The impact of the temperature in the premises on the extent of the radiator's heat flow capacity regulation

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This article provides calculation and analysis of the impact of individual regulation on the convective flow capacity emanating from the heating unit, depending on the value of the temperature on its surface and temperature fluctuation in the room. Recommendations for the effective operation of heating systems are presented.

Keywords: heater, regulation of the heat capacity, convective flow, the temperature on the surface, systems of door-to-door heat consumption metering, energy losses.

I. Introduction

Since modern man spends most of his time indoors, the main task apparently is to control main factors affecting human health condition, i.e. the optimal room microclimate. For premises, during cold season established rules [1] for the values of temperature, humidity and air mobility are reached by heating and ventilation systems. This paper focuses on the radiators as one of the main components of the heating system and the heat source in the room. The amount of heat needed for certain areas is defined by designed conditions and sets the area of the device's heating surface. Meanwhile, it is well known, that these criteria are not always met. During the heating season ambient air is changing, building is occasionally affected by wind and solar radiation and heat releases in the premises are often uneven. Therefore, to maintain the heat mode at a predetermined level, the heat transfer devices must be adjusted during their operation.

Regulation of the radiator's heat flow can be qualitative and quantitative. Qualitative is achieved by changing the temperature of the heating medium, quantitative – by varying the amount of heat medium applied to the radiator. In case of individual automatic regulation the heat transfer's changing can be achieved according to the deviation of the room temperature to a predetermined level, by perturbation, which is created by changes in weather conditions, and combining both methods. However, the use of each one of them meets certain difficulties, for example, regulation by the deviation is inertial because heated buildings have, as a rule, high thermal inertia. As opposed to this method, the method of regulation by the perturbation does not have any inertia - supply of the heat to the heating system changes simultaneously with the temperature of the outdoor air. The diurnal variation of external air temperature is very often to be ten or even more degrees, leading to the dramatic change in the load networks and the source of heat. Underestimation of the thermal inertia of the building will cause fluctuations in air temperature. Disadvantages of both of these methods have led to the development of regulating systems by the perturbation with the correction by the deviation. Unfortunately, due to its high complexity, this method is most feasible only for the group of heating units and in most cases individual adjustment by the "deviation" is selected by the consumers due to its relative cheapness.

Ability to adjust the temperature inside of premises by the residents is provided by faucets that are installed on the radiators, or by flappers if using convectors. In most cases these devices are not available or do not work. By equipping the radiator with automatic controls one can maintain the desired temperature using the amount of necessary heat gain. The cost of such upgrade depends on the design of the heating system. In turn, the design of the control valve is chosen according to the type of water heating system. For example, in two-pipe systems individually controlled valves are required to meet two conditions: they should have high hydraulic resistance and allow installation-adjusting (primary) and operational (secondary) quantitative regulation. These taps are called "dual control" faucets. Regardless of the choice in setting regulation equipment or not, for the effective operation of the system it is essential to make hydraulic linkage, which contributes to energy savings providing the necessary amount of the heating medium.

Recently, as thermoregulators, the greatest spread is received from thermostatic control valves, that operate as proportional regulators functioning without any application of energy, i.e., for the implementation of the adjustment effect it is not needed to run the electrical or a mechanical energy. The principle of its operation is based on the fact that with a fluctuation of the temperature in the room, the changing of the heat irradiation conditions on the temperature-rated sensor occurs and associated with it change in the internal energy of the sensor activates the valve actuator. Thus, sensor reacts to the room temperature, and the thermostat (sensor + coil) compares the measured value with the set value and changes proportionally to the deviation, the degree of valve's closing. Due to this heating medium flow through the radiator is changed, and thus its heat output also does. Thereby, by using quantitative individual automatic regulation, consumers has the ability to change and to maintain the temperature in the room, depending on their needs.

II. The main part

While the temperature inside the room is dropping, thermoregulator is changing the water flow of the heating medium, that is why the temperature on the surface of the radiator is ultimately increased, which in turn changes the power of the thermal radiation, as the temperature in the premises is achieved by the heated convective flow. It is necessary to determine how the change of the heater's temperature will affect the supply capacity of the convective flow.

To track the change in the supplied heat we use the expression for calculating the flow of heated air, m^3/s in the convective flow at the surface of the radiator that was presented by I.A. Shepelev in [2]:

$$L_o = 0{,}3 \cdot F_o \sqrt[3]{\frac{g \cdot Q_o}{c_p \cdot \rho_\infty \cdot T_\infty \cdot \sqrt{F_o}}} \qquad (1)$$

where F_o - an area of the heat source, m^2; $g = 9{,}81\ m/s^2$ - acceleration due to gravity; Q_o - the amount of convective heat liberated by the heat source, KW; here $c_p = 1$ kJ/(kg·K) - specific heat capacity of air at constant pressure; $\rho_\infty = 1{,}2\ kg/m^3$ - density of ambient air ; T_∞ - absolute temperature of the ambient air, K.

