

TECHNICAL MANUAL
INSTRUMENT CALIBRATION PROCEDURE

DIGITAL THERMOMETERS



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LIST OF EFFECTIVE PAGES

The purpose of this list is to identify the pages in this document affected by any technical content changes made since the previous release of the document.

NOTE: On a revised page, with the exception of the Title, the A, and the i pages, the technical changes are indicated by a vertical line in the outer margin of the page.

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SECTION 1

INTRODUCTION AND DESCRIPTION

1.1 This procedure describes the calibration of Digital Thermometers, with or without accompanying thermocouple probe(s). Digital thermometers that may be calibrated using this procedure include, but are not limited to, the models listed in Appendix A. The instrument being calibrated is referred to herein as the TI (Test Instrument).

1.2 All comments concerning this procedure should be directed to the Navy Measurement Science Directorate, Naval Warfare Assessment Station, P.O. Box 5000, Corona, CA 92878-5000.

1.3 This procedure includes tests of essential performance parameters only. Any malfunction noticed during calibration, whether specifically tested for or not, should be corrected.

Table 1. Calibration Description

TI Characteristics	Performance Specifications	Test Method
Indicator temperature response	Range: -328° up to +2552°F or -180° up to +760°C, depending on TI model Tolerance: ±1° up to ±2.5°F, or ±0.5° up to ±1.5°C, depending on TI model and range	A direct voltage is applied through ice point referenced thermocouple wires to the TI to obtain a TI indication. The equivalent applied voltage is then compared to a thermocouple emf vs. temperature table.
System temperature response	Range: 32° to 450°F Tolerance: ±2.5° up to ±20°F or ±1.4° up to ±11°C, depending on TI model and range	Indication of TI temperature indicator and thermocouple(s) is compared to the indication of a ruggedized reference thermometer (RRT) in a temperature bath. System response tests are required only if one or more thermocouples are submitted with the indicator.

SECTION 2
EQUIPMENT REQUIREMENTS

NOTE

Minimum use specifications are the principal parameters required for performance of the calibration, and are included to assist in the selection of alternate equipment, which may be used at the discretion of the using laboratory. Satisfactory performance of alternate items shall be verified prior to use. All applicable equipment must bear evidence of current calibration.

The instruments utilized in this procedure were selected from those known to be available at Navy calibration facilities and the listing by make or model number carries no implication of preference, recommendation, or approval for use by other agencies. It is recognized that equivalent equipment produced by other manufacturers may be capable of equally satisfactory performance in this procedure.

Table 2. Equipment Requirements

Item	Minimum Use Specifications	Calibration Equipment
2.1 Meter calibrator	Range: 0 to 1100 V Uncertainty: $\pm(9 \text{ ppm iv} + 0.8 \mu\text{V})$ on the 0 to 220 mV range used here	Fluke 5700AAN
2.2 Thermocouple wire	Type J, K or T, as required for the TI	Local supply
2.3 Copper wire	To connect the equipment or to provide extension leads for item 2.2	Local supply
2.4 Temperature bath	Range: ambient to 450°F (ambient to 232°C)	Precision Scientific 41132; or Hallikainen 1132
2.5 Bath fluid	Range: ambient to 450°F (ambient to 232°C)	Dow Corning 210H
2.6 Thermometer holder	Used with item 2.4 to hold item 2.7	Hallikainen 1143A
2.7 Ruggedized Reference Thermometer (RRT)	Range and Uncertainty: -196°C to -40°C; $\pm 0.01^\circ\text{C}$ -40°C to 125°C; $\pm 0.035^\circ\text{C}$ 125°C to 320°C; $\pm 0.01^\circ\text{C}$ linearly increasing to $\pm 0.03^\circ\text{C}$ at 670°C	Isothermal Technology 935-14-59-25.5
2.8 Digital temperature indicator	Range: -40 to +660°C Uncertainty: $\pm 0.03^\circ\text{C}$	Instrulab 4202B-13-15
2.9 Thermocouple ice point reference	Range point: 32.00°F (0.00°C) Uncertainty: $\pm 0.1^\circ\text{F}$ ($\pm 0.05^\circ\text{C}$)	Kaye Instruments, Inc. K140-4 or K150-8
2.10 Thermocouple conversion tables	For converting temperature to equivalent thermocouple EMF	NBS Monograph 125 or NIST Monograph 175 as applicable

SECTION 3

PRELIMINARY OPERATIONS

3.1 Ensure that the TI is clean and free from defects that would impair its operation.

3.2 Connect the meter calibrator (item 2.1) to an appropriate power source. Turn on the power by pushing in the POWER button. If STANDBY is not displayed, press OPR/STBY button to toggle to the standby mode.

