

UDC 697.133

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Method of calculation of thermal loss energy in double and triple glass packaging

The paper presents a method of calculating the heat energy loss from the room through double and triple glazing. In this article algorithms of calculation of losses of energy through the processes of conduction, convection and radiation heat transfer. The article shows that the replacement of the standard double-glazed window (total thickness of the double-glazed 24 mm) with the upgraded triple-glazed window (total thickness of the upgraded glass 47 mm) leads to a reduction in heat energy losses by at least 50 percent; at the same time, with an increase in the difference between the temperature of the street and the temperature of the room, it leads to an increase in thermal energy savings. The article shows that the loss of thermal energy through the Windows is not dependent on the thickness of the glass, but there is a strong dependence of the flow of thermal energy going through the Windows into the street, the number of glasses in the glass and the distance between the glasses. The given article technique allows you to quickly calculate the energy loss through 1 m² of double-glazed glass; knowing the total area of Windows in the room, you can calculate the total energy loss through all the Windows and, if necessary, adjust the supply of heat energy to the room: for example, increase or decrease the number of ribs of heating batteries.

Keywords: double insulating glass, heat loss, thermal conductivity of a double-glazed unit, radiant heat exchange in a double-glazed unit.

In order to study the effect of the number of glasses in a double-glazed window, an experiment was conducted in which it was investigated how the flow of thermal energy passing through the double glazed window would change when installed in this double-glazed window of the third glass.

1) At the first stage of the experiment, the flow of thermal energy passing through a standard double glazed window was determined.

It is assumed that heat exchange processes taking place in a double-glazed unit, the main elements of which are standard silicate glasses 4 mm thick. Figure 1 shows a system from a standard double glazing unit and a room wall.

This double-glazed window has already two glasses separated by an air standard gap $L = 16$ mm: it is believed that with such a thickness of the air gap, there is practically no convection in the double-glazed unit, and only processes of thermal conductivity and radial heat exchange should be considered. Each standard silicate glass in a double-glazed window has a thickness of 4 mm. An experiment was carried out under the following conditions: the air temperature in the street $T_{out} = -11.5$ °C, the air temperature in the room $T_{air} = +11$ °C, the wall temperature in front of the window $T_{wall} = +9.3$ °C; measurements showed that under given temperature conditions on the surface of glass № 1 bordering on the warm air of the room, the temperature $T_1 = +2.75$ °C. On the outer surface of glass № 2, the temperature is $T_4 = -6.8$ °C (Fig. 1). The experiment was carried out at a wind speed on the street $V = 0$ m/s. The obtained experimental data made it possible to calculate the heat flux through a double glazing unit using the following algorithm:

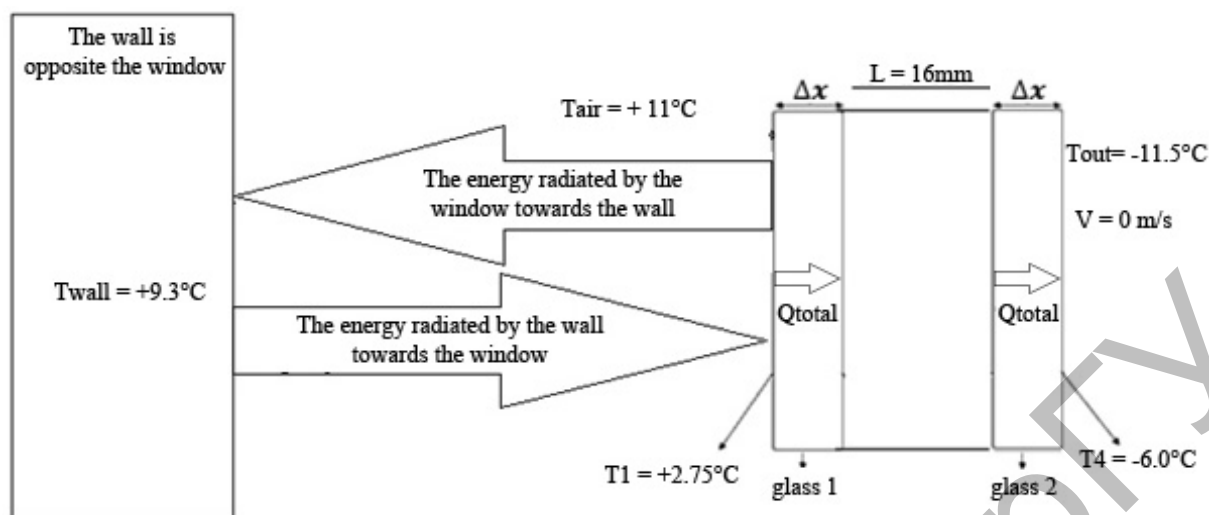


Figure 1. Scheme of energy flows passing through a double glazed window onto the street

