RETURN TO MAIN TABLE OF CONTENTS
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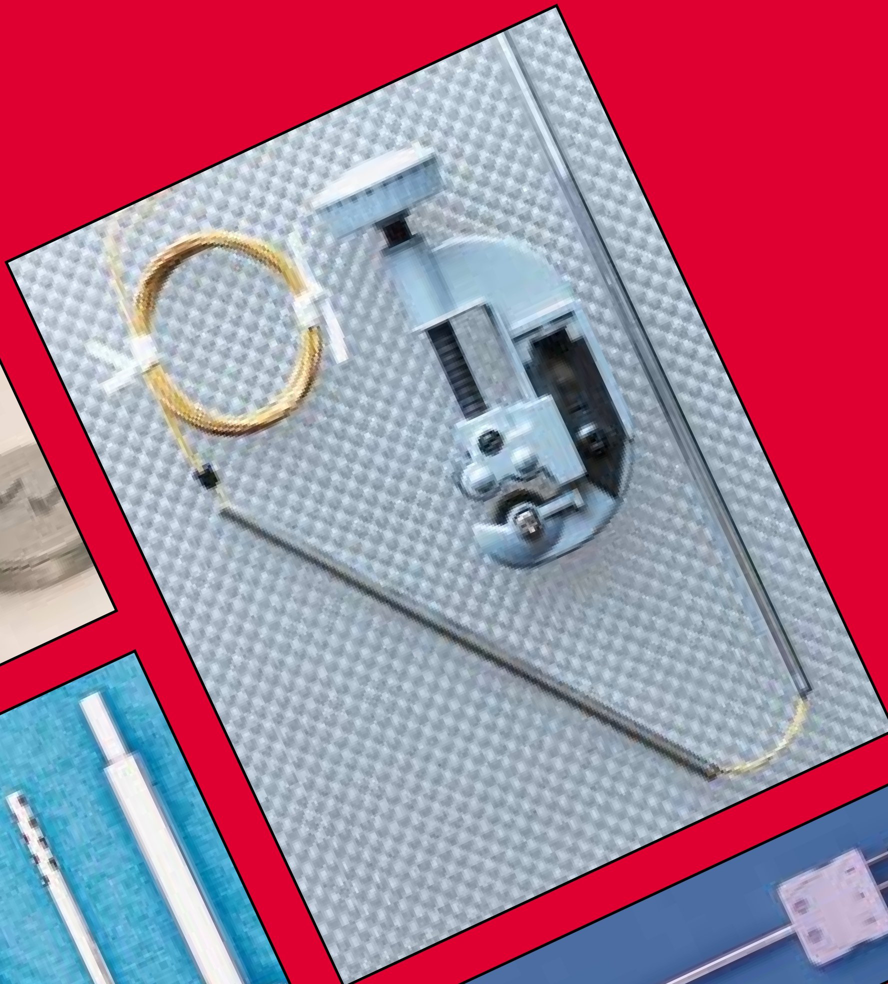
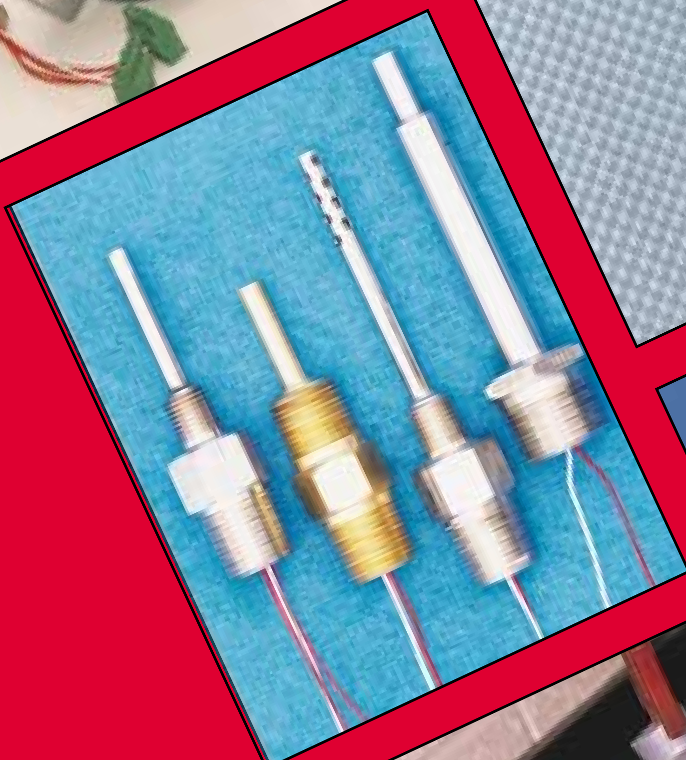
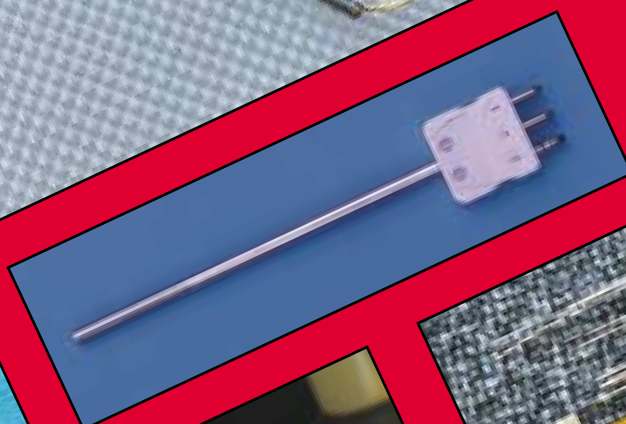
SEARCH SECTION

JMS Southeast, Inc.
Temperature Measurement

Resistance Temperature Devices







RESISTANCE TEMPERATURE DETECTORS

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Note: JMS Southeast, Inc. uses the new volt, ohm international standard approved by the National Institute of Standards and Technology (NIST) - formerly the National Bureau of Standards - to be effective 1/90.

RESISTANCE TEMPERATURE DEVICES (RTD'S)

#1	SERIES
3	RTD (You may also use these pages to order integrated circuit sensors. Use X in symbol #2)

#2 ELEMENT TYPE [9, 10, 11, 15, 18, 19] [32] Platinum 0.00385 alpha (Ω/Ω/°C)

	Resistor Accuracy at 0°C\	Thermometer Class (Table 3, page 3-18)	Resistor Class (Table 1 & 2, page 3-18)
B	± 0.25° C (Competitor's Std)	B	≥ F 0.15
E	± 0.1° C (Standard)	A	≥ F 0.1
P	± 0.06° C *	AA	≥ 1/2 W 0.1
S	± 0.01° C (Best Accuracy *)	1/4 AA	≥ 1/10 W 0.1
X	Other, specify		

Note: Type E available for high temp. applications. See page 3-4.

* For best results, use a 4 wire RTD for high accuracy (types P & S).

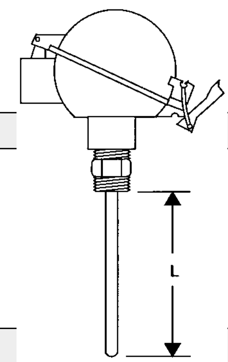
#3 ELEMENT CONSTRUCTION [4] [3-11]

Note: See other letter selections on page 3-22 or use X and describe if not listed there.

S	Single	Standard construction
D	Dual	Standard construction
J	Single	Swaged construction
K	Dual	Swaged construction
X	Other, specify	

Note: Use swaged for high temperature, bendability, high vibration, or longer than 6'

Add "S" here for TempIRsense i.e. SS (See Pg. 8-15)



#4 TUBE DIAMETER [5-30]

A	3/8" (.375")
B	1/4" (.250")
C	3/16" (.188")
D	1/8" (.125")
Q	Cuttable, See page 3-4 for details
X	Other, specify
Z	N/A

Note: To specify a special junction (i.e. gas air, tube skins, reduced tip...) use an "X" in #4 and describe. See page1-13 for a list of special junctions.

#5 TUBE MATERIAL [11, 12]

K	316 Stainless Steel
L	316 LSS
M	I-600 (Use if symbol #7 >500°F)
C	Teflon Coated SS
X	Other, specify

For fixed fittings and types S, C,B, D & N (symbol #8) this length normally equals the "A" dimension if a thermowell is used. (See Section 5)

[ ]BRACKETS INDICATE PAGE NUMBERS TO REFER TO FOR ADDITIONAL TECHNICAL INFORMATION

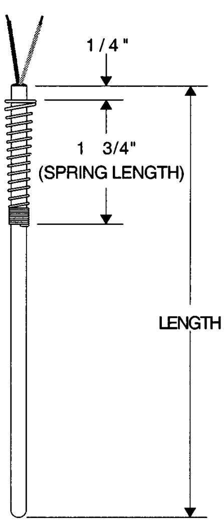
#6 LENGTH (L) (See sketches on Pg. 3-1, 2, & 3 for lengths)

__"	Immersion length in inches

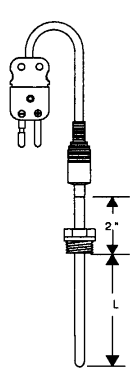
#7 MAX. TEMPERATURE AT WHICH TIP WILL BE EXPOSED [4, 8, 9,11, 12]

A	<100°C (212°F)	=2 PVC*
B	<200°C (392°F)	=3 Teflon*
C	<285°C (550°F)	=5 Kapton*
D	<482°C (900°F)	=1 Fiberglass*
E	<705°C (1300°F)	=4 HT Fiberglass*
F	>705°C (1300°F)	=7 Bare ends (heat shrink)*

*If no transition (Z) is in symbol 13, we recommend these corresponding selections for primary wire insulation in symbol 10.



Immersion for Symbol #8-E



Immersion for Symbol #8-G & D

#8 STANDARD INDUSTRIAL FITTINGS [SECTION 6]

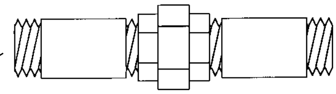
W	Fixed NPT ss fitting - double threaded
S	Spring-loaded NPT SS fitting - double threaded
C	Spring-loaded NPT SS fitting w/ oil ring - double threaded
D	Spring-loaded ss fitting - single threaded
B	Bayonet spring loaded assembly for thermowells & heads
E	Adjustable spring over .250", .188", .125" sheath
F	Reverse mounted steel plug fixed for attaching head
G	Fixed stainless steel to sheath
H	Compression fitting ss w/ ss ferrule
I	Compression fitting ss w/ teflon ferrule
J	Compression fitting ss w/ lava ferrule
K	Compression fitting ss w/ nylon ferrule
L	Compression fitting brass w/ brass ferrule
N	Nipple-Union-Nipple (NUN6G1) See page 2-3
X	Other, specify or if more than 1 is needed
Z	N/A (No fitting needed)

For materials other than SS, (ex: brass, carbon steel, etc.) Use X + material + letter designation

3	E	S	B	K	12"	B	W	

RESISTANCE TEMPERATURE DEVICES (RTD'S)

#9	PROCESS NPT [5-]
L	1/8"
M	1/4"
P	1/2" (Std w/ symbols W, S, & C above)
O	3/4"
X	Other, specify
Z	Note: To specify extensions such as nipples or unions, use X and see pg 3 for complete part #



#10	LEAD WIRE TYPE & LENGTH IN INCHES [SEE SECTION 7]		
1__"	Fiberglass braid	6__"	Bare wire
2__"	PVC	8	PVC coil cord - use when ordering symbol #8-B and symbol #14R
3__"	Teflon (Standard)		
4__"	Hi-temp glass braid	X__"	Other, specify
5__"	Kapton	Z	N/A

NOTE: All wire will be 24 awg in tubes > 1/8" OD. Smaller tubes will have a max. of 28 awg. If no transition or armor is specified, wire may be fragile. JMS standard wire for RTD's is Stranded Plated Copper.

#11	ARMOR OR HEAT SHRINK / JACKET [7-7]		
A	3/16" ID SS flex armor (Standard)	G	Heat shrink / sleeving
B	3/16" ID SS flex armor PVC coated white	H	Jacket to match primary insulation
C	3/16" ID SS flex armor PVC coated black	J	Aluminum mylar shielded and jacketed to match primary insulation
D	1/8" ID SS flex armor	Z	N/A
F	SS overbraid	X	Other, specify

#12	WIRE CONFIGURATION [17, 18]
T	2 Wire
Y	3 Wire
W	4 Wire
V	4 Wire (Compensating loop)

Note: Use a double symbol for 2 separate lead wires if dual elements. i.e. TT.

#13	TYPE OF TRANSITION [14]
H	Heat shrink
S	Size on size
T	3/8" OD
R	1/4" OD
X	Other,specify
Z	No transition

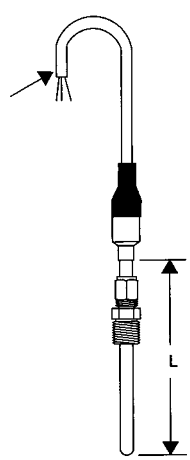
Note: For extra high humidity / moisture environments, put a "2" after your selection. [See page 3-14.]

For high temperature at the transition area use an X + type of transition and maximum temperature.