NOTE

The TI does not require a warm up. However, the Doric DS100T3 requires one hour for warm up.

3.3 If the TI is an Omega 199 series or Atkins 396 series model proceed directly to paragraph 3.5. If the TI is an Omega 400A series model equipped with a Model 406 power pack, it may be operated on battery power. Check battery status by depressing the power switch ON button. If the LED light illuminates, the battery is low and must be recharged by connecting the AC power cord to a 115 V ac, 60 Hz power source and charging for 5-8 hours.

3.4 If a checklist is not provided for the TI, use an existing checklist as a guide, and select four equally-spaced calibration points over the TI range span, including the minimum and maximum values. If the TI is submitted with a thermocouple, the TI indicator-thermocouple system temperature response must be also tested at the ice point and at 300°F or 450°F, as applicable. Record the applicable values in the FUNCTION TESTED column on the checklist. Using NBS Monograph 125 or NIST Monograph 175 (item 2.10), as applicable, record equivalent EMF values in the NOMINAL column.

3.5 If the TI is not provided with a thermocouple, skip directly to section 4.1. If one or more thermocouple(s) are submitted, prepare for TI indicator-thermocouple system temperature response calibration as follows:

3.5.1 Open the overflow valve on the temperature bath (item 2.4). Ensure that a container is provided to catch any overflow.

3.5.2 Ensure that the bath is filled with Dow Corning 210H silicone oil (item 2.5) to the overflow valve.

NOTE

The liquid level in the bath should be maintained at the point of overflow during the TI system calibration.

3.5.3 Mount the thermometer holder (item 2.6) in the bath as required.

3.5.4 Ensure that the TI thermocouple can be mounted in the holder or adjacent to it in close proximity to the PRT probe, but do not install the thermocouple in the bath at this time.

3.5.5 Set the temperature bath switch to ON; set the bath controls to 300°F or 450°F as required.

3.5.6 Connect the ruggedized reference thermometer (item 2.7) and RRT probe to an appropriate power source, set the power switch to ON, and allow the thermometer to warm up for 15 minutes.

3.6 If a thermocouple is connected to the TI indicator, note the location of the thermocouple leads, and disconnect the leads.

NOTE

If the TI is a 400A series model, the power switch OFF button should be depressed before connecting or disconnecting a thermocouple.

SECTION 4

CALIBRATION PROCESS

NOTE

Unless otherwise specified, verify the results of each test and take corrective action whenever the test requirement is not met before proceeding.

4.1 INDICATOR TEMPERATURE RESPONSE TEST

4.1.1 Connect the equipment as shown in Figure 1, using the appropriate thermocouple wires (item 2.2) and copper leads (item 2.3). Refer to Appendix A when selecting the thermocouple wire.

