temperature difference between the ends of the wires.

(a)

THERMOCOUPLE TECHNICAL REFERENCE

Thermocouple Science cont'd.

Thus, we see that when subjected to a temperature gradient, selected wires with different known thermoelectric properties will produce a useful electrical signal that varies with the temperature difference in a predictable way. It should be apparent that if the temperature does not change along a particular length of a thermo element pair, then the emf will not change along that length. It also follows that a temperature difference of any magnitude cannot produce a thermal emf between two conductors traversing that difference, if the conductors are thermoelectrically identical.

Identification of noble metal thermocouple wires is made difficult by the fact that all alloys are nearly identical in color and all are non-magnetic. Sometimes it is possible to distinguish the positive wire from the negative one by observing the "limpness" of the wires. Pure platinum wires tend to be more soft, or limp, while the rhodium-alloyed conductors are a little stiffer, enough so to permit identification.

The difference, however, is subtle, and it is not possible to tell one rhodium alloy from another by these means. Proper connections for these thermocouples can be reliably determined by gently heating the junction and observing the resulting polarity on a sensitive indicator. In a related way, qualitative identification of rhodium alloys may be made by forming a junction between an unknown wire and another whose composition is known. If the wires are the same, no significant emf will result when their junction is heated to a considerable degree.

Accuracy

Thermocouple materials are produced, tested and sold in two tolerance grades, called standard and special. These tolerance classes are intended to ensure interchangeability of thermocouple sensors without special calibration testing reported to the user. Then, if necessary, corrections based on the test results may be made. A unique advantage of thermocouples is that "lot calibration tests" may be made of samples from a given spool (or lot) of wire, and those test results will apply to all sensors made from that same lot. In this way significantly closer control of tolerance variations may be gained without incurring the high cost of testing a large number of individual thermocouples.

Design Rationale

The choice of thermocouple type is dependent upon the temperatures and conditions of use. Whatever the choice, it is usually necessary to provide the thermo element with suitable protection from the often-harsh conditions in which temperature measurements must be made. Another important factor in selecting a design can be the ease with which a sensor may be serviced or replaced.

Materials Selection

One class of thermocouple material, referred to as "metal-sheathed", has an integral outer sheath, or tube, whose material is chosen to be compatible with the test and to resist deterioration by it. Inside this sealed tube, a compacted ceramic (metal oxide) powder supports and insulates the thermocouple wires. These sensors are rugged and may be bent. Materials inside the sheath are made pure and dry at time of manufacture and effective seals are formed at both ends. These seals must remain intact so that the ceramic powder inside remains completely dry, because moisture intrusion is apt to shorten service life.

(b)

THERMOCOUPLE TECHNICAL REFERENCE

Thermocouple Science cont'd.

In another frequently used construction, bare thermo elements are simply strung through holes in hard-fired ceramic beads. Under very favorable conditions, it may be possible to insert such a bare, insulated thermo element directly into a space to obtain temperature measurements. However, in most instances, isolation from the test medium is necessary. Therefore, bare-wire, insulated thermo elements are usually inserted into single, or multiple concentric, closed-end protecting tubes for isolation and protection from the measurement environment.

Metal-sheathed assemblies are often installed in such tubes, too. By such means, measurements in very hostile environments can be successfully taken. Where measurements are to be obtained in fluids under pressure, drilled thermowells, machined from solid metal, are sometimes required to obtain the necessary mechanical properties.

For moderate temperature applications, it may be possible to utilize soft insulated single or duplex thermo elements with a simple welded junction bead at the end. Depending on the type of insulation and conditions of use, these economical constructions may be directly inserted into the medium to be measured, or may be provided with some type of tube or other enclosure for isolation from potentially harmful test atmospheres.

Hardware Choices

Once the basic materials selections have been made, the mechanical details of the installation can be determined. Mounting may be accomplished by simply sliding the sensor into a hole, or it may be necessary to rigidly connect it to the process by means of threads or clamps. Pipe fittings are often used for this purpose. Note that the hardware associated with the complete design can often be as important to the success of an application as the choice of thermocouple type inside.

Connecting means for wiring to an instrument often occurs at the outer end of a sensor assembly. In some instances this may take the form of an open or enclosed connecting head, or a terminal block. At other times, a plug and jack type of quick disconnect may be used. It is important that all current carrying portions of the circuit that may be subjected to a temperature gradient should be made of matching thermocouple materials. This is because each incremental length in the circuit must make its contribution according to the temperature difference that it "sees".

