On Influence of the Height of Heated Room on the Heat Transfer of the Heating Device

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Abstract The analysis of the functioning of the heating device in a heated room. The methods of testing the heating device to determine the nominal heat flow in the isothermal test chamber are presented. Presents a methodology of thermal calculation of the heating device for identifying the type of a collapsible radiator and convector, with an area of heating surface for the transmission of heat not less than that required for the heat flux in the room or the number of partitions portable radiator. It is shown that the heat transfer coefficient of the heating device is influenced by the average temperature head, the amount of coolant flowing through it, atmospheric pressure and the method of connecting the device to the heating system. The process of heat transfer from the coolant in the heating device to the heated room is analyzed. A laboratory study was conducted to determine the effect of the height of the heated room on the value of the actual heat flow of the heating device. It is established that the amount of actual heat flow from the heating device depends, among other things, on the space-planning solution of the heated room (the height of the heated room).

1. Introduction

Heating devices are one of the main elements of the heating system designed to supply heat to the serviced premises minus the heat transfer of pipes. The nominal heat flow of heating devices is determined in a non-ventilated isothermal test chamber with cooled internal surfaces, where the specified parameters of the internal environment are provided. The wall at which the tested heater is installed is cooled. For the instrument section of the wall is insulated along the entire length to a height of one meter, with thermal resistance of the insulating layer more than 2 (m20s)/W. There are two methods for determining the nominal heat flow of the heating device, electric and weight [1,2,3,4]. The value of the actual heat flow of the heating device depends on the average temperature head and the amount of coolant flowing through it.

2. Scientific significance of the issue

The nominal heat flow of the tested heating device is determined by the dependence (1):

\[ Q_{\text{nom}} = G(I_1 - I_2) \]  

where:
\( G \) – flow of coolant, \(^0\text{C}\); \( I_1 \) is the enthalpy of the coolant at the entrance to the subject heater at a temperature of \( t_{vs} \); \( I_2 \) – enthalpy of the coolant at the outlet of the test of the heater at a temperature of \( t_{vix} \).

The actual heat flux, adjusted for atmospheric pressure, is defined as
\[
Q = Q_{\text{nom}} \left[ S + (1 - S) f_B \right].
\]
where: \( S \) is the share of heat radiation; \( f_B \) – correction for atmospheric pressure.

Heating devices are one of the main elements of the heating system designed to supply heat in the amount of \( Q_{pr} \), corresponding to the heat loss of the heated room \( Q_{ot} \) minus the heat transfer of \( Q_{tr} \) pipes. Thus, the equality must be respected,
\[
Q_{ot} = Q_{pr} + \beta_u Q_{tr},
\]
where: \( \beta_u \) – coefficient corresponding to the share of useful heat transfer of pipelines laid in the room; \( Q_{pr} \) – the amount of heat released by the heating device; \( Q_{tr} \) – the amount of heat released by vertical and horizontal heat pipes.

The thermal calculation of heating devices consists in determining the type of non-separable radiator and convector, with the area of the heating surface providing heat transfer at least the required heat flow in the room or the number of sections of the collapsible radiator [5-10].

The minimum number of sections of the radiator is determined by the formula
\[
N_{pr} = \left( Q_{ot} - 0.9 Q_{tr} \right) \beta \left[ Q_{\text{nom}} \left( \frac{\Delta t_u}{70} \right)^{1+\alpha} \left( \frac{G}{360} \right)^{\rho} \right].
\]

The type of non-separable radiators or convectors is determined from the condition that the calculated heat transfer of the heating device must be at least the value of the heat consumption of the room:
\[
Q_{pr} \geq Q_{\text{nom}} = \left( Q_{ot} - 0.9 Q_{tr} \right) \beta \left[ \left( \frac{\Delta t_u}{70} \right)^{1+\alpha} \left( \frac{G}{360} \right)^{\rho} \right].
\]

Heat transfer pipes \( Q_{tr} \) is determined by the expression
\[
Q_{tr} = q_v l_v + q_g l_g,
\]
where \( q_v, q_g \) – heat transfer of one meter of vertical and horizontal pipes respectively; \( l_v, l_g \) – length of vertical and horizontal sections of pipes.

The heat transfer of the selected instrument should not be reduced by more than 5% or 60 W compared to \( Q_{pr} \).

The heat transfer coefficient of the heating device is influenced by the average temperature head, the amount of coolant flowing through it, atmospheric pressure and the method of connecting the device to the heating system.

3. **Theoretical part**

Transfer of heat from the coolant in the heated room is through the wall of the heater. The heat flux intensity is characterized by the heat transfer coefficient \( K_{pr} \). The value of the heat transfer coefficient is expressed by the density of the heat flow on the outer surface of the wall related to the temperature difference between the coolant and the air separated by the wall.

