METHODS AND DEVICES FOR MEASURING
THE PELTIER COEFFICIENT OF AN
INHOMOGENEOUS ELECTRIC CIRCUIT

Yu. A. Skripnik and A. I. Khimicheva

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Existing methods of determining the Peltier coefficient of an inhomogeneous electric circuit are analyzed. The proposed algorithmic method of determining the Peltier coefficient is more accurate than are the methods analyzed, because it excludes the influence of Joule heat and the Seebeck coefficient on the results of the measurement.

In recent years the Peltier effect has been employed widely in measuring devices for forming thermophysical tests that are used to correct the errors of temperature-measuring instruments and a series of thermophysical quantities [1, 2]. The technical and reference literature, however, gives scanty information about the values of the Peltier coefficient for various thermoelectrodes and its temperature dependence.

In the article we consider existing methods of measuring the Peltier coefficient and evaluate possible regions where those methods can be applied.

Shtenbek and Baranskii [3] described a method of determining the Peltier coefficient of an inhomogeneous electric circuit. The method is based on passing a constant current through a specimen of the material under study, which is in contact with copper electrodes. The difference of the temperatures at the ends of the specimen is measured, the cooled electrode is heated additionally, and the Peltier coefficient \( \pi \) is determined (when the temperature difference becomes zero) is determined from

\[ \pi = 0.5 W I, \]

where \( W \) is the compensating power of the additional heating and \( I \) is the constant current.

A compensating action is effected by means of electric heaters inside the copper electrodes. A fraction of the electrical power used directly to compensate for the Peltier effect cooling is difficult to evaluate since part of the power goes to cover the loss due to heat transfer into the ambient medium. As a result the Peltier coefficient is determined with a large error, especially in measurements over a wide temperature range.

Higher accuracy is ensured by the method of Kuritinik et al. [4], where a constant current is passed through an electrical circuit containing two electrodes of different materials (forming a common junction); that current cools the junction, the TEMF the terminals of the circuit and the current in the circuit are measured, and the Peltier coefficient \( \pi \) calculated from the formula. At the same time, that current is passed through a similar junction of materials in the opposite direction, causing the junction to heat; the TEMF at the circuit terminals with cooled and heated common junctions is measured and the Peltier coefficient is found from

\[ \pi = cm \Delta T / (2 I t), \]

where \( c \) and \( m \), respectively, are the specific heat and mass of the materials of the junction, \( \Delta T \) is the temperature difference, and \( t \) is the time for which current flows.

The method employs two calorimeters while the junctions heated and cooled are adiabatically and the temperature difference is measured with a differential thermocouple. The main difficulty in the measurements is posed by adiabatization,
Fig. 1. Block diagram of the device for determining the Peltier coefficient of an inhomogeneous electric circuit: 1) constant voltage supply; 2) variable resistor; 3) gauge of thermoelectric thermometer; 4) milliampmeter; 5, 6) three-pole switch; 7) regulated constant voltage supply; 8) heater; 9, 10) electrodes of the materials under study; 11) constant resistor; 12) differential amplifier; 13) millivoltmeter; 14) regulated voltage divider.

especially at high temperatures, to eliminate the influence of lateral losses. The end losses due to the thermal conductivity of the materials studied are difficult to eliminate and they do affect the results of the measurements. Considerable errors are due to the instability and unequal heat capacities and masses of the two calorimeters, as well as to the low accuracy of temperature difference measurement by the thermocouples, the thermoelectromotive force (Seebeck coefficient) TEMF of which is unstable and depends on the junction temperature. As a result, the error of the Peltier coefficient measurements by the above method over a wide range of temperatures reaches 7-10%.

Kuritnik et al. [4] also considered a device containing a constant-voltage supply, milliampmeter, electrodes of the materials under study, a millivoltmeter, and two three-pole switches. The device also includes two differential calorimeters and a differential thermocouple, with the millivoltmeter connected to its output. The electrodes of the materials under study are series-connected and their junctions are put into the calorimeters separately. Auxiliary comparison electrodes of different materials with precisely known Peltier coefficient are required for determining the Peltier coefficient of the materials. Thermally the auxiliary electrodes should be identical with the electrodes under study and should form common junctions with them. The uncontrolled heat loss through the comparison electrodes, the differences in the thermophysical characteristics of the calorimeters, and the instability of the calibration characteristics of the thermocouples connected in a differential circuit mean that the Peltier coefficient measurement cannot be measured with high accuracy.

Jimenez et al. [5] propose that the Peltier coefficient of an inhomogeneous electric circuit be measured with a device that contain a thermoelectric bridge of common junctions of different materials placed in a thermostat, a constant-voltage supply, a milliampmeter, a millivoltmeter, and a constant-voltage potentiometer. Since the thermophysical characteristics of the two junctions inevitably are different and the results of the measurements depend on the junction heating time the Peltier coefficient cannot be measured with a high degree of accuracy.

The analysis of the known methods of measuring the Peltier coefficient has shown that they are not applicable for operative inspection. Moreover, the result of the measurement is affected strongly by the Joule heat, which is dissipated by the thermoelectric and other elements of the thermoelectric circuits. Below we propose a new method of measuring the Peltier coefficient of an inhomogeneous electric circuit.

A constant current is passed through an electric circuit, consisting of two electrodes which are made of different materials and form a common junction. The direction of current flow is chosen so that in the general case the common junction would absorb the Peltier heat and thus be cooled. The junction temperature decreases by

\[-\Delta T = T_2 - T_1,\]

where \(T_1\) is the temperature of the electrodes and \(T_2\) is the temperature of the junction of the electrodes.

When the Peltier effect in the plane of the junction and the release of Joule heat into the bulk of the electrodes (we ignore the Thomson effect) we can assume that half of the Joule effect from the electrodes is transferred to the cold junction.