Questions of metrological provisions for contact heat flow transducers by means of which it is possible to monitor heat losses at the surface of thermal energy objects are considered.

Key words: metrological provision, contact heat flow transducers, thermal energy object surface.

In solving the problem of energy conservation, it is becoming increasingly important to determine accurately heat losses at the surface of thermal energy objects. For this purpose, there is extensive use of contact heat flow transducers (HFT) of the “subsidiary wall” type in the form of disks or plates. Sensitive elements of differential, for example thermoelectric, temperature transducers [1] are mounted close to their contact surfaces. These HFT (heat flow meters) are placed on an object.

A temperature difference arises with passage of a heat flux between the heat flow meter surfaces. The temperature transducer signal proportional to this difference makes it possible to determine heat flux density at the surface of an object. An important metrological characteristic of HFT is the error in determining the conversion factor \( K \) equal to the ratio in thermal flux density \( q \) passing through the HFT to its output signal \( E \), i.e., \( K = q / E \).

In the USSR and Russia most widespread are galvanic thermoelectric HFT developed at the Institute of Technical Thermal Physics, Academy of Sciences of the UkrSSR (Kiev). They are a multi-junction (up to 1000 junctions) galvanic thermopile convoluted into a flat spiral and placed in dielectric material. Similar transducers have been created at the Institute of Measurement Technology (Korolev) on the basis of a galvanic thermopile in a plate of acrylic plastic. In order to increase the HFT sensitivity, semiconductor thermopiles are used in the Special Design Bureau for Thermophysical Equipment (St. Petersburg), the Design Bureau Foton (Ternopil’), and the Sukhumi Physicotechnical Institute. Currently, the technology for commercial production of contact heat flow meters is carried out at the Étalon plant (Omsk).

All of these transducers are used extensively in studying heat processes primarily in the thermal energy engineering [2, 3] and also in the aviation and space rocket technologies, geophysics, and medicine. HFT conversion factors normally have the value 1–100 W/(m\(^2\)·mV). Transducers differ in size and shape [4]. They are normally round, square, or rectangular in shape with typical dimensions of 10–330 mm and a thickness of 0.5–15 mm. The range of measured heat flux densities is 1–10000 W/m\(^2\) at –200 to +650°C.

In the USSR in 1989, a state verification scheme was introduced for measuring the surface density of a heat flux in the range 10–2000 W/m\(^2\) [5]. The verification scheme is headed by a high accuracy unit UVT 53-A–88 created at SNIIM that is intended for reproducing and storing units of heat flux density with an error of less than 1% (a systematic error is not excluded) in the range 200–400 K, and also for converting the size of a unit by means of standard measurement provisions (MP) with working MP having a acceptable relative error of 4–10%. The verification scheme uses conductive, radiation, and convective comparators as a means of converting the size of a unit. The method of conductive comparison is realized in the work place of the verifier for checking the heat flux transducer that has also been developed at SNIIM, and five items have been manufactured at the Alma-Ata plant Étalon and passed into state tests in 1988.

Currently there is a requirement for an increase in the level of accuracy and the range of measurement facilities for reproducing and converting the size of unit $q$, and also for universality of their measurement cells (HFT shape and dimensions). In addition, there is a requirement for measuring the UVTS status to a state standard with a simultaneous reduction in errors, in particular in order to provide a metrological reserve of accuracy and an overall increase in the verification scheme.

Ways for improving the metrological provisions for a contact heat flow meter and the work of SNIIM carried out in this direction are considered below.

In the existing UVTS in order to form the required heat flux, a “semi-open” adiabatic shell is used [6]. For this purpose, the heat flux source (Fig. 1) in the form of a flat electric heater 3 of one plane is in contact with the surface of the heat flow meter 2 that converts the size of unit $q$. The other plane of the heater is surrounded by an adiabatic shell 4 whose temperature by means of a differential thermocouple and automatic regulator is maintained equal to the heater temperature. Here the thermal flux from the heater is entirely directed through the HFT that is pressed to the thermostatically controlled block 1, i.e., a cooler. The measured electric power $P$, area $S$, and signal $E$ of the transducer make it possible to find the conversion factor

$$K = q/E = P/SE, \quad 10 \leq q \leq 2000 \, \text{W/m}^2.$$

With a stepwise change in temperature of the cooler, it is possible to determine the temperature dependence of the conversion factor $K(T)$. The average square error here does not exceed 0.5% ($n = 20, p = 0.95$), and the accepted systematic error in 1%. As analysis shows, the main source of systematic error is imperfection of the adiabatic system for the heat flux source. This system consists of three channels of analog temperature regulation for the adiabatic shell, the refrigerator, and the external thermostatically controlled shell. Therefore an increase in accuracy is possible with:

- use of a multichannel digital regulator in the adiabatic system;
- use of HFT as differential sensors for the temperature difference that have greater sensitivity by a factor of ten compared with traditional differential thermoelectric transducers;
- improvement of measuring cell design for the calorimetric system.

It is necessary to note that by means of the UVTS 53-A–88 unit the size of the unit is converted by a standard HFT of small dimensions (less than 45 mm). In order to solve the problem of energy conservation, it is necessary to have a standard unit for checking large heat flow meters in a temperature range corresponding to the temperature of the surroundings and a heat carrier in a heat supply water system in the range of heat flux densities of 10 to $1 \cdot 10^4 \, \text{W/m}^2$ with a reproduction error of less than 0.1%.

In order to achieve this aim, a standard unit has been created and a method has been realized for a “semi-open” adiabatic shell (Fig. 2). The flat heater 1 is surrounded on one side by an adiabatic screen 3 whose temperature is maintained by regulator 9 equal to that of the heater surface. Equality of the temperature is determined according to the zero signal of a spe-