Laboratory work No 1: Calibration of Thermocouples

1. Objective

Find the relation between the thermal electromotive force (*E)* generated by the thermocouple and the temperature. Draw the graphs $E_1 = f_1\ (t)$ and $t_1 = f_1\ (t)$. Calculate the absolute error of the thermocouple.

2. Necessary equipment

1. Electric furnace
2. Etalon thermocouple (S-type) sdgf
3. The thermocouple (K-type) for calibration
4. Voltmeters
5. The resistance thermometer
6. Extension cords for thermocouples
7. Thermostat for thermocouples cold junction
8. Thermocouple reference tables for K-type and S type

3. The experimental apparatus and basics

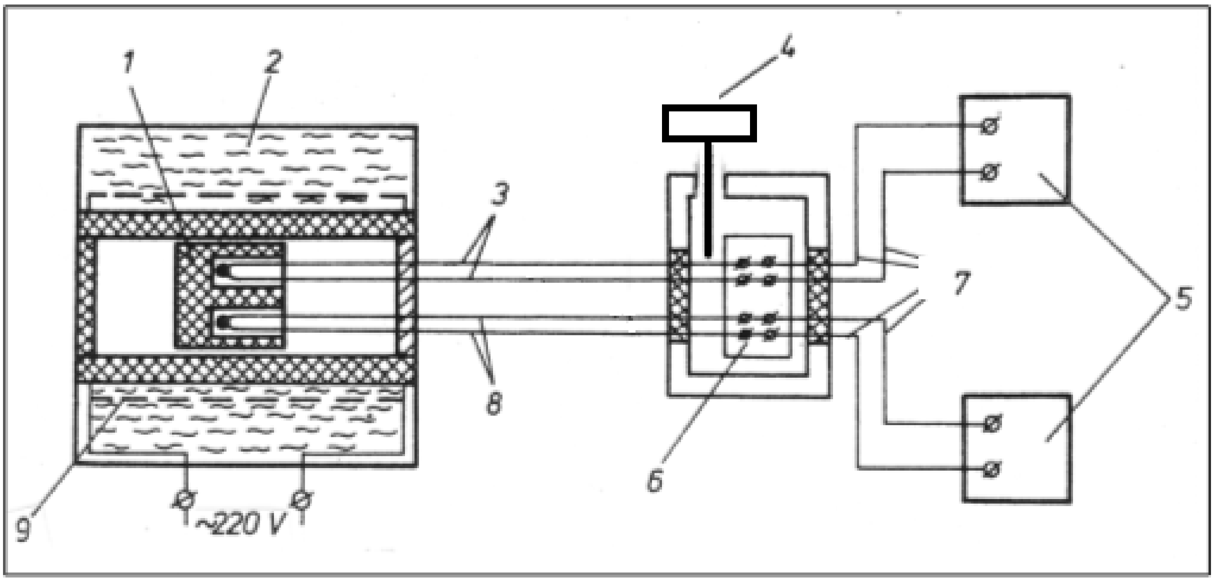

Figure 1.1. Thermocouple calibration apparatus scheme: 1 - a metal block; 2 – electric furnace;3 - etalon thermocouple; 4 - resistance thermometer; 5 - voltmeter; 6 - thermostat for thermocouples cold junction; 7 - extension cords for thermocouples; 8 - thermocouple for calibration; 9 – electric heating coil; 10 - connecting wires

In order to achieve the traceability and reliability measuring instruments and sensors should be controlled by verification, validation and calibration. Calibration in measurement technology and metrology is the process of comparison of measurement values delivered by a device under test with a calibration standard of known accuracy. Calibration of working measuring instruments is not mandatory.

Calibration of the instrument can be defined as finding the dependence between the input and output of the measuring instrument and finding the deviation of measurements. The input for thermocouples is the measured temperature and the output is the thermal electromotive force generated by thermocouple. The results are presented as a table, chart or formulas. The aim of this laboratory work is to calibrate an industrially manufactured standard thermocouple. The manufacturer of the industrial thermocouple must ensure compliance to standard that gives the relation between the measured temperature and electromotive force within allowable tolerances.