The heat transfer coefficient of the heating device is numerically equal to the value inverse to the total resistance of \( R_{pr} \) to the heat flow from the coolant through the wall of the heating device into the room:
\[
K_{pr} = \frac{1}{R_{pr}}.
\]
The value of $R_{pr}$ is composed of the resistance of the heat exchange $R_v$ at the inner surface of the heater, the resistance of the thermal conductivity of the $R_{st}$ wall and the resistance of the heat exchange $R_n$ at the outer surface of the device:

$$R_{pr} = R_v + R_{st} + R_n.$$  \hfill (8)

Heat exchange resistance at the outer surface of the device is equal to:

$$R_n = 1/\alpha_n.$$  \hfill (9)

This coefficient of external heat transfer can be represented by the equality of $t_{com} = t_v = t_R$ as the sum of the coefficients of convective $\alpha_k$ and radiant $\alpha_i$ heat transfer:

$$A_n = \alpha_k + \alpha_i.$$  \hfill (10)

Heat exchange by convection in the free movement of air is due to the temperature head. The coefficient of convective heat transfer is determined from the similarity equation:

$$Nu_{st} = \beta (Gr \cdot Pr) c_{p,n}.$$  \hfill (11)

The average temperature of the boundary layer is taken as the determining temperature

$$t_{st} = 0.5 (\tau_{st} - t_v).$$  \hfill (12)

Heat transfer radiation depends on the material and shape of the heating device, size, temperature on the surface of the heating device, the relative position of the elements of the heating device and the inner surfaces of the heated room fences. The formula (13) can be used to calculate the value of $\alpha_i$ for heaters with a smooth surface:

$$\alpha_i = b_{i,R} C_{prev} \rho_{i,R}.$$  \hfill (13)

A significant influence on the intensity of convective heat transfer at the surface of the vertical fin of the heating device has a mutual direction of heat and air flow.

The above-described form of heat transfer in heating devices takes place at various schemes of movement of water in them. The influence of the direction of propagation of heat and air flows is smoothed as the temperature field on the surface of the heating devices is equalized, and the process of convective heat exchange is intensified.

Based on the above should be repeated in a more general way the conclusion drawn earlier about the predominant influence of the intensity of heat transfer from the outer surface of the heating devices to the heat flux from the coolant in and be of the decisive value of the external convection in the process.

The main factors determining the value of the heat transfer coefficient of the heating device are the design features of the device and its operating conditions.

In the process of operation, the value of the heat transfer coefficient of the heating device is primarily due to the value of the average temperature head and the amount of coolant flowing through it:

$$K_{pr} = f (\Delta t_{st}, G_{pr}).$$  \hfill (14)

The heat transfer coefficient of heating devices is also influenced by other factors: atmospheric pressure, the way the device is connected to the system.

4. Results of experimental studies

The study to determine the effect on the actual heat flow of the heating device of the height of the heated room was carried out in the isothermal test chamber of the laboratory of the Scientific educational center "heat and gas Supply and ventilation" of the National research University of Moscow state construction University.

The layout of the heater at different heights inside the test chamber is shown in Fig. 1. As the results of the experimental study showed, in the room under the ceiling there is a zone of braking of heated air, which, accumulating, gradually goes down, reaches the level at which the heating device is
installed. As a result, the speed of convective flow through the heating device decreases, which leads to a decrease in the convective component of heat transfer from the external surface of the heating device.

![Figure 1. Layout of the heating device inside the test chamber.](image)

The change in the actual heat flow of the heating device, in relative terms \( Q = Q_{\text{fact.}} / Q_{\text{nom.}} \) depending on the relative height of the heated room \( H = h_i / \text{Nom.} \), shown in fig. 2. Where the dependence 1 shows the change in the relative value of the heat flow of the heating device, where the convective component of the heat transfer from the heating device dominates. For the heating device at which domination of the radiant component of heat transfer is observed change of relative size of the actual heat flow of the heating device depending on relative size of the heated room is described by the diagram 2.

![Figure 2. The dependence of the relative value of the actual heat flow of the heating device on the relative value of the heated room: 1-convector; 2-radiator.](image)
5. Conclusions
The amount of actual heat flow from the heating device depends on the average temperature head, the amount of coolant flowing through it, atmospheric pressure, the method of connecting the device to the heating system and the space-planning solution of the heated room (the height of the heated room).

Under a ceiling of the heated premise, in a zone of installation of the heating device, there is a zone of braking of the heated air (an ascending convective stream) which, accumulating, gradually descends, reaching level on which the heating device is established, the speed of movement of the convective stream through the heating device decreases that leads to reduction of a convective component of a heat transfer of the heating device.

The relative value of the heat flow from the outer surface of the heating device, where the convective component of heat transfer dominates, with a decrease in the height of the heated room decreases more intensively than for the heating device, which has a dominance of the radiant component of heat transfer from the outer surface.

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