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Investigation of the operation of a thermoelectric converter

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In this article, a heat flux meter is considered for diagnosing the state of thermal insulation of underground pipelines by measuring the surface distributions of the heat radiation density over the laying. The heat flux meter is an indicator of the state of the underground heat pipeline by the nature of changes in heat losses or the temperature of the ground surface above the researched object. The developed heat flow meter is based on the principle of using an "auxiliary wall". On the transducer of heat flux, which is applied to the surface of the enclosing structure, a temperature difference is created in the steady-state heat exchange mode, proportional to the density of the heat flux passing through the barrier. This heat flux meter consists of a thermometric unit, which is based on a battery-operated thermoelectric transducer. The battery sensor is a sealed laminated round disk, which is mounted in a stainless steel ring with an internal groove and filled with epoxy resin. The lamp soot is added to the epoxy resin to increase the level of disc absorption. The disk provides the same conditions for heating the sensor element by the radiation flow and the electric current passed through the heater. This allows the equivalent heating of the sensor element by the radiation current flow. The developed device is designed to analyze the state of thermal insulation of underground pipelines of heat networks.

Keywords: heat flux meter, heat flow, thermometric unit, battery-operated thermoelectric transducer

INTRODUCTION

Research and modernization of thermal power plants and energy-intensive technologies are now particularly relevant in connection with energy and resource conservation issues. 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, consumption, etc.

Measurements of heat flow density are of great importance in engineering, they are necessary in thermophysical experiments devoted to the study of the properties of substances and heat exchange processes, as well as for the diagnosis of industrial thermal power equipment and technological processes and control of its operation modes. The methods of heat measurement can be successfully used for the operational quality control of thermal insulation of power plants and pipelines and determination of heat-protective properties of building structures. Such control contributes, on the one hand, to the rational use of insulating materials and, on the other, to the saving of thermal energy. Therefore, the new course in the field of energy development is aimed at increasing, promoting and introducing new methods and devices aimed at reducing heat losses [1].

In order to increase the efficiency of the Republic of Kazakhstan's heat supply and reduce the shortage of thermal energy, the use of devices for operational quality control of heating installations and heating networks, as well as modernization of production at existing capacities and expansion of the possibilities of modern methods of heat saving is needed.

Numerous studies have shown that the methods of non-destructive testing, which are based on the observation and automated registration of the temperature state of processes, currently meet all the requirements of technical diagnostics of heating networks and technological facilities. The experience of foreign countries shows the effective use of heat flow meters of non-destructive testing for the purposes of the normative state of objects and construction structures [2].

Heat flow devices are used not only for research but also for control and regulation of processes in various fields of science and technology. In devices of heat flow measuring, the basis of all achievements is a thermoelectric battery converter, where the auxiliary wall method is used.

This article discusses the developed modifications of devices for measuring the heat flow. A 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 heating element. In this case, the thermoelectric battery converter is combined with the heating element, and its "hot" junctions are combined with the receiving plate, and the "cold" junctions are brought into thermal

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contact with the heating element. The article is devoted to the principle and creation of the main element of the device, a battery thermoelectric converter [3].

The heat flow converter is embodied in the form of an auxiliary wall and consists of a battery of identical galvanic thermoelectric conductors which are connected in parallel according to the measured heat flow and in series according to the electrical signal being generated. The monolithic converter in a rigid or flexible design is provided by a pouring electrical insulation compound. When operating a converter installed on the surface of the object under study, in a stationary heat exchange mode, a temperature drop proportional to the measured density of the passing heat flow occurs on opposite flat surfaces of the converter, due to which a thermo-EMF is generated in the battery of thermoelements [4].

The principle of operation of a thermocouple is the thermoelectric effect, or the Seebeck effect, which is based on the occurrence of a potential difference in conductors, so the metals of thermoelectrodes should differ in chemical and physical characteristics.

EXPERIMENTAL

In the laboratory "Measurement of thermophysical quantities" of the Department of Engineering Thermophysics named after Professor Zh. S. Akylbayev of the Faculty of Physics and Technology of E. A. Buketov Karaganda University a device for measuring heat flow for recording and measuring heat flows was developed.

Heat flow instruments are used not only for research but also for the control and regulation of processes in a wide variety of fields of science and technology. In heat flow measuring devices, the basis of all achievements is a thermoelectric battery converter, where the auxiliary wall method is used.

The heat flow converter is a disk with a thickness of 1.80 mm and a diameter of 26 mm. There is a battery of galvanic thermoelements, which are rigidly held in a given position by an epoxy compound placed between the end surfaces. The technology for producing galvanic laminated sensors is carried out on the winding machine of two wires with filament insulation on a celluloid strip. The wire is served by rubber rollers. The wire is winded on a spool which rotates around a celluloid strip in the form of a spiral of a bifilar winding in the form of a circle. The pitch is approximately 2-2.5 times the diameter of the wire. The length of the covered 20-30 m is limited to the capacity of the spool. For a size of 20×20 mm, the length of the necessary blank must be 800 mm, which is approximately more than 50 pairs of elementary junctions. Further control takes place by electric resistance of the fixed wire, strips of strips are twice covered with zapon. The battery transducer shall be dried after each coating for one hour and installed in a special mist box. During the copper plating process, the frame is lowered into a galvanic bath to precipitate copper. About 1% if ethyl alcohol is added to the electrolyte, which improves the density and strength of the coating. For copper-constant wires with a diameter of 0.7 mm, the thickness of the coating should be between 6 and 6.5 µm. The copper-plated celluloid base and the zapon are dissolved in acetone, the helix is varnished and kept at room temperature for 60 minutes. A helix coated with varnish is placed in the drying oven and conditioned at a temperature of 70-90°C for 150 minutes. The resultant blank is lubricated with an ED-6 resin hardener and a FAED-13 furano-epoxy resin, the operating temperature of the converter can be increased to 130°C and placed in the mold and compressed on all sides, respectively, is heated in a thermostat up to 100°C and held for 5 hours for glue polymerization (Figure 1).