As an exception to the matching materials rule, judicious use can sometimes be made of short, heavy splices containing non-matching materials as long as the connections are well protected and remain essentially isothermal. Where properly applied, such splices may be used without causing a significant error. Often it is desirable to select wiring used beyond a connecting head or plug that is different in some respects from the construction needed for the thermocouple itself.

Because the ambient temperatures in this "extension" part of the circuit are often less severe than those seen by the thermocouple itself. Economical extension grade wires are available that have the same nominal composition as costlier thermocouple grades, but are usually guaranteed over more limited temperature ranges and may also have moderately relaxed tolerance levels.

(c)

THERMOCOUPLE TECHNICAL REFERENCE

Thermocouple Science cont'd.

In those cases where thermocouple wires are made of noble metals or other costly alloys, the extension wires can be made of totally different material as an economy measure. Such specially produced extension alloys have thermoelectric properties that are closely matched to those of the particular thermocouple type with which they are to be used. These materials are called compensating thermocouple extension wires.

Selection Factors - Why chose one T/C over another?

The usual goals in choosing a thermocouple type are to provide an adequate measurement over the longest possible life, and at the lowest cost. It is prudent, for such comparisons, to consider the total cost over some suitable time period. It is easy to overlook such hidden costs as maintenance, testing, and replacement, or loss of production due to down time or as a result of inaccurate readings.

Other factors in making the best choice might be the availability of instrumentation, and sometimes a need to standardize on the thermocouple type or types to be used at a given site.

Service Life

Useful thermocouple life is a very difficult prediction to make, even when most of the details of an application are known. And unfortunately, such information is often very hard to determine. The very best test for any application is to actually install, use, and evaluate the in-use performance of a design that is thought likely to succeed. The recommendations, and non-recommendations, listed under the thermocouple type descriptions are a good starting place to pick a type to try.

Decalibration and Drift

All thermocouples are subject to calibration drift with use, it is just a matter of how much, and how fast this may happen. Thermocouple performance is critically dependent upon absolute uniformity of both physical and chemical properties along the entire length of the circuit. When thermo element materials are produced, careful steps are taken to assure that this uniformity (or homogeneity) is achieved. In use, different parts of the circuit experience different conditions of heat, chemical exposure etc., and as a result, such parts actually do grow to be "different" from each other physically.

Because the thermoelectric emf resulting from a given temperature difference is sensitive to changes in the chemical and metallurgical properties of the wire, the total emf produced by a used probe can be different from an otherwise identical new one under the same conditions. The changes are usually small (often negligibly small) over appreciable periods of time. But under adverse conditions, it is possible to realize large drifts at rapid rates.

To achieve long and reliable thermocouple life, the usual strategy is to operate the device comfortably under its maximum temperature, and provide it with the cleanest possible environment in which to work. Enclosures, such as sheaths, protecting tubes, and thermowells are the usual means of controlling the conditions that actually surround the thermo elements themselves.

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THERMOCOUPLE TECHNICAL REFERENCE

Thermocouple Science cont'd.

What can go wrong

Protecting tubes, sheaths, and even thermowells can fail due to corrosion or mechanical damage. Processes can go over temperature and expose thermo elements to higher than anticipated temperatures. If a sensor controlling a process drifts low in its output, the process, in response to its controller, may as a result be forced to temperatures higher than intended.

Base metal assemblies are vulnerable to attack by a number of chemical agents. They can also be altered by unfavorable operating conditions.

As supplied, noble metal thermocouple wire of good quality has very low impurity levels. Consequently, it is quite susceptible to contamination that can affect its thermoelectric properties. Platinum is especially sensitive to the presence of free silicon, with which it can combine to form a eutectic alloy that will melt at, or below, normal service temperatures. High-purity insulators and protecting tubes for precious metal assemblies, as well as careful attention to cleanliness in handling, are therefore essential to help prevent this.

Human error can be a contributing factor, as well. Controls may be improperly set, connections may be improperly made, and inappropriate action in response to the operating conditions may be taken by mistake. Redundancy in instrumentation combined with training and responsibility are the usual means to combat these kinds of errors.

Troubleshooting - The Approach

There is no better way to go about finding troubles than to use plain common sense. One should ask if system performance seems to be reasonable for the conditions? Do changes in the controls produce a logical result? What about the product? Does its condition correspond with what the instruments are saying?

How to test a used T/C

First of all, one cannot ordinarily remove a suspect thermocouple from service and "test" it in another place. The very fact that the device is used means that it may no longer be homogeneous. Subjecting an inhomogeneous thermocouple to a different set of temperature gradients, even if only subtly different, can result in a different output and reading. So, "recalibrating" a used t/c will certainly yield a "number", but that number will probably be meaningless in the thermocouple's place of use.