1. We find the loss of thermal energy from the room, produced by the heat flow caused by the process of thermal conductivity. For the convenience of calculations, we assume that the glass area in the double-glazed window is one square meter. This heat flux is found from the formula [1]:

$$Q_{\text{thermal conductivity}} = K * (T_{\text{air}} - T_{\text{out}}). \quad (1)$$

Here K is the heat transfer coefficient, which takes into account all the processes of transfer of thermal energy between the two media through two flat separation walls. This heat transfer coefficient is calculated by the formula [1]:

$$K = \frac{1}{\frac{3}{\alpha_1} + \frac{1}{\alpha_2} + \frac{L}{\lambda_{\text{air}}} + 2 \frac{\Delta x}{\lambda_{\text{glass}}}}, \quad (2)$$

where $\alpha_1 = 5.6 \text{ [W/(m}^2 \cdot \text{K)]}$ — this is the heat transfer coefficient of the medium - the surface (air - glass) of the wall in an environment where there is no wind; α_2 — this is the heat transfer coefficient of the medium-outdoor surface T_4 (outdoor air-glass) of the second glass, which borders on the cold air of the street, where there may be wind. The external heat transfer coefficient is calculated by the formula [1].

$$\alpha_2 = \alpha_1 + 4 \times V = 5.6 \text{ [W / (m}^2 \cdot \text{K)]}, \quad (3)$$

where V — this is the wind speed in the street near the window, equal in our case to 0 m/s.

Δx — thickness of the separation walls from glass (4 mm).

L is the distance between the panes in the double-glazed window (standard 16 mm).

$\lambda_{\text{glass}} = 0.8 \text{ [W / m} \cdot \text{K]}$ is the coefficient of thermal conductivity of the wall (glass) [2].

$\lambda_{\text{air}} = 0.025 \text{ [W / m} \cdot \text{K]}$ — coefficient of thermal conductivity of air [2].

In our case, the coefficient of heat transfer from the warm environment to the street through a double glazed window $K = 0.734 \text{ [W / (m}^2 \cdot \text{K)]}$.

Calculating the coefficient of heat transfer of a double glazed window, according to formula 1, we find the amount of energy coming from the room air to the inner surface T_1 of the first glass as a result of thermal conductivity.

$Q_{\text{thermal conductivity}} = 16,49 \text{ W}$ is the amount of energy lost by a warm room through 1 m^2 of double glazing as a result of heat conduction processes.

2. Next, we find the amount of energy absorbed by the window glass in the process of radiative heat transfer. First, using the Stefan-Boltzmann law, we find the amount of thermal energy $Q_{\text{to_glass1}}$ coming through the process of radiant heat transfer to the inner surface T_1 of the inner window glass № 1 of the double-glazed window from the warm wall opposite the window [3]:

$$Q_{\text{to_glass1}} = C_0 E \left(\frac{T_{\text{wall}}}{100} \right)^4 = 331,3 \text{ [W]}, \quad (4)$$

where, E is the coefficient of grayness of the radiating body: the walls in the room are made of bricks, which, like glass, has a coefficient of grayness equal to 0.92 [4]. This coefficient is equal to $5.67 \text{ [W / m}^2 \cdot \text{K}^4]$. The calculation showed that 1 square meter of the wall opposite the window radiates per second 331.3 [J] of energy.

Then determine the radiant flux coming from the inner surface T1 of the window glass № 1 into the room:

$$Q_{\text{from glass 1}} = C_0 E \left(\frac{T_1}{100} \right)^4 = 301,6 [\text{W}]. \quad (5)$$

Knowing the energy flow coming from the room to the inner surface T1 of the first pane, and knowing the energy flux emitted from the inner surface T1 of the first pane of glass into the room, we determine the amount of radiant energy absorbed by the square meter of the surface T1 of the window glass № 1.

$$Q_{\text{to glass 1}} - Q_{\text{from glass 1}} = Q_{\text{absorbed radiation}}. \quad (6)$$

$Q_{\text{absorbed radiation}} = 29,69 [\text{W}]$ real energy losses through the absorption of infrared radiation on the T1 surface of the inner glass No. 1 with further movement of this energy to the outer surface T2 of Glass No. 1. It should be noted that the energy absorbed as a result of thermal conductivity is also transferred to the surface T2 of glass No. 1, together with the energy absorbed as a result of radiant heat exchange. Thus, it was determined that when calculating heat losses through a double-glazed window pan, it is necessary to take into account both convective heat transfer and radiant heat exchange.

It remains only to determine the total energy loss that occurs through the window glass:

$$Q_{\text{total}} = Q_{\text{absorbed radiation}} + Q_{\text{thermal conductivity}} = 46,19 [\text{W}], \quad (7)$$

Q_{total} — the total energy loss is through a 1 meter square double glazing unit.

