EXPERIMENTAL INVESTIGATION OF THE SPECIAL FEATURES OF HEAT TRANSFER THROUGH GLASS PACKETS

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We consider experimental procedures for determining the thermal resistances of certain types of commercial glass packets based on investigation of thermal and temperature fields on the outer packet surfaces at a stationary temperature head (~40°C), which corresponds to extreme climatic conditions of the middle belt. We evaluate the inhomogeneity of thermal losses over the glass-packet area caused by edge effects. The error in measuring the thermophysical parameters does not exceed ±5%.

Recent years have seen wide introduction of glass packets into civil and industrial engineering due to their heat-insulating properties, which exceed those of traditional sashes. This progressive innovation makes it possible to decrease considerably the heat losses through windows and thereby to resolve some problems in the field of energy saving. In this connection, extensive study of the processes of heat transfer through glass packets of various modifications is an urgent task for evaluating the saving of heat or cold in heat-engineering calculations of buildings that have translucent structures.

It should be noted that the process of heat transfer through a glass packet is complicated, since it includes three components: conductive, convective, and radiant. The exact solution of this problem with account for edge effects involves certain difficulties [1, 2], and therefore, in the present work we did not evaluate the contribution of every component. In this connection, certain assumptions were made, namely: a glass packet is considered to be a homogeneous infinite multilayer plate, and the principal heat-engineering parameter, namely, the effective thermal resistance, is introduced. This parameter characterizes comprehensively the heat-insulating properties of the glass packet and is very important in calculations of the heat transfer in building structures. We represent a glass packet in the form of a complex plane wall consisting of n layers packed close to each other, with different thickness δ_i and thermal conductivity λ_i (Fig. 1) and, naturally, with different thermal resistance R_i.

Since there is good thermal contact at the boundary of two adjacent layers, the heat fluxes at their interface are identical, and the total thermal resistance of the glass packet will be equal to the sum of the resistances of the individual layers.

In structural thermal physics, there exists the concept of resistance to heat transfer, in which the heat-transfer coefficient on both sides of the glass packet is taken into account. Therefore, it is worthwhile to consider a glass packet to be an infinite plate, and then from the solution of the heat conduction problem with boundary conditions of the first and third kind [2, 3] in a steady-state regime it is possible to write the total heat-transfer resistance \( R_{eff} \) in the form

\[
R_{eff} = \sum_{i=1}^{n} \frac{\delta_i}{\lambda_i} + \frac{1}{\alpha_1} + \frac{1}{\alpha_2},
\]

where \( \delta_i \) and \( \lambda_i \) are the thickness and thermal conductivity of the \( i \)-th layer; \( \alpha_1 \) and \( \alpha_2 \) are the heat transfer coefficients on either side of the glass packet. We denote the first term in Eq. (1) by \( R \) and then obtain the following simplified relation for the effective thermal parameter:

At large values of the heat-transfer coefficients \( \alpha_1 \) and \( \alpha_2 \) the total resistance of the glass packet will be \( R_{\text{eff}} = R \). According to the Fourier law, the thermal resistance can be represented in terms of the specific heat flux \( q \) and the temperature difference:

\[
R = \frac{\Delta t}{q},
\]

where \( \Delta t = t_1 - t_6 \) is the temperature difference between the outer and inner glass-packet surfaces, while the heat-transfer coefficients are \( \alpha_1 = \frac{q_1}{\Delta t_1} \) and \( \alpha_2 = \frac{q_2}{\Delta t_2} \) (\( \Delta t_1 \) and \( \Delta t_2 \) are the temperature difference between the surface on either side of the glass packet and the surrounding medium).

Finally, we obtain a simple expression for determining the effective resistance of the glass packet to heat transfer:

\[
R_{\text{eff}} = \frac{\Delta t}{q} + \frac{\Delta t_1}{q_1} + \frac{\Delta t_2}{q_2}.
\]

Expression (4) allows us to calculate the local \( R_{\text{eff}} \) in terms of the measured heat fluxes and temperature differences.

The thermal resistance is not identical over the entire glass-packet surface [3]. At the places of fastening the glass, i.e., in the edge region along the perimeter of the glass packet, the conditions of heat transfer will undoubtedly differ from the heat-transfer conditions in the central translucent structure. Therefore, it is of practical interest to determine the influence of the edge effect on the total heat transfer through a glass packet. For this purpose, an experimental setup similar to a climatic chamber [4] was created in which during the experiment we maintained a constant temperature head that corresponded to the extreme winter conditions of the middle belt.

Figure 2 presents the schematic setup. As objects of investigation we selected different glass packets: one-, two-, and three-chamber ones with aluminum thrust frames and, for comparison, a two-chamber glass