#14	COLD END TERMINATION [SEE SECTION 6] Pick as many as applicable
A	Bare ends
B	Miniature plug (6A1B2)*
C	Standard plug (6A1C2)*
I	Explosion proof Nema 7 head (6I / 6B2)
K	Spade lugs (6SL)
L	Aluminum head w/ hinged cover (6LW / 6NTB)
M	Aluminum head w/ screw cover & chain (6M / 6G)
N	Cast iron head w/ screw cover (6N / 6G)
O	Open ceramic terminal block (6N)
Q	Black nylon Nema 4 head (6Q / 6C)
R	High dome head (6R)
V	Hermetic connector (6DC) - Male*
W	Microphone style connector (6DA) - Male*
X	Other, specify

* Use double symbol here for matching female connector. i.e. B/BB (male with matching female).

Note: For any other cold end termination, use appropriate part numbers from section 6 in place of symbol #14.

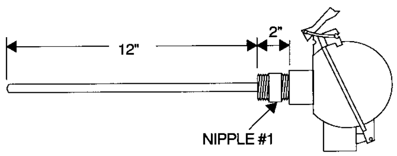


Immersion is overall length of tube for compression fittings

#15	OPTIONS USE ONLY IF APPLICABLE [INTRODUCTION]				
1	TAGGING	Stainless steel tag	5	CALIBRATION	Calibrate at specified point(s). Corrections data will be provided for each point.
2		Plastic tag			
3		Paper tag	6		Calibrate specified temperature range. Corrections data will be provided for all temperatures within the range. **Note:** You must specify increments & range. Ex. 0 to 300°F, 0.1° increments
4		Electroetch on probe **Note:** You must always specify information required on tag			
			7		CE Marking [PAGE XV]

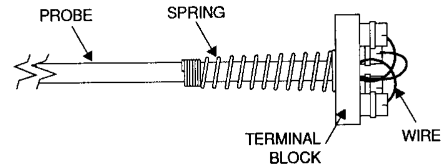
P	3-36"	A	Y	T	A		

NIPPLE-UNION-NIPPLE EXTENSION ASSEMBLIES

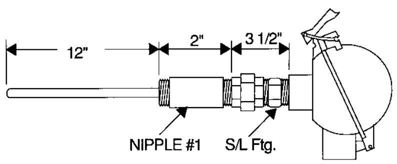


Drawing 1 External View

Drawing 1 - Nipple Only
Minimum Nipple L=1"
Ex. Part#: 3ESBK12"CEXZZYPZL
X = N2"G

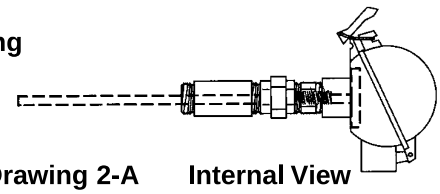


Direct Mounted Spring on Terminal Block

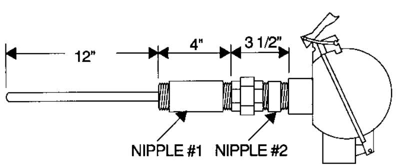


Drawing 2 External View

Drawing 2 - Nipple-Union with Machined 1/2" x 1/2" Spring Loaded Fitting
Minimum NU L=4" (includes S/L fitting)
Ex. Part#: 3ESBK12"CSXZZYPZL
X = NU5 $^{1}/_{2}$"G

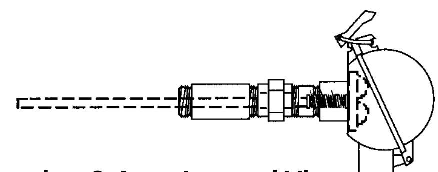


Drawing 2-A Internal View



Drawing 3 External View

Drawing 3 - Nipple-Union-Nipple with Spring Against Terminal Block
Minimum NUN L=4"
EX. Part#: 3ESBK12"CEXZZYPZL
X = NUN7 $^{1}/_{2}$"G



Drawing 3-A Internal View

An extension assembly may be needed to provide extra length for your RTD in order to extend your RTD head through insulation, or away from the heat of the process. This extension can include a pipe nipple only or a nipple-union-nipple or a nipple-union with a spring-loaded fitting from symbol #8 page 3-1.

Standard nipples and unions are 1/2" NPT and are available in galvanized or stainless steel. The union joins two nipples in an extension assembly and has a standard pressure rating of 150 pounds.

When a nipple-union-nipple or nipple only assembly is used and spring loading of the thermocouple element is required, there are two different methods of spring loading the sensor. The preferred method is to use the machined 1/2" by 1/2" NPT spring-loaded stainless steel fitting as one of the nipples (see symbol #8, S page 3-1). With this design, the probe is secured within the fitting and is mounted to the head in a rigid manner (see drawing #2 above). The appropriate part number for this assembly would be selected from symbols #8 (S) and #9 (X) from page 3-1 and 3-2, in addition to the symbols on this page. A cheaper method is a spring mounted over the probe and loaded against the bottom of the terminal block in the head. With this method the probe is not supported within the nipple-union-nipple. It is secured only by the wires into the terminal block. (See drawings 1 & 3 above). We do not recommend that you use this method of spring loading if your probe is mounted horizontally.

When a nipple-union-nipple is specified, the nipple and union closest to the head or cold end termination (drawing 2 & 3 above) is kept at an approximate length of 3 1/2". The length of the NUN is varied by the nipple length beyond the union on the probe end of the assembly.

For example, if a NUN 6" G is required, nipple #2 length would equal approximately 2 1/2".

When specifying this sensor extension, the nipple-union-nipple length tolerance is ± 3/4".

#1	EXTENSION ASSEMBLY
N	Nipple Only (Dwg #1)
NU	Nipple-Union (Dwg #2)
NUN	Nipple-Union-Nipple (Dwg #3)

#2	LENGTH
--"	Specify length in inches

#3	MATERIAL
G	Galvanized Steel
H	304 Stainless Steel
C	Black Steel

#4	PRESSURE RATING	
1	#150 - A351 spec (Standard)	ASTM
2	#3000 - A182 spec	ASTM
3	#6000 - A182 spec	ASTM
X	Other, specify	

NUN	6"	G	1	

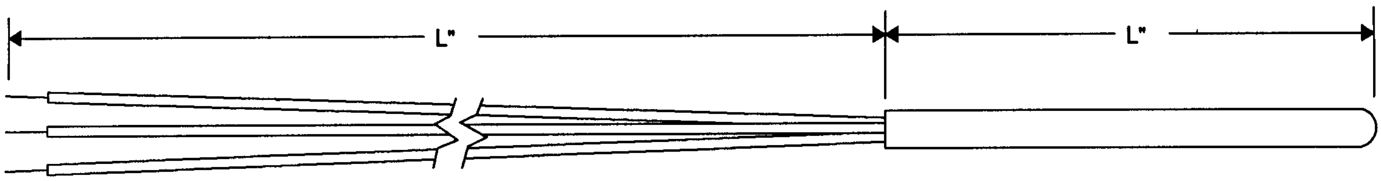
CUT TO LENGTH / UNIVERSAL RTD

JMS Southeast manufactures a cuttable resistance temperature detector that can be cut to 4" in length from a standard length of 24". The design provides flexibility to the end user that enables him/her to order one RTD length for all applications. The standard universal RTD is the 100 ohm, .00385 ohm/ohm/C DIN, single element. The tubing is 316 stainless with an outside diameter of 1/4". This unit is potted with high temperature cement and assembled with 48" of fiberglass lead-wire with no cold end termination. If a different fitting or longer leadwire is required, change these characters in the part number accordingly on pages 3-1 and 3-2. If the probe will be used at temperatures above 550°F change symbol "7" accordingly.

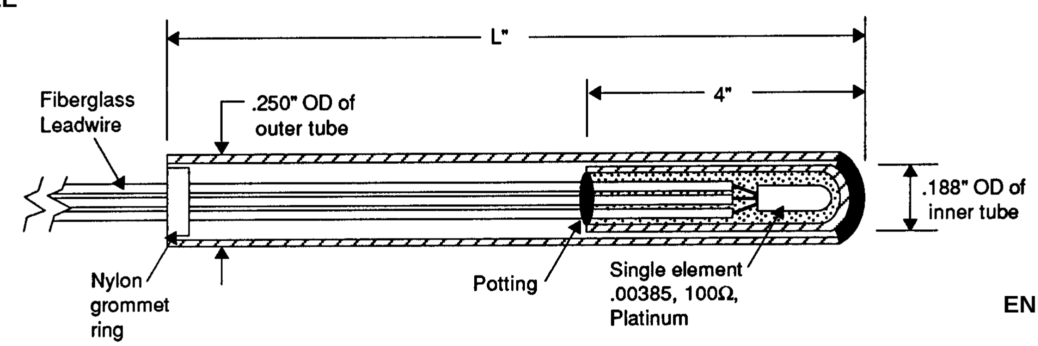
Feel free to call JMS for additional information. A typical JMS part number for this standard unit is as follows:

3ESQK24"DZZ1-48"ZYQZA
[For Cuttable Thermocouples go to page 2-1 and 2-2]

Special note: Cuttable sensors may not provide the best accuracy over periods of time. They are not recommended for critical applications.



NOT TO SCALE



ENLARGED VIEW

HIGH TEMPERATURE RTD'S

JMS now offers an industrial RTD, capable of withstanding temperatures and vibration previously requiring a thermocouple. Manufactured using a special high temperature cable, the probe can be bent to a radius of twice its diameter.

Inconel 600 is primarily used for high temperature applications; while 316 stainless steel is available for situations where high vibration is the main concern. Solid leads of 24 awg. for the .188" diameter probes and 22 awg. for the .250" diameter probes match the temperature and vibration resistant qualities of this special design.

Following is a table outlining the available initial calibration specifications for this probe design. Ordering of these elements may be made on page 3-1.

Tube Material	Tube Diameters	Element Construction	Resistor Class
316 SS, Inconel 600	.188"	Single 3-wire, Single 4-wire Dual 3-wire	≥1/2 W 0.1
316 SS, Inconel 600	.250"	Single 3-wire, Dual 3-wire Single 4-wire	

AVERAGING RTD'S

Continuous averaging resistance temperature detectors are most frequently used in air washing and air handling systems where turbulent and stratified air flow may effect the temperature measurement in a tip sensitive probe. The average temperature of the air in the duct can be measured with this type of sensor.

Any application which requires an averaging of temperature across an area would be ideally suited for this sensor type.

The operating temperature range for a continuous averaging RTD is from -100 to 400°F. Temperatures of up to 900°F are handled with a multipoint design (4, 8, or 16 points).

Please contact JMS Southeast with any questions or application problems you may have.

#1	SERIES
3A	Averaging RTD

#2	Element Type 0.00385, IEC 751; 1983, 100Ω @ 0°C
E	Platinum, continuous below 400°F (only)
P4	Platinum 4 point, <900°F
P8	Platinum 8 point, <900°F
P16	Platinum 16 point, <900°F
X	Other, specify

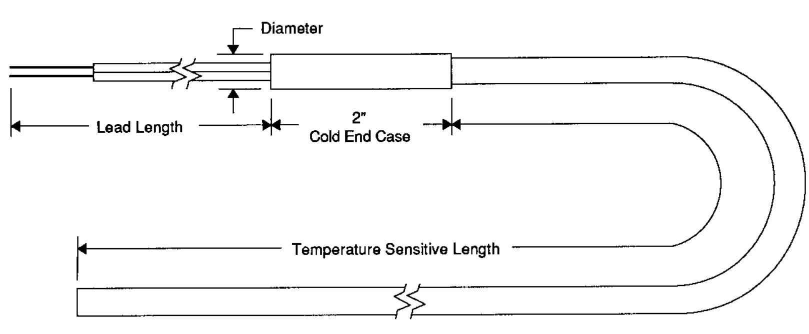
Note: Call the JMS Engineering Department for information about averaging thermocouples, swamp boxes and special proprietary multipoint designs.

#3	TUBE DIAMETER
B	1/4" (.250")
C	3/16" (.188")

#4	SENSING LENGTH
__"	In inches

#5	TUBE MATERIAL
K	316 Stainless Steel
C	Copper

#6	TOTAL PROBE LENGTH
__"	Length in inches



3A	E	B	12"	K	18"

AVERAGING RTD'S

#7	STANDARD INDUSTRIAL FITTINGS
W	Fixed NPT ss fitting - double threaded. Sheath diameters less than 3/16", fittings are brazed to sheath.
B	Bayonet spring loaded assembly for thermowells & heads
F	Reverse mounted steel plug fixed to sheath for attaching head
G	Fixed stainless steel to sheath
H	Compression fitting ss w/ ss ferrule
I	Compression fitting ss w/ teflon ferrule
J	Compression fitting ss w/ lava ferrule
K	Compression fitting ss w/ nylon ferrule
X	Other, specify
Z	N/A (No fitting needed)

For all compression fittings except "6", immersion is overall length of the tube.

Note: To specify extensions such as nipples, unions, couplings, use X and see pg 3 for complete part #.

#8	PROCESS NPT
L	1/8"
M	1/4"
P	1/2"
X	Other, specify

#9	LEAD WIRE TYPE & LENGTH IN INCHES [SEE SECTION 7]
1__"	Glass braid
3__"	Teflon
6__"	Glass braid / flex armor overall
7__"	Teflon / flexible armor overall
8__"	Glass braid / SS overbraid (3 wire only)
9__"	Three conductor teflon with overall jacket of teflon tape
10__"	Three conductor teflon / SS overbraid with overall jacket of teflon tape
X	Other, specify
Z	No leadwire

#10	WIRE CONFIGURATION
T	2 Wire
Y	3 Wire
W	4 Wire
V	4 Wire (Compensating loop)

#11	MAX TEMP. OF TRANSITION
P	< 500° F
Q	500° F to 1300° F
H	> 1300° F

Note: Q potting may not comply with ASTM megohm check.

