TECHNICAL MANUAL

INSTRUMENT CALIBRATION PROCEDURE

DIGITAL THERMOMETERS

OMEGA ENGINEERING, INC.
650 SERIES,
DSS–650 SERIES,
AND DP465 SERIES

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SECTION 1

INTRODUCTION AND DESCRIPTION

1.1 This procedure describes the calibration of the Omega Engineering Inc. 650 Series, DSS–650 Series, and DP465 Series Digital Thermometers, with or without accompanying thermocouple(s). Instruments that can 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 Navy Measurement Science Directorate, Naval Warfare Assessment Division, P.O. Box 5000, Corona, CA 91718–5000.

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: specified in Appendix A Tolerance: specified in Appendix A	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 points: 32°F and 300°F Tolerance: specified in Appendix A	Indication of TI temperature indicator and thermocouple(s) is compared to the indication of a digital thermometer in ice–point and temperature baths. 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.

Item	Minimum Use Specifications	Calibration Equipment
2.1 DC voltage calibrator	Range: -10 to +80 V Uncertainty: ±(0.002% iv + 20 μV)	Fluke 332B or 332A
2.2 Voltage divider	Type: Fixed ratio, resistive Divider ratio: 1000 to 1 Ratio Uncertainty: ±0.025% iv Input Resistance: 10,000 ohms Temperature coefficient: 5 ppm/°C	Electro–Scientific CA6042
2.3 Thermocouple wire	Type: as required by the TI, with copper extension leads	Local supply
2.4 Temperature bath	Range: ambient to 300°F (ambient to 150°C)	Hallikainen 1132
2.5 Bath fluid	Range: ambient to 300°F (ambient to 150°C)	Dow Corning 210H
2.6 Thermometer holder	Used with item 2.4 to hold item 2.7	Hallikainen 1143A
2.7 Digital thermometer	Range: 32 to 300°F Uncertainty: ±0.6°F	Doric DS100T5APRT34A100

Item	Minimum Use Specifications	Calibration Equipment
	NOTE Items 2.4 through 2.7 are required only if the TI is submitted with thermocouple(s) which must be calibrated together for TI system temperature response.	
2.8 Ice–point bath, consisting of	Value: 32.00°F (0.00°C) Uncertainty: ±0.02°F (±0.01°C)	Local supply
2.8.1 Dewar Flask:	For use in preparing an ice bath; capacity 600 to 1000 mb; depth 8 to 12 in.	
2.8.2 Ice	To make slush for ice–point bath	
2.8.3 Distilled water	To make slush for ice–point bath	
2.9 Ice shaver	To crush ice for slush	Fisher Scientific 8–495
2.10 Thermocouple conversion tables	For converting temperature to equivalent thermocouple EMF	NBS Monograph 125

SECTION 3

PRELIMINARY OPERATIONS

3.1 Ensure that all power switches are set to off, and set all auxiliary equipment controls as necessary to avoid damage to the equipment and so that dangerous voltages will not be present on output terminals when the power switches are turned on.

3.2 Connect the DC voltage calibrator (item 2.1) to an appropriate power source. Set the calibrator POWER switch to STDBY/RESET and allow one hour for warm–up.

NOTE

The TI does not require a warm up.
(DP465 Series requires a 10 min. warm up)

3.3 Prepare an ice-point bath (item 2.8) in the Dewar flask.

NOTE

The Dewar flask, the shaved or crushed ice and the distilled water must be clean and free from all impurities. Fill the Dewar flask with shaved or crushed ice and add distilled water to make a slush. Use only enough water to obtain good contact with the thermocouple wires, (item 2.3) but not so much as to float the ice. As the ice melts, siphon off the excess water and add more ice.

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 one or more thermocouples, the TI indicator-thermocouple system must also be tested at the ice-point and at 150°C or 302°F. Record the applicable values in the FUNCTION TESTED column on the checklist. Using NBS Monograph 125 (item 2.10), record equivalent EMF values in the NOMINAL column.

