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MAIN CHARACTERISTICS OF THE HEAT FLOW METER

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The problems and prospects of application of non-destructive testing methods for technical diagnostics of the thermal networks state and various technological objects are discussed. The recording of the temperature state of thermal processes by using a flow meter is due to its sensitivity to the change of thermophysical characteristics and the ability to control without the use of an external energy source, etc. The description of the developed device to measuring of the heat flow using of a thermoelectric heat flow converter of a special design is shown. A distinctive feature of the device is the heating element that installed on an insulating layer serving as a support surface. Calibration of the device is proposed to be carried out by replacing the heat flow from the investigated object with the heat flow released in the heating element when an electric current passes through it. The developed device can register the changes in the heat flux density in the range of (25-100) W/m2, which allows it possible to detect the smallest thermal insulation defects.

Keywords: heat flow meter, thermoelectric battery converter, integral sensitivity of heat flow meters, copper-constantan thermocouple, thermal energy.

Introduction

Energy conservation is one of the priorities of the state policy of Kazakhstan. The strategy «Kazakhstan-2050» presented a program of socio-economic development of the Republic of Kazakhstan, aimed at improving energy security. Over the past decade, due to population growth and the rapid industrial development, energy consumption has increased by more than 2 times. The shortage of energy leads to a shift in the worse of socio-economic stability and deterioration of the development of the state as a whole. The main energy problems caused by economic growth, excessive and extremely uneven use of energy resources, and the energy burden of infrastructure on the environment are related to thermal energy. Heating and power generation costs account for up to 45% of the total energy produced in the country. At the same time, more than half of these resources are accounted for by utilities, which are a fundamental component of the development of the economy and the main factor in ensuring the normal life of citizens [1, 2].

In these conditions, measurements, operational control and regulation of thermal parameters are essential, among which a significant place is occupied by heat flow, which has become today the same informative parameter as temperature, pressure, flux, etc. Measurements of heat flows characterizing heat leaks are carried out by a direct method using contact heat flow meters (HFM) of the «auxiliary wall» type [3]. Heat flow meters have a number of advantages over other non-destructive testing methods. They are characterized by high sensitivity to changes in the thermophysical characteristics of the control objects, the possibility of control without using an external energy source, economy, compactness and simplification of its operation. In this regard, of particular interest is development and creation of heat flow devices for heat supply systems are. As the results of numerous studies of thermal insulation of underground heating networks show, the most effective is the method of non-destructive testing based on a comparison of calculated and experimental values of the temperature distribution on the ground surface over heating networks [4-6].

1. Experimental part

Some modifications of heat flow devices are developed in the laboratory «Measurement of thermophysical quantities» of the Department of Engineering Thermophysics named after professor Zh.S. Akylbayev of the E.A. Buketov Karaganda University. The distinctive design of the heat flow device is that it contains a thermoelectric battery converter and a receiving plate, additionally equipped with a temperature-dependent and heating element. In this case, the thermoelectric battery converter is combined with the

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heating element, and its «active» junctions are combined with the receiving plate, the «passive» junctions are in thermal contact with the heating element. In one of the modifications, the heat flow meter HFM-1M comprises a heating element, which performs the function of a receiving plate, a thermal battery, a thermoelectric battery converter of heat flow, a thermoelectric refrigerator, radiator, an electronic unit for converting and measuring the signal [7,8].

The developed device for measuring heat flow contains an insulating layer 1, which serves as a reference surface on which a heating element 2, a thermoelectric battery converter of heat flow 3, a thermoelectric refrigerator 4, a radiator 5, a measuring unit 6 (figure 1), [9].