#12	COLD END TERMINATION [SEE SECTION 6] Pick as many as applicable
A	Bare ends
B	Miniature plug (6A1B2)*
C	Standard plug (6A1C2)*
I	Explosion proof Nema 7 head (6I / 6B2)
K	Spade lugs (6SL)
L	Aluminum head w/ hinged cover (6LW / 6NTB)
M	Aluminum head w/ screw cover & chain (6M / 6G)
N	Cast iron head w/ screw cover (6N / 6G)
O	Open ceramic terminal block (6N)
Q	Black nylon Nema 4 head (6Q / 6C)
R	Hi dome head (6R)
V	Hermetic connector (6DC) - Male *
W	Microphone style connector (6DA) - Male*
X	Other, specify

* Use double symbol here for matching female connector. i.e. B/BB (male with matching female).

Note: For any other cold end termination, use appropriate part numbers from section 6 in place of symbol #12.

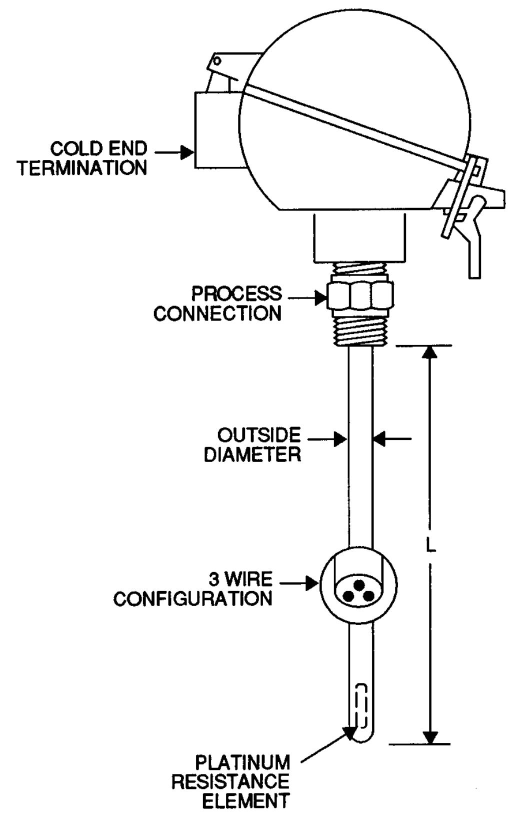
#13	TAGGING AND CALIBRATION OPTIONS (USE ONLY IF APPLICABLE)		
	TAGGING		**CALIBRATION**
1	Stainless steel tag	5	Calibrate at specified point(s). Corrections data will be provided for each point.
2	Plastic tag	6	Calibrate specified temperature range. Corrections data will be provided for all temperatures within the range. **Note:** You must specify increments & range. Ex. 0 to 300°F, 0.1° increments
3	Paper tag	7	CE Marking [PAGE XV]
4	Electroetch on probe **Note:** You must always specify information required on tag		

I	M	3-36"	Y	P	C		

RTD'S - RESISTANCE TEMPERATURE DETECTORS

RTD's work on the principle that there is a positive correlation between the electrical resistance of a metal conductor and changes in temperature. The standard temperature range is from -200°F to 900°F. High temperature assemblies are available which can operate at up to 1475°F.

The advantages of using RTD's include accuracy, repeatability, and stability. Another advantage is that cold junction compensation is unnecessary. Copper wire is used for all connections. The signal level of an RTD is over ten times higher than that of a thermocouple which eliminates the need for high gain amplifiers. The signal is also less susceptible to noise than thermocouples. The accuracy of a 4 wire RTD is independent of the distance between the sensor and the readout instrument.



COMPONENTS OF RTD's

The Platinum Resistance Element
This is the actual temperature sensing portion of the RTD. Elements range in length from 1/8" to 3" (See Pg 3-8). There are many options. The standard resistance is 100 ohms at 0°C and the standard temperature coefficient is an alpha of 0.00385. A complete list of options is listed on page 3-22.

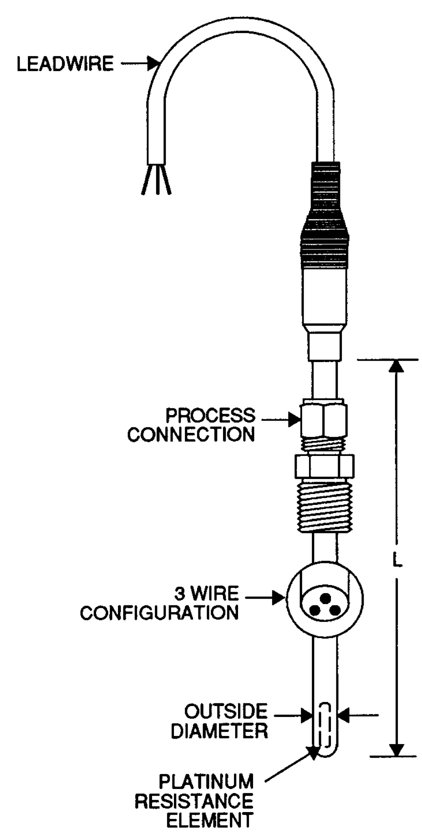
Outside diameter / Inside diameter
The most standard outside diameter is 1/4". However, outside diameters range from .063" to .500". A selection of tube diameters can be found on page 1.

Tubing Material
316 Stainless steel is commonly used for all assemblies up to 500°F. Above 500°F it is advisable to use Inconel 600. A list of some materials available is on page 1.

Process Connection
Process connection fittings include compression fittings and 1/2" N.P.T. x 1/2" N.P.T. welded or spring-loaded fittings. Various connection options are listed on page 1.

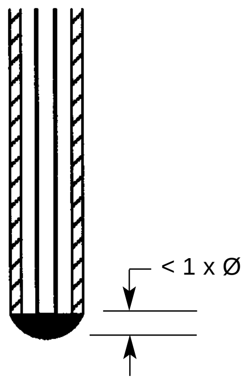
Wire Configuration and Insulation
RTD's are available in two, three, and four wire configurations. Three wire configuration is the most common. See page 3-17 for further information on selecting wire configuration for your application. Teflon and fiberglass are the standard wire insulation materials. Teflon is moisture resistant and has a maximum temperature rating of 400°F. Fiberglass is used for high temperature applications because it has a maximum temperature rating of 1000°F.

Cold End Termination
This may be in the form of bare wires, plugs, or terminal heads. The accessory section contains a wide variety of these options. Standard cold end terminations are listed on page 3-2.

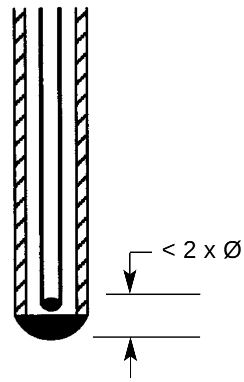


TIP SENSITIVITY

Tip sensitivity in the finished probe is usually not considered a serious factor in sensor specifications. However, JMS SE believes tip sensitivity is extremely critical if the customer is to receive the same results time after time. For instance, if the sensor was originally designed to minimize penetration into the process, a thin film sensor might have been used. If that sensor is later replaced with a standard 15mm long element, response time will change drastically, affecting the PID of a control situation and certainly the total temperature reading of the process would be upset.



GROUNDED T/C

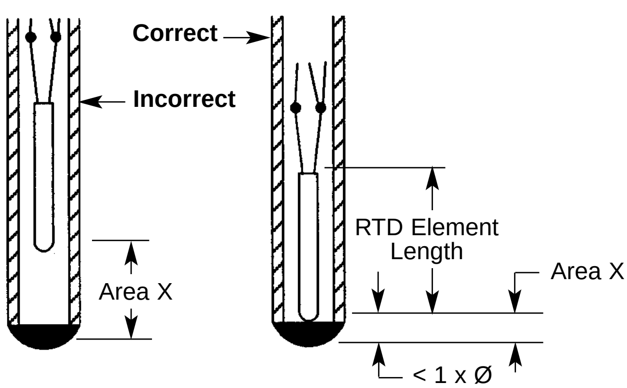


UNGROUNDED T/C

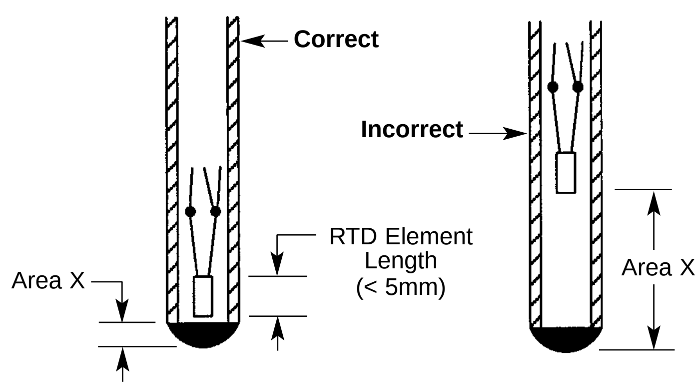
AREA X (How far is the tip of the sensing element from the tip of the tube?)

In any sensor or probe the location of the element inside the tube is critical. Even if the sensor element was 2" away from the tip, that condition would go undetected using the ASTM tests. (18 x Ø for wire thermocouples) JMS tests for the element placement on our sensors in order to assure consistency of your measurements.

Area X = <1 x Ø.



RTD ELEMENT



TYPE T RTD ELEMENT

RTD element length: E, P, S standard = 8mm - 15mm
"T" thin film = 2mm - 5mm
Others = 8mm - 50mm

Special designs can be used to obtain certain tip sensitivity. Ask your sales representative at JMS.

RTD STANDARDS

Maximum Operating Range = -200°C to 850°C (-392°F to 1562°F)
Note: RTD's are not commonly used above 900°F. However, JMS offers a special high temperature RTD which will withstand temperatures up to 1560°F.

Interchangeability = ±.01°C to .25°C at 0°C

Stability = Less than .05°C shift per year.

Electric Supply = AC or DC ≤ 500 Hz.

Nominal Operating Current ≤ 1 milliampere.

Maximum Safe Current = 20 Milliamperes.

Insulation Resistance = 100 mega ohms minimum at 50 VDC.

Probe Encapsulation = High purity alumina oxide.

Time constant for RTD element without tubing = 1 second maximum for the sensor to reach 63.2% of a step change in temperature in water at 3 feet per second.

RTD probes will usually not have a transition if the lead wires are less than 12" in length.

Accuracy
The standard accuracy of JMS Southeast's RTD is .1% of resistance at 0°C . Accuracies of .03% and .01% of resistance at 0°C are also available.

Stability
JMS Southeast bulbs are aged as part of the manufacturing process, thus ensuring high levels of stability. Generally the resistance at 0°C will hold less than a .05°C shift per year.

Vibration
JMS detectors can withstand a vibration level of 30g over the frequency range 10 Hz to 1 KHz.

Pressure
JMS RTD's are insensitive to large changes of pressure.

Response Time
Response time of JMS Southeast metal encapsulated probes is dependent on the outside diameter of the probe and the immersion media, usually matches that of the same size ungrounded thermocouple. (See page 1-13)

Self Heating
When tested in accordance with requirements of BS 1904: 1964 Section 3.16 the indicated temperature rise in the temperature detector with a power of 10.0mW dissipated in it, will not exceed +.3°C.

RESISTANCE TEMPERATURE DETECTORS

General Information

A resistance temperature detector or platinum resistance thermometer works on the principle that the electrical resistance of a metal changes in a significant and repeatable way when temperature changes. This resistance is inversely proportional to cross sectional area and proportional to length.

Platinum is the most widely used metal for resistance temperature detection due to the following characteristics:

1) chemical inertness
2) a temperature coefficient of resistance that is large enough to give readily measurable resistance changes with temperature
3) an almost strain free fabrication metal (in that resistance doesn't drastically change with strain)
4) an almost linear relation between resistance and temperature

Each resistance versus temperature relation for an RTD is qualified by a term known as "alpha". "Alpha" is the slope of the resistance between 0°C and 100°C. This is also referred to as the temperature coefficient of resistance, with the most common being 0.00385Ω/Ω/°C.

Other types of RTD's manufactured include copper, nickel and nickel alloys.

The amount of resistance of an individual RTD bulb (100Ω, 200Ω, etc.) is determined by the amount of metal between the terminal points and by the configuration of the element.

When ordering an RTD, the alpha and resistance value at 0°C (i.e.: Ro) must be specified to match the measuring instrumentation used with the RTD.

The RTD standard must also be specified. There are several RTD standards set by various organizations. These specifications are not identical and read out instrumentation must be adjusted for the specific standard of the RTD used with that equipment. Differences in the alpha values of these standards can cause errors in measurement of an RTD if one standard is connected to the instrumentation of another standard.