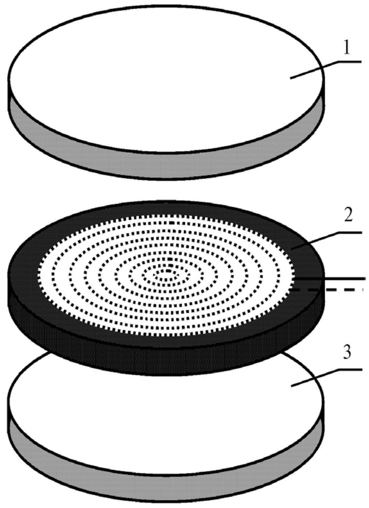

Figure 1. Appearance of the thermoelectric battery converter: 1,3 - upper and lower disc; 2 - thermoelectric battery converter.

As a result, a compact laminated round disc is obtained, the quality being evaluated on a grading board, where the values of its operating coefficients are determined [5].

The resulting disc is mounted in a ring made of stainless steel with an internal duct and is filled with epoxy resin, into which lamp soot is added in order to increase the degree of absorption.

RESULTS AND DISCUSSION

Previously, we carried out experimental work on the calibration of thermocouples used to determine the temperature change in the ground and calculating the calibration coefficient, which relates the value of the thermo-EMF of thermocouples with the temperature value in Celsius [6]. The laboratory stand for the calibration of thermocouples is shown in Figure 2.

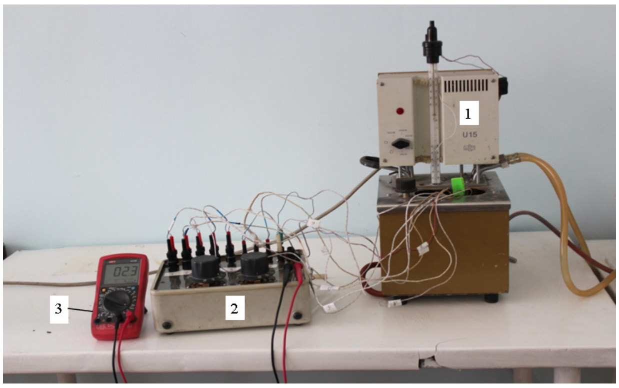

Figure 2. Calibration of thermocouples: 1 - thermostat, 2 - thermocouple switch, 3 - measuring device

Temperature changes were investigated using an earlier developed heat flow meter [7] with a device for measuring heat flow [8]. Based on the results of experimental data, a calibration graph of the thermocouple was constructed (Figure 3).

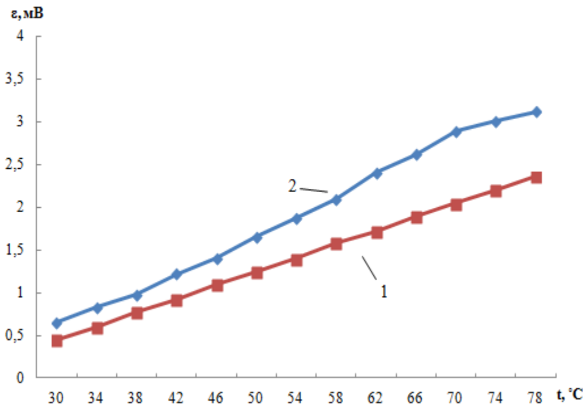

Figure 3. Graph of the calibration thermocouple: 1 – heat flow meter [8]; 2 - device for measuring heat flow [9].

In the device for measuring the heat flow [8], the sensitivity of the device has been increased, that is increase the number of hot junctions in the thermal battery per unit area of the sensing element. The obtained studies of the thermal batteries of these converters showed (Fig. 3) that by increasing the number of hot junctions, we increased the sensitivity of the newly developed sensor.

CONCLUSIONS

Numerous studies of the converter have shown that the manufactured heat flow device has a high sensitivity, which allows it to be used for measuring heat flows of not only high, but also low intensity. Heat flow devices are of great interest, since they do not need an additional power source, therefore, the appearance of current noise characteristic of others is excluded. These methods made it possible to increase the sensitivity and reduce the temperature measurement error. The analysis of errors in measuring the energy parameters of radiation is carried out. It is shown that the relative non-excluded error of measuring energy parameters using the developed devices and methods does not exceed 2.0% [9, 10].

Thus, the control and measurement of heat flows are of interest for many branches of science, technology and industry, but, above all, for solving issues of rational use of energy resources.

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