Reduction in heat losses during room heating

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Abstract. Today heating devices in most cases are located in window niche in order to save space in a room and improve its interior. However, this leads to unnecessary heat loss. The paper provides a comparative analysis of the dependence of heat losses on the location of heating devices in a room. A comparative analysis of various energy-saving measures for the value of heat losses during heating of buildings is carried out. The influence of heat-reflecting screens and false fronts on heating efficiency is considered. The dependence of heat losses on the temperature difference inside and outside a room is shown.

1. Introduction

What is the best place to install a heating device (a heater, a fireplace) in a rectangular room in order to warm it up as much as possible with minimal losses? The answer is obvious: in the center of a room and as close to floor level as possible, since the heated air rises up and spreads evenly in all directions.

Our ancestors knew this secret. Even in the smallest house the size of a garage, where every square centimeter of area is necessary, there was always a wall inside (the fifth wall). Hence the name - five-wall hut. It was this fifth inner wall that was a part of the heating device - a Russian stove. A chimney was located in this wall with a pipe in the end. It was also the back of a Russian stove.

It would be much more ergonomic and technically much easier to place the stove along any of the outer walls or in the corner. In this case the fifth wall was not needed. It was not necessary to make a hole in the roof so that the roof did not leak at the joint with the pipe. It was not necessary to divide the space of the room with a fifth wall.

However in those days the stove was not a decoration, but a heat engineering device designed to heat a room. The ancestors understood that if they place the stove along the outer wall, where a chimney was provided, then either it would be cold in a house or it would be necessary to consume more wood or coal in order to achieve the same effect of heating.

Indeed, the back of the fifth inner wall (Figure 1) heated a house inside not outside. Thus, heat losses were minimized and whole house was evenly warmed up.

The technical progress of the 20th century also covered the issue of room heating. Coal stoves were replaced by gas boilers, water and steam heating systems [1, 2]. It is difficult to imagine a modern heating system radiator located in the middle of a room. The conclusion was obvious. Radiators were placed along the outer walls. Although the apartments also have internal walls, it is believed that cold
comes from the external walls and these walls need to be heated in order to neutralize it [3, 4]. It is
difficult to argue with this statement. Indeed, in Russian huts, here was a difference in the temperature
of the internal air as the distance from the stove to the outer walls was observed.

However the radiator above the wall spoiled the interior of a room. Therefore, they began to be
installed under windows. In order to make it more convenient the window niches began to be used,
reducing the thickness of the walls in these places [5]. Thus, for decorative purposes they began to
cover the radiator with curtains, false fronts etc. However, chasing decorative purposes, they
completely forgot about the functional purpose of a radiator - to heat a room. It is from the heat
engineering point of view a window sill is the most inappropriate place to install a heating device
unless we place it under the ceiling. However this is not very aesthetic. Indeed, one of the two sides of
a radiator does not heat a room, but the outer wall. To make it easier for heat energy to leave a room,
the wall at the place of a radiator was thinner than the main outer walls. In order to enhance the
heating of the outer space, they created an obstacle to the penetration of warm air into room in the
form of curtains and false fonts.

Modern aluminum and bimetallic radiators look quite good in comparison with their cast iron
counterparts. They practically do not spoil the interior of a room, even if they are not covered with
false fonts and curtains. All kinds of design developments that can be installed along the walls or even
in the central part of a room look even more beautiful. However the cost of such “works of art” ranges
from 10 to 200 thousand rubles a piece. The best combination of design and functionality is a warm
floor. It is not visible. The heat spreads from bottom to top evenly throughout a room. However its
arrangement is not only an expensive thing. It is associated with a large amount of repair work and is
not always technically feasible. If one prefers a floor made of natural wood (parquet, solid board), then
the efficiency of warm floor will be low, due to the low thermal conductivity of wood.