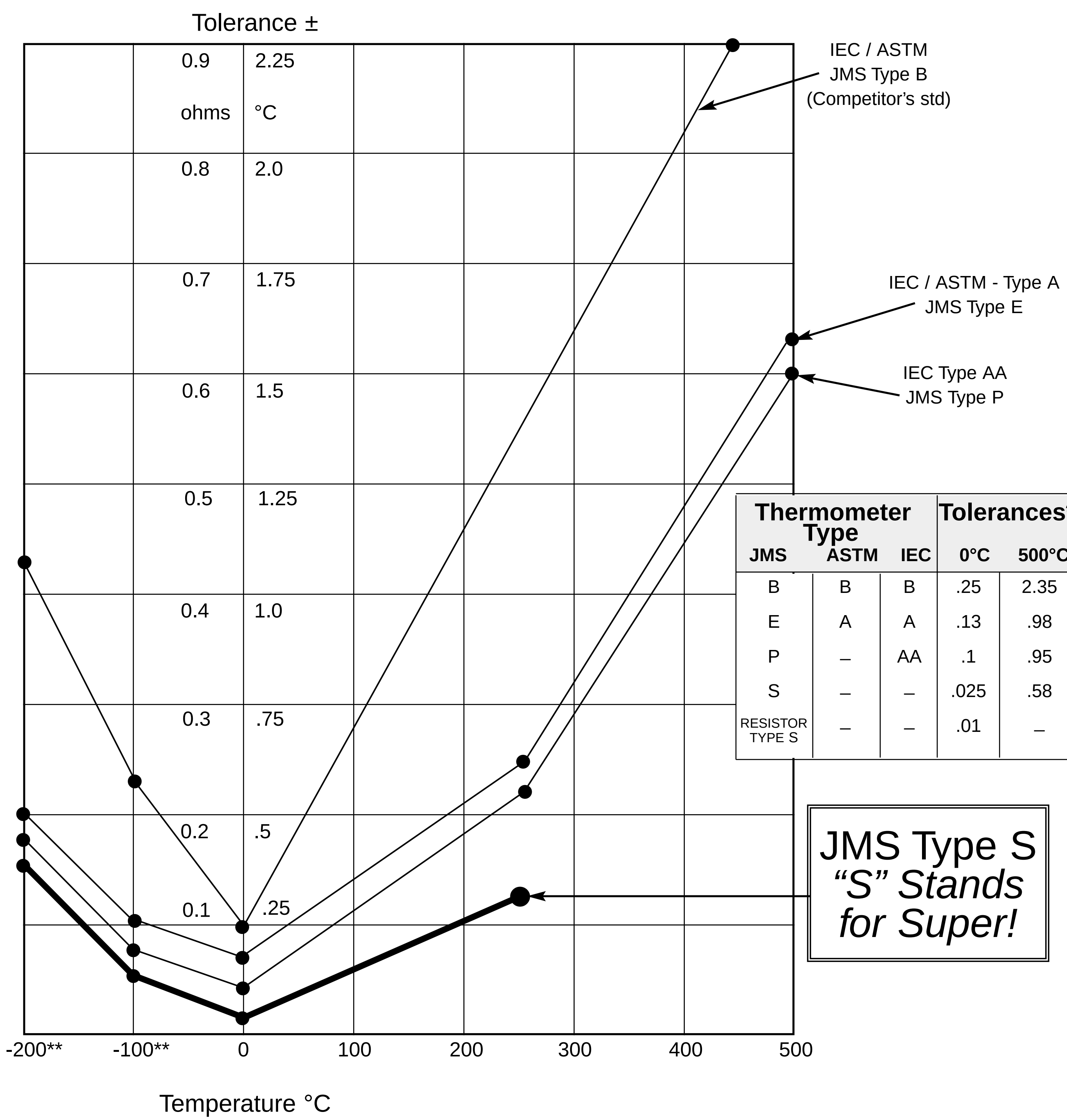
The following chart indicates some common RTD standards.

ORGANIZATION	STANDARD	ALPHA	NOMINAL RESISTANCE(ohms) AT 0°C
American Scientific Apparatus Makers Association (SAMA)	RC21-4-1966	0.003923	98.129
British Standards Association	B.S. 1904-1964	0.003850	100
FachnormenausschuB Elektrotchnek im Deutschen NormenausschuB	DIN 43760	0.003850	100
International Electrotechnical Commission (Supersedes BS & DIN)	IEC 751: 1983	0.003850	100
US Department of Defense	MIL-T-24388	0.00392	100

RESISTANCE TEMPERATURE DETECTORS

JMS TYPE "S" ("S" Stands for SUPER!)

-Meets DIN 43760, I.E.C. 751 .00385 ohms/ohms/°C, to
1/10 design tolerance at initial resistor calibration
Not available in dual element swaged
-Tip sensitivity = 1 Ø + 1/2" (See page 3-8)
-Probe can be manufactured as a 3/32", 1/8", 1/4" or larger tube



Thermometer Type			Tolerances*	
JMS	ASTM	IEC	0°C	500°C
B	B	B	.25	2.35
E	A	A	.13	.98
P	–	AA	.1	.95
S	–	–	.025	.58
RESISTOR TYPE S	–	–	.01	–

* Initial Calibration Accuracy
** Negative tolerances extrapolated from ASTM E1137

TUBE MATERIAL

JMS Southeast, Inc., recommends stainless steel tubing as the encapsulation for RTD's in most industrial applications.

If a corrosive environment exists, 316 low carbon stainless steel is recommended due to its resistance to corrosiveness. A more detailed explanation of this phenomenon follows.

For high temperature RTD's above 500°F, we recommend I600 encapsulation due to the absence of iron in I600. Platinum RTD bulbs sometimes experience "poisoning" at high temperatures due to iron migration. The iron attacks the grain boundaries of the platinum and the alpha of the bulb is erroneously lowered, thus yielding lower temperature readings than actual.

Please contact JMS for questions concerning environmental condition questions or exotic material needs for probe encapsulation.

CORROSION IN 316 STAINLESS STEEL VERSUS 316 LOW CARBON STAINLESS STEEL

Barbara Feldhacker Hudson
JMS Southeast, Inc.
Statesville, NC

BACKGROUND:

When 316 stainless steel is welded it is exposed to temperatures in the range of 1000°F to 1600°F and carbon readily diffuses toward the grain boundaries in this temperature range. This excess carbon in these areas adjacent to the grain boundaries combines with the chromium in the steel to form chromium carbides. This action depletes the effective chromium content near and at the grain boundaries, leaving this area of the metal susceptible to corrosive attack. When welding occurs and this phenomenon occurs, the chromium from within these grains cannot replenish this shortage rapidly enough to overcome this susceptibility. This is called "sensitization."

Stainless steel loses its resistance to corrosion when the chromium content drops below 10.5-11%. Intergranular corrosion occurs when the chromium content along the grain boundaries drops below this amount. The less chromium present the more rapid the attack that could ensue.

Corrosion also occurs more readily in austenitic stainless steels that contain more than .03% carbon due to the fact that complex chromium carbides precipitate along grain boundaries when the chromium ties up with this carbon. After the metal is cooled from the 1000°F-1600°F temperature range, any areas that experienced that temperature and are depleted of chromium are very susceptible to corrosion. In the manufacture of resistance temperature detectors, approximately the last 3 inches of the probe and the weld area experience these temperatures. Therefore, they are prime candidates for corrosion.

CORROSION PREVENTION:

There are a number of ways to combat the susceptibility of corrosion in 316 stainless steel. We have investigated a number of options. Water quenching of the entire susceptible area would avoid this corrosive property due to the fact that this cooling would dissolve the chromium carbides and the chromium content would be again uniform throughout the metal. Water quenching cools the metals rapidly enough to prevent the combination of chromium with carbon. We, at JMS, felt this option was not as feasible due to the problem of quenching every probe in manufacturing. This could not be done to an RTD assembly due to the fact that it would cause thermal shock to the probe and a sudden strain to the RTD bulb. RTD's are susceptible to strain and thermal shock and this could be detrimental to the sensor.

A second method of avoiding the corrosion phenomenon in 316 stainless steel is to add carbide forming elements to the stainless steels. If the carbon in the metal is tied up with other elements, it can not tie up with chromium and the free chromium present could not form chromium carbides and migrate to the grain boundaries. Some elements added to stainless steels for this purpose are titanium, columbium and tantalum. These elements have greater affinity for carbon than chromium so they stabilize the steel against chromium depletion. An example of this is Monel. This is a

TUBE MATERIAL

more expensive option than what JMS Southeast decided upon.

A third method to avoid this possibility of corrosion of 316 stainless steel is to keep the steel in the "sensitizing" temperature range (1000°F-1600°F) for a long enough time for thermal stabilization to take place. The chromium carbides do form at the grain boundaries; however, after additional time, the chromium can diffuse into the area of impoverished grain boundaries.

The option was not feasible however, due to the fact that this thermal stabilization usually takes four hours. This is difficult to impossible to accomplish during welding.The method that JMS Southeast decided upon to combat corrosion in 316 stainless steel is to keep the carbon content so low in the metal that there is not adequate carbon present to form detrimental amounts of chromium carbide. If there is not enough carbon to tie up with the chromium then the chromium does not become depleted and corrosion is much less likely to occur. This type of protection is accomplished by using 316 low carbon stainless steel (316L) which has a maximum carbon content of .03%.

In an environment containing chlorides, the 316 stainless steel probe is at an even greater risk due to the fact that chlorides promote the formation of active/passive electrolytic cells. This can be explained by the fact that all stainless steels are passive under most conditions; however, if the probe is exposed to the "sensitization" temperature range and this molecular transformation occurs it forms anodic area (opposite the passive area). The oxygen around these two areas serves as a depolarizer and corrosion proceeds at an accelerated rate at the point the two areas meet.

Chlorides also have a higher valence state. Any chloride in an appreciable concentration is a source of trouble in promoting corrosion. Therefore, the use of 316 low carbon stainless steel becomes even more necessary in a chloride atmosphere if the metal is to endure a satisfactory lifetime. This occurs in an area that has been welded and is adjacent to the non-effected area.

Another problem of chlorides is that deposits may occur in crevices on the probe. In a crevice, oxygen supply is limited and cannot repair the passive oxide film. A crevice stays damp longer than a fully exposed surface. Salts are likely to accumulate in crevices particularly if the area around the crevice is alternately wet and dry. If the oxygen concentration decreases below a level necessary to maintain passivity in the anodic area, there is a double electrolytic effect. The difference in oxygen concentration alone will tend to promote attack on the anodic area and the potential between the passive and active area is already quite high, so corrosion becomes even more aggressive. Chlorides, being electrolytes will not contribute to passivity and will become very acidic thus accelerating the corrosive attack even more.

It is to difficult to predict the corrosion rate of 316 stainless steel or 316 low carbon stainless steel due to the environmental variables; however, our experience has shown an increase of up to twice the life in a low carbon stainless steel probe versus a standard stainless steel probe. The problem with pitting corrosion and crevice corrosion in an RTD probe is that through these openings in the metal sheath, the RTD bulb can become contaminated and fail. If quantified specimen tests are needed, the ASTM lists some approved corrosion testing procedures.

In the ASTM A262-64 Standard two widely used intergranular corrosion susceptibility tests are described. They include the Huey test, which test subject samples to five 48 hours boils in 65% nitric acid solutions. A weight loss after each boil is noted and translated to a corrosion rate in inches per month. This test, however, indicates overall corrosion not grain boundary corrosion.

A second test is the oxalic acid etch test which involves etching a polished specimen then examining the appearance under a microscope. Comparisons are then made to some ASTM photographs.

Two other tests listed in A262 are the boiling sulfuric acid-ferric sulfate solution test and the nitric acid-hydrofluoric acid test at room temperature. These are not as widely used, however.

In conclusion, corrosion of 316 stainless steel in a chloride environment is a definite problem. To minimize this problem, low carbon stainless steel metal should be used in this environment as the encapsulation for RTD probes. If this is not done, the RTD longevity will be substantially reduced. JMS Southeast recommends the use of 316 low carbon stainless steel to all our customers who are using RTD's for temperature measurement in a process that contains chlorides.

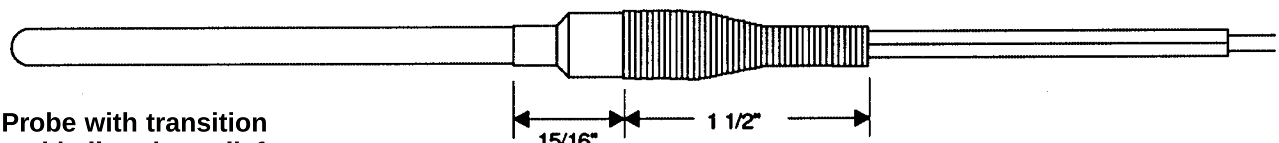
REFERENCES:

1. Zak, C.A., "Intergranular Corrosion of Austenitic Stainless Steels" Metallurgy of Tubing/Volume 8
2. American Society for Metals, "Metals Handbook" Volume 8, No. 1, 1961

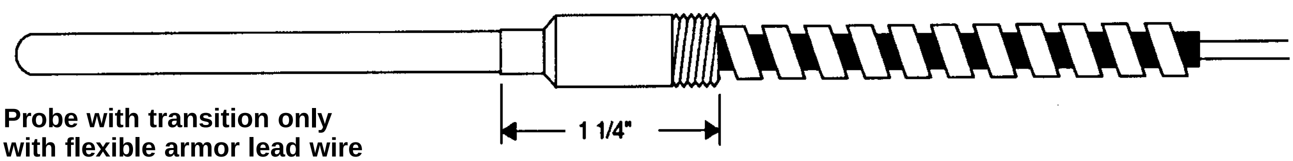
RTD TRANSITIONS

The transition on an RTD assembly supports the lead wires attached to the RTD probe and contains the protective potting compound used to encapsulate the probe. The transition is stainless steel and has a .375” outside diameter for 3/4”, and tapers down over the probe for an additional 1/4”. This 1/4” outer diameter is approximately .055” larger than the probe outer diameter.