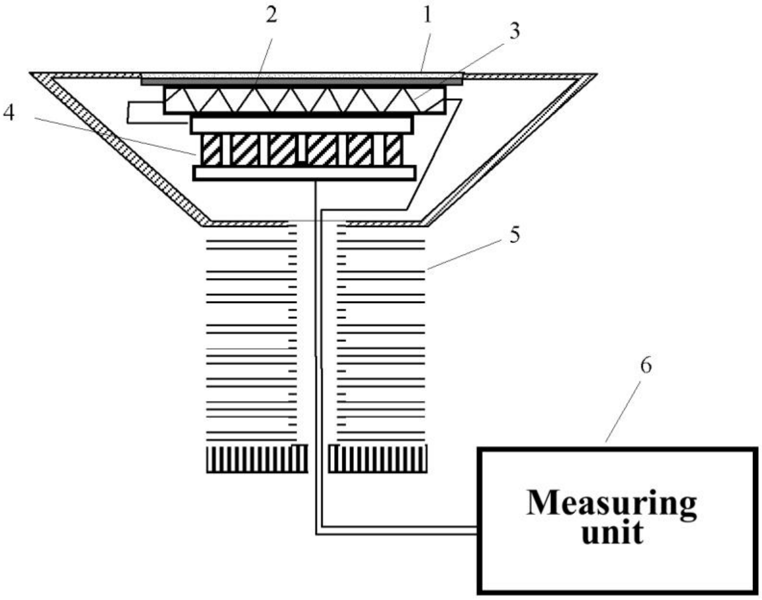

Fig.1. Schematic representation of the device for measuring heat flow:
1 - insulation layer; 2 - heating element; 3 - thermoelectric battery converter of heat flow;
4 - thermoelectric refrigerator; 5 - radiator; 6 - measuring unit

The closest in technical essence to the achieved result to the model is a thermoelectric battery of heat flow converter containing a thermoelectric element battery made of a thermoelectronic wire in the form of a flat spiral, composed of alternating half-turns, covered with a paired thermoelectrode material, a copper constantan, spaced to the thickness of the thermobattery, connected to the recording device. This thermoelectric battery converter of heat flow has high sensitivity, which allows it to be used for measuring heat fluxes not only high, but also low intensities.

On the insulated reference surface 1, a heating element 2 is installed, that in thermal contact with the «hot junctions» of the thermoelectric battery converter 3, the «cold junctions» of which are in contact with the «hot junctions» of the thermoelectric refrigerator 4, and the cold junctions» of the thermoelectric refrigerator are in contact with the radiator 5, while «hot junctions» are sealed between the heating element 2 and the thermoelectric battery converter 3, and the cold junctions» are in thermal contact with the housing of the device having an ambient temperature. The output signal from the thermoelectric battery converter of heat flow 3, the heating element 1 and the thermoelectric refrigerator 4 is transmitted to the measuring unit 6. The device for measuring the heat flow works as follows. An electric current of such magnitude is passed through the heating element so that the released power is obviously greater than the possible heat flow from the object under study. A signal appears at the output of the thermoelectric battery converter. In this case, the signal at the output of the thermoelectric battery converter will be proportional to the heat flow diverted from the converter by the thermoelectric refrigerator, and the temperature of the heating element is close to the temperature of the environment. The device is in working mode.

The device is brought to the object under study in an area where there are no defects. We bring the heat flow meter to the object under study in the field of the presence of a defect. By changing the signal at the output of a thermoelectric battery converter, the presence of a defect is judged.

2. Results and discussion

The principle of operation of the device is based on the substitution of the effect of incident radiation by the effect of Joule heat released in the calorimetric load when an electric current is passed during calibration. The role of the calorimetric load is performed by the heating element [10]. In order to calibrate the developed device for measuring heat flow, studies were conducted with the HFM-1M heat flow meter and the results are shown in fig. 2 and in table 1.

Table 1. Calibration table

t,^{0}C	**HFM-1M ε, mV**	**Device for measuring heat flow ε, mV**
20	0.44	0.76
25	0.80	1.16
30	1.20	1.57
35	1.61	1.98
40	2.02	2.39
45	2.43	2.81
50	2.85	3.22
55	3.26	3.64
60	3.68	4.06
65	3.81	4.52
70	3.94	4.85

