Thermal conditions of a single-pipe heating system of an apartment block

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Abstract. The heating system is one of the life support systems. The discrepancy between the thermal (temperature) conditions of the living quarters is one of the most urgent complaints of residents of apartment blocks in most regions of the Russian Federation. The object of the study is a single-pipe water heating system of a 14-storey apartment block with an overhead distribution, for which the heat output is determined to compensate for heat losses under various initial conditions (outdoor air temperature and infiltration airflow rate). As a result of the calculation of the thermal conditions, deviations in the indoor air temperature of living quarters from the permissible range are determined. To eliminate violations of the microclimate parameters, this paper considers ways to increase the heat transfer of heating appliances by increasing the area of the heating appliance, as well as increasing the flow rate of the heat-transfer agent passing through the appliance. The results of the calculation of the thermal conditions showed the impossibility of eliminating the violation of the thermal conditions by these methods: depending on the temperature of the outdoor air in the living quarters, there is an excess or lack of heat. To eliminate the thermal and hydraulic disarrangement, a mechanical method for adjusting the heat transfer is proposed by switching off the sections of the heating appliance with an increased number of them. Taking into account the recommendations on the need to ensure that the length of the radiator corresponds to 50-70% of the length of the window opening, this method is functional for use.

1. Introduction
Heating is one of the life support systems. The discrepancy between the thermal (temperature) conditions of the living quarters is one of the most urgent complaints of residents of apartment blocks in most regions of the Russian Federation [1]. A violation of the operation of the heating system is the discrepancy between the internal air temperature and the permissible temperature range: lower values correspond to “insufficient heating”, and higher values correspond to “excessive heating” [2]. These violations lead to an increase in morbidity among the population, as well as overspending of resources. In addition, the historical heritage of the USSR [3], the lack of funds from housing and utility services enterprises for the implementation of energy-saving programs [4], as well as the lack of a mass household culture of energy saving is the reason for high energy costs [5-8]. To reduce them, it is necessary to reconstruct and modernize boiler houses, introduce cogeneration plants [9-12]; eliminate dilapidated heat networks and heat networks in areas of excessive centralization of heat supply and build heat networks using new technologies [13]; increase the thermal protection of buildings [14].

The thermal conditions of the living quarters can be brought into proper condition by correcting the heating systems: structural or regime. In the case of centralized heat supply, the most common
qualitative and quantitative adjustment of heating systems [2]. Qualitative one – in the central (or individual) heating points based on the temperature schedule and quantitative one – directly in front of the heating appliances. However, most single-pipe systems are equipped only with ball valves related to shut-off valves and quantitative regulation by consumers is difficult. Therefore, when complaining about inappropriate thermal conditions, management companies usually resort to the following methods: increasing the flow of heat through the riser or increasing the number of sections of heating appliances.

2. Materials and methods
The object of the study is a single-pipe water heating system of a 14-storey apartment block, with an upper supply of heat-transfer agent. The characteristics of the system and the values of the thermal conditions of the living quarters at different outdoor air temperatures are given in [15], taking into account the unevenness of the incoming air due to infiltration in [16]. As in many rooms there is a decrease in the actual temperature [15-16] of the internal air relative to the calculated value, numerically equal to 20°C, the most popular ways of bringing the thermal conditions to the standard conditions are considered in this paper: an increase in the number of sections of heating appliances and an increase in the flow rate of the heat-transfer agent passing through the heating appliances.

The calculation of the thermal conditions was carried out in accordance with the algorithm presented in [15], according to which the indoor air temperature was determined at various outdoor air temperatures (t\text{ext}): at the temperature of the coldest five-day period for the city of Belgorod -23°C, the temperature corresponding to the beginning of the heating season +8 °C, as well as intermediate values of this range: -20; -10; -5; 0°C.

3. Results and discussion
3.1. Calculation with an increased number of radiator sections
Increasing the number of sections of heating appliances is one of the main ways of unauthorized reconstruction of heating systems by residents of an apartment block. As such an increase is difficult to predict, we change the number of sections in the calculations until the condition is met, under which the length of the radiator must correspond to the length of the window opening by 50-70% [14].

We calculate the actual value of the indoor air temperature for rooms of 1-14 floors at the outdoor air temperature (t\text{ext}) -23;-20;-10;-5;0; and +8 °C, taking into account the change in the number of sections and, as a result, the change in the heat transfer of heating radiators.

The result of the calculation of the internal air temperature, when recalculating the number of sections of heating appliances, is presented in the form of a diagram (fig. 1), which shows the discrepancy between the values of the permissible value of 18-20 °C. So the maximum temperature value is 29.6 °C, which is observed on the 14th floor at an outdoor temperature of -23 °C, and the minimum value of 13.2 °C - on the 2nd floor at t\text{int}=0 and -5 °C.
3.2. Calculation with increased heat-transfer agent consumption

As it is known, in the case of deviation of the indoor microclimate parameters from the comfortable values in accordance with regulatory documents [13], including when the air temperature in the apartment is below +18 °C, the final heat consumer has the right to complain about the provision of services to management companies. The supplier of thermal energy, in order to solve the problem, is forced to take certain measures, one of which is an increase in the flow rate of the heat-transfer agent.