3.5 If the TI is not provided with a thermocouple, proceed directly to subsection 4.1 If one of more thermocouple(s) are submitted, prepare for TI indicator-thermocouple system 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. Secure the digital thermometer (item 2.7) PRT probe in the thermometer holder.

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 power switch to ON; set the bath controls to 302°F.

3.5.6 Connect the digital thermometer and PRT 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 probe is connected to the TI indicator, T/C INPUT terminals, note the location of the thermocouple leads and disconnect the leads.

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 and copper extension leads (item 2.3). Refer to Appendix A when selecting the thermocouple wire.

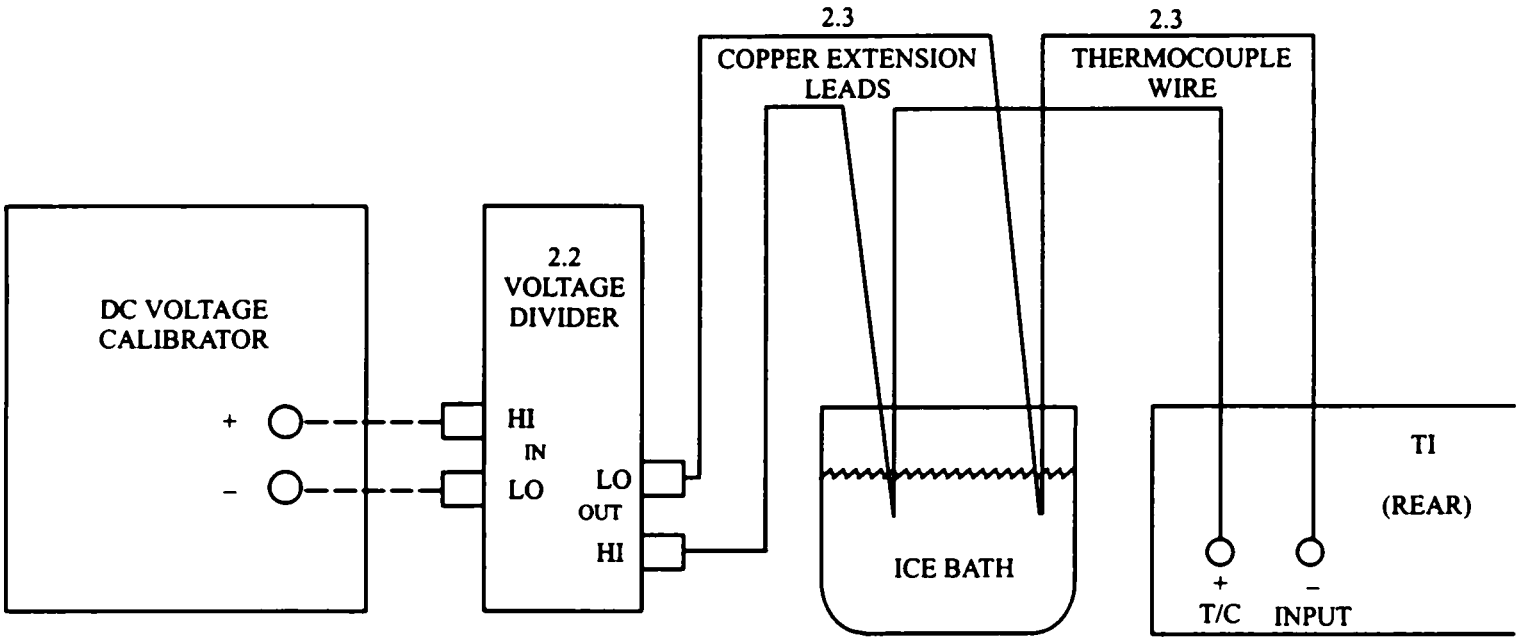

Figure 1. TI Indicator Test Configuration

NOTES

Care must be exercised when connecting the thermocouple wires and copper extension leads to ensure correct TI response and polarity. If the TI is a 650 series model, connect the higher potential wire to the TI indicator T/C INPUT plus (+) terminal and the lower potential wire to the minus (-) terminal. If the TI is a DSS–650 series model, ensure that the same convention is followed, and that the No. 1 terminals are used.

