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Thermocouples

Measurement task :

Calibrate two types of thermocouples (Ch-A, Fe-Ko) according to the normal (the normal is the thermocouple
NiCr-Ni). Calibrate for at least four temperatures.

Theoretical introduction :

The essence of the thermoelectric phenomenon is the direct conversion of thermal energy into electrical energy and vice versa. The explanation of the formation of thermoelectric voltage can be made on the basis of the theory of the division of conductors into monopolar type n and p and ambipolar conductors. A monopolar n-type conductor contains mostly carriers of negative electric charges (electrons), while a p-type conductor contains carriers of apparently positive charges (holes). The two types of conductors differ from each other in the way the electric charges move in the conductor when there is a temperature difference. A monopolar n-type conductor (copper) behaves in such a way that when it is heated, free electrons move to the cooler end of the conductor. This creates an excess of negative charges (negative polarity) at the cooler end and positive polarity at the warmer end. A p-type (constant) conductor, with the same sense of temperature gradient as the n-type, behaves in the opposite way (the cooler end has positive polarity).

This movement of particles in the conductor occurs only within the conductor itself, because the potential barrier created by the ions of the crystal lattice prevents electrons from leaving the conductor. However, if two dissimilar metals are joined together in a perfectly conductive manner, electrons can pass from the metal with the lower potential barrier to the metal with the higher potential barrier, creating an electric current through the joined conductors. This explains the formation of the thermo-electric cell.

The magnitude of the thermoelectric voltage depends on the type of metals used and the temperature difference of the joints. This dependence can be expressed by the relation:

$$U = (\alpha_A - \alpha_B)(\vartheta_T - \vartheta_S)[mV]$$

Where

α_A, α_B coefficients determining the magnitude of the thermoelectric stress corresponding to the materials used [mV/°C]

ϑ_S cold junction temperature [°C]

ϑ_T hot junction temperature [°C]

If a thermoelectric cell is formed from conductors of the same type, the coefficients a are subtracted, if a conductor of type n and p is used, then the coefficients a are added and the thermoelectric voltage reaches the maximum magnitude.

The proportionality of the thermoelectric voltage to the temperature difference of the two junctions of the thermoelectric cell is most often used to measure temperatures. Typically, the temperature of the cold (reference) junction is known, and the temperature of the warm (reference) junction can be determined using the voltage and the calibration curve for the materials used.

Calibration of thermocouples :

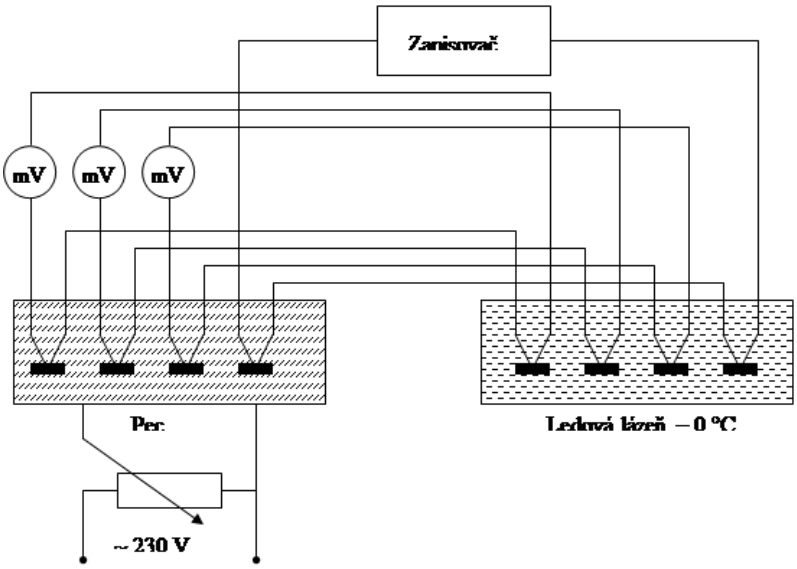
The purpose of calibrating thermocouples is to determine the dependence of their thermoelectric voltage on the respective temperature difference between the reference and measuring end. This dependence is then expressed by a table or a calibration curve.

By comparison with the standard, thermocouples are usually calibrated in an electric furnace. In doing so, it is necessary to ensure that the depth of immersion of the standard and the calibration cell in the furnace is the same to ensure that they are placed at the same temperature. The temperature at the furnace site must be increased slowly, as often a rapid rise in temperature would not compensate for the time delays in measuring the temperature of the thermocouple being verified and the standard.

The temperature of the comparison end is usually 0°C. This method can be used up to about 1200°C. When comparing the measured values of the thermoelectric voltage of the cell being tested with the values specified in the standard, some deviations are always found.

The result of thermocouple calibration is a correction curve.

Wiring diagram :



Measurement procedure :

Three types of thermocouples (Fe-Ko, Ch-A, NiCr-Ni normal) are immersed at one end in a bath of ice water at 0°C and at the other end in a heated oven.

To achieve a slow temperature rise, the furnace is fed from a control transformer with a reduced voltage. Monitor the temperature rise on the temperature recorder.

Switch off the power when the temperature starts to rise. Since the system has thermal inertia, the temperature will continue to rise for some time. When the temperature stabilizes (watch the recorder), read the voltage readings on the thermocouples.

Then turn on the heating of the oven again and continue the same procedure until you have measured at least four sets of values.

Plot the measured characteristics and compare them with the allowable dependence deviation (specified by the manufacturer).

Instruments used:

Measured and calculated values:

graphs:

Conclusion: