Dependence of the temperature of the beginning of the heating season on the energy efficiency class of the building

M V Svirin*, D M Kosilov, and A S Seminenko

*Department of Heat and Gas Supply and Ventilation, Belgorod State Technological University named after V G Shukhov, Kostyukov St, 46, Belgorod, 308012, Russia

E-mail: svirinmv@ya.ru

Abstract. The heat supply of most Russian cities is provided by centralized sources of thermal energy. During the operation of buildings, the transition period of the year is not given due attention. The transition periods of the year (before and after the heating season) complicate the task of providing thermal comfort in the rooms of residential and community buildings. The paper deals with the problem of microclimate troubles in multistorey residential buildings during transition periods. The purpose of this work is to test the hypothesis that there is a dependency of the temperature of the beginning of the heating season, depending on its energy efficiency class. For the thermal conditions of the rooms, the classical dependences of the thermal balance, technical thermodynamics and the theory of heat and mass transfer are used. On the example of a nine-storey apartment block, a calculation was carried out, as a result of which the rational temperature of the beginning of the heating season for various energy efficiency classes was determined, as well as the internal air temperature at the outdoor air temperature equal to 8°C (the existing value of the temperature of the beginning and end of the heating season). The results obtained confirm the hypothesis of the study that there is a dependency of the rational temperature of the beginning of the heating season for a particular building, depending on its energy efficiency class. At the temperature of the beginning of the heating season, the internal air temperature of 20°C will be achievable with a deviation of -41.182%, which corresponds to energy efficiency class A (excluding heat gain from solar radiation). It is established that at the current temperature of the beginning of the heating season, the internal air temperature of 20°C will be achievable with a deviation of -41.182%, which corresponds to energy efficiency class A, for buildings of a lower class, the temperature of the beginning of the heating season is not optimal.

1. Introduction

Certain parameters of the microclimate must be maintained in the rooms: the temperature of the internal air, the relative humidity of the internal air, the speed of air movement, the normalized temperature difference between the temperature of the internal air and the temperature of the internal surface of the enclosing structure, the resulting room temperature; local asymmetry of the resulting temperature [1, 2]. During the year, people spend from 12 to 24 hours daily in living quarters, so the parameters of the microclimate with prolonged and systematic exposure to a person should ensure a normal thermal state of the body with minimal stress on the mechanisms of thermoregulation and a sense of comfort in at least 80% of people who are in the room [1, 2].

The heat supply of most cities is provided from centralized sources of thermal energy. At the same time, it is assumed that there is a directly proportional relationship between the size of the city, the
degree of comfort of the population, and the capacity of the centralized heat supply system, so in most large cities, 70-95% of the housing stock is provided with centralized heat supply [3].

When designing heating systems, the characteristics of the climatic period are important, as a rule, the following are distinguished:

– heating season of the year. It is characterized by the operation of the heating system at an average daily outdoor temperature below 10 or 8°C, depending on the type of building (according to GOST R 51617-2000 “Housing and utility services. General technical conditions”);
– the transition period of the year – spring. It is characterized by climate warming. The duration of the period – from the time of switching off the heating system of the building to the equalization of the outdoor and indoor air temperatures;
– the transition period of the year – autumn. It is characterized by climatic cooling. The duration of the period – from the equality of the outdoor and indoor air temperatures to the switching on the heating system of the building.

During the operation of buildings, the transition period of the year is not given due attention. According to GOST RF “Housing and utility services. General technical conditions” the minimum average daily temperature in living quarters after the beginning of the heating season should be in the range of 18-20°C. Yu.V. Kononovich’s research [4] showed comfortable conditions with permissible deviations $t_{mn} = 20 \pm 1.7°C$. SNiP 23-02-2003 also sets the amplitude of the resulting room temperature fluctuation for the cold period of the year for central heating $A_{R} = 1.5°C$ [5]. Approximately the same deviations of air temperature $\pm(1-2)$ °C are given in SNiP 41-01-2003 and SP 41-101-95 [6, 7]. In the off-season, the heating is switched on at an average daily temperature of 8°C or lower, for at least 5 consecutive days. Switching off, respectively, will occur when the temperature is set to 8°C or higher. During the transition period of the year, the comfort of the rooms is most dependent on the outdoor weather conditions, as the domestic heat supply practically does not change. A significant part of its time, the human thermoregulation system, most often due to supercooling, is in tension [8, 9].