For voltage indication requiring minus (-) millivolts from the voltage divider (item 2.2) OUT terminals, connect the divider HI and LO IN banana plugs directly to the calibrator - and + OUTPUT terminals, respectively, instead of the connections shown in Figure 1.

Care must be taken to prevent the thermocouple–copper wire junctions from contacting one another or to allow the junctions to be surrounded by pure water, as may occur at the bottom of the flask. A significant temperature error can be created if the above precautions are not observed.

Thermocouple and copper wire connections should be coated with paraffin or placed in a test tube to prevent electrical conductivity in the bath.

4.1.2 Connect the TI POWER HI and LO terminals at the rear to an appropriate power source, observing the correct polarity; set the TI ON–OFF power switch to ON.

4.1.3 Set the TI °C/°F Scaling Switch to obtain a °C or °F indication; as required. If the TI is a DSS–650 series model, ensure that the Terminal Selector Rotary Switch is set to 1.

4.1.4 Set the DC voltage calibrator POWER switch to OPR/ON and the VOLTAGE RANGE switch to the appropriate setting.

CAUTION

DO NOT EXCEED 100 VOLTS OR DAMAGE TO THE VOLTAGE DIVIDER MAY OCCUR.

4.1.5 Perform the following steps at each calibration point on the checklist:

4.1.5.1 Set the calibrator controls to obtain an exact TI indication, in °F, at the calibration point.

NOTE

The equivalent millivolt value to the TI indication is listed in the NOMINAL column of the checklist for reference. The millivolt value, multiplied by 1000, is indicated in volts, without a + or – sign, on the calibrator display.

4.1.5.2 Verify that the calibrator indicates within the TI tolerance limits, expressed in volts. Refer to the second note under step 4.1.1 regarding connections for minus (–) NOMINAL settings.

NOTE

Reset the TI °C/°F Scaling Switch for a °C or °F indication, as necessary, to test the TI in the alternate temperature units.

4.1.6 If the TI is a DSS–650 series model, perform steps 4.1.5.1 and 4.1.5.2 at one calibration point for each remaining TI terminal connection to be tested, reconnecting the thermocouple wires, as required.

4.1.7 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 TI and calibrator POWER switches to OFF, disconnect and secure the equipment.

4.1.8 If one or more thermocouples are submitted with the

indicator, set the calibrator POWER switch to OFF, disconnect the test setup and proceed to section 4.2 to perform TI system tests, maintaining the ice-point bath for further use.

4.2 SYSTEM TEMPERATURE RESPONSE TESTS

4.2.1 Connect the First TI Thermocouple to the TI indicator, observing correct polarity.

4.2.2 Ensure that the TI ON-OFF power switch is set to ON and that the °C or °F indication, as required.

4.2.3 Carefully immerse the digital thermometer PRT and the TI thermocouple probe in the ice-point bath. Refer to the Note under paragraph 3.3 and the third Note under step 4.1.1 on the proper use and maintenance of the bath and possible sources of temperature deviations.

4.2.4 Ensure that the digital thermometer indicates with the tolerance limits on the PRT Report of Calibration.

NOTE

Adjust the digital thermometer to indicate 32.00°F or 00.0°C, as applicable, and if necessary.

4.2.5 Allow sufficient time for temperature stabilization, as displayed on the TI indicator. Verify that the TI indicated the ice point within the tolerance limits on the checklist.

4.2.6 Set the TI °C/°F Scaling Switch to the alternate temperature unit, if required. Verify that the TI indicates the ice point within the tolerance limits listed.

4.2.7 Remove the TI probe and digital thermometer PRT from the ice-point bath and allow them to dry. Carry them to the temperature bath prepared for use in paragraph 3.5.

4.2.8 Install the TI probe in the temperature bath, as close to the PRT as feasible. Provide adequate support for the TI and digital thermometer indicators, well away from the temperature bath fluid.

