EVALUATION OF THE INTEGRAL ABSORPTION FACTOR
IN RADIATION HEATING

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In radiation installations the source of heat (radiator) is raised to a high temperature and radiates its heat thus transmitting it to the heated object. The energy radiating sources comprise quartz lamps, resistors made of silit, silicified graphite and molybdenum disilicide, as well as black-heat radiators consisting of flat panels or tubes heated up to a temperature of the order of 150-500°C.

The heating process in radiation installations depends to a great extent on the absorption coefficients of the reflector and of the object's heated surface. The absorption coefficient depends on the nature and condition of the surface, on the temperature of the heated material, and on the spectral composition, intensity and incidence angle of the radiated flow. The printed reference data on the absorption coefficients are based on experiments made, as a rule, with clean polished surfaces at fixed incidence angle of the radiated flow. The radiation sources consist usually of a black body. In industry materials are heated in the same condition as received from the suppliers. The surfaces have often large microirregularities and are covered with films of oxide, which change considerably their absorption coefficient. The spectral composition of some of the radiation sources (in particular of quartz lamps) differs considerably from that of a black body. The incidence angles of the flow components transmitted from various parts of the radiator extend from 0 to 90°. The above factors make the absorption components in radiation heating differ considerably from those provided in handbooks and, therefore, it is necessary to measure the absorption coefficients under production conditions.

The existing methods for measuring absorption coefficients have been developed for laboratory conditions [1, 2, 3]. They are rather complicated and labor consuming. Experiments often last 4 hours, thus making it difficult to apply them in industry. Below we describe a simple method for measuring the absorption coefficient under production conditions with adequate precision for practical purposes. The coefficient is determined from the heating curve of the sample. The radiation sources are made up of the radiators used in the existing equipment.

The experiments are made with the maximum possible values of the specific radiated flows. Thus, the share of heat losses in the thermal balance of the heated sample is reduced, which raises the measurement precision. For the same reason the sample is heated up during the experiment to relatively low temperatures, which do not exceed 100°C.

The heat losses of samples are evaluated experimentally, since the characteristic formulas for determining the convensional heat emission coefficient are inaccurate and there are no reliable data on the optical absorptivity of the tested samples.

The heated samples are made small in order to simplify the design formulas.

The schematic of an instrument for measuring the integral absorption coefficient is shown in Fig. 1. The energy flow from radiator 1 (in this circuit from a silit resistor) passes through diaphragm 2 onto sample 3 made of sheet material and fixed in heat-insulating holders. The temperature of the sample is measured with a flat thermocouple 4 by means of potentiometer 5.

The copper diaphragm 2 is cooled with water and located in such a manner that the flow incident to the sample comes only from the working segment of the resistor. This segment is made as long as possible in order to eliminate at its ends any changes in the temperature along the resistor. Under these conditions the electrical energy consumed by the working segment is equal to the sum of the energy it radiates into space and the convection losses.
The power is measured with an ammeter and a voltmeter, which are connected by means of platinum wires.

Screen 6 is made of seven sheets of aluminum foil separated by air spaces, and it serves for isolating the sample from the radiator during its heating up to the operating temperature.

The small size of the sample (20 x 20 mm) makes it possible to neglect the effect of multiple reflections.

The differentiated thermal-balance equation of the sample has the following form

\[ AE \frac{d\varepsilon}{dz} = cG dt + q_1 F_d \tau, \]  

where \( A \) is the sought-for absorption coefficient of the sample; \( E \) is the radiator's specific flow in W/m\(^2\); \( F_s \) is the irradiated area in m\(^2\) of the sample; \( \tau \) is the heating up time in sec; \( c \) is the specific heat in J/kg \cdot deg of the sample; \( G \) is the mass of the sample in kg; \( t \) is the sample temperature in °C; \( q_1 \) are the specific heat losses in W/m\(^2\) per unit area of the sample surface; \( F \) is the common area of the sample in m\(^2\).

A precise analytical solution of (1) is impossible owing to the complicated nature of the relationship between the specific heat losses and temperature. In order to find the possibility of approximating relationship \( q_1 = f(t) \) by a simple function which would lead to an analytical solution of (1), we analyzed the effect of heat losses on the result of the experiments for evaluating the absorption coefficient. Specific computations have shown that when the sample is removed to a distance not exceeding 50 mm from the radiator (a mass-produced silit resistor or a quartz lamp) the evaluation of heat losses with an error of 10% produces an error of 1.5% in determining the absorption coefficient. The utilization of an approximate relationship \( q_1 = f(t) \) in subsequent calculations is based on this computation.

Figure 2 shows the precise curves of \( q_1 = f(t) \) plotted for samples of a size of 20 x 20 mm with different values of optical absorptivity \( \varepsilon \). It will be seen that over a wide range of the values of \( \varepsilon \) from 0.05 to 1 the relationship \( q_1 = f(t) \) can be approximated by linear equations:

\[ q_1 = k(t - 30). \]  

By denoting

\[ t - 30 = t^* \]  

and bearing in mind that \( dt = dt^* \), we transform (1)

\[ AE \frac{d\varepsilon}{dz} = cG dt^* + k t^* F_d \tau, \]  

The approximating equations in Fig. 2 are shown by thin straight lines.