According to SNiP 41-01-2003 “Heating, ventilation, air conditioning”, the consumption of heat energy for heating depends on heat losses through the external fences of buildings, heat losses with infiltrating air, internal heat emissions [6]. If there is a lack or excess of thermal energy, the consumer can independently regulate the temperature inside the premises by changing the infiltration component or additional internal heat emissions [10, 11].

The heat storage and heat protection capabilities of buildings and rooms may not be sufficient to prevent a decrease in the internal air temperature. In this case, the comfort conditions will not be met in the rooms: the actual parameters of the internal air differ from the normed with SNiP and sanitary standards, which forces consumers to voluntarily interfere with the operation of heat supply systems, using various mechanisms for compensating for insufficient heating at heat sources [12, 13].

The aim of this work is to test the hypothesis that there is a dependency of the rational temperature of the beginning of the heating season for a particular building, depending on its energy efficiency class.

2. Materials and methods
The object of research is a multi-storey residential building located at the address: Russia, Belgorod region, Belgorod, Boulevard of the First Salyut, 1. According to the GIS Utilities Sector[14], the building is a nine-storey apartment block of the 91-014 series, built in 1977. The choice is due to the sufficient prevalence of this type of multi-storey buildings in the Belgorod region and neighboring regions.

To calculate the indoor temperature, the dependences between the heat capacities of the air, the heated volume, the considered time interval, and the dynamically changing amounts of heat energy input and consumption are used [15]. The dynamics of changes in the air temperature inside the object under consideration can be studied using the following formula:
where $t_{i+1}$ – indoor temperature at the next time point, °C; $c_{air}$ – specific heat capacity of air, kJ/m$^3$·K; $V_{heat}$ – heated volume of the building, m$^3$; $t_i$ – indoor temperature at the previous time, °C; $\Delta t$ – time step, sec.; $Q_{vent}$ – heat loss through ventilation, kW; $Q_{attic}$ – heat loss through the attic floor, kW; $Q_{basem}$ – heat loss through the basement, kW; $Q_{wind}$ – heat loss through windows, kW; $Q_{wall}$ – heat loss through walls, kW; $Q_{in}$ – heat input from the heat supply system of the building, kW.

According to the Order “On approval of the rules for determining the energy efficiency class of apartment buildings” dated 6.06.2016 No. 399/pr (hereinafter referred to as Order No. 399), the energy efficiency class is defined as the value of the deviation of the actual specific annual consumption of energy resources from the base level, measured in percentage (Table 1).

### Table 1. Energy efficiency classes.

| Designation of energy efficiency class | Name of the energy efficiency class | The value of the deviation of the actual specific annual consumption of energy resources from the base level, % |
|--------------------------------------|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| A++                                  | Highest                            | -60 inclusive and less than                                                                                            |
| A+                                   | Highest                            | from -50 inclusive to -60                                                                                             |
| A                                    | Very high                          | from -40 inclusive to -50                                                                                             |
| B                                    | High                               | from -30 inclusive to -40                                                                                             |
| C                                    | Increased                          | from -15 inclusive to -30                                                                                             |
| D                                    | Standard                           | from 0 inclusive to -15                                                                                               |
| E                                    | Lowered                            | from +25 inclusive to 0                                                                                               |
| F                                    | Low                                | from +50 inclusive to +25                                                                                             |
| G                                    | Very low                           | more than +50                                                                                                          |

### 3. Results and discussions

The document also specifies the basic level of the specific annual consumption of energy resources in an apartment block, with which the actual specific annual consumption should be compared. The calculation of the required indicator for an apartment block of the required number of floors and the heating degree day (HDD) of the heating period (for Belgorod it is 4182.9 °C·day) according to the Order was performed by linear interpolation by the number of floors and HDD (Table 2).