2) At the second stage of the experiment, the flow of thermal energy was determined, under the same temperature conditions, when the third glass was double sealed. Figure 2 shows the distribution of energy flows in the resulting triple-glazed unit. The resulting triple-glazed window has already two glasses separated by an air standard gap L1 = 16 mm plus one glass No. 3 of the same thickness located at a distance L2 = 19 mm from the inner surface of glass No. 1. All three glasses had a thickness of 4 mm. An experiment was carried out under the following conditions: the air temperature in the street $T_{\text{out}} = -11.5^\circ\text{C}$, the air temperature in the room $T_{\text{air}} = +11^\circ\text{C}$, the wall temperature in front of the window $T_{\text{wall}} = +9.3^\circ\text{C}$; measurements showed that, given the temperature conditions on the surface of glass № 3, the temperature, bordering on the warm air, is $T_1 = +7.45^\circ\text{C}$. On the outer surface of glass № 2, the temperature is $T_6 = -7^\circ\text{C}$ (Fig. 2). The experiment was carried out at a wind speed on the street $V = 0 \text{ m/s}$.

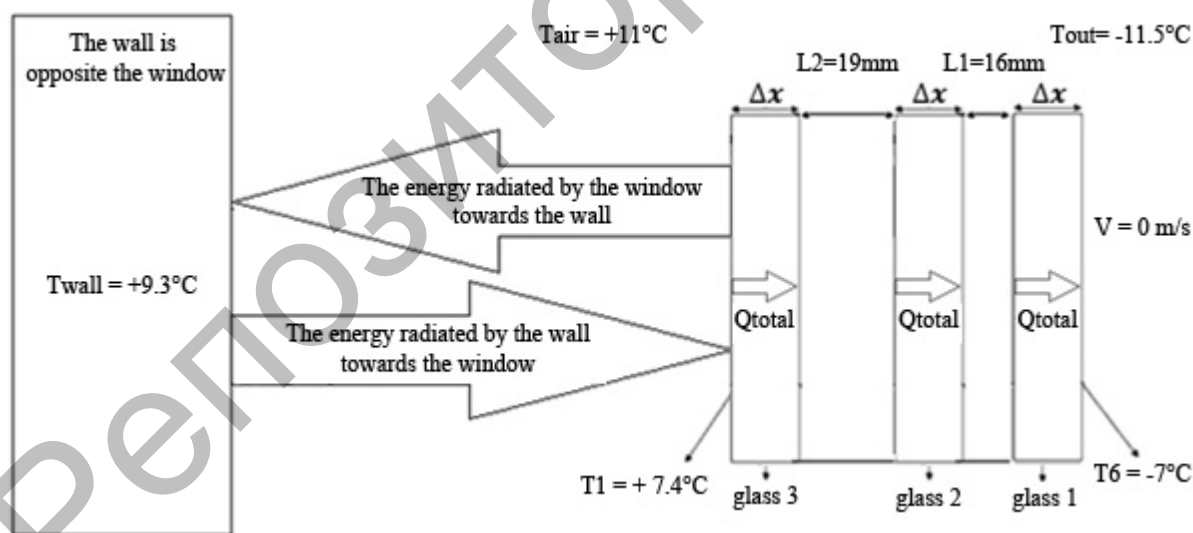


Figure 2. The scheme of energy flows passing through a triple-glazed window to the street

The loss of energy through the glass packet is found by an algorithm similar to the algorithm for calculating energy losses in a double-glazed unit. First, we find the energy flow lost through a triple-pane as a result of thermal conductivity. Determine the heat transfer coefficient for a triple-glazed unit:

$$K = \left(\frac{1}{\frac{5}{\alpha_1} + \frac{1}{\alpha_2} + \frac{L_1 + L_2}{\lambda_{air}} + 3 \frac{\Delta x}{\lambda_{glass}}} \right), \quad (8)$$

where L_1 — the distance between the glasses No. 1 and No. 2 in the double-glazed unit (standard 16 mm); L_2 — the distance between the glasses No. 1 and No. 3 in the insulating glass unit (19 mm); $K = 0,402$ [W/(m² * K)] — calculated heat transfer coefficient from a warm environment to a street through a triple glazing unit.

Calculating the heat transfer coefficient of a triple-glazed window, according to formula (1), we find the amount of energy coming from the room air to the inner surface T1 of the first glass as a result of thermal conductivity.

$Q_{\text{thermal conductivity}} = 9,05[\text{W}]$ — the amount of energy lost by a warm room through a 1m² triple-glazed window as a result of heat conduction processes.