Relation between the measured temperature and the thermal electromotive force generated by standard thermocouple is given in tables. Thermocouples from serial production are not individually calibrated. The aim of this laboratory work is to experimentally find out the relation between the measured temperature and the thermal electromotive force generated by the real thermocouple. The experiment allows determining a deviation of the results from the values in the thermocouple standard table.

High precision and highly stable type S thermocouple (Platinum Rhodium - 10% / Platinum) is used in this work to measure correctly the actual temperature. Any kind of standard or non-standard thermocouple can be any calibrated. K-type (Chromel /Alumel) thermocouple is calibrated in this work.

Hot junctions of the both thermocouples, 3 and 8 on Figure 1.1 are inside the metal block 1 situated inside the furnace 2. The function of the metal block is to prevent the temperature unevenness inside it enabling the both hot junctions to maintain the equal temperature. Thermocouple wires are coming out from the furnace through sealed opening. Thermocouple cold junctions are moved away from the oven into thermostat 6, where the cold junction temperature is measured with resistance thermometer 4. From thermostat the thermocouples are connected with voltmeters 5 with copper extension wires 7. Temperature of the furnace is controlled with PID controller.

4. Procedure of experiment

Procedure of experiment will be given by supervisor prior the experiment.

5. Processing of the Experimental Data

The measurement results are compiled in Table 1.1. Draw the graphs $E_1 = f_1\ (t)$ and $t_1 = f_1\ (t)$ based on experimental results.

The measured thermal electromotive force has to be converted into temperature using the thermocouple reference tables. The tables are made on condition that the cold junction temperatures are held at 0°C. If the cold junction is at the different temperature the measured electromotive force is different ($E' = E - \Delta E$, mV). To find the real temperature the correction to measured electromotive force has to be implemented based on the temperature of cold junction measured in the thermostat. The correction ΔE can be found from thermocouple tables also. The procedure for this conversion is described in Appendix A and thermocouple reference table for S-type thermocouple is in Appendix B and for K-type thermocouple in Appendix C.

The temperature measured by etalon thermocouple is taken as the real temperature in the furnace. K-type thermocouple wires are made in two grades of purity: Standard Limits of Error (accuracy the greater of ± 2.2°C or ±0.75% of reading) and Special Limits of Error (accuracy the greater of ± 1.1°C or 0.4% of reading).

The absolute error of the thermocouple to be calibrated can be found

$$\Delta t = t - t_1 \text{ °C} \tag{1.1}$$

where t - the oven temperature measured with etalon thermocouple, °C;
t_1 – temperature measured with thermocouple to be calibrated, ° C,

and

$$\Delta E_{mV} = E_0 - E_1 \tag{1.1}$$

where E_0 – electromotive force that the thermocouple to be calibrated should generate at furnace temperature measured by etalon thermocouple, if working correctly from K –type table, mV;
E_1 – electromotive force measured by the thermocouple to be calibrated, mV.

The report of the laboratory work compares the absolute error calculated from measurement results with allowable error of the K-type thermocouple grades and draws conclusions is this thermocouple belong in Standard Limits of Error or Special Limits of Error grade.

Table 1.1 Table for measurement data and results

Reading number	Etalon thermocouple (S-type)			Thermocouple to be calibrated (K-type)			Thermocouple cold junction			Absolute error	
								Correction			
								S-type	K-type		
	Reading E'	Actual electromotive force $.E = E'+\Delta E$	Temperature t	Reading E'_1	Actual electromotive force $E_1 = E'_{1+}\Delta E_1$	Temperature t_1	Temperature t_{kl}	ΔE	ΔE_1	$\Delta = t - t_1$	$\Delta E_{mV} = E_0 - E_1$
	mV	mV	°C	mV	mV	°C	°C	mV	mV	°C	mV
1											
2											
3											
4											
5											