### Table 2. Specific heat consumption for heating and ventilation.

| °C·day of heating season | Number of floors of an apartment block |
|--------------------------|----------------------------------------|
|                          | 8 floor | 10 floor | 9 fl. (obtained by linear interpolation) |
| 4000                     | 84      | 80       | 82                                   |
| 5000                     | 106     | 100      | 103                                  |

For the object of study and the climatic conditions of Belgorod region, a specific indicator equal to 85.8409 kWh/m$^2$ was obtained.

The calculation was carried out according to the initial data recommended by Order No. 399 (the indoor air temperature in the apartments is 20 °C, the occupancy of 20 m$^2$ of the total area of the room...
per inhabitant, which corresponds to the standard air exchange of 30 m$^3$/h per inhabitant and the specific domestic internal heat supply of 17 W/m$^2$ of the total area).

For further calculation, we will assign the designation of the energy efficiency class the minimum value of the deviation of the actual specific annual consumption of energy resources from the base level within the limits set by Order No. 399 (A++=-60%, A+=-50%, etc. according to Table 1).

The calculation was carried out in the Microsoft Excel environment by selecting the specified value of the deviation of the value of the actual specific annual consumption of energy resources from the base level, changing the value of the thermal conductivity of the material of the external enclosing structure.

For buildings of different energy efficiency classes, the specified deviation from the value of the actual specific annual consumption of energy resources from the base level (Table 1), the calculation results are given in Table 3: the indoor air temperatures of the living quarters at an outdoor temperature of 8°C (the existing value of the temperature of the beginning and end of the heating season), as well as the outdoor air temperatures corresponding to the rational value of the beginning of the heating season are determined, at which the internal air temperature in the absence of heating will be equal to 20°C (the minimum value of the optimal temperature range for living quarters).

**Table 3.** The dependence of the internal air temperature and the temperature of the beginning of the heating season on the deviation of the value of the actual specific annual consumption of energy resources from the base level.

| Designation of energy efficiency class | Deviation, % | Internal air temperature, °C | Temperature of the beginning of the heating season, °C |
|---------------------------------------|-------------|-------------------------------|------------------------------------------------------|
| A++                                   | -60         | 22.03                         | 5.97                                                 |
| A+                                    | -50         | 20.87                         | 7.13                                                 |
| A                                     | -40         | 19.89                         | 8.11                                                 |
| B                                     | -30         | 19.05                         | 8.95                                                 |
| C                                     | -15         | 17.99                         | 10.01                                                |
| D                                     | 0           | 17.12                         | 10.88                                                |
| E                                     | 25          | 15.95                         | 12.05                                                |
| F                                     | 50          | 15.06                         | 12.94                                                |

Figure 2 shows the graphical dependence of the internal air temperature and the temperature of the beginning of the heating season on the deviation of the actual specific annual consumption of energy resources from the base level.
Figure 1. The dependence of the internal air temperature and the rational value of the temperature of the beginning of the heating season on the value of the deviation of the actual specific annual consumption of energy resources from the base level.

4. Summary
According to the Decree of the Government of the Russian Federation of 06.05.2011 No. 354 (ed. of 02.03.2021) “On the provision of utility services to owners and users of rooms in apartment blocks and residential buildings”, the heating season “must begin no later than and end no earlier than the day following the day of the end of the 5-day period, during which, respectively, the average daily outdoor temperature is below 8 degrees Celsius or the average daily outdoor temperature is above 8 degrees Celsius”.

The results obtained confirm the hypothesis of the study that there is a relationship between the rational temperature of the beginning of the heating season for a particular building, depending on its energy efficiency class, so the temperature specified in the Resolution of the beginning of the heating season is not always enough to ensure a comfortable indoor air temperature for residents of apartment blocks.

At the start temperature of the heating season set by the Decree, the indoor air temperature of 20°C will be achievable with a deviation of -41.182% (which corresponds to energy efficiency class A). For multi-storey buildings of a lower class, the temperature at the beginning of the heating season is not optimal.

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