Then, according to the law of Stefan-Bolman, we find the loss of radiation energy through a triple-glazed unit.

$$Q_{\text{to_glass 1}} = C_0 E \left(\frac{T_{\text{wall}}}{100} \right)^4 = 331,3[\text{W}]. \quad (9)$$

Then determine the radiant flux coming from the inner surface T1 of the window glass No. 1 into the room:

$$Q_{\text{from_glass 1}} = C_0 E \left(\frac{T_1}{100} \right)^4 = 322,7[\text{W}]. \quad (10)$$

Knowing the energy flow Q_{toglass1} coming from the room to the inner surface T1 of the first pane, and knowing the energy $Q_{\text{from glass1}}$ flux emitted from the inner surface T1 of the first pane of glass into the room, we determine the amount of radiant energy absorbed by the square meter of the surface T1 of the window glass No. 1.

$$Q_{\text{to_glass 1}} - Q_{\text{from_glass 1}} = Q_{\text{absorbed_radiation}}, \quad (11)$$

$Q_{\text{absorbed_radiation}} = 8,6[\text{W}]$ the real energy losses through the absorption of infrared radiation on the T1 surface of the inner glass No. 1 with further movement of this energy to the outer surface T2 of Glass No. 1.

It remains only to determine the total energy loss occurring through a triple-glazed unit:

$$Q_{\text{total}} = Q_{\text{absorbed_radiation}} + Q_{\text{thermal conductivity}} = 17,65[\text{W}], \quad (12)$$

Q_{total} — the total energy loss is through a 1 meter square double glazing unit.

When comparing the heat losses at these temperature conditions (the temperature difference between room and street temperature is 22.5 °C), it is revealed that heat losses are reduced when the double-glazed window is replaced by a triple-pane glass by 61 percent. Taking into account this fact, that the main heat losses in buildings occur through windows, the general modernization of double-glazed windows to triple ones would have a great economic effect, allowing to reduce the cost of heating or, at the same energy consumption, significantly raise the temperature in the premises.

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Екі- және үшқабатты шыны пакетінде термиялық энергияның жоғалуын есептеу әдістемесі

Мақалада екі- және үшқабатты шыны терезе арқылы бөлмедегі жылу энергияның жоғалуын есептеу әдістемесі келтірілген. Сәулелік және конвективті жылу алмасу, жылуөткізгіштік процестері арқылы энергия жоғалуының есептеу алгоритмі қарастырылған. Авторлар стандартты екіорамды шыны пакетін (жалпы қалыңдығы 24 мм) үшорамды шыны пакетіне (жалпы қалыңдығы 47 мм) 50 пайызға жылу энергиясын жоғалтудан үнемдеуге әкеледі; өз кезегінде, ол даладағы ауа температурасы мен үйдегі температурасы айырмасының көрсеткіші жылуды үнемдеуге септігін тигізеді деген қорытындыға келген. Мақалада шыны қалыңдығы және олардың ортасындағы арақашықтықтық жылу энергиясын сақтауға тікелей байланысты. Келтірілген әдістеме 1 м² екіорамды шыны пакеті энергия жоғалтуды тез есептеп шығаруға көмектеседі. Яғни бөлмедегі терезе көлемін біле тұра, керек кезде, жылу энергия көлемін есептеп шығаруға болады. Мысалы, жылу беру құрылғылары санын азайту немесе көбейту, сондай-ақ жылу энергияны керегінше беруді қадағалауға мүмкіндік бар.

Кілт сөздер: екіорамды шыныпакеті, жылу энергиясының жоғалуы, сәулелік жылу алмасу, конвективті жылу алмасу.

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Методика расчета потерь тепловой энергии в двойном и тройном стеклопакете

В работе приведена методика расчета потерь тепловой энергии из помещения через двойной и тройной стеклопакет. Рассматриваются алгоритмы расчета потерь энергии через процессы теплопроводности, конвективного и лучевого теплообмена. В статье показано, что замена стандартного двойного стеклопакета (общая толщина двойного стеклопакета 24 мм) на модернизированный тройной стеклопакет (общая толщина модернизированного стеклопакета 47 мм) приводит к уменьшению потерь тепловой энергии не менее чем на 50 процентов; при этом увеличение разницы между температурой улицы и температурой помещения приводит к увеличению экономии тепловой энергии. Потери тепловой энергии через окна мало зависят от толщины стекол, но существует сильная зависимость потока тепловой энергии, уходящего через окна на улицу, от количества стекол в стеклопакете и от расстояния между стеклами. Приведенная в статье методика позволяет быстро рассчитать потери энергии через 1 м² стекла двойного стеклопакета; зная общую площадь окон в помещении, можно рассчитать общие потери энергии через все окна и при необходимости скорректировать подачу тепловой энергии в данное помещение, например, повысить или понизить количество ребер батарей отопления.

Ключевые слова: двойной стеклопакет, потери тепловой энергии, лучевой теплообмен, конвективный теплообмен.

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