We will calculate the actual air temperature, taking into account the increase in the flow rate of the heat-transfer agent, without increasing the area of the appliances. The flow rate value is increased until the condition is met at an outdoor temperature of more than +18 °C in rooms on all floors at an outdoor temperature of -23...+8 °C, but not more than 2 times relative to the original value (to ensure noiselessness in the system with a riser diameter of d=25 mm, the heat-transfer agent flow rate should not exceed 1600 kg/h [11].

The obtained values of the internal air temperature, °C, are presented in the form of a diagram (fig. 2).
Figure 2. Diagram of the calculated data of the actual indoor air temperature $t_{int}$, °C in rooms from the 1st to the 14th floor inclusive, taking into account the increase in the flow rate of the heat-transfer agent, but without increasing the area of the appliances.

The increase in the heat-transfer agent flow rate in the riser by 2 times did not lead to the achievement of internal air temperatures to the permissible values of $t_{int} > +18$ °C in some rooms. In this case, the minimum value of $t_{int} = 12$ °C according to the diagram (fig. 2) corresponds to the temperature value on the 12th floor at $t_{ext} = 0$ °C.

3.3. Calculation with an increased number of radiator sections and an increased heat-transfer agent flow rate

In order to meet the requirements of [11] $t_{int} = 18 ... 20$ °C in rooms on all floors, we will increase the area of heating appliances according to clause 3.1 and the flow rate of the heat-transfer agent according to clause 3.2. The calculated values of $t_{int}$, °C at $t_{ext} = -23 ... +8$ °C, are displayed using the diagram (fig 3).
Analyzing the final data of calculation 4, we note that the minimum value of $t_{int}=14.1 \, ^\circ C$ (fig. 3) is observed on the 12th floor at $t_{ext}=+8 \, ^\circ C$, and the maximum value of $t_{int}=32.3 \, ^\circ C$ on the 1st floor at $t_{ext}=-23 \, ^\circ C$.

We will determine the number of disconnected sections on each floor at different values of $t_{ext}$, to prevent “excessive heating” in rooms where the $t_{int}$ exceeds 20 °C. To do this, we reduce the number of sections in the formula (18) for the calculation conditions 4 until the parameters $t_{int}=+18...20 \, ^\circ C$. Thus, in a room on the 14th floor, the actual air temperature reaches the required value when 4 sections are turned off, which corresponds to $t_{int}=21 \, ^\circ C$ in the operating conditions of 9 sections out of 13 calculated ones.

3.4. Calculation at the mechanical adjustment of the heat transfer of the radiator

It should be noted that the variation in the number of radiator sections affects the parameter of the average temperature head of the appliance $\Delta t_{rad}$, due to changes in the values of the inlet and outlet temperatures of the heat-transfer agent from the heating appliance. Therefore, it is necessary to recalculate the heat losses $Q$, $W$ and $t_{int} \, ^\circ C$, taking into account the changes in $\Delta t_{rad} \, ^\circ C$ and $K_{rad}$, W/(m²·°C) based on the corresponding calculation formulas 1 ((8); (9); (12); (4); (18)).

The adjusted indicators of $t_{int} \, ^\circ C$ under the conditions of calculation 4, taking into account the disconnection of sections, are expressed in the form of a diagram (fig. 4).
Figure 4. Diagram of the values of the actual air temperature $t_{\text{ext}}$, °C when disconnecting the radiator sections.

Using the data (fig. 4), let us note that the change in the area of the heating appliance due to the overlap of the sections, allows achieving the required value of $t_{\text{int}}$, °C [15] at different values of $t_{\text{ext}}$, °C. In rooms with a $t_{\text{int}} < 18$ °C, it is necessary to adjust the calculation of the required heating area, taking into account the fulfillment of the conditions of the radiator length of 50-70 % of the length of the window opening and changes in the indicators $\Delta t_{\text{rad}}$, °C and $K_{\text{rad}}$, W/(m$^2$·°C).

4. Summary
Based on the calculations, we note that the accuracy of the method of thermal calculation of radiators, in particular, determining their required heating surface area, depends on the thermal and physical properties of both the heat-transfer agent and the heating appliances themselves. Thus, the correspondence of the calculated and real values of the heat transfer of the appliances, in order to design accurately the heating system, requires account of changes in the thermal and physical parameters of the heat-transfer agent and the heating appliance in the conditions of thermal calculation.

The results of the calculations allow stating that comfortable indoor air temperature values can be achieved by changing the number of radiator sections, and the mechanical method of adjusting heating appliances is a promising solution.

5. References
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