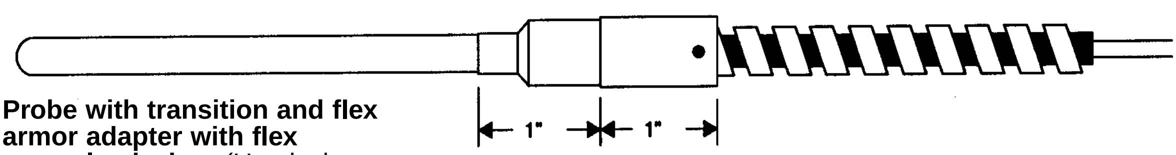
The bell spring adds approximately 1” to the rigid length of the probe.



Probe with transition and bell spring relief



Probe with transition only with flexible armor lead wire
(Standard on low temp. (transition) single elements)



Probe with transition and flex armor adapter with flex armor lead wire. (Used when armor is 60” or greater.)

JMS provides special hermetic sealing from moisture for those sensors used in high humidity / moisture or total immersion environments. Use a “2” after your selection in symbol #13 page 3-2. Any moisture penetrating the transition will kill the integrity of the electrical property of the sensor. Our special hermetic sealing will prevent this as well as possible in any environment. See page1-16 for more information.

TOLERANCES

Tolerances of RTD's are specified as a function of temperature.

They can be expressed in ohms, temperature, or percentages.

JMS now features RTD Thermometers using platinum resistors with a tolerance as low as 0.01% of resistance @ 0°C.

Better accuracies are possible by performing calibrations on a sensor at several different temperatures and listing exact resistance readings of that RTD at those temperatures. This is a more expensive method, but can be cost effective when accuracy is critical in a process. (See pages VIII, IX, X)

Readout instrumentation of RTD's converts resistance to temperature. Typical accuracies of this equipment are 0.1%. Lead wire and connection error for 2 and 3 wire RTD's can be significant.

After an RTD is manufactured there are some conditions that can alter the accuracy and reliability of an RTD. Moisture within the RTD can decrease the resistance value of the RTD and cause errors. Bad seals on the RTD are usually the cause. High temperatures can cause the insulation material's electrical resistance to decrease significantly. Also, at high temperatures, if any iron exists within the probe, iron migration can cause a poisoning of the platinum, thus measurement errors.

Physical or mechanical changes can cause shifts in the calibration of RTD's.

Rapid cooling can cause defects in the platinum structure and thus measurement errors. The defects can usually be eliminated by reannealing at 450°C.

Vibration in the process can also cause a drift in RTD's by causing a shift in the windings.

Stretching or strain on a metal can change it's resistance independent of temperature.

Due to the fact that RTD's are wound on a mandrel and supported in some way, the expansion coefficient of the supporting medium should match that of platinum, or else the actual contact of the winding with the medium used should be minimized. Thin film, thick film, totally supported, partially supported and bird cage constructions all have specific applications. JMS Southeast, Inc. manufactures high quality RTD's using thin film and semi-supported bulbs.

THERMOCOUPLES VS RTD'S

The following chart indicates some inherent advantages and disadvantages of RTD's or thermocouples.

	THERMOCOUPLE	**RTD'S**
Accuracy	Limits of error wider than RTD	Limits of error smaller than thermocouples
Ruggedness	Excellent	Sensitive to strain, shock, and pressure
Temperature	-400° to 4200°F	-200° to 1500° F
Size	Can be as small as .01" sheath material, tip sensitive	Size limited to 1/16", temperature sensitive for length of bulb
Drift	Should be checked periodically, higher than RTD's	0.01 to 0.1°C per year, less drift than thermocouple
Resolution	Must resolve millivolts per degree, lower signal to noise ratio	Ohms per degree, much higher signal to noise ratio than thermocouple
Cold Junction Reference	Required	Not required
Lead wire	Must match lead wire calibration to thermocouple calibration	Can use copper lead wire for extension wire
Response	Can be made small enough for millisecond response time	Thermal mass restricts time to seconds or more
Cost	Low	Higher than thermocouples

Why a 3 minute egg in Denver, Colorado is softer than a 3 minute egg in Denver, North Carolina.

BOILING POINT OF WATER

ALTITUDE FT	B>P> °F	ATM. PRESS. PSIA	ALTITUDE FT	B>P> °F	ATM. PRESS. PSIA
0	212	14.7	8000	198	10.98
1000	210	14.21	9000	196	10.58
2000	209	13.72	10000	194	10.19
3000	207	13.23	11000	192	9.81
4000	205	12.75	12000	191	9.45
5000	203	12.29	13000	189	9.09
6000	201	11.83	14000	187	8.75
7000	199	11.39	15000	185	8.41

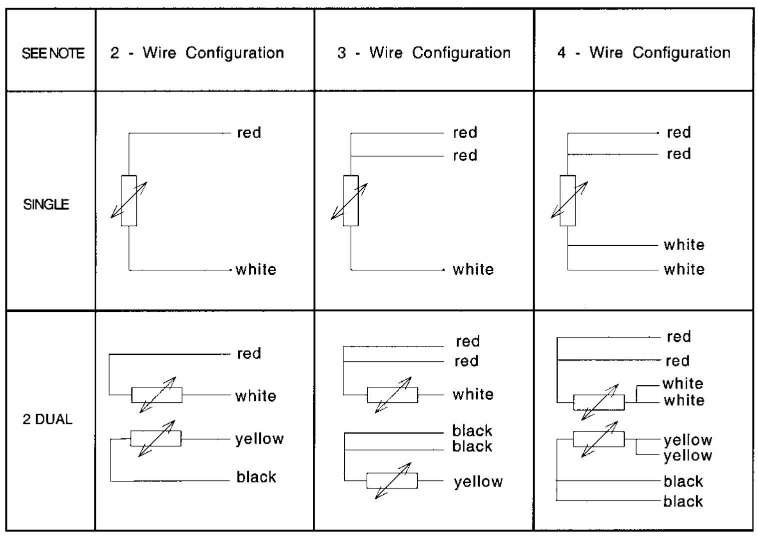
LEADWIRE CONFIGURATION EXPLANATION

A resistance temperature detector determines the temperature by measuring resistance. The sensing element is usually a small diameter wire manufactured so that its resistance will change in a known and consistent manner. To measure the resistance accurately and consistently, other extraneous resistances must be compensated for or minimized. A major cause of extraneous resistance is leadwire in series with the RTD. The readout is the sum of the bulb resistance and the leadwire resistances. The leadwire resistance can be compensated in most applications by a three wire RTD leadwire configuration.

In the three wire configuration, the power supply is taken to one side of the resistance temperature detector. This puts the other two leadwires in opposite arms of the wheatstone bridge so that they cancel each other out and have little effect on the bridge output voltage. In the 3 wire configuration, the resistance of the lead wire length is compensated for in the Wheatstone bridge. This design is recommended for most industrial applications.

An even more accurate wire configuration is the 4 wire design. In this design, leadwires #1 and #2 are on one side of the power supply while leadwires #3 and #4 are on the other side of the power supply. All four leadwire resistances in this case are negated and the bulb resistance stands as the resistance input alone. We strongly recommend this design. You must have a good 4 wire input device. Call us for recommendations.

Note:
For numbering sequence of connectors and terminal blocks see Section 6.



RTD Operation and Installation Instructions:

RTD’s are installed by means of compression fittings, welded or spring-loaded NPT fittings, or bayonet fittings.

Follow these instructions for installation of an RTD with a 1/2” x 1/2” NPT fitting:

(1) Insert RTD into process hole or opening.

(2) Tighten probe into place by turning probe into threaded connection.

If cold-end termination of the RTD is wired into head and you have a spring loaded fitting, then the wires should be disconnected from the terminal block to prevent twisting and shorting.

ELECTRICAL:

Make sure the extension wire is clean so that a good electrical connection will result at the terminal block. We recommend the use of a lacquer, cement, or other moisture proof sealing to prevent oxidation and the loosening of terminals. Connect the positive extension wire to the positive RTD wire and the negative extension wire to the negative RTD wire. Wires are color coded for identification as follows:

Two Wire Configuration:
Connect the white wire to the positive connection terminal and connect the red wire to the negative connection terminal.

Three Wire Configuration:
The two red wires are common. Connect the white wire to the positive connection terminal and the two red wires to the negative connection terminals. The second red wire is the compensating lead wire.

Four Wire Configuration:
The two white wires are common and the two red wires are common. Connect the two red wires to the negative connection terminals and the two white wires to the positive connection terminals.

RESISTANCE CHARACTERISTICS

Characteristics

The temperature/resistance relationships and tolerances on this page are valid for the sensing resistor at its measuring points. For thermometers they are valid for the complete thermometer at its terminals.

In the case of two-wire connections the resistance values of the leads between the measuring point of the resistor and the terminals must be considered. They may be indicated on the thermometer and must be subtracted from measured values in ohms. In some cases it also may be advisable to consider the temperature coefficient of the leadwires and the temperature distribution along their length.

Temperature/resistance relationships

The temperature/resistance relationships used in this standard are as follows:

for the range of -200°C to 0°C:

$$R_t = R_o[1 + At + Bt^2 + c(t - 100°C)\, t^3]$$

for the range of 0°C to 850°C:

$$R_t = R_o(1 + At + Bt^2)$$

For the quality of platinum commonly used for industrial resistance thermometers, the values of the constants in these equations are:

$A = 3.9083 \times 10^{-3}\ °C^{-1}$ | $C = 4.183 \times 10^{-12}\ °C^{-4}$

$B = 5.775 \times 10^{-7}\ °C^{-2}$ | t = Modulus of temperature without sign

For resistance thermometers satisfying the above relationships, the temperature coefficient *is defined as:*

$$a = \frac{(R_{100} - R_0)}{100 \times R_0}$$

has the value $0.00385055°C^{-1}$

where

R_{100} is the resistance at 100°C;
R_0 is the resistance at 0°C.

These equations and coefficients are listed as the basis for the temperature / resistance tables in this book. The calibration of individual thermometers will yield different coefficients.

Values of temperatures in this book are based on the International Temperature Scale of 1990 (ITS 90).

Resistance values

Most resistors are constructed to have a nominal resistance of 100Ω. The resistance vs. temperature table is calculated for a resistance of 100.00 Ω at 0°C. For other nominal resistances R_{nom} such as 500 Ω or 1000Ω the table can be used by multiplying the table values with the factor $R_{nom}/100$.

General Requirements (Tolerances)

Sensing resistors
The tolerance values of wirewound resistors are classified in table 1 and the values of film resistors are classified in table 2.

Table 1: Tolerance classes for wound resistors

Tolerance class	Tolerance value (°C)	Temperature range of validity of tolerances
W 0.1	±(0.1°C + 0.0017 [t])	-50°C + 250°C
W 0.15	±(0.15°C + 0.002 [t])	-100°C to 450°C
W 0.3	±(0.3°C + 0.005 [t])	-196°C to 661°C
W 0.6	±(0.6°C + 0.01 [t])	-196°C to 661°C

Table 2: Tolerance classes for film resistors

Tolerance class	Tolerance value (°C)	Temperature range of validity of tolerances
F 0.1	±(0.1°C + 0.0017 [t])	-50°C + 250°C
F 0.15	±(0.15°C + 0.002 [t])	-50°C to 450°C
F 0.3	±(0.3°C + 0.005 [t])	-50°C to 661°C
F 0.6	±(0.6°C + 0.01 [t])	-50°C to 661°C

Table 3: Tolerance classes for thermometers (finished probes)

Tolerance * class	Tolerance values (°C)	
AA	±(0.1 °C + 0.0017 [t])	-50 to 250°C
A	±(0.13°C + 0.0017 [t])	-100 to 450°C
B	±(0.25°C + 0.0042 [t])	-196 to 600°C
C	±(0.6°C + 0.01 [t])	-196 to 600°C

* These tolerances meet or exceed ASTM / IEC thermometer class. They do not necessarily determine the working range of the thermometer.

