Calibration of a type N thermocouple at 1000 °C: Furnace temperature

In the N-type thermocouple calibration at 1000 °C the temperature of the furnace is determined by two R-type thermocouples placed the same distance above and below the thermocouple two be calibated. The tempearture at the location of the hot junction of the thermocouple to be calibrated is given as the mean of the temperatures of the hot junction of the two reference thermocouples.

Model Equation:

$$t_X = t_S + \delta t_S + C_S \times (\delta V_{iS1} + \delta V_{iS2} + \delta V_R) - C_S / C_{S0} \times \delta t_{0S} + \delta t_D + \delta t_F$$

List of Quantities:

Quantity	Unit	Definition
t_X	°C	temperature to be measured of the furnace
t_S	°C	temperature of the reference thermometer in terms of voltage with cold junction at 0 °C. The function is given in the calibration certificate.
δt_S	°C	correction of the temperature of the reference thermocouples due to their calibration
C_S	°C/µV	sensitivities of the reference thermocouples for voltage at the measuring temperature of 1000 °C
δV_{iS1}	µV	voltage correction obtained from the calibration of the voltmeter
δV_{iS2}	µV	voltage correction due to the limited resolution of the voltmeter
δV_R	µV	voltage correction due to contact effects of the reversing switch
C_{S0}	°C/µV	sensitivities of the reference thermocouples for voltage at the reference temperature of 0 °C
δt_{0S}	°C	temperature correction due to the deviation of the reference temperature from 0 °C
δt_D	°C	change of the values of the reference thermometers since their last calibration due to drift
δt_F	°C	temperature correction due to non-uniformity of the temperature of the furnace

t_S:

Type A
Method of observation: Direct
Number of observations: 1

No.	Observation
1	1000.5 °C

Arithmetic Mean: 1000.5000 °C
Pooled Standard Deviation: 0.10 °C
Pooled Degrees of Freedom: 9
Standard Uncertainty: 0.1000 °C

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 temperature of the furnace at the location of the thermocouple to be cailbrated. 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 temperature of the furnace.

δt_S: Type B normal distribution
Value: 0.0 °C
Expanded Uncertainty: 0.3 °C
Coverage Factor: 2

REFERENCE STANDARDS: The reference thermocouples are supplied with calibration certificates that relate the temperature at their hot junction with their cold junction at 0 °C to the voltage across their wires. The expanded uncertainty of measurement at 1000 °C is U=0,3 °C (coverage factor k=2)

C_S: Constant
Value: 0.077 °C/µV

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

δV_{iS1}: Type B normal distribution
Value: 0.0 µV
Expanded Uncertainty: 2.0 µV
Coverage Factor: 2.0

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 µV (coverage factor k=2)

δV_{iS2}: 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 ±0,5 µV 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 ±2 µV.

C_{S0}: Constant
Value: 0.189 °C/µV

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

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

REFERENCE TEMPERATURE: The temperature of the reference point of each thermocouple is known to be 0 °C within ±0,1 °C.

δt_D: Type B rectangular distribution
Value: 0.0 °C
Halfwidth of Limits: 0.3 °C

DRIFT OF THE REFERENCE STANDARDS: From previous calibrations the drift of the reference standards are estimated to be zero within the limits ±0,3 °C.

δt_F: Type B rectangular distribution
Value: 0.0 °C
Halfwidth of Limits: 1 °C

TEMPERATURE GRADIENTS: The temperature gradients inside the furnace have been measured. At 1000 °C deviations from non-uniformity of temperature in the region of measurement are within ±1 °C.

Uncertainty Budgets:

t_X: temperature to be measured of the furnace

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
t_S	1000.5000 °C	0.1000 °C	normal	1.0	0.10 °C	2.4 %
δt_S	0.0 °C	0.1500 °C	normal	1.0	0.15 °C	5.5 %
C_S	0.077 °C/µV					
δV_{iS1}	0.0 µV	1.000 µV	normal	0.077	0.077 °C	1.4 %
δV_{iS2}	0.0 µV	0.2887 µV	rectangular	0.077	0.022 °C	0.1 %
δV_R	0.0 µV	1.155 µV	rectangular	0.077	0.089 °C	1.9 %
C_{S0}	0.189 °C/µV					
δt_{0S}	0.0 °C	0.05774 °C	rectangular	-0.41	-0.024 °C	0.1 %
δt_D	0.0 °C	0.1732 °C	rectangular	1.0	0.17 °C	7.3 %
δt_F	0.0 °C	0.5774 °C	rectangular	1.0	0.58 °C	81.2 %
t_X	1000.5000 °C	0.6409 °C				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
t_X	1000.5 °C	1.3 °C	2.00	95% (t-table 95.45%)