When there is no money, the emphasis is put on thermal insulation of the wall in window sill niche.
Various heat-insulating and heat-reflecting materials are used, for example, foam foil [6]. The cost of
such materials is low - 30-50 rubles per m² and its effectiveness is quite high. In this case, as in the
previous ones, it is necessary to refuse from false fronts and curtains during the heating season.

2. Theory

Let us consider a single room of 4x4 meters in size and 3 meters high. One of the walls of the room is
external, 0.5 m thick. The wall material is bricks. In the same wall there is a 1.5 x 1.5 m window. The
window is made of metal-plastic with a single-chamber double-glazed window. The wall thickness
under the window is 0.25 m. A heating radiator is located in this niche.

Let us assume that there are heated rooms (corridors and other rooms) behind the other three walls
and there are no heat losses through these walls and the front door. There are rooms with the same
temperature above and below this room.

The calculation of the consumption of thermal energy through the outer wall is carried out
according to the following formula [7]:

\[
\Delta Q = \frac{0.86 \times (t_{in} - t_{out}) \times a \times 24}{1000000} \left( \frac{S_{wall}}{R_{wall}} + \frac{S_{nic}}{R_{nic}} + \frac{S_{win}}{R_{win}} \right) \text{Hkall/year}
\]

where:
0.86 x 10⁻⁶ – conversion factor of Watt in Hkall;
\(a\) - Number of days in heating period 180;
Indoor air temperature \(t_{in} = 18^\circ C\);

\(t_{out} = 1^\circ C\) - Average outdoor temperature during heating period
\(R_{wall} = 1,23 \text{ m}^2 \cdot \text{K/C Watt} - \text{resistance to heat transfer of the main wall}\);

\(R_{nic} = 0,73 \text{ m}^2 \cdot \text{K/Watt} - \text{resistance to heat transfer of the wall in the window niche}\);
$R_{\text{win}} = 0.56 \text{ m}^2\text{K/W} \ - \text{resistance to heat transfer of the window;}$

$S_{\text{wall}} = 8.55 \text{m}^2 \ - \text{Wall area}$

$S_{\text{nic}} = 1.2 \text{m}^2 \ - \text{Window niche area}$

$S_{\text{win}} = 2.25 \text{m}^2 \ - \text{Window area}$

Then

$$\Delta Q = \frac{0.86 \times (18 - 1) \times 180 \times 24 \times (8.55 + 1.2 + 2.25)}{1000000 \times (1.23 + 0.73 + 0.56)} = 0.439 + 0.104 + 0.254 = 0.797 \text{Hkall year}.$$ 

That is in order to maintain the temperature inside the room equal to $18^\circ \text{C}$ during the heating period with an average outside air temperature of $+10^\circ \text{C}$ we theoretically need an amount of heat energy equal to 0.797 Hkall.

Why theoretically? In practice everything is much more complicated.

First, let us remember the location of the heating radiator.

A working device actively heats up the section of the wall located directly behind it. Thus, the temperature of this area is significantly higher than the rest of the wall area and can reach $50^\circ \text{C}$. Instead of using all the warmth to heat the indoor air, the radiator diligently spends warmth to heat the cold bricks of the outer wall of the building [8].

If we assume that a radiator located in the middle of the room or near the internal wall is 100% efficient, then, when located near the outer wall, its efficiency will be 75%, in a window niche it will be 60-65%, when closed with a curtain or false front it is 55-60%.

Therefore, to create a comfortable temperature, we need

$$\Delta Q = 0.797 \times 1.25 = 0.996 \text{Hkall year} \quad (2)$$

Moreover, it is necessary to regulate the heat transfer of the radiator depending on the outside temperature, which during the heating period ranges from $-25^\circ \text{C}$ to $+20^\circ \text{C}$ in our region. Otherwise, with the outside temperature lower than $+1^\circ \text{C}$, the room will be cold and we will have to consume electricity additionally to heat it [9]. With the outside temperature higher than $+1^\circ \text{C}$, the air in the room will be warmer than $+18^\circ \text{C}$, which according to dependence (1) will lead to an overconsumption of thermal energy.