4.2.9 Allow sufficient time for temperature stabilization, as displayed on the TI indicator.

4.2.10 Verify that the TI indicates within the tolerance limits listed.

4.2.11 Set the TI °C/°F Scaling Switch to a °C or °F indication, as required. Verify that the TI indicates within the tolerance limits listed.

4.2.12 Disconnect the TI probe from the indicator.

4.2.13 Perform steps 4.2.1, 4.2.3, and 4.2.5 through 4.2.12 for each remaining thermocouple probe submitted with the TI indicator for calibration.

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

CALIBRATION CHECKLIST

TEST INST (S) Omega Engineering, Inc. DP465KFDDSS02 Digital Thermometer

PROC. NO.	NA 17-20ST-134	MFG.	MODEL			SER. NO.
PROCEDURE STEP NO. (1)	FUNCTION TESTED (2)	NOMINAL (3)	MEASURED VALUES FIRST RUN (4)	MEASURED VALUES SECOND RUN (5)	OUT OF TOL (6)	CALIBRATION TOLERANCES (7)
3.1	TI Inspection	—	ck ( )		NA	
3.3	Ice-pt. bath prepared	—	ck ( )		NA	
3.5	Temp. bath prepared	—	ck ( )		NA	
4.1	Indicator Temperature Response Test					
	#1 (°F)	(mV)	(V)			(V)
4.1.5.2	337	-5.965				5.957 to 5.973
"	608	13.039				13.016 to 13.062
"	1544	34.909				34.886 to 34.931
"	2502	54.875				54.855 to 54.895
4.1.6	#2 "	"				"
"	#3 "	"				"
"	#4 "	"				"
"	#5 "	"				"
"	#6 "	"				"
"	#7 "	"				"
"	#8 "	"				"
"	#9 "	"				"
"	#10 "	"				"
4.2	System Temperature Response Tests					
4.2.4	Adj. std. thermometer	—	ck ( )		NA	32.00°F
		(°F)	(°F)			(°F)
4.2.5	TI indication, 32°F	32				27 to 37
4.2.10	TI indication, 302°F	302				±5 of std. value

APPENDIX A

REPRESENTATIVE TI'S

TI's which may be calibrated using this procedure inlcude, but are not limited to, the following:

Model	Manufacturer	T/C Type	Range	System Accuracy	
				Indicator	T/C
DSS-650-TF-X	Omega Engineering, Inc.	T	-238° to +752°	±1.9°F	±2% iv or ±1.5°F or ±0.75% iv*
650-TC	Omega Engineering, Inc.	T	-150° to +400°C	±1.3°C	±2% iv or ±0.8°C or ±0.75% iv*
650-TF	Omega Engineering Inc.	T	-238° to +752°F	±1.9°F	±2% iv or ±1.5°F or ±0.75% iv*
DP465KFDDSS02	Omega Engineering	K	-337° to 2502°F -337° to 32°F 32° to 2502°F	±0.7°F	±4°F or ±2.0% iv ±4°F or ±0.75% iv whichever is larger

* ±2% iv applies to the -150° to -75°F or -101° to -59°C temperature range:
±1.5°F applies to the -75° to +200°F range; ±0.8°C applies to the -59° to +93°C range;
±0.75% iv applies to the 200° to 700°F or 93° to 371°C range.

6.0 CALIBRATION

6.1 CALIBRATION OF V REF, COLD-JUNCTION COMPENSATION AND FULL SCALE

Your model DP465 was calibrated at the factory with a precision voltage source. Frequent calibration is not necessary due to the stability and internal accuracy of the meter. When verification of calibration is necessary, the following procedure can be used.

The linearization algorithms use the millivolt and cold-junction values plus the S1 jumper configuration to determine the appropriate temperature display. Thus the millivolt and cold-junction displays are sufficient to determine the calibration of the meter. To expedite the calibration check, a 4PST switch can be connected to the S1 A, C, E, and G positions of the pin forest located behind the front lens. The meter will be unharmed if the operational modes are changed while it is operating. Results will be obtained more quickly if the digital filtering is disabled. (See Section 5.4.)

