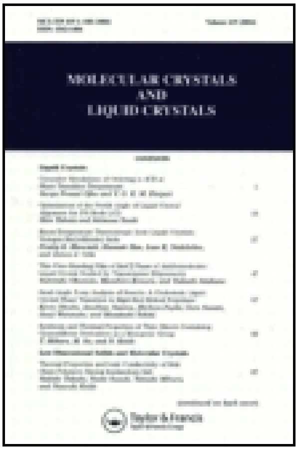

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The Study of a Liquid Crystalline Heat Flow Transducer†

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The possibility of liquid crystalline transducers for the direct measurement of heat flow is under study. For this purpose a method using an auxiliary wall with a known heat conduction is employed. The layers of liquid crystalline heat-indicators are used for measuring the temperature gradients across the auxiliary wall. The compositions of liquid crystals for measuring heat flows within a range from 20 up to 800 W/m^2 are selected and studied.

1. INTRODUCTION

Liquid crystalline heat-indicators are widely adopted for studying local heat exchange. With that end in view and with the help of liquid crystals, the temperature is measured on the surface under study and the heat flow value is calculated with respect to the rate of temperature change for a specific configuration.[1] As the thickness and the thermophysical properties of the heat-indicating coating are not always known, the application of the liquid crystalline indicators for measuring the heat flows can lead to considerable errors. In this connection a method of direct determination of the heat flow based on the method using an auxiliary wall is suggested.[2] The essence of the matter is that a wall with a known heat conduction is placed in the heat flow path and the temperature difference across the wall is measured with the help of liquid crystalline thermo-indicators. The application of liquid crystalline thermo-indicators for these purposes

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enables one to decrease considerably the thickness of auxiliary wall, and to carry out measurements while not destroying the surface under study.

The present paper suggests a design of a heat flow transducer, and the liquid crystalline thermo-indicators which should satisfy the application conditions of such a device are studied.

2. DESIGN OF THE HEAT FLOW TRANSDUCER

A heat flow transducer consists of several layers of polymer materials. By using a method of casting, the following layers are put successively on a mylar substrate (2) (Fig. 1): the first layer (3) contains a thermo-indicator in a polymer; an intermediate layer (4) of a pure polymer of less size plays the role of an auxiliary wall, the second layer of a polymer with a thermo-indicator (5) is of equal size to the intermediate layer. The linear dimensions of the layers are determined by the necessary spatial resolution in a specific problem, as well as by the optical properties of the system which will be employed for measuring the color of the first and second layers with thermo-indicators. The thickness of each layer is 10–20 mμ. Any polymer in which the liquid crystalline thermo-indicators are well encapsulated may be used as a polymer, e.g. polyvinyl alcohol and its derivatives.

3. CALIBRATION OF THE HEAT FLOW TRANSDUCER

For measuring the dependences of the colors of the first and second thermo-indicating layers on the heat flow value the following installation has been utilized (Fig. 2). A pick-up of the type PHF-2 was used as a standard heat flow pick-up, which was placed into a heat-chamber. The heat flow was excited by a flat heater, and the readings from a standard pick-up were recorded by a microvoltmeter. The transducer examined was attached to a standard pick-up with the help of heat conducting grease. The transducer dimensions correspond exactly to those of a standard pick-up. After the constant heat flow is established the light spectra reflected from the first and second heat-indicating transducer layers are recorded. On the basis of these recordings a function relating the dependence of the color correlation of these layers on the heat flow value is constructed. Thus, for determination of the transducer dimensions a characteristic curve was de-

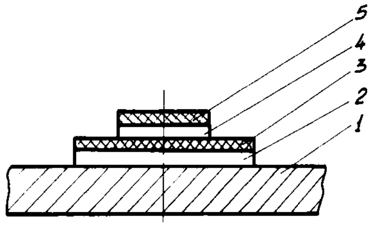

FIGURE 1 Scheme for the heat flow transducer

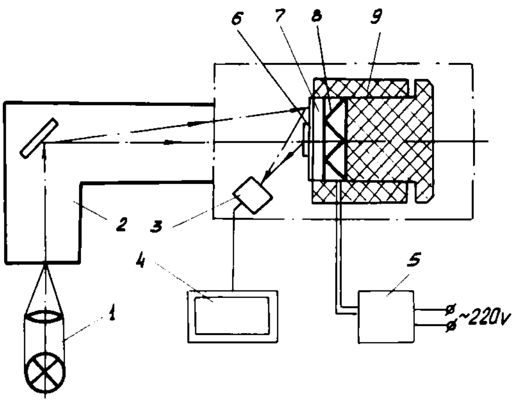

FIGURE 2 The installation: 1) light source, 2) monochromator, 3) photomultiplier, 4) recorder, 5) controllable supply source, 6) liquid crystalline transducer, 7) standard heat flow pick-up, 8) flat heater, 9) heat-insulating body

rived, with whose help the heat flow can be obtained when using a known correlation of colors of the thermo-indicating layers.