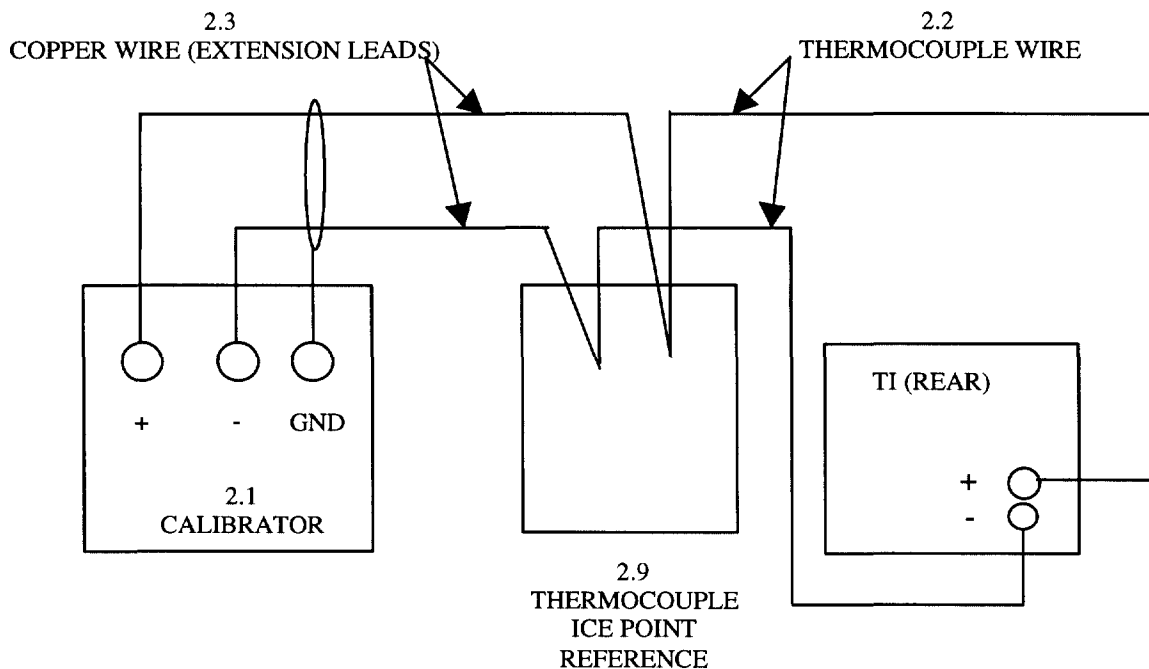


Figure 1. Indicator Temperature Response Test Configuration

NOTES

Care must be exercised when connecting the thermocouple wires to the TI to ensure correct TI response and polarity. For voltage settings generating minus (-) millivolts from the calibrator (item 2.1), reverse the thermocouple wire connections at the TI output terminals with respect to Figure 1.

If the TI is an Omega 199 series model connect the high potential wire to the TI positive (outer) terminal and the lower potential wire to the TI negative (inner) terminal.

If the TI is a Doric or Omega 400A series model, connect the higher potential wire to the +V terminal and the lower potential wire to the TI -V terminal.

If the TI is an Omega model 115JF, connect a Type J thermocouple wire to pins 4 and 5 of the 6 pin input plug.

NOTES

Prior to calibration the program lock-out switch must be off to permit program changes.

Care must be taken to prevent the thermocouple-copper wire junction from contacting one another. A significant temperature error can be created if the above precautions are not observed.

4.1.1.1 Press PGM key of calibrator to enter program mode. Then press ENT key which will prompt you through the menu.

4.1.1.2 When (reference junction) is displayed, press any arrow key to display (RJ DISAB) (Reference Junction Disabled), then press ENT key. (CALIB) will be displayed, press ENT key. (INSTRMNT) will be displayed. (SET O M.V.) will be displayed.

4.1.1.3 Set meter calibrator (item 2.1) to Zero M.V. Press ENT key to calibrate for Zero. The display will show (BUSY). If calibration was successful, (PASS CAL) is displayed for about 2 seconds. Then the user is prompted on the display (SET 54 M.V.) (for span input). Set the calibrator source to this input. Then press ENT key. If successful again (PASS CAL) is displayed. At this time set calibrator for Zero M.V., then press PMG key, and (PROCESS) will be displayed.

4.1.1.4 TI should read (32.0°F or 0°C). Then skip to step 4.1.4.

4.1.2 If the TI is a 199 series model, connect it to an appropriate power source. If the TI is a 396 or 400A series model, depress the power switch ON button.

4.1.3 Ensure that the meter calibrator POWER switch is set to OPR/ON.

4.1.4 Perform the following steps at each calibration point on the checklist.

4.1.4.1 Adjust the meter calibrator to obtain the exact TI indication at the calibration point.

4.1.4.2 Verify that the meter calibrator indicates within the TI tolerance limits listed.

4.1.4.3 Place program lock-out switches in the ON position, to prevent program changes.

4.1.5 If the TI indicator is submitted for calibration without a thermocouple, attach a SPECIAL CALIBRATION LABEL/TAG indicating that the TI indicator only was calibrated. If no other measurements are to be made, set the calibrator POWER switch to OFF, disconnect and secure the equipment.