RESISTANCE vs. RTD TEMPERATURE SPECIFICATIONS

Temperature (°C) vs. Resistance (Ω)

°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	/C°
-200	18.52										
-100	60.26	56.19	52.11	48.00	43.88	39.72	35.54	31.34	27.10	22.83	.415
0	100.00	99.09	92.16	88.22	84.27	80.31	76.33	72.33	68.33	64.30	.357
°C	0	10	20	30	40	50	60	70	80	90	/C°
0	100.00	103.90	107.79	111.67	115.54	119.40	123.24	127.08	130.90	134.71	.385
100	138.51	142.29	146.07	149.83	153.58	157.33	161.05	164.77	168.48	172.17	.374
200	175.86	179.53	183.19	186.84	190.47	194.10	197.71	201.31	204.90	208.48	.361
300	212.05	215.61	219.15	222.68	226.21	229.72	233.21	236.70	240.18	243.64	.350
400	247.09	250.53	253.96	257.38	260.78	264.18	267.56	270.93	274.29	277.64	.339
500	280.98	284.30	287.62	290.92	294.21	297.49	300.75	304.01	307.25	310.49	.327
600	313.71	316.92	320.12	323.30	326.48	329.64	332.79	335.93	339.06	342.18	.316
700	345.28	348.38	351.46	354.53	357.59	360.64	363.67	366.70	369.71	372.71	.304
800	375.70	378.68	381.65	384.60	387.55	390.48					

JMS Type B (Industry standard)

Temperature (°C)	-250	-220	-200	-100	0	100	200	300	400	500	600	700	800	850
Tolerance (±°C)	1.6	1.4	1.3	0.8	0.3	0.8	1.3	1.8	2.3	2.8	3.3	3.8	4.3	4.6
(± Ω)	1.0	0.7	0.6	0.3	0.1	0.3	0.5	0.6	0.8	0.9	1.1	1.3	1.4	1.5

Temperature (°F) vs. Resistance (Ω)

°F	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	/F°
-200	48.49										
-100	71.01	68.78	66.55	64.31	62.07	59.82	57.57	55.31	53.04	50.77	.225
0	93.03	90.85	88.66	86.47	84.27	82.07	79.87	77.66	75.45	73.23	.220
°F	0	10	20	30	40	50	60	70	80	90	/F°
0	93.03	95.21	97.39	99.56	101.73	103.90	106.06	108.22	110.37	112.53	.216
100	114.67	116.82	118.96	121.10	123.23	125.36	127.49	129.61	131.73	133.85	.213
200	135.96	138.07	140.18	142.28	144.38	146.48	148.57	150.66	152.74	154.82	.209
300	156.90	158.97	161.04	163.11	165.17	167.23	169.29	171.34	173.39	175.44	.206
400	177.48	179.52	181.56	183.59	185.61	187.64	189.66	191.68	193.69	195.70	.202
500	197.71	199.71	201.71	203.71	205.70	207.69	209.68	211.66	213.64	215.61	.199
600	217.58	219.55	221.51	223.47	225.43	227.39	229.34	231.68	233.23	235.17	.195
700	237.10	239.03	240.96	242.89	244.81	246.73	248.64	250.55	252.46	254.37	.192
800	256.27	258.16	260.06	261.95	263.83	265.72	267.60	269.47	271.34	273.21	.188
900	275.08	276.94	278.80	280.65	282.50	284.35	286.19	288.03	289.87	291.70	.185
1000	293.53	295.36	297.18	299.00	300.82	302.63	304.44	306.24	308.04	309.84	.181
1100	311.64	313.43	315.22	317.00	318.78	320.56	322.33	324.10	325.86	327.63	.177
1200	329.30	331.03	332.79	334.76	336.74	338.71	340.69	342.66	344.64	346.62	.169
1300	347.50	348.38	350.07	351.77	353.46	355.16	356.85	358.55	360.25	361.94	.162
1400	363.67	365.17	366.67	368.17	369.67	371.17	372.67	374.18	375.68	377.12	.150
1500	378.68	380.58	382.48	384.38	386.30	388.21	390.12				

JMS Type B (Industry standard)

Temperature (°F)	-200	-100	0	32	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1560
Tolerance (±°F)	1.8	1.1	0.7	0.6	0.7	0.9	1.5	2.0	2.7	3.3	3.9	4.5	5.4	6.0	6.5	7.0	7.6	8.4	9.0	9.4
(± Ω)		0.3	0.2	0.1	0.2	0.2	0.3	0.4	0.6	0.7	0.8	.09	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.5

Nominal Resistance

The platinum element of the standard industrial type RTD has a base reference resistance of 100 Ω at 0°C.
Platinum 100 Ω, temperature coefficient = 0.00385/Ω/Ω/°C.
This meets the ASTM standard 1157 and also meets the IEC 751. All readings based on ITS 90 - International Temperature Scale 1990.

TEMPERATURE vs RESISTANCE TABLE

Din 43760, 100Ω Platinum RTD
Alpha=.00385

Temp. (degrees C)	0	(-10)	(-20)	(-30)	(-40)	(-50)	(-60)	(-70)	(-80)	(-90)
-200	18.53	14.36	10.41							
-100	60.20	56.13	52.04	47.93	43.80	39.65	35.48	31.28	27.05	22.78
0	100.00	96.07	92.13	88.17	84.21	80.25	76.28	72.29	68.28	64.25
	0	(10)	(20)	(30)	(40)	(50)	(60)	(70)	(80)	(90)
0	100.00	103.90	107.79	111.67	115.54	119.40	123.24	127.07	130.89	134.70
100	138.50	142.28	146.06	149.82	153.57	157.32	161.04	164.76	168.47	172.16
200	175.84	179.51	183.17	186.82	190.46	194.08	197.70	201.30	204.88	208.46
300	212.03	215.58	219.13	222.66	226.18	229.69	233.19	236.67	240.15	243.61
400	247.06	250.50	253.93	257.34	260.75	264.14	267.52	270.89	274.25	277.60
500	280.93	284.26	287.57	290.87	294.16	297.43	300.70	303.95	307.20	310.43
600	313.65	316.86	320.05	323.24	326.41	329.57	332.72	335.86	338.99	342.10

NOTE: Due to the interchangeability tolerance of the RTD's, the JMS type E matches both DIN 43760 / IEC 751, and British Standard BS 1904 curves.

BS 1904, 100Ω Platinum RTD
Alpha=.00385

Temp. (degrees C)	0	(-10)	(-20)	(-30)	(-40)	(-50)	(-60)	(-70)	(-80)	(-90)
-200	18.56	14.40	10.45							
-100	60.28	56.21	52.12	48.01	43.88	39.72	35.54	31.34	27.11	22.83
0	100.00	96.09	92.16	88.23	84.29	80.32	76.34	72.35	68.34	64.32
	0	(10)	(20)	(30)	(40)	(50)	(60)	(70)	(80)	(90)
0	100.00	103.90	107.79	111.67	115.54	119.40	123.24	127.07	130.89	134.70
100	138.50	142.29	146.06	149.82	153.57	157.31	161.04	164.76	168.46	172.16
200	175.83	179.50	183.16	186.82	190.45	194.07	197.69	201.29	204.88	208.46
300	212.02	215.58	219.12	222.66	226.18	229.69	233.19	236.68	240.16	243.61
400	247.08	250.52	253.95	257.37	260.77	264.17	267.56	270.94	274.29	277.64
500	280.98	284.31	287.67	290.93	294.22	297.50	300.76	304.02	307.27	310.51
600	313.72	316.93	320.12	323.31	326.50	329.60	332.80	335.90	339.10	342.20

NOTE: Due to the interchangeability tolerance of the RTD's, the JMS type E matches both DIN 43760 / IEC 751, and British Standard BS 1904 curves.

SAMA RC21-4 1966, 98.1Ω Platinum RTD
Alpha=.003923
JMS TYPE F [3-22]

Temp. (degrees C)	0	(-10)	(-20)	(-30)	(-40)	(-50)	(-60)	(-70)	(-80)	(-90)
-200	16.67									
-100	58.40	54.34	50.26	46.15	42.02	37.87	33.69	29.48	25.24	20.97
0	98.13	94.22	90.29	86.36	84.41	78.44	74.47	70.47	66.47	62.44
	0	(10)	(20)	(30)	(40)	(50)	(60)	(70)	(80)	(90)
0	98.13	102.03	105.92	109.80	113.67	117.52	121.37	125.20	129.02	132.83
100	136.63	140.41	144.19	147.95	151.70	155.44	159..17	162.89	166.06	170.29
200	173.97	177.64	181.30	184.95	188.58	192.22	195.83	199.43	203.02	206.60
300	210.17	213.73	217.27	220.80	224.33	227.84	231.34	234.83	238.30	241.77
400	245.22	248.66	252.09	255.51	258.92	262.32	265.70	269.07	272.43	275.78
500	279.12	282.45	285.76	289.07	292.36	295.64	298.91	302.17	305.42	308.65
600	311.88									

TEMPERATURE vs RESISTANCE TABLE

JISC 1604-1981, 100Ω Platinum RTD
Alpha=.003916
JMS TYPE G

Temp. (degrees C)	0	(-10)	(-20)	(-30)	(-40)	(-50)	(-60)	(-70)	(-80)	(-90)
-200	17.05									
-100	59.57	55.43	51.28	47.10	42.90	38.67	34.41	03.12	25.80	21.44
0	100.00	92.03	92.03	88.02	84.00	79.97	75.92	71.86	67.78	63.68
	0	(10)	(20)	(30)	(40)	(50)	(60)	(70)	(80)	(90)
0	100.00	103.97	107.93	111.87	115.81	119.73	123.64	127.54	131.42	135.30
100	139.16	143.01	146.85	150.68	154.49	158.30	162.09	165.87	169.64	173.40
200	177.14	180.87	184.60	188.30	192.00	195.69	199.36	203.03	206.68	210.31
300	213.94	217.56	221.16	224.75	228.33	231.90	235.46	239.00	242.53	246.05
400	249.56	253.06	256.55	260.02	263.48	266.93	270.37	273.80	277.21	280.61
500	284.00	287.38	290.75	294.11	297.45	300.78	304.10	307.41	310.71	313.99
600	317.27	320.53	323.78							

Laboratory Grade, 100Ω Platinum RTD
Alpha=.003925
JMS TYPE L

Temp. (degrees C)	0	(-10)	(-20)	(-30)	(-40)	(-50)	(-60)	(-70)	(-80)	(-90)
0	100.00	96.02	92.02	88.01	83.99	79.96	75.91			
	0	(10)	(20)	(30)	(40)	(50)	(60)	(70)	(80)	(90)
0	100.00	103.97	107.93	111.88	115.82	119.75	123.66	127.56	131.45	135.33
100	139.20	143.06	146.90	150.73	154.55	158.36	162.16	165.94	169.72	173.48
200	177.23	180.97	184.69	188.41	192.11	195.80	199.48	203.15	206.80	210.45
300	214.08	217.70	221.31	224.91	228.50	232.07	235.63	239.19	242.72	246.25
400	249.76	253.27	256.76	260.24	263.71	267.16	270.61	274.04	277.46	280.88
500	284.27	287.66	291.03	294.40	297.75	301.09	304.42	307.73	3011.04	314.33
600	317.61	320.88	324.14	327.38	330.62	333.84	337.05	340.25	343.44	346.61

NOTE: Based on NIST Supplementary ITS-90. These values were available at time if publication but subject to approval by ASTM as laboratory grade.

Uncommon American 100Ω Platinum RTD
Alpha=.003902
JMS TYPE H

Temp. (degrees C)	0	(-10)	(-20)	(-30)	(-40)	(-50)	(-60)	(-70)	(-80)	(-90)
-100	59.69									
0	100.00	96.03	92.06	88.06	84.06	80.04	76.01	71.96	67.89	63.80
	0	(10)	(20)	(30)	(40)	(50)	(60)	(70)	(80)	(90)
0	100.00	103.96	107.90	111.83	115.75	119.66	123.55	127.44	131.31	135.17
100	139.02	142.86	146.68	150.50	154.30	158.09	161.87	165.64	169.39	173.14
200	176.87	180.59	184.30	188.00	191.68	195.35	199.02	202.67	206.31	209.93
300	213.55	217.15	220.74	224.32	227.89	231.45	234.99	238.52	242.05	245.56
400	249.05	252.54	256.01	259.48	262.93	266.37	269.79	273.21	276.62	280.01
500	283.39	286.76	290.11	239.46	296.79	300.12	303.43	306.73	310.01	313.29
600	316.55	319.80	323.04	326.27	329.49	332.70				

NON STANDARD RESISTORS

NON STANDARD, BUT COMMONLY USED RTD'S

B - IEC Standard, 100Ω Platinum, .00385 Alpha, ±.25°C at 0°C [3-11]
G - JISC Standard, 100Ω Platinum, .003916 Alpha, ±.1°C at 0°C [3-21]

Letter Designation	Standard	Alpha	Resistor Tolerance at 0°C	Reference page
B	IEC / ASTM	.00385	0.25	3-11
F	SAMA	.003923	0.1	3-22
G	JISC	.003916	0.1	3-21
L	NIST	.003925	0.007	3-21
H	NONE	.003902	0.15	3-21

ADDITIONAL RTD ELEMENT TYPES

The following are available in addition to the RTD element types listed on page 3-1. Elements may be specified with an "X" in the part number.