4. CHOICE OF LIQUID CRYSTALLINE COMPOSITIONS FOR HEAT FLOW TRANSDUCERS

For the pick-up suggested, a choice of liquid crystalline compositions is determined by the following conditions: 1) both thermo-indicating layers of the transducer should have a color simultaneously; 2) the temperature interval of selective light reflection by each layer should be wide; 3) the function determining the dependence of color correlation on the heat flow value should be linear or close to it. The table illustrates a series of the compositions under study, and their color-temperature characteristics.

TABLE I

Composition of Liquid Crystals	Weight %	Temperature, °C		
		630 nm	546 nm	430 nm
1. cholesteryl monanoate	56.5	32.5	36.3	42.4
cholesteryl valerate	23.2			
cholesteryl oleate	20.0			
2. cholesteryl nonanoate	30.0	7.0	29.0	40.0
cholesteryl valerate	70.0			
3. cholesteryl-*p*-nonyloxybenzoate	70.0	60.5	81.0	112.0
cholesteryl benzoate	30.0			
4. cholesteryl-*p*-eight-oxybenzoate	50	115.0	124.0	170.0
cholesteryl-Cl-benzoate	50			

5. EXPERIMENTAL RESULTS

We have analysed a series of functions relating the dependence of maximum wavelengths of selective light reflection of the first (λ_1) and second (λ_2) heat-indicator layers on the heat flow value. As the heat flow passing through a heat flow transducer is proportional to the temperature difference (T_1 and T_2 of the first and second heat-indicating layers) and the temperatures in general are proportional to $1/\lambda$, then the heat flow equals $q \simeq f(1/\lambda_1 - 1/\lambda_2)$. However, for most compositions examined this function proved to be nonlinear. The analysis of other functions for many compositions has shown that the dependence $q \simeq f(\lambda_1 + \lambda_2/2)$ is close to linear. That is why the given function was chosen for processing experimental data.

Figure 3 illustrates the experimental curves obtained for different heat flow transducers, the heat-indicating layers of which contain the compositions of liquid crystals (1–4) given in the table. Transducers in which the layers contain equal or different compositions of liquid crystals were considered. It is seen from Fig. 3 that by choosing the composition of the heat-indicating layers, one can get the heat flow transducer operating within a range from 20 up to 800 W/m^2. The heat flow sensitivity of the transducer is determined by the temperature sensitivity of the compositions deposited on the transducer. If the heat-indicating layers contain liquid crystals of the same composition, then the color difference in layers arising due to the temperature gradient across the auxiliary wall is small and accounts for 10–20 nm. In order to increase this difference it is necessary either to increase the thickness of the auxiliary wall or to make use of different heat-

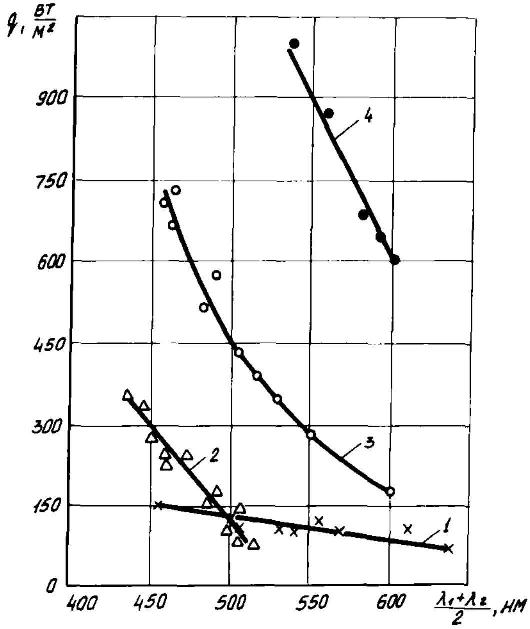

FIGURE 3 Heat flow as a function the wavelengths of selective light reflection from the first and second heat-indicating layers for compositions 1–4.

indicating compositions with different color-temperature characteristics for the first and second layers.

6. CONCLUSIONS

The studies performed show that when making use of an auxiliary wall, two-layer heat-indicating coating and of spectral analysis, it is possible to measure quantitatively the heat flows within a range from 20 up to 800 W/m^2 with an accuracy of 10–15%. Similar transducers can be also employed for a qualitative visualization of the heat flow on the surface, if under the action of the heat flow the color difference of both transducer layers is noticeable for observation with the naked eye. With that end in view, one layer of the heat-indicator is put on the surface under study, when using a stencil the two layers: a pure polymer and the second heat-indicating layer are put on successively with a certain step. With the help of such a transducer a qualitative pattern of the heat flow distributions on the surface can be determined in the course of one experiment.

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