Perhaps the best way to evaluate a used thermocouple is to "probe" the location by placing a new, or nearly new thermocouple that is known to be good alongside the suspect one in an operating process and compare the readings. If it is not practical to have two sensors in place at the same time, the next best thing is to remove the suspect probe and replace it with another one known to be good. Then, as long as the good probe is located in the same place as the removed one had been, and the process has not changed during the exchange, the readings from the two probes can be compared.

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THERMOCOUPLE TECHNICAL REFERENCE

Thermocouple Science cont'd.

Note that it is not necessary to keep and use an unlimited supply of new probes for these tests. A few suitable replacement devices can be kept on hand and one of them selected for testing use. Under normal circumstances, thermocouple drift, or degradation, is a gradual, and very slow process. A single replacement probe can thus be used a number of times to probe a process before it accumulates very much time at operating temperature, and can usually be considered reliable for a number of such repeated tests.

And, when a drifted probe has been found, the test probe may simply be left in place as a working sensor, while the next replacement becomes the test device.

System tests

One very useful instrument for troubleshooting thermocouple systems is a portable temperature indicator. A number of these devices are capable of operating with two or more different thermocouple types, and some offer an "output" function that will produce an electrical output to simulate a thermocouple operating at any temperature of choice.

In use, the instrument is normally "clipped on" to the wires of a circuit being tested at some convenient access point, such as in a connecting head. There, the output of an operating sensor may be monitored and evaluated. Or, using an instrument's "output" function, a synthesized signal may be sent back to the circuit's permanent indicator or controller to verify proper operation of the rest of the circuit. When driving a signal back towards an instrument, it is usually necessary to break one side of the circuit to avoid "loading" the portable tester by the low resistance of the thermocouple itself.

Sections of extension wiring in thermocouple circuits may be checked for proper connections with a portable tester, as well. The section being tested should be electrically isolated from the rest of the loop, and one end of an extension wire pair should be shorted together. If a tester is connected to the opposite end of the shorted pair, the tester should indicate the approximate temperature of the shorted end.

Note that if both ends of the extension pair happen to be at the same temperature, it may be necessary to warm the shorted end a little and verify that the tester "sees" the temperature change correctly. Note that there is the possibility of an incorrect, reversed connection that is being checked in this test.

Summary

A key to the successful use of thermocouples is the understanding of how and why they operate. Once the basic principle – namely distributed generation of the thermocouple's emf, driven by the temperature gradients, or differences, through which the wires pass – is known and understood, applying thermocouples to most applications becomes straightforward and logical.

Commercially available thermocouples are standardized by letter-designated type and by tolerance levels of conformance to published tables or "curves" of emf versus temperature. Custom calibration of thermocouple materials is available to answer needs more critical than can be covered by the usual tolerance grades.

(f)

THERMOCOUPLE TECHNICAL REFERENCE

Thermocouple Science cont'd.

An important fact to be remembered is that laboratory calibration of thermo elements is predicated upon good uniformity or homogeneity of the thermo element being tested. New materials will possess this property, but used materials may not, so it is not normally advisable to recalibrate used thermocouples. This is particularly true for base metal types after use at high temperatures .

Thermocouples are available in an almost endless variety of constructions and configurations. It is possible and practical to connect them in special ways to sense either temperature differences or temperature averages over a number of sites. It is even possible to "gang" these devices together to boost the amount of electrical signal arising from small temperature differences. But applications like these are specialized.

The major use for thermocouples is to make reliable and direct measurements of temperature in many diverse applications. Thermocouples are fundamentally simple devices. They are extremely versatile and rugged, and are capable of operating over a very wide range of temperatures. Thermocouples can be made to very tiny dimensions and into many different forms for standard or special purposes. In addition, they are low in cost and are readily interchanged or replaced. But they do need to be understood, so that they will measure the quantity that is desired with the precision that is required.

(g)



Duro-Sense Corporation

A pair of hands is holding a tablet computer. The screen of the tablet displays the words 'TERMS & CONDITIONS' in a large, white, sans-serif font. The background of the screen is a solid blue color. The tablet is held at an angle, and the hands are visible on the left and right sides. The background of the entire image is a light gray with a large, abstract yellow and orange geometric pattern on the right side.