Obviously, it is necessary to provide the regulation of the heat emission of the heating device. Currently, there are many types of automatic heat regulators. Some of them are regulated for the dependence of the radiator temperature on the internal air temperature; others are regulated according to the outside temperature. The most budgetary option is manual regulation by means of a ball valve, which must be carried out when the weather changes.

Thus, if we maintain the temperature of the internal air at $18^\circ \text{C}$ and do not carry out any heat-saving measures, then we will spend 0.996 Hkall a year to heat the room.

As it can be seen from dependence (1), heat losses are made up of three components

$$\Delta Q = \Delta Q_{\text{wall}} + \Delta Q_{\text{nic}} + \Delta Q_{\text{win}} = 0.439 + 0.303 + 0.254 = 0.996 \text{Hkall year} \quad (3)$$

At the same time, it is the heat losses that account for 25% of the heat energy through the niche from dependence (2), which increase the total heat losses due to the location of the radiator in the window niche [10].

In this case, the specific heat losses through a unit area of a particular enclosure structure are:

$$q_{\text{wall}} = 0.439 / 8.55 = 0.0513 \frac{\text{Hkalm}}{\text{m}^2 \text{year}};$$
The greatest value of specific losses is observed through the window-sill niche, in the second place is the window and in the third place is the wall.

The following question immediately arises: why is the specific heat loss through the wall of the niche higher than through the window, if the resistance to heat transfer at the window is lower than at the wall of the niche?

Calculating the heat consumption through the niche wall in the dependence (1), the internal air temperature should be higher than 18°C. Due to the close location of the rear surface of the radiator to the inner side of the niche wall (about 4 - 5 cm) the air temperature between them is close to the temperature of the radiator. This is 55 - 60°C. In turn, the inner surface of the niche wall heats up to almost the same temperature with all the consequences arising from formula (1).

Substituting into (1) \( t_{in} = 50°C \), we get

\[
\Delta Q_{nic} = \frac{0.86*(50-1)*180*24}{100000} * \frac{1.2}{0.73} = 0.299\text{Hkall/year}
\]

The error of the obtained value \( \Delta Q_{nic} \), obtained by the formula (4) in comparison with the same value from (3) is

\[
\frac{0.303 - 0.299}{0.303} * 100% = 1.32%.
\]

If the radiator in the niche is closed with a decorative false front, then the temperature of the internal air in the space between the wall of the niche and the radiator can be equal to the temperature of the radiator surface, that is, not 50°C, but 55 – 60°C. In this case, the value of heat losses through the niche will be 0.360 \( \text{Hkall/year} \). The total losses will increase to 1.027 - 1.053 \( \text{Hkall/year} \).

Thus, the false cover in front of the radiator increases the total consumption of thermal energy spent on heating the room by 2.9 - 5.7%.

3. Results and Discussion

Various heat-saving measures can return 19% or 0.15 \( \text{Hkall/year} \) for useful heating of the room out of 25% of heat energy losses or 0.2 \( \text{Hkall/year} \) due to the location of the heating device in the window sill. The remaining 6% or 0.05 \( \text{Hkall} \), unfortunately, is irreversibly lost. To return them, we must eliminate the niche and make the wall in this place as thick as the main wall, or move the heating device to another place.

4. Conclusion

As the calculations show, removing false fronts during the heating season and installing heat-reflecting screens, we can return from 55-60% to 75% -80% of the efficiency of the use of the radiator.

When laying out the heating system from polypropylene (plastic) pipes, it is not technically difficult to remove the radiators from the niches, pushing them out into the room, while laying the niches with aerated concrete blocks 100 mm thick. The costs will be cheap and the effect is about 10% (provided that a heat-reflecting screen is installed behind the radiator and there is no false front). This will reduce the space of the room and spoil the interior.

The analysis of the obtained results shows that the location of the heater in the room has a significant effect on the heating efficiency of a simple one-room facility. The irrational arrangement of heating devices leads to a loss of up to 40 - 45% of thermal energy.
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