The V ref (meter internal voltage reference), is initially factory set to a value which results in a minimum temperature coefficient, i.e., V ref versus ambient temperature. This value is not the same for all meters. If the voltage reference must be replaced, return the meter to the factory. The V ref potentiometer (R20) is sealed after adjustment at the factory. If this seal is broken, the accuracy of V ref is questionable.

Potentiometer R21, the cold-junction reference adjustment, is also factory set and sealed. Proper operation can be checked, however, by simply configuring the meter for CJ temperature display (Section 5.1) and comparing the CJ temperature with the actual temperature of the terminal block. Note that the temperature of the block must be known with an accuracy commensurate with the Model DP465 specifications.

Full scale adjustment is controlled by potentiometer R11, located behind the lens (Figure 1-1), and is front panel accessible. Adjustment can be made by configuring the Model DP465 as a millivoltmeter (see Section 5.1). Verify that the unit indicates ± 0.00 mV with shorted inputs (TB1-5 and TB1-6). Then apply + 80.005 mV to TB1-6, referenced to Analog Ground (TB1-5), and then adjust R11 for a reading of + 80.00/80.01 mV. The 1/2 count is obtained when the display alternates between + 80.00 and + 80.01 mV.

If S4A is in place (Normal Position), approximately 50 nA will be flowing into the signal input terminal: therefore the input resistance of the calibration source can offset the reading.

Calibrating the meter for plus full scale should automatically insure calibration for minus full scale; however, minus full scale can be checked to verify proper operation of the meter. In this case, although −19.99 mV is the most negative display value, it is more convenient to check the meter at −19.90 mV, which will avoid a possible underscale condition. If Digital Filtering is OFF (S3), recovery from underscale will appear to be instantaneous, i.e., as soon as the input voltage is in range, the display will indicate in-range operation. If Digital Filtering is ON, recovery will take longer because the digital filtering is not automatically disengaged while the meter is in the overrange condition.

Note that for positive inputs, overrange does not occur in the mV mode until the display attempts to exceed 99.99 or until the overrange condition causes internal operation of the analog section of the meter to cease, whichever occurs at a lower value. The meter cannot display mV values more negative than −19.99, because the g-segment (center segment) of the leading display digit is used to indicate minus.

6.2 CALIBRATION VERIFICATION USING THERMOCOUPLES

The following procedure can be used to verify the calibration of the Model DP465 using T/Cs.

1. Connect test cables as shown in Figure 6-1.
2. Apply power and allow meter to warm up for ten minutes.
3. Apply zero volts from the Calibrated Voltage Source and verify readout of ± 0°C or 32°F.
4. Verify that the Model DP465 is operating within specification per the International Practical Temperature Scale, IPTS-68, as published in the NIST Monograph 125 Thermocouple Tables issued March 1974 (or DIN 43710), by applying the appropriate voltage to the input.

Note that this method only requires that the simulated measure junction temperature. The ice bath will zero the copper - T/C junctions for the copper wires which are connected to the Calibrated Voltage Source; however, the cold junction compensation detector of the Model DP465 must first be calibrated so the meter will properly compensate for the T/C junctions at the meter barrier block. For accurate results, T/C wires which have a known accuracy should be used.