TERMS & CONDITIONS

TERMS & CONDITIONS

TERMS AND CONDITIONS

WARRANTY:

Duro-Sense Corporation products and related parts are sold under the foregoing warranties, which extend only to the first buyer of said products as new merchandise directly from Duro-Sense Corporation or from an authorized distributor, representative or reseller.

Duro-Sense Corporation products and related parts are warranted to be free from defects in workmanship and material at the time of manufacture, and will conform to specifications set forth in relevant Duro-Sense Corporation catalog pages for such products.

Duro-Sense Corporation's sole and exclusive obligation and the purchaser's sole and exclusive remedy under the above warranty is limited to repair or replacement, at Duro-Sense Corporation's option. All claims hereunder shall be deemed waived unless made in writing, within thirty days of delivery, to Duro-Sense Corporation's main office at 869 Sandhill Avenue, Carson, CA 90746, and which, if so advised by Duro-Sense Corporation, are returned to the designated facility during normal business hours, transportation prepaid, and which, upon examination by Duro-Sense Corporation, are found to be non-compliant with the above warranty.

Duro-Sense Corporation sells products only under the above terms and conditions, which are expressly in lieu of all other warranties whatsoever, expressed, implied or statutory, including without limitation the implied warranties of merchantability and fitness for a particular purpose. Duro-Sense Corporation will not be bound by terms and conditions stated by any purchaser in any offer, acceptance or other contractual document, nor shall purchaser be entitled to incidental, special or consequential costs, expenses or damages excepting only the repair or replacement described above.

PAYMENT TERMS:

Net 30 Days (Pending Credit Approval). Account balances that are past due will be charged a \$1.00 service charge or a 1.5% finance charge per month, of the outstanding balance, whichever is greater.

ORDER MINIMUM:

\$25.00 Net per order.

PRICING:

Prices are subject to change without notice. There is no published price list. Please contact the sales department or your local sales representative for current pricing.

TERMS AND CONDITIONS

SHIPPING TERMS:

All orders are shipped F.O.B. Duro-Sense Corporation factory. All shipments are made prepaid and additional, unless otherwise negotiated in advance. Packing and handling charges are included in the shipping charges. Insurance charges are added only at the request of the purchaser.

Drop shipments will be made at the purchaser's request, providing that the invoice is issued to the "purchaser" and not to the "receiver".

Damage to shipments beyond the F.O.B. point is the responsibility of the carrier. Shipments should be opened promptly upon receipt and any claim for damage is to be initiated by the purchaser with the carrier. Replacement shipments will be made on a chargeable basis.

Each shipment should be examined by the purchaser promptly upon receipt. Any claims for shipment shortages must be made to Duro-Sense Corporation within 72 hours of receipt of shipment.

MATERIAL RETURNS:

Returns for credit, evaluation or repair will not be allowed without prior factory authorization. Purchaser must contact the factory for a "Return Merchandise Authorization" (RMA) number, and clearly describe the item, the reason for its return, the original purchase order number, order date, invoice number, and any other pertinent information germane to the item(s) in question.

RESTOCKING CHARGES:

Products and related parts that are returned to Duro-Sense Corporation in unused and like-new condition, that are returned for credit, will be subject to a minimum 20% restocking charge. The actual charges will be determined, by Duro-Sense Corporation, based on the type of material, its resale value and inspection and evaluation of the material in question.

CERTIFICATION:

N.I.S.T. traceable calibration and certification is available for thermocouples, RTD's and thermocouple wire. Certifications are limited to temperatures between -109°F and 2650°F (-78°C and 1454°C). Certifications are dependent upon calibration limitations of element materials and sheaths where applicable. The minimum sensor assembly length for certification is 18 inches of sheath length and the minimum length for certifying insulated thermocouple wire is 24 inches. Thermocouple wire is certified by making thermocouples from each end of the wire spool and evaluating them at specified temperatures. Lead-time for certification is dependent upon the quantity of items being certified as well as the capacity of the calibration laboratory at the time. Purchaser should contact Duro-Sense Corporation directly for current certification lead times.

COMPLIANCE:

Duro-Sense Corporation is dedicated to maintaining the highest level of quality in both manufacturing and testing. Duro-Sense Corporation operates under its own quality standard, DSQ-2000, which is compliant with the following quality and testing standards:

ISO-9001, AS-9100, MIL-I-45208, MIL-STD-45662A, ISO 10012-1:2003, ANSI/NCSL Z-540-3-2006, AMS2750E, ASTM E 220-7A, ASTM E 230-03, ASTM E 207-08, ANSI/ASQC Z1.4-1993.

Copies of the Duro-Sense Corporation quality manual and any existing certifications are available upon request.



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