4.1.6 If one or more thermocouples are submitted with the indicator, set the calibrator POWER switch to OFF, disconnect the test setup, and skip to section 4.2 to perform the TI indicator-thermocouple system tests.

4.2 SYSTEM TEMPERATURE RESPONSE TESTS

4.2.1 Connect the TI thermocouple to the TI indicator, observing the polarity as noted in step 3.6.

NOTE

If the TI is a 199 series model, connect the red lead from the thermocouple to the TI negative (inner) terminal and the other lead to the positive (outer) terminal.

If the TI is a 400A series model, connect the high potential lead from the thermocouple to the TI +V terminal and the low potential lead to the -V terminal.

4.2.2 If the TI is a 199 series model, connect it to an appropriate power source. If the TI is a 396 or 400A series model operating on battery power, depress the power switch ON button.

4.2.3 Carefully insert the RRT and the TI thermocouple in separate thermocouple ice point reference wells (item 2.9).

4.2.4 Ensure that the RRT digital temperature indicator reads within the tolerance limits on the RRT Report of Calibration.

NOTE

Adjust the RRT temperature indicator to indicate 32.00°F if necessary.

4.2.5 Allow sufficient time for temperature stabilization, as displayed on the TI indicator and the RRT digital temperature indicator. Verify that the TI indicates 0°C/32°F, as applicable, within the tolerance limits on the checklist.

4.2.6 Remove the RRT and the TI thermocouple from the thermocouple ice point reference wells. Carry them to the temperature bath prepared for use in paragraph 3.5.

4.2.7 Install the TI thermocouple and the RRT in the temperature bath, as close together as the holder will allow (see Figure 2 following). Provide adequate support for the TI and RRT indicators well away from the temperature bath fluid.