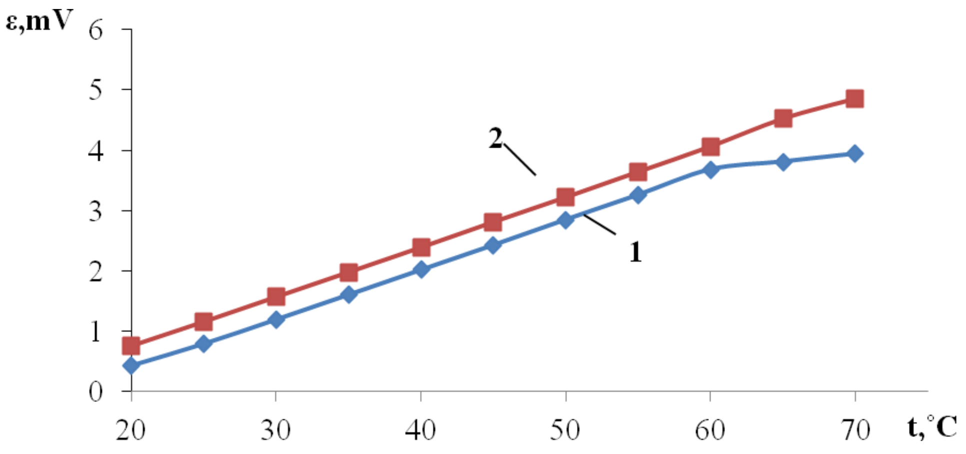

Fig.2. Graph of the dependence of the thermal EMF on temperature changes:
1 - HFM-1M, 2 - device for measuring heat flow.

The data obtained show that the thermal-EMF of the device for measuring heat flow exceeds 1.5 - 2 times. This is due to the fact that the sensitivity of the device the total value of the thermal-EMF in the thermal battery circuit is N times greater than in the HFM-1M thermoelectric converter, that is, the sensitivity of the device increases, and the resulting thermal-EMF. This is due to the fact that the sensitive element in the device for measuring heat flow is made in the form of a spiral of metal wire in an insulating layer, the non-radiated surface of which is controlled by hot thermal battery junctions. To reduce the heterogeneity of the zonal sensitivity, the hot junctions of the thermal battery were distributed according to a special technique. This technique is based on the condition that the total reactions received from each zone of the sensitive element are equal to each other, i.e. the identity must be fulfilled:

$$\frac{n_0 U_0}{F_0} = \frac{n_i U_i}{F_i} \tag{1}$$

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where n_0, U_0 and F_0 – the number of thermocouples, the reaction from each thermocouple and the area of the central or zero zone, respectively, a F_i - the same parameters of the i-th zone.

The application of condition (1) for the number of thermocouple junctions by zones made it possible to obtain receivers with zonal sensitivity, the spread of values of which does not exceed 2%. In general, the sensitive elements are multi-layered: black coating, calorimetric load, heat-sensitive elements, alternating lacquer and adhesive layers. That is, the sensitive elements are inhomogeneous, both in the direction perpendicular to the irradiated surface and in parallel. The heterogeneity in the first case is due to the multi-layered of the sensing element. Knowledge of the temperature profile inside the multi-layer sensitive element is necessary in determining the error due to the non-equivalence of heat losses in radiant and electric heating.

Conclusion

The objectives of research require the measurement of the heat flux density, the determination of the parameters of the heat flow and temperature, which vary depending on the degree of damage to the pipeline from 20 to 100 W/m^2 temperature from 5 to 20 ^{0}C, in case of violation of the thermal insulation structure between 25 and 35 W/m^2, The calculation of all the data to obtain the necessary sensitivity, which ensures the measurement of these flows with great accuracy, showed that the heat-sensitive element must be made with a height of 1.5 mm, a diameter of the receiving area of 80 mm from a wire with a cross section of 0.05 mm. In this case, the value of the working coefficient of the converter should be in the range from 4.0 to 12.0 W/(m^2·mV), and the value of the electrical resistance of the converter should be in the range of 12-20 kOhm.

This type of converter is relatively simple and easy to use, it has small dimensions. It's not selective in a wide spectral range (from 1.0 to 25.0 μm). Moreover, the developed devise has high sensitivity (from 10 W/(m^2·mV), and reliably works in harsh operating conditions.

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