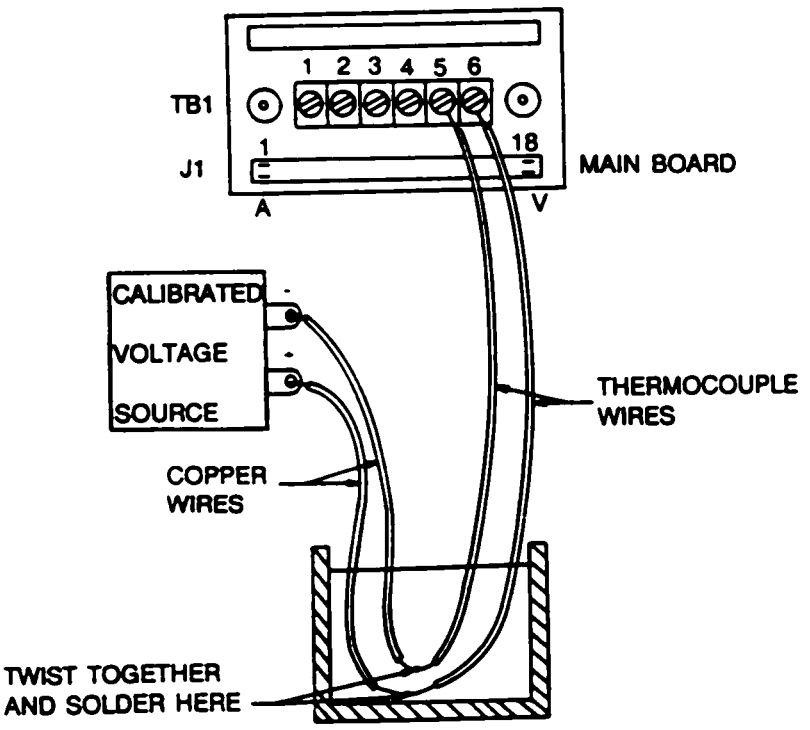

Figure 6-1 Ice Bath Calibration Setup

6.3 CONFORMITY VERIFICATION AFTER CALIBRATION

Even if the meter is not properly calibrated, the conformity can be verified for the indicated CJ temperature and millivolts displayed by the meter, then determine the temperature from the appropriate NIST (or DIN) table. The example below is for the J T/C, °C, configuration with the meter indicating CJ = 23.6°C and 41.09 mV (mV display). Note that in this procedure, only a stable millivolt source is required; neither T/C wires nor a separate millivoltmeter is required. This conformity verification demonstrates that, for given net MJ (measure junction) CJ voltage and CJ temperature meter display values, the correct MJ temperature result will be obtained when the meter is switched to the appropriate T/C configuration (using S1).

Millivolts displayed by meter:	41.09
Cold junction temperature displayed, °C:	23.6
NIST value for 23.6°C:	1.2098 mV
NIST value for 750.2°C:	42.2960
NIST value for CJ = 23.6, MJ = 750.2:	41.0862 mV

(use linear interpolations of NIST values)

The expected meter display value is 750°C when switched to the J T/C mode.

Note that the meter display has a resolution of one degree in this case (J T/C). Noise in the millivolt source or a change in the cold junction value will cause variations.

The following is another example of how to check the conformity. This time the T T/C configuration, which has a display resolution of 0.1°, will be used. The object is to determine if the meter will display 390.3°C for values obtained from the NIST table.

STEP	MODE	DISPLAY	NIST VALUE
1.	CJ	23.6°C	934.9 μV
2.	MV	19.33/19.34 mV	19335.9 μV
3.	T T/C	390.3°C	20270.8 μV

In the above example, the Model DP465 was first configured to read CJ temperature in °C. A value of 23.6°C was displayed. Linear interpolation between the values for 23 and 24°C in the NIST table for the T T/C yields 934.9 μV. Likewise, 390.3°C yields 20270.8 μV which gives a net value of 19335.9 μV. The meter configuration was then changed to mV and a stable millivolt source was adjusted to obtain a display of 19.33/19.34 mV (alternating between 19.33 and 19.34 mV). This would be the voltage expected for "perfect" T T/Cs. Changing the mode to T T/C should then yield a display of 390.3°C.

After step 3, it is advisable to recheck the CJ value since, in a realistic situation, a change of 0.1°C (or more) ambient temperature could occur during the time interval required for the procedure. The procedure can be made more efficient by providing a 4PST switch connected to the pin-forest, plus a SPST switch connected to S3A. (See 5.3 for an alternative which avoids removing the meter case.) When the SPST switch is on, it simulates an external serial data source, thereby disabling the DP465 digital filtering.