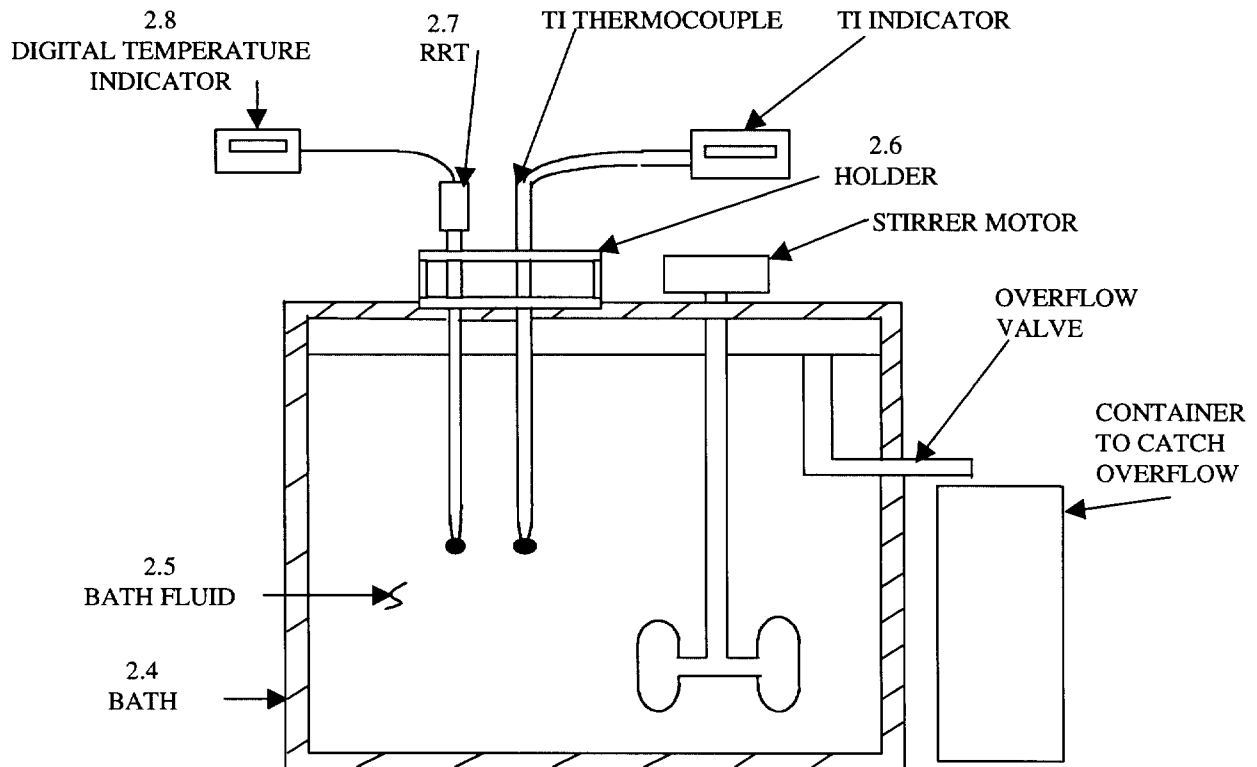


Figure 2. System Temperature Response Test Configuration

CAUTION

DO NOT EXCEED THE TEMPERATURE RANGE OF THE THERMOCOUPLE

NOTE

Immerse the TI thermocouple to the depth recommended by the manufacturer. Do not allow the bath fluid to contact the holder.

4.2.8 Allow sufficient time for temperature stabilization, as displayed on the TI indicator and the RRT digital temperature indicator.

4.2.9 Compare the TI indication to that of the digital thermometer, converting from °F to °C as necessary. Verify that the TI indicates within the tolerance limits on the checklist.

4.2.10 Disconnect the thermocouple from the indicator.

4.2.11 Perform steps 4.2.1, 4.2.3, and 4.2.5 through 4.2.10 for each remaining thermocouple submitted with the TI indicator for calibration.

4.2.12 If no other measurements are to be performed, set all applicable switches to OFF, disconnect and secure the equipment.

APPENDIX A

REPRESENTATIVE TEST INSTRUMENTS

TIs which may be calibrated using this procedure include, but are not limited to, the following:

Model	Manufacturer	T/C Type	Range	System Accuracy	
				Indicator	T/C
DP26-TC	Omega Engineering	J	-346 to 1400°F	±0.8°F > -148°F ±1.8°F < -148°F	±4°F or ±0.75% iv*
		K	-454 to 2500°F	“	±4°F or ±0.75% iv > 32°F ±4°F or ±2.0% iv < 32°F
		T	-346 to 1652°F	“	±1.8°F or ±0.75% > 32°F ±1.8°F or ±1.5% < 32°F
DP41TCMDSS	Omega Engineering	J	-346 to 1400°F	±0.3°F	±4°F
		K	-454 to 2500°F	±0.3°F	±4°F
		T	-454 to 752°F	±0.3°F	±1.8°F
DP460	Omega Engineering	J	-337 to 1403°F	±0.03%	±4°F
		K	-331 to 2510°F	±0.03%	±4°F
		T	-346 to 775°F	±0.03%	±1.8°F
DS100T3	Doric Scientific	see Appendix B	-400 to 1600°F	±0.2°F	see Appendix B
115JF	Omega Engineering	J	-148 to 1400°F	±3.6°F	±4°F or ±0.75% iv*
199JF	Omega Engineering	J	-170 to 1400°F	±1.5°F	±4°F or ±0.75% iv*
199JKXADS	Omega Engineering	J	-170 to 1400°F	±1.5°F	±4°F or ±0.75% iv*
		K	-50 to 1250°C	±2.1°C	±2.2°C or ±0.75% > 0°C ±2.2°C or ±2.0% < 0°C
199KCAX	Omega Engineering	K	-50 to 1250°C	±2.1°C	±2.2°C or ±0.75% > 0°C ±2.2°C or ±2.0% < 0°C
2455 11, 14	Yokogawa Corp.	K	-256 to 2502°F	±(0.3% iv + 1.8°F)	±4°F or ±0.75% > 32°F ±4°F or ±2.0% < 32°F