ALPHA	RESISTANCE VALUE	TOLERANCE
Platinum - 0.003750	1000 ohms @ 0 deg. C	±0.2%
Platinum - 0.003850	10 ohms @ 0 deg.C	±0.2%
Platinum - 0.003850	10 ohms @ 20 deg. C	±0.2%
Platinum - 0.003850	10 ohms @ 25 deg. C	±0.2%
Platinum - 0.003850	20 ohms @ 0 deg. C	±0.2%
Platinum - 0.003850	50 ohms @ 0 deg. C	±0.2%
Platinum - 0.003850	200 ohms @ 0 deg. C	±0.1%
Platinum - 0.003850	500 ohms @ 0 deg. C	±0.1%
Platinum - 0.003850	1000 ohms @ 0 deg. C	±0.1%
Platinum - 0.003900	100 ohms @ 0 deg. C	±0.2%
Platinum - 0.003900	130 ohms @ 0 deg. C	±0.1%
Platinum - 0.003910	8 ohms @ 0 deg. C	±0.5%
Platinum - 0.003910	10 ohms @ 0 deg. C	±0.5%
Platinum - 0.003910	32 ohms @ 0 deg. C	±0.5%
Platinum - 0.003910	98.129 ohms @ 0 deg. C	±0.1%
Platinum - 0.003910	100 ohms @ 0 deg. C	±0.5%
Platinum - 0.003910	500 ohms @ deg. C	±0.5%
Platinum - 0.003920	100 ohms @ 0 deg. C	±0.1 deg. C
Platinum - 0.003920	200 ohms @ 0 deg. C	±0.1 deg. C
Platinum - 0.003920	500 ohms @ 0 deg. C	±0.1 deg. C
Platinum - 0.003926	25.5 ohms @ 0 deg. C	±0.1%
Platinum - 0.003926	100 ohms @ 0 deg. C	±0.5%
Platinum - 0.003926	200 ohms @ 0 deg. C	±0.5%
Platinum - 0.003926	470 ohms @ 0 deg. C	±0.5%
Platinum - 0.003926	500 ohms @ 0 deg. C	±0.5%
Nickel - N/A	110 ohms @ 0 deg. C	±0.5%
Ni Fe - N/A	1000 ohms deg. @ 21.1 deg. C	±0.5%
Ni Fe - N/A	2000 ohms @ 21.1 deg. C	±0.5%
Copper - N/A	100 ohms @ 25 deg.C	±0.2%

RESISTANCE / TEMPERATURE TABLE

COPPER 10Ω AT 25°C

°C	0	1	2	3	4	5	6	7	8	9
-190	1.471	1.430	1.389	1.348	1.306	1.265	1.223	1.182	1.140	1.009
-180	1.884	1.843	1.802	1.761	1.719	1.678	1.637	1.596	1.554	1.513
-170	2.295	2.254	2.213	2.172	2.131	2.090	2.049	2.008	1.967	1.925
-160	2.705	2.664	2.623	2.582	2.541	2.500	2.459	2.418	2.377	2.336
-150	3.112	3.072	3.031	2.990	2.949	2.909	2.868	2.827	2.786	2.745
-140	3.519	3.478	3.437	3.397	3.356	3.316	3.275	3.234	3.194	3.153
-130	3.923	3.883	3.842	3.802	3.762	3.721	3.681	3.640	3.600	3.559
-120	4.326	4.286	4.246	4.206	4.165	4.125	4.085	4.044	4.004	3.964
-110	4.728	4.688	4.648	4.608	4.567	4.527	4.487	4.447	4.407	4.366
-100	5.128	5.088	5.048	5.008	4.968	4.928	4.888	4.848	4.808	4.768
-90	5.526	5.486	5.446	5.407	5.367	5.327	5.287	5.247	5.208	5.168
-80	5.923	5.883	5.844	5.804	5.764	5.725	5.685	5.645	5.606	5.566
-70	6.318	6.279	6.239	6.200	6.160	6.121	6.081	6.042	6.002	5.962
-60	6.712	6.672	6.633	6.594	6.554	6.515	6.476	6.436	6.397	6.358
-50	7.104	7.064	7.025	6.986	6.947	6.908	6.869	6.830	6.790	6.751
-40	7.490	7.451	7.413	7.374	7.335	7.296	7.258	7.220	7.181	7.142
-30	7.876	7.838	7.799	7.761	7.722	7.683	7.645	7.606	7.568	7.529
-20	8.263	8.224	8.185	8.147	8.108	8.070	8.031	7.992	7.954	7.915
-10	8.649	8.610	8.572	8.533	8.494	8.456	8.417	8.378	8.340	8.301
0	9.035	9.996	9.958	8.919	8.881	8.842	8.805	8.765	8.726	8.687
0	9.035	9.074	9.112	9.151	9.189	9.228	9.267	9.305	9.344	9.383
10	9.421	9.460	9.498	9.537	9.576	9.614	9.653	9.692	9.730	9.769
20	9.807	9.846	9.885	9.923	9.962	10.000	10.039	10.078	10.116	10.155
30	10.194	10.232	10.271	10.309	10.348	10.387	10.425	10.464	10.502	10.541
40	10.580	10.618	10.657	10.696	10.734	10.773	10.811	10.850	10.889	10.927
50	10.966	11.005	11.043	11.082	11.120	11.159	11.198	11.236	11.275	11.313
60	11.352	11.391	11.429	11.468	11.507	11.545	11.584	11.622	11.661	11.700
70	11.738	11.777	11.816	11.854	11.893	11.931	11.970	12.009	12.047	12.086
80	12.124	12.163	12.202	12.240	12.279	12.318	12.356	12.395	12.433	12.472
90	12.511	12.549	12.588	12.627	12.665	12.704	12.742	12.781	12.820	12.858
100	12.897	12.935	12.974	13.013	13.051	13.090	13.129	13.167	13.206	13.244
110	13.283	13.322	13.360	13.399	13.437	13.476	13.515	13.553	13.592	13.631
120	13.669	13.708	13.746	13.785	13.824	13.862	13.901	13.940	13.978	14.017
130	14.055	14.094	14.133	14.171	14.210	14.248	14.287	14.326	14.364	14.403
140	14.442	14.480	14.519	14.557	14.596	14.635	14.673	14.712	14.751	14.789
150	14.828	14.867	14.906	14.945	14.984	15.022	15.061	15.100	15.139	15.178
160	15.217	15.256	15.295	15.334	15.373	15.412	15.451	15.490	15.529	15.568
170	15.607	15.646	15.685	15.724	15.736	15.802	15.840	15.879	15.918	15.957
180	15.996	16.035	16.074	16.113	16.152	16.191	16.230	16.269	16.308	16.347
190	16.386	16.425	16.464	16.503	16.542	16.581	16.620	16.659	16.698	16.737
200	16.776	16.815	16.854	16.893	16.932	16.971	17.010	17.049	17.088	17.127
210	17.166	17.205	17.244	17.283	17.321	17.360	17.399	17.348	17.477	17.516
220	17.555	17.594	17.633	17.672	17.711	17.750	17.789	17.828	17.867	17.906
230	17.945	17.984	18.023	18.062	18.101	18.140	18.179	18.218	18.257	18.296
240	18.335	18.374	18.413	18.452	18.491	18.530	18.569	18.608	18.648	18.687
250	18.726	18.765	18.804	18.843	18.882	18.921	18.960	18.999	18.038	18.077
260	19.116									

RESISTANCE / TEMPERATURE TABLE

NICKEL 120Ω AT 0°C

°C	0	1	2	3	4	5	6	7	8	9
-70	73.10	72.45	71.80	71.15	70.50	69.85	69.20	68.55	67.90	67.25
-60	79.62	78.97	78.31	77.66	77.01	76.36	75.71	75.06	74.40	73.75
-50	86.17	85.51	84.86	84.20	83.55	82.89	82.84	81.58	80.93	80.27
-40	92.76	92.10	91.44	90.78	90.12	89.46	88.80	88.14	87.48	86.83
-30	99.41	98.74	98.07	97.41	96.74	96.07	95.41	94.75	94.08	93.42
-20	106.15	105.47	104.79	104.11	103.44	102.77	102.09	101.42	100.75	100.08
-10	113.00	112.31	111.62	110.93	110.25	109.56	108.87	108.19	107.51	106.83
0	120.00	119.29	118.58	117.88	117.17	116.47	115.77	115.08	114.38	113.69
0	120.00	120.71	121.42	122.13	112.85	123.57	124.28	125.00	125.72	126.45
10	127.17	127.90	128.63	129.36	130.09	130.82	131.56	132.29	133.03	133.77
20	134.52	135.26	136.01	136.76	137.51	138.26	139.02	139.77	140.53	141.29
30	142.06	142.82	143.59	144.36	145.13	145.90	145.68	147.46	148.23	149.01
40	149.79	150.58	151.36	152.15	152.94	153.74	154.53	155.33	156.13	156.93
50	157.74	158.55	159.36	160.17	160.98	161.80	162.62	163.44	164.26	165.08
60	165.90	166.73	167.56	168.38	169.21	170.05	170.88	171.72	172.56	173.40
70	174.25	175.10	175.95	176.80	177.66	178.51	179.37	180.24	181.10	181.97
80	182.84	183.71	184.59	185.46	186.34	187.22	188.10	188.98	189.87	190.75
90	191.64	192.53	194.32	193.42	195.21	196.11	197.01	197.91	198.82	199.73
100	200.64	201.55	202.46	203.38	204.30	205.22	206.14	207.06	207.99	208.92
110	209.85	210.78	211.72	212.66	213.60	214.54	215.49	216.44	217.39	218.34
120	219.29	220.25	221.21	222.17	223.14	224.10	225.07	226.04	227.01	227.99
130	228.96	229.94	230.92	231.90	232.89	233.88	234.87	235.86	236.85	237.85
140	238.85	239.85	240.85	241.86	242.86	243.87	244.88	245.89	246.91	247.93
150	248.95	249.97	251.00	242.02	253.05	254.09	255.12	256.16	257.21	258.25
160	259.30	260.35	261.40	262.45	263.51	264.57	265.63	266.60	267.76	268.83
170	269.91	270.98	272.06	273.14	274.22	275.30	276.39	277.48	278.57	279.67
180	280.77	281.87	282.98	284.09	285.21	286.33	287.45	288.57	289.70	290.83
190	291.96	293.10	294.24	295.38	296.52	297.67	298.82	299.97	301.13	302.29
200	303.46	304.62	305.80	306.97	308.15	309.34	310.52	311.72	312.91	314.11
210	315.31	316.52	317.72	318.94	320.15	321.37	322.59	323.82	325.05	326.29
220	327.53	328.77	330.02	331.27	332.52	335.05	333.78	336.32	337.59	338.86
230	340.14	314.42	342.71	344.00	345.30	346.59	234.90	349.20	350.51	351.82
240	353.14	354.46	355.79	357.12	358.45	359.79	361.13	362.47	363.82	365.18
250	366.53	376.89	369.26	370.62	372.00	373.37	374.75	376.13	377.52	378.91
260	380.31	381.70	385.11	384.52	385.93	387.34	388.77	390.19	391.62	393.05
270	394.49	395.93	379.38	398.82	400.28	401.73	403.19	404.66	406.12	407.60
280	409.07	410.55	412.03	413.52	415.01	416.51	418.01	419.51	421.02	422.53
290	424.05	425.57	427.09	428.62	430.16	431.70	433.24	434.78	436.33	437.89
300	439.44	441.00	442.57	444.13	445.70	447.28	448.86	450.44	452.02	453.61
310	455.20	456.80	458.40	460.00	461.60	463.20	464.80	466.40	468.00	46.60
320	471.20									

TEMPERATURE CONVERSION TABLE

Read known temperature in bold face type.
Corresponding temperature in degrees Fahrenheit will be found in column to the right
Corresponding temperature in degrees Centigrade will be found in column to the left.

C.		F.	C.		F.
0.56	1	1.8	3.33	6	10.8
1.11	2	3.6	3.89	7	12.6
1.67	3	5.4	4.44	8	14.4
2.22	4	7.2	5.00	9	16.2
2.78	5	9.0	5.56	10	18.0

0 to 100

C.		F.	C.		F.
—17.8	**0**	32	10.0	**50**	122.0
—17.2	**1**	33.8	10.6	**51**	123.8
—16.7	**2**	35.6	11.1	**52**	125.6
—16.1	**3**	37.4	11.7	**53**	127.4
—15.6	**4**	39.2	12.2	**54**	129.2
—15.0	**5**	41.0	12.8	**55**	131.0
—14.4	**6**	42.8	13.3	**56**	132.8
—13.9	**7**	44.6	13.9	**57**	134.6
—13.3	**8**	46.4	14.4	**58**	136.4
—12.8	**9**	48.2	15.0	**59**	138.2
—12.2	**10**	50.0	15.6	**60**	140.0
—11.7	**11**	51.8	16.1	**61**	141.8
—11.1	**12**	53.6	16.7	**62**	143.6
—10.6	**13**	55.4	17.2	**63**	145.4
—10.0	**14**	57.2	17.8	**64**	147.2
—9.44	**15**	59.0	18.3	**65**	149.0
—8.89	**16**	60.8	18.9	**66**	150.8
—8.33	**17**	62.6	19.4	**67**	152.6
—7.78	**18**	64.4	20.0	**68**	154.4
—7.22	**19**	66.2	20.6	**69**	156.2
—6.67	**20**	68.0	21.1	**70**	158.0
—6.11	**21**	69.8	21.7	**71**	159.8
—5.56	**22**	71.6	22.2	**72**	161.6
—5.00	**23**	73.4	22.8	**73**	163.4
—4.44	**24**	75.2	23.3	**74**	165.2
—3.89	**25**	77.0	23.9	**75**	167.0
—3.33	**26**	78.8	24.4	**76**	168.8
—2.78	**27**	80.6	25.0	**77**	170.6
—2.22	**28**	82.4	25.6	**78**	172.4
—1.67	**29**	84.2	26.1	**79**	174.2
—1.11	**30**	86.0	26.7	**80**	176.0
—0.56	**31**	87.8	27.2	**81**	177.8
0	**32**	89.6	27.8	**82**	179.6
0.56	**33**	91.4	28.3	**83**	181.4
1.11	**34**	93.2	28.9	**84**	183.2
1.67	**35**	95.0	29.4	**85**	185.0
2.22	**36**	96.8	30.0	**86**	186.8
2.78	**37**	98.6	30.6	**87**	188.6
3.33	**38**	100.4	31.1	**88**	190.4
3.89	**39**	102.2	31.7	**89**	192.2
4.44	**40**	104.0	32.2	**90**	194.0
5.00	**41**	105.8	32.8	**91**	195.8
5.56	**42**	107.6	33.3	**92**	197.6
6.11	**43**	109.4	33.9	**93**	199.4
6.67	**44**	111.2	34.4	**94**	201.2
7.22	**45**	113.0	35.0	**95**	203.0
7.78	**46**	114.8	35.6	**96**	204.8
8.33	**47**	116.6	36.1	**97**	206.6
8.89	**48**	118.4	36.7	**98**	208.4
9.44	**49**	120.2	37.2	**99**	210.2
			37.8	**100**	212.0

