

Calibration of a type N thermocouple at 1000 °C

A type N thermocouple is calibrated by comparison with two reference thermocouples of type R in a horizontal furnace at a temperature of 1000 °C. The emfs generated by the thermocouples are measured with a digital voltmeter through a selector/reversing switch. All thermocouples have their reference junctions at 0 °C. The thermocouple to be calibrated is connected to the reference point using compensating cables.

Model Equation:

$$V_X = V_{iX} + \delta V_{iX1} + \delta V_{iX2} + \delta V_R + \delta V_{LX} + \delta t_X / C_X - \delta t_{0X} / C_{X0};$$

$$\delta t_X = t_X - t_0;$$

List of Quantities:

Quantity	Unit	Definition
V_X	μV	emf of the thermocouple to be calibrated
V_{iX}	μV	indication of the voltmeter
δV_{iX1}	μV	voltage correction obtained from the calibration of the voltmeter
δV_{iX2}	μV	voltage corrections due to the limited resolution of the voltmeter
δV_R	μV	voltage correction due to contact effects of the reversing switch
δV_{LX}	μV	voltage correction due to the compensating cables
δt_X	$^{\circ}\text{C}$	deviation of the temperature of the calibration point from the temperature of the furnace
C_X	$^{\circ}\text{C}/\mu\text{V}$	sensitivity of the thermocouple for voltage at the measuring at the temperature of 1000 °C
δt_{0X}	$^{\circ}\text{C}$	temperature correction due to the deviation of the reference temperature of 0 °C
C_{X0}	$^{\circ}\text{C}/\mu\text{V}$	sensitivity of the thermocouple for voltage at the measuring at the temperature of 0 °C
t_X	$^{\circ}\text{C}$	temperature of the furnace
t_0	$^{\circ}\text{C}$	nominal temperature of the calibration point

V_{iX} :

Type A

Method of observation: Direct

Number of observations: 1

No.	Observation
1	36248 μV

Arithmetic Mean: 36248.000 μV

Pooled Standard Deviation: 1.6 μV

Pooled Degrees of Freedom: 9

Standard Uncertainty: 1.600 μV

MEASUREMENTS: The indications of the voltmeter are precalculated to reduce the effects of temperature drift in the thermal source and parasitic thermal voltages (see EAL-R2-S1:S5.15). The readings are combined to one observation only, which is the voltage of the thermocouple to be calibrated. In order to evaluate the uncertainty of measurement associated with the observation, a series of ten measurements has been previously undertaken at the same temperature of operation. It gave a pooled estimate of standard deviation for the voltage of the thermocouple.

δV_{iX1} : Type B normal distribution
 Value: 0.0 μV
 Expanded Uncertainty: 2 μV
 Coverage Factor: 2

CALIBRATION OF THE VOLTMETER: The voltmeter has been calibrated. Corrections to the measured voltages are made to all results. The calibration certificate gives a constant expanded uncertainty of measurement for voltages smaller than 50 mV of $U=2 \mu V$ (coverage factor $k=2$).

δV_{iX2} : Type B rectangular distribution
 Value: 0.0 μV
 Halfwidth of Limits: 0.5 μV

RESOLUTION OF THE VOLTMETER: A 4½ digit microvoltmeter has been used in its 10 mV range resulting in resolution limits of $\pm 0,5$ mV at each indication.

δV_R : Type B rectangular distribution
 Value: 0.0 μV
 Halfwidth of Limits: 2.0 μV

PARASITIC VOLTAGES: Residual parasitic offset voltages due to the switch contacts have been estimated to be zero within $\pm 2 \mu V$.

δV_{LX} : Type B rectangular distribution
 Value: 0.0 μV
 Halfwidth of Limits: 5 μV

COMPENSATING CABLES: The compensating cables have been investigated in the range 0 °C to 40 °C. From this the voltage differences between the cables and the thermocouple wires are estimated to be within $\pm 5 \mu V$.

δt_x : Interim Result

CORRECTION OF THE CALIBRATION POINT: Deviation of the temperature of the calibration point from the temperature of the furnace.

C_x : Constant
 Value: 0.026 °C/ μV

VOLTAGE SENSITIVITIES: The voltage sensitivities of the thermocouples have been taken from reference tables.

δt_{0X} : Type B rectangular distribution
 Value: 0.0 °C
 Halfwidth of Limits: 0.1 °C

REFERENCE TEMPERATURES: The temperature of the reference point of each thermocouple is known to be 0 °C within $\pm 0,1$ °C.

C_{X0} : Constant
 Value: 0.039 °C/ μV

VOLTAGE SENSITIVITIES: The voltage sensitivities of the thermocouples have been taken from reference tables.

t_x : Type B normal distribution
 Value: 1000.5 °C
 Expanded Uncertainty: 0.641 °C
 Coverage Factor: 1.0

TEMPERATURE OF THE FURNACE: The temperature of the furnace is evaluated in a second analysis named temperature

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t_0 : Constant
Value: 1000.0 °C

CALIBRATION POINT: The nominal temperature of the calibration point is 1000.0 °C.

Interim Results:

Quantity	Value	Standard Uncertainty
δt_x	0.5000 °C	0.6410 °C

Uncertainty Budgets:

V_x : emf of the thermocouple to be calibrated

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
V_{ix}	36248.000 μ V	1.600 μ V	normal	1.0	1.6 μ V	0.4 %
δV_{ix1}	0.0 μ V	1.000 μ V	normal	1.0	1.0 μ V	0.2 %
δV_{ix2}	0.0 μ V	0.2887 μ V	rectangular	1.0	0.29 μ V	0.0 %
δV_R	0.0 μ V	1.155 μ V	rectangular	1.0	1.2 μ V	0.2 %
δV_{LX}	0.0 μ V	2.887 μ V	rectangular	1.0	2.9 μ V	1.3 %
δt_x	0.5000 °C	0.6410 °C				
C_x	0.026 °C/ μ V					
δt_{0x}	0.0 °C	0.05774 °C	rectangular	-26	-1.5 μ V	0.4 %
C_{x0}	0.039 °C/ μ V					
t_x	1000.5000 °C	0.6410 °C	normal	38	25 μ V	97.5 %
t_0	1000.0 °C					
V_x	36267.23 μ V	24.97 μ V				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
V_x	36267 μ V	50 μ V	2.00	95% (t-table 95.45%)