Model	Manufacturer	T/C Type	Range	System Accuracy	
				Indicator	T/C
2455 12, 15	Yokogawa Corp.	K	-256 to 2502°F	±(0.1% iv + 1.3°F) From 32°F to 391.8°F	±4°F or ±0.75%>32°F
				±(0.2% iv + 1.8°F) 392°F or more 31.8°F or less	±4°F or ±2.0%<32°F
		J	-274 to 1832°F	±(0.1% iv + 1.3°F) From 32°F to 391.8°F	±4°F or ±0.75%iv*
				±(0.2% iv + 1.8°F) 392°F or more 31.8°F or less	
39658-J	Atkins	J	-112 to 1382°F	±1% iv +1 digit	±2.2°C or ±0.75%iv*
400A-KF	Omega Engineering	K	-208 to 2552°F	±1.5°F up to 0°F then ±1.0°F	±4°F or ±0.75% iv*
400ATF406	Omega Engineering	T	-328 to 752°F	±1.0°F	±2% iv or ±1.5°F* or ±0.75% iv**
650TFXDSS	Omega Engineering	T	-238 to 752°F	±1.9°F	±1.8°F or 0.75%* Above 32°F ±1.8°F or 1.5%* Below 32°F

* Whichever is greater.

** Whichever applies to the test temperature.

APPENDIX B

DORIC DS100T3 PLUG IN MODULE OPTIONS

TYPE J (IRON CONSTANTAN)

RANGE	OVERALL ACCURACY	OPTION NUMBER
0 to 600.0 °F	±0.4°F	J07
0 to 800.0 °F	±0.6°F	J09
0 to 1000.0 °F	±0.7°F	J08
0 to 1200.0 °F	±0.8°F	J06
0 to 1600.0 °F	±1.3°F	J01
0 to 1600.0 °F	±0.7°F	J25A
-80.0 to +320.0°F	±0.4°F	J02
-120.0 to +480.0°F	±0.6<0°F ±0.4>0°F	J04
-160.0 to +640.0°F	±0.9°F	J12
0 to 300.0 °C	±0.3°C	J03
0 to 600.0 °C	±0.4°C	J10
0 to 800.0 °C	±0.9°C	J11
-40.0 to +160.0°C	±0.3°C	J16
-80.0 to +320.0°C	±0.5°C<0 ±0.3°C>0	J15
-160.0 to +640.0°C	±2.3°C<0 ±0.8°C<+80°C ±0.5°C>+80°C	J14
-120.0 to +480.0°C	±1°C<0 ±0.3°C>0	J29

TYPE K (CHROMEL ALUMEL)

RANGE	OVERALL ACCURACY	OPTION NUMBER
0 to 600.0 °F	±0.6°F	K16
0 to 1000.0 °F	±0.8°F<400°F ±0.7°F>400°F	K06
0 to 1200.0 °F	±0.7°F	L18,A
0 to 1600.0 °F	±2°F<480°F ±1°F>480°F	K05
0 to 1999.9 °F	±2°F<600°F ±1.3°F>600°F	K02
0 to 2400.0 °F	±2°F	K01
0 to 2400.0 °F	±1.2°F	K19,A
-100.0 to +1600.0 °F	±2°F<+800°F ±1°F>+800°F	K15
-120.0 to +1080.0 °F	±0.8°F	K38,A
0 to 400.0 °C	±0.3°C	K22,A
0 to 1000.0 °C	±1°C<400°C ±0.6°C>400°C	K07
0 to 1370.0 °C	±1.2°C	K03
0 to 1370.0 °C	±0.8°C	K21,A
-160.0 to +640.0 °C	±2.8°C<0 ±1.0°C<+320°C ±0.4°C>+320°C	K20
-200.0 to 0°C	±0.6°C	K10
-200.0 to 1000°C	±1°C	K25,A

TYPE T (COPPER CONSTANTAN)

