AUTOMATIC DETERMINATION OF THE THERMAL DIFFUSIVITY OF HEAT INSULATORS

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This paper describes the construction, operating principle, and technical specifications of an automatic apparatus for determining the thermal diffusivity of heat insulators. The automatically determined temperature dependences of the thermal diffusivities of asbestos cement, textolite, micarta, and polystyrene are discussed.

The principle of mathematical simulation was used to solve the problem of automatic determination of thermal diffusivity. The design of the computer was based on a simulation formula [1] connecting the measured physical parameters—the heating temperature and the temperature drop on the investigated plates. These parameters, which vary continuously during the experiment, are converted to a direct voltage and fed into the computer.

The result of the computation—the thermal diffusivity—is obtained almost immediately after the input of the initial data and is recorded on graph tape of an electronic recorder.

This apparatus (Fig. 1) is free from the faults inherent to the apparatus in [1, 2], since it has an electronic computer. The determination of the thermal diffusivity in a wide temperature range entails three operations: differentiation, multiplication by a constant factor, and division.

The sensors for the initial values—the heating temperature \( t_h \) of the specimen and the temperature drop \( \Delta t \) on the specimen—consist of chromel-copel thermocouples \( T_2 \) and \( T_1 \), the latter being of the differential type. The thermo-emf of these thermocouples is converted to a proportional direct current by the electronic converters \( CC_1 \) and \( CC_2 \). The signal proportional to the temperature drop \( \Delta t \) is fed directly into the division circuit and the signal proportional to the heating temperature \( t_h \) of the external side faces of the specimen is first differentiated and then amplified by the converter \( CC_2 \).

The division circuit is based on an EPP-09 automatic millivoltmeter with a uniform scale. The circuit consists of a slide wire, connected up in a particular manner, and a servo system. Currents proportional to the derivative of the heating temperature with respect to the time \( \frac{dt_h}{d\tau} \) and the temperature drop \( \Delta t \) are fed to the two inputs of the slide wire. The voltage applied to the input of the null indicator of the servo system from the slide wire is proportional to the difference

\[ k_1 \frac{dt_h}{d\tau} - k_2 \Delta t. \]

The scale readings on the millivoltmeter are proportional to

\[ n = 2 - \frac{l_1}{l_2}, \]

where \( n \) is the ratio of the pointer reading to the whole scale, \( l_1 \) is the output current of \( CC_2 \), which is proportional to \( \frac{dt_h}{d\tau} \); \( l_2 \) is the output current, which is proportional to \( \Delta t \).

Thus

\[ n = 2 - k_1 \frac{dt_h}{d\tau} / k_2 \Delta t, \]

from which

\[ \frac{dt_h}{d\tau} / \Delta t = \frac{k_2}{k_1} (2 - n). \]

The formula for calculating the thermal diffusivity has the form

\[ a = (2 - n) l^2 / 43.6R, \]  

where \( l \) is the thickness of the specimen plate in mm; \( R \) is the resistance (in ohm) in the differentiating circuit, which determines the range of measurement of the thermal diffusivity \( a \). From this formula \( a \) is obtained in m²/h.

It follows from expression (1) that a reduction in the thermal diffusivity corresponds to an increase in the scale reading of the instrument. The scale is calculated for each specific expression for the thickness of the specimen plate.

The apparatus can be used for automatic measurement of the thermal diffusivity of heat insulators in the range 0.6-5·10⁻¹ m²/sec. This range is divided into three subranges. Changeover from one to the other is effected by switching the resistors in the differentiating circuit. The specimens consist of 100 x 100 mm plates, 3-10 mm thick. The contacting surfaces of the plates are polished for good thermal contact.

Quasi-stationary thermal conditions are produced in the plates by an automatic programmed regulating system in which the regulating device is a EP-T-59 electronic regulator [3]. The prescribed rate of heating is fixed by a programmed controller consisting of a device producing a linearly increasing voltage. The temperature sensor for the regulating system is a chromel-copel thermocouple \( T_3 \). By means of two RKN electromagnetic relays the regulator controls a reversible motor RM, which is connected through a reducing gear to the slider of an autotransformer. The latter alters the current through the heaters \( H_1 \) and \( H_2 \) so that the temperature on the outer faces of the specimens varies linearly.

The range of variation of the heating temperature is 20°-400° C. The upper limit can be increased to 600°-800° C; it depends on the design of the heaters and the electrical circuit of the current converters.
Fig. 1. Block diagram of apparatus. CC₁, CC₂, CC₃: Current converters; H₁, H₂: flat heaters; T₁, T₂, T₃: thermocouples; S: specimens; SS: servo system of electronic millivoltmeter; ER: electronic regulator; PC: programmed controller; RM: reversible motor with reducing gear; VR: voltage regulator; SW: slide wire of electronic millivoltmeter.

Fig. 2. Plots of thermal diffusivity $\alpha (m^2 \cdot sec^{-1})$ of tex-tolite (1), asbestos cement (2), polystyrene (3), and micarta (4) against temperature $t (^{\circ}C)$: a) Determined by automatic device; b) by manual method; c) from data of [5]; d and e) from data of [6] and [4].