Given that the results of many experiments on convective jets are treated not according to the amount of convective heat from the source, Q_o, but as a function of excess temperature on the surface of the heat source $\Delta t_s = t_s$- $-t_\infty$ and the characteristic geometric size of the source, we can express the formula mentioned earlier depending on these variables. It is not difficult to do, because the amount of emitted convective heat, W can be measured this way:

$$Q_o = \alpha \cdot F_o \cdot \Delta t_n \qquad (2)$$

where α - heat transfer coefficient W/($m^2 \cdot {}^oC$) that can be represented as:

$$\alpha = 0{,}135 \cdot \lambda \cdot \left[\frac{g}{\nu \cdot a \cdot (273 + t_{cp})} \right]^{1/3} \Delta t_n^{1/3} \qquad (3)$$

where λ - thermal conductivity, W/(m·°C); ν - kinematic viscosity, m^2/s; a - thermal diffusivity, m^2/s; $t_{av} = (t_s + t_\infty)/2$ - the average air temperature ^oC.

The use of the presented above formulas are recommended by M.I. Grimitlin in [3].

For easier accounting we transform the expression (1), using formulas (2) and (3) to obtain the final expression for calculating the flow of heated air at the surface of the heating device:

$$L_o = 0{,}015 \cdot \sqrt[9]{\frac{g^4 \Delta t_n^4}{\nu \cdot a \cdot T_{cp}}} \cdot \sqrt[3]{\frac{\lambda \cdot F_o^{3,5}}{c_p \cdot \rho_\infty \cdot T_\infty}} \qquad (4)$$

In this paper, living quarters located in Odessa City (Ukraine), area of 30 m^2. Convective losses are replenished by heat emanated from the radiator of area 0,6 m^2. As automatic regulation by the "deviation" is applied, when the room temperature increases from 18 to 22 °C, the thermostatic valve changes the amount of transmitted heating medium and the temperature of the heater's surface is reduced accordingly from 70 °C to 50 °C, 5 °C increments. Some initial and received data is brought together in Table 1.

TABLE 1

t_s, ^oC	t_∞, ^oC	$\nu \cdot 10^{-6}$, m^2/s	$a \cdot 10^{-6}$, m^2/s	λ, W/(m·K)	L_o, m^3/s
70	18	20,02	28,51	0,0296	0,0326
65	19	19,50	27,87	0,0293	0,0309
60	20	18,97	27,22	0,029	0,0291
55	21	18,46	26,49	0,0287	0,0271
50	22	17,95	25,76	0,0283	0,0249

According to the results, consequently to the increase of the room temperature by 4 °C, in response to regulation temperature on the surface is decreased by 28,6 % respectively, and the convective flow stream is reduced by 23,6%, i.e. the rate of the heat capacity change in a way doesn't keep pace with the regulation. This difference is explained by the fact that the heat transfer of the radiator is changed gradually since it has thermal inertia and is cooling more slowly than heating.

On the other hand, if t_∞ alters 1 °C increments, the heat flow will be reduced by 5-10 %, then one can assume that at a constant room temperature value, individual regulation of the heater won't to the considerable extent influence convective flow capacity.

For this calculation, the temperature in the room, is taken according to the standards [1], i.e. t_∞ = 20 °C. The results are displayed in Table 2.

TABLE 2

t_s, ^oC	70	65	60	55	50
L_o, m^3/s	0,0319	0,0305	0,0291	0,0275	0,0257

Analyzing the results, it can be seen that lowering the temperature on the surface of the heating device down to 65 °C, there is a gradual decrease of the heat flux by 4,3%, and with further reduction 5 °C increments to 50°C, this percentage increases up to 7,5 %. It can be assumed that the individual regulation of radiator's heat within its inertia, will reduce consumption without sacrificing comfort of the people in the premises. If the premises are located in the private household such savings can be achieved automatically by the decrease of the pump frequency and consequently decrease in the temperature of the heated flow. However, for owners of the apartments located in the average multi-storied buildings without access either to the boiler or to the pump itself, this method will help to reduce heating costs, provided the apartment is equipped with individual thermal energy meters. Analysis of previously installed systems are presented in [4]. Installing such devices is mandatory under Ukrainian Law, however, due to the lack of material and technical base, their widespread application hasn't been observed.

III. Conclusions

Ensuring optimal microclimate in the premises directly depends on the thermal capacity of the heater and for its effective operation using individual quantitative regulation is recommended. Comparing the rate of the temperature changing in the room and the heat flow from the radiator, it can be concluded that applying such regulation seems to be the optimal one, though not the most efficient choice from the point of view of the consumers.

Received findings suggest that reducing capacity of the heating system, for example, during the day, alternately increasing and decreasing the flow rate, and thus the temperature on the heater's surface consequently, can help to preserve thermal comfort and simultaneously cut energy losses.

References

[1] DBN B.2.6-31: 2006. Teplova izolyatciya budivel [Thermal isolation of buildings].

[2] I.A. Shepelev Aerodinamika vozdushnuh potokov v pomeshenii, [Aerodynamic airflows in the closed areas]. M.: Stroyizdat, 1978, 145 p.

[3] M.I. Grimitlin, Raspredelenie vozduha v pomescheniyah. [The distribution of air in the premises]. M.: Stroyizdat, 1982. 164 p.

[4] V.N. Karpov, Problemu vnedreniya pokvartirnogo ucheta rashoda tepla v sistemah otopleniya [Problems of implementation of individual apartment heat consumption metering in heating systems], AVOK # 4, 2012.