METHOD AND APPARATUS FOR ACCURATE MEASUREMENT OF TEMPERATURE OF A HOT PLATE BY A COMPENSATION THERMOSENSOR

V. Pak and P. S. Glazyrin

UDC 536.532

A method is described for accurate temperature measurement by a contact thermosensor, based on eliminating heat loss through the sensor during measurement. The error in measurement of the temperature of heated thermally "thin" plates comprises 1.6°C.

The technique of thermophysical experimentation is simplified significantly when the specimen to be investigated is chosen in the form of thermally "thin" plates or cylinders. However, as a rule, accurate measurements of temperature then present great difficulty. In a number of cases accurate temperature measurements on thin plates may be performed by radiation pyrometry methods which do not require a knowledge of the material's emissivity [1, 2]. However, the area in which such techniques may be employed is limited to optically opaque bodies and requires special experimental conditions.

Contact methods of measurement provide highly accurate information if special measures are taken to eliminate the disturbing influence of the thermoprobe on the ribbon temperature field.

The appropriate corrections may be calculated, for example, with the formula presented in [3].

For the case where the thermoprobe can be approximated by a bar, the formula relating the actual temperature of the ribbon \( t_0 \) before contact of the thermoprobe with that after contact \( t_e \), as measured by the thermoprobe, is written in the form

\[
t_0 = t_e \left[ 1 + \frac{\sqrt{\frac{\lambda a h_0}{\lambda_p R}}} {K_0(v) \cdot K_1(v)} \right],
\]

where \( K_0(v) \) and \( K_1(v) \) are modified Bessel functions of the second kind of zero and first orders.

The parameter

\[
v^2 = \frac{2\pi a_0}{\lambda_0 h_0} R^2;
\]

Fig. 2. Schematic diagram of experimental apparatus for accurate temperature measurements on heated plates: 1) object to be measured; 2) chamber; 3) current leads; 4) thermocouple; 5) objective; 6) scanning mirror; 7) slit; 8) photodetector; 9) preamplifier; 10) phase-sensitive amplifier; 11) slave mechanism; 12) generator; 13) power amplifier; 14) matching transformer; 15) blocking capacitor; 16) dc potentiometer; 17) low-frequency filter.

\( \lambda_0 \) and \( \lambda \) are thermal-conductivity coefficients of the ribbon of thickness \( h_0 \) and thermoprobe of radius \( R \).

Equation (1) is valid under the condition of equality of the coefficient \( \alpha_0 \) on both ribbon surfaces heated by the current, and the heat-exchange coefficient \( \alpha \) is taken constant over the entire extent of the thermoprobe. Also, Eq. (1) does not consider thermal resistance in the thermoprobe—ribbon contact area of radius \( R \).

Thus, the real model of the temperature experiment only reflects the theoretical model to a certain approximation, and in estimating necessary corrections significant methodic error can develop, depending on the degree of this noncorrespondence.

Calculations with Eq. (1) reveal that the error due to temperature distortion, for example, with a platinum ribbon 50 \( \mu \)m thick and a platinum—rhodium thermoprobe 0.2 mm in diameter, reaches 10% and more of the measured temperature.

Since there appear in the formula together with the physical characteristics of the thermoprobe and specimen, the heat exchange coefficients \( \alpha_0 \) and \( \alpha \), which are not always possible to measure to an accuracy of even 20%, attempts to increase the accuracy of temperature measurements on thin ribbons and wires by introducing corrections for heat lost to the thermoprobe are, as a rule, ineffective, even if the theoretical heat-exchange model of the specimen—thermoprobe—surrounding medium system is made more detailed.

Attempts to increase accuracy by decreasing heat loss through use, for example, of microthermocouples with thermoelectrode diameter of 0.05 mm and less, as is often done by experimenters, is still questionable, because of the significant thermoelectric inhomogeneity of thin thermoelectrodes. Moreover, difficulties develop in calibrating such thermocouples under conditions approximating their intended use.

Thus, these methods are useful in which the error can be determined experimentally, for example, by measuring the temperature with two thermopropbes differing in construction and physical properties [3].

However, a shortcoming of such methods of increasing accuracy is that they do not eliminate disturbance of the initial temperature field, which is undesirable in thermophysical experiments.