RANGE	OVERALL ACCURACY	OPTION NUMBER
0 to +200.0°F	±0.3°F	T07
0 to +400°F	±0.3°F	T22
0 to +600.0°F	+0.5°F	T14
0 to +750°F	±0.8°F<320°F ±0.5°F>320°F	T23
-80.0 to +320.0°F	±0.4°F<0 ±0.3°F>0	T04
-120.0 to +480.0°F	±0.8°F<+60°F ±0.5°F>+60°F	T02
-160.0 to +640.0°F	±1.3°F<0 ±0.8°F>0	T15
-200.0 to +750.0°F	±2°F<0 ±1°F>0	T01
-200.0 to +0°F	±0.4°F	T06
-310.0 to +160.0°F	±2°F<0 ±1°F>+160°F	T09
-310.0 to +400.0°F	±0.8°F<0 ±0.4°F>0	T12,A
-400.0 to +400.0°F	±0.9°F<-120°F ±0.5°F>-120°F	T26,A
0 to +200.0°C	±0.2°C	T21
0 to +400.0°C	±0.4°C	T11
-40.0 to +160.0°C	±0.2°C	T03
-80.0 to +320.0°C	±0.6°C<+80°C ±0.3°C>+80°C	T17
-190.0 to 0°C	±0.4°C	T10
-190.0 to +120.0°C	±2.5°C<-60°C ±1°C>-60°C	T13
-190.0 to +100.0°C	±2.5°C<-60°C ±1°C>-60°C	T18,A
-190.0 to +400.0°C	±0.4°C<+80°C ±0.3°C>+80°C	T19,A

TYPE E (CHROMEL CONSTANTAN)

RANGE	OVERALL ACCURACY	OPTION NUMBER
0 to 800.0 °F	±0.7°F<400°F ±0.4°F>400°F	E05
0 to +1200.0 °F	±1.2°F<+480°F ±0.5°F>+480°F	E02
0 to +1600.0 °F	±2°F<320°F ±0.9°F>320°F	E03
0 to +1830.0 °F	±3°F<600°F ±0.9°F>600°F	E04
-120.0 to +480.0 °F	±0.6°F	E01
-320.0 to +1000.0 °F	±1°F<300°F ±0.5°F>300°F	E09,A

TYPE YBS (IRON CONSTANTAN)

RANGE	OVERALL ACCURACY	OPTION NUMBER
0 to +1000.0 °F	±0.6°F	Y01
0 to +1200.0 °F	±0.8°F	Y04
-160.0 to +640.0 °F	±0.9°F<+80°F ±0.5°F>+80°F	Y02
-240.0 to +960.0 °F	±2.6°F<+120°F ±0.6°F>+120°F	Y03

TYPE R (PT-PT 13% Rh)		
RANGE	OVERALL ACCURACY	OPTION NUMBER
600 to 3000°F	±1.2°F	R08, A, F
720 to 3100°F	±2°F	R01, F
200.0 to 1700.0°C	±1.4°C, 200 to 400°C ±0.8°C, 400 to 1080°C ±0.7°C > 1080°C	R09, A, F
300.0 to 1300.0°C	±0.9°C	R07, F
300.0 to 1500.0°C	±0.6°C	R06, A, F
500.0 to 1500.0°C	±0.8°C	R13, F
800.0 to 1600.0°C	±0.6°C	R02, F
880.0 to 1320.0°C	±0.5°C	R05, A, F

TYPE S (PT-PT 10% Rh)		
RANGE	OVERALL ACCURACY	OPTION NUMBER
0 to 2400°F	±9°F < 480°F ±2.5°F, 480 to 720°F ±2°F > 720°F	S08
600 to 3200°F	±2.4°F	S01,F
0 to 1600.0°C	±2°C < 400°C ±0.6°C > 400°C	S11,A
300.0 to 1300.0°C	±0.8°C	S05,F
300.0 to 1380.0°C	±0.7°C	S06,A,F
400.0 to 1400.0°C	±0.8°C	S04,F
600.0 to 1400.0°C	±0.6°C	S07,A,F
640.0 to 1440.0°C	±0.6°C	S03,F
800.0 to 1600.0°C	±0.7°C	S02,F

PT 6% Rh-PT 30% Rh

RANGE	OVERALL ACCURACY	OPTION NUMBER
800.0 to 3270°F	±8°F, 1500 to 2100°F ±3°F, > 2100°F	X01, F
60 to 1760°C	±3°C, 640 to 960°C ±3°C, 640 to 960°C	X02, F
800 to 1500°C	±2°C < 660°C ±1°C > 660°C	X04, F