100 to 1000

C.		F.	C.		F.
38	**100**	212	260	**500**	932
43	**110**	230	266	**510**	950
49	**120**	248	271	**520**	968
54	**130**	266	277	**530**	986
60	**140**	284	282	**540**	1004
66	**150**	302	288	**550**	1022
71	**160**	320	293	**560**	1040
77	**170**	338	299	**570**	1058
82	**180**	356	304	**580**	1076
88	**190**	374	310	**590**	1094
93	**200**	392	316	**600**	1112
99	**210**	410	321	**610**	1130
100	**212**	413	327	**620**	1148
104	**220**	428	332	**630**	1166
110	**230**	446	338	**640**	1184
116	**240**	464	343	**650**	1202
121	**250**	482	349	**660**	1220
127	**260**	500	354	**670**	1238
132	**270**	518	360	**680**	1256
138	**280**	536	366	**690**	1274
143	**290**	554	371	**700**	1292
149	**300**	572	377	**710**	1310
154	**310**	590	382	**720**	1328
160	**320**	608	388	**730**	1346
166	**330**	626	393	**740**	1364
171	**340**	644	399	**750**	1382
177	**350**	662	404	**760**	1400
182	**360**	680	410	**770**	1418
188	**370**	698	416	**780**	1436
193	**380**	716	421	**790**	1454
199	**390**	734	427	**800**	1472
204	**400**	752	432	**810**	1490
210	**410**	770	438	**820**	1508
216	**420**	788	443	**830**	1526
221	**430**	806	449	**840**	1544
227	**440**	824	454	**850**	1562
232	**450**	842	460	**860**	1580
238	**460**	860	466	**870**	1598
243	**470**	878	471	**880**	1616
249	**480**	896	477	**890**	1634
254	**490**	914	482	**900**	1652
			488	**910**	1670
			493	**920**	1688
			499	**930**	1706
			504	**940**	1724
			510	**950**	1742
			516	**960**	1760
			521	**970**	1778
			527	**980**	1796
			532	**990**	1814
			538	**1000**	1832

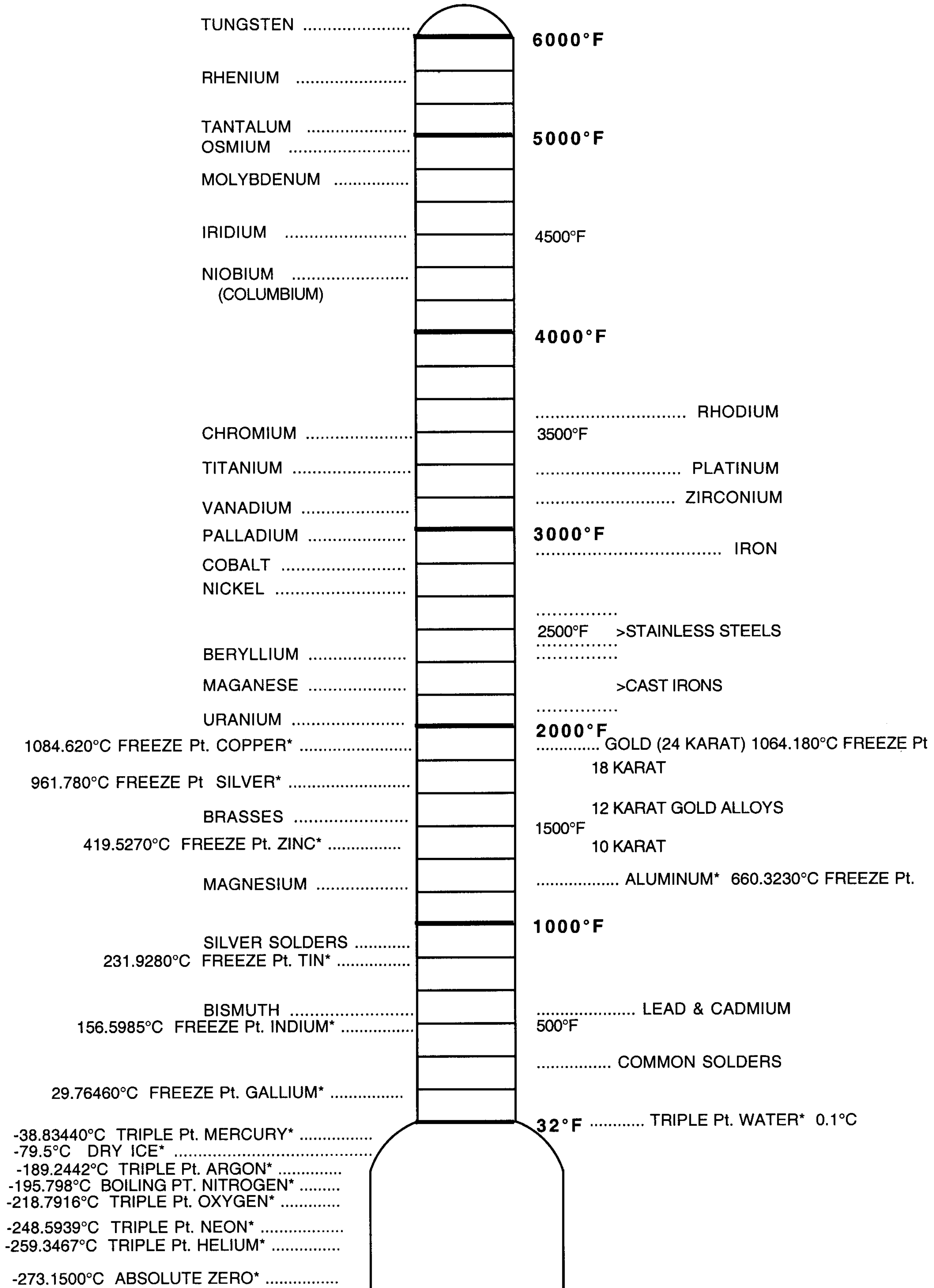
1000 to 2000

C.		F.	C.		F.
538	**1000**	1832	816	**1500**	2732
543	**1010**	1850	821	**1510**	2750
549	**1020**	1868	827	**1520**	2768
554	**1030**	1886	832	**1530**	2786
560	**1040**	1904	838	**1540**	2804
566	**1050**	1922	843	**1550**	2822
571	**1060**	1940	849	**1560**	2840
577	**1070**	1958	854	**1570**	2858
582	**1080**	1976	860	**1580**	2876
588	**1090**	1994	866	**1590**	2894
593	**1100**	2012	871	**1600**	2912
599	**1110**	2030	877	**1610**	2930
604	**1120**	2048	882	**1620**	2948
610	**1130**	2066	888	**1630**	2966
616	**1140**	2084	893	**1640**	2984
621	**1150**	2102	899	**1650**	3002
627	**1160**	2120	904	**1660**	3020
632	**1170**	2138	910	**1670**	3038
638	**1180**	2156	916	**1680**	3056
643	**1190**	2174	921	**1690**	3074
649	**1200**	2192	927	**1700**	3092
654	**1210**	2210	932	**1710**	3110
660	**1220**	2228	938	**1720**	3128
666	**1230**	2246	943	**1730**	3146
671	**1240**	2264	949	**1740**	3164
677	**1250**	2282	954	**1750**	3182
682	**1260**	2300	960	**1760**	3200
688	**1270**	2318	966	**1770**	3218
693	**1280**	2336	971	**1780**	3236
699	**1290**	2354	977	**1790**	3254
704	**1300**	2372	982	**1800**	3272
710	**1310**	2390	988	**1810**	3290
716	**1320**	2408	993	**1820**	3308
721	**1330**	2426	999	**1830**	3326
727	**1340**	2444	1004	**1840**	3344
732	**1350**	2462	1010	**1850**	3362
738	**1360**	2480	1016	**1860**	3380
743	**1370**	2498	1021	**1870**	3398
749	**1380**	2516	1027	**1880**	3416
754	**1390**	2534	1032	**1890**	3434
760	**1400**	2552	1038	**1900**	3452
766	**1410**	2570	1043	**1910**	3470
771	**1420**	2588	1049	**1920**	3488
777	**1430**	2606	1054	**1930**	3506
782	**1440**	2624	1060	**1940**	3524
788	**1450**	2642	1066	**1950**	3542
793	**1460**	2660	1071	**1960**	3560
799	**1470**	2678	1077	**1970**	3578
804	**1480**	2696	1082	**1980**	3596
810	**1490**	2714	1088	**1990**	3614
			1093	**2000**	3632

2000 to 3000

C.		F.	C.		F.
1093	**2000**	3632	1371	**2500**	4532
1099	**2010**	3650	1377	**2510**	4550
1104	**2020**	3668	1382	**2520**	4568
1110	**2030**	3686	1388	**2530**	4586
1116	**2040**	3704	1393	**2540**	4604
1121	**2050**	3722	1399	**2550**	4622
1127	**2060**	3740	1404	**2560**	4640
1132	**2070**	3758	1410	**2570**	4658
1138	**2080**	3776	1416	**2580**	4676
1143	**2090**	3794	1421	**2590**	4694
1149	**2100**	3812	1427	**2600**	4712
1154	**2110**	3830	1432	**2610**	4730
1160	**2120**	3848	1438	**2620**	4748
1166	**2130**	3866	1443	**2630**	4766
1171	**2140**	3884	1449	**2640**	4784
1177	**2150**	3902	1454	**2650**	4802
1182	**2160**	3920	1460	**2660**	4820
1188	**2170**	3938	1466	**2670**	4838
1193	**2180**	3956	1471	**2680**	4856
1199	**2190**	3974	1477	**2690**	4874
1204	**2200**	3992	1482	**2700**	4892
1210	**2210**	4010	1488	**2710**	4910
1216	**2220**	4028	1493	**2720**	4928
1221	**2230**	4046	1499	**2730**	4946
1227	**2240**	4064	1504	**2740**	4964
1232	**2250**	4082	1510	**2750**	4982
1238	**2260**	4100	1516	**2760**	5000
1243	**2270**	4118	1521	**2770**	5018
1249	**2280**	4136	1527	**2780**	5036
1254	**2290**	4154	1532	**2790**	5054
1260	**2300**	4172	1538	**2800**	5072
1266	**2310**	4190	1543	**2810**	5090
1271	**2320**	4208	1549	**2820**	5108
1277	**2330**	4226	1554	**2830**	5126
1282	**2340**	4244	1560	**2840**	5144
1288	**2350**	4262	1566	**2850**	5162
1293	**2360**	4280	1571	**2860**	5180
1299	**2370**	4298	1577	**2870**	5198
1304	**2380**	4316	1582	**2880**	5216
1310	**2390**	4334	1588	**2890**	5234
1316	**2400**	4352	1593	**2900**	5252
1321	**2410**	4370	1599	**2910**	5270
1327	**2420**	4388	1604	**2920**	5288
1332	**2430**	4406	1610	**2930**	5306
1338	**2440**	4424	1616	**2940**	5324
1343	**2450**	4442	1621	**2950**	5342
1349	**2460**	4460	1627	**2960**	5360
1354	**2470**	4478	1632	**2970**	5378
1360	**2480**	4496	1638	**2980**	5396
1366	**2490**	4514	1643	**2990**	5414
			1649	**3000**	5432

FREEZING TEMPERATURE OF METALS



* Represents information from ITS-90 Temperaure Scale.

THE INTERNATIONAL SYSTEM OF UNITS (SI)

The information provided below is for convenient reference in providing product specification is SI.

SI Base Units
SI is founded on seven base units:

Quantity	Name of Unit	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	centigrade or fahrenheit	C or F
amount of substance	mole	mole
luminous intensity	candela	cd

There are also two supplementary units:

Quantity	Name of Unit	Symbol
plane angle	radian	rad
solid angle	steradian	sr

SI Derived Units
Derived units are formed with base and/or supplementary units.

Quantity	Name	Symbol	Equivalent to
force	newton	N	kg•m/s^2
pressure	pascal	Pa	N/m^2
work, energy, quantity of heat	joule	J	N•m
power, heat flow rate	watt	W	J/s
quantity of electricity	coulomb	C	A•s
electrical potential	volt	V	V/A
electric resistance	ohm	Ω	V/A
electric capacitance	farad	F	C/V
electric conductance	siemens	S	A/V
magnetic flux	weber	Wb	V•s
inductance	henry	H	Wb/A
magnetic flux density	tesla	T	Wb/m^2
frequency	hertz	Hz	1/s
luminous flux	lumen	Im	cd•sr
illuminance	lux	Ix	Im/m^2
activity	becquerel	Bq	1/s
absorbed dose	gray	Gy	J/kg

Common Prefixes

Prefix	Symbol	Means Multiple by	Or by
mega	M	1,000,00	10^6
kilo	k	1,000	10^3
hecto*	h	100	10^2
deka*	da	10	10
deci*	d	0.1	10^{-1}
centi*	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	u	0.000,0001	10^{-6}

*should be avoided when possible