# Contents

# INTRODUCTION

The use of microclimate control systems is essential for life in civil buildings, as well as for the technological processes in industrial buildings. In a civil building, internal systems such as heating, ventilation, air conditioning systems allow to provide comfortable conditions for human stay, excluding the negative impact of various factors on human health.

At the stage of construction justification it is necessary to determine the approximate construction of the building and preliminary selection of technical solutions of engineering systems. The design of engineering systems should be carried out by a specialist in the field, and, as a rule, as part of a working group, an organization with experience and ability to make technical decisions.

The educational and methodical manual consider the regulations for the selection of engineering solutions in the field of heating, ventilation and air conditioning systems. Provided recommendations and rules of course work, the purpose of which – acquaintance with typical solutions of engineering systems of heating and ventilation, as well as learning to make calculations to take engineering decisions.

In the course work is tasked to develop optimal solutions for heating, ventilation and air conditioning systems of a public building in a given city set by the professor. The design is based on current regulations and the architectural basis is represented by plans provided by the department.

# 1. THERMAL PROTECTION OF BUILDINGS

The initial data for designing thermal protection of a building and heating and ventilation systems are:

– purpose of the facility;

– area of construction of the facility;

– architecture of the building and composition of the interior spaces;

– parameters of existing networks to which the facility is to be connected.

As part of the coursework, the student is given a standard plan of a public building as well as the construction area as initial data.

In this section, a description of the object and the choice of thermal protection of the building necessary for calculating the thermal loads on the heating system are compiled.

## 1.1. Description of the object

The building, within which engineering decisions will be made, is public. The initial data includes a plan of a typical floor of the building with an explication of the premises. Examples of calculations for the course work in this educational and methodical manual will be given for the building, the plans of which are shown in Fig. 1.1. This is a two-story building of the central library for 50 thousand storage units in the city of Irkutsk with the orientation of the main facade (along axis 6) to the North. The building has a flat roof without an attic and an unheated basement under the entire building. Along axis 6 on the 2nd floor there is a long balcony 14 m long with one balcony door.

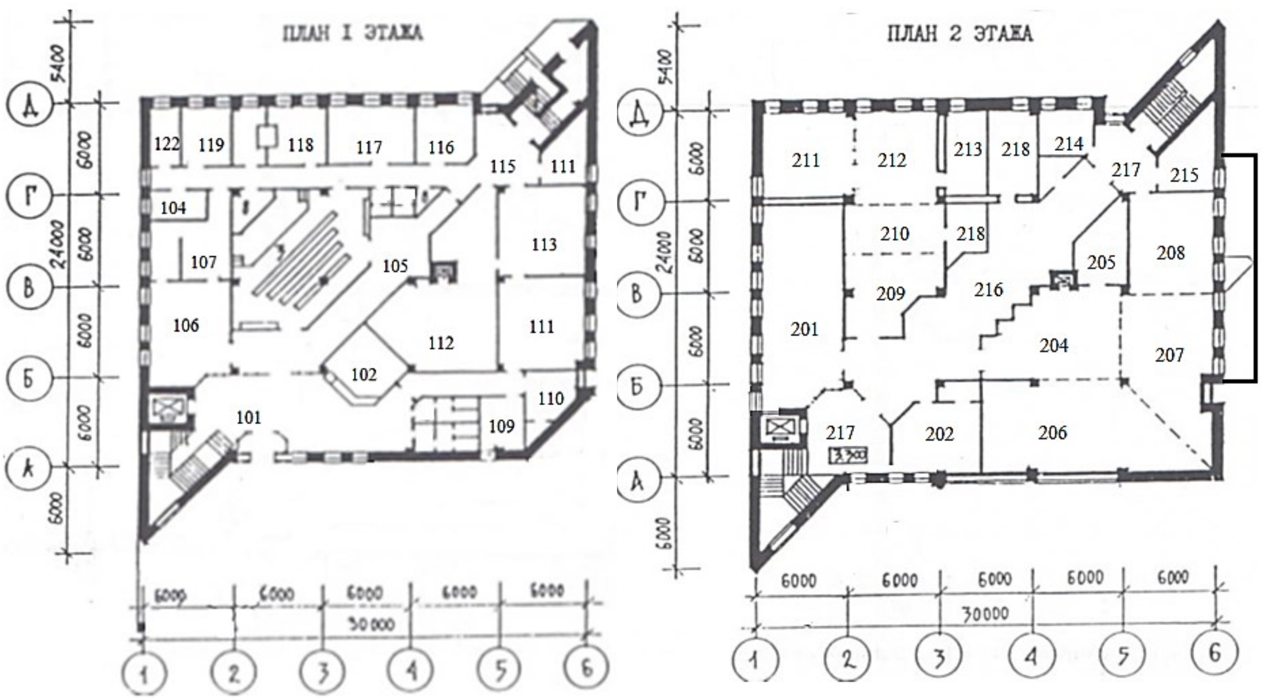


Fig. 1.1. Floor plans of the designed building

## 1.2. Basic requirements for the design of thermal protection of a building

When designing a building in accordance with SP 50.13330.2024 “Thermal performance of the buildings” [1], the following requirements must be taken into account:

– reduced heat-transfer resistance of all external enclosing structures (in the course work, these resistances are always assumed to be equal to the required values for energy saving);

– specific heat-protective characteristics;

– limiting the minimum temperature and preventing moisture condensation on the inner surface of enclosing structures with the exception of windows (in the course work, compliance with this requirement is not checked);

– air permeability of the external wall (in the course work, compliance with this requirement is not checked);

– moisture state of the external wall (in the course work, compliance with this requirement is not checked).

Thus, the heat engineering calculation of the enclosing structure is the basis for choosing the thermal protection of the building, ensuring the elemental requirements for the reduced resistance to heat transfer of each external enclosing structure, limiting the minimum temperature and preventing moisture condensation on the internal surface of the enclosing structures. The specific heat protection characteristic of the building is a complex indicator of the adequacy of the thermal protection of the totality of all external enclosing structures.

## 1.3. Internal and external conditions of the heating period

Calculated indoor air temperature during the heating season of the year ($t_{in}$), °C, adopted:

– when calculating the enclosing structures of groups of buildings specified in Table 3 of SP 50.13330.2024 “Thermal performance of the buildings” [1] for positions 1 and 2 – according to the minimum values of the optimal temperature of buildings in accordance with the classification of premises according to GOST 30494-2011 “Residential and public buildings. Microclimate parameters for indoor enclosures” [2]. For the heat engineering calculation of external enclosing structures according to Section 3 [2], the main premises of the library belong to the 2nd category: premises in which people are engaged in mental work. According to paragraph 5.2 [1], the minimum value from the optimal temperature range according to Table 3 [2] is taken as the calculated indoor air temperature for premises of the 2nd category, i.e. $t_{in}$ = 19 °C;

– when calculating heat loads on heating and ventilation systems in accordance with Appendix G SP 60.13330.2020 “Heating, ventilation and air conditioning” [3] for residential buildings, as well as when air conditioning public and administrative buildings – according to the minimum values of the optimal temperature of buildings in accordance with the classification of premises according to GOST 30494-2011 “Residential and public buildings. Microclimate parameters for indoor enclosures” [2], in the absence of air conditioning in public and administrative buildings – according to the minimum values of the permissible temperature of buildings in accordance with the classification of premises according to GOST 30494-2011 “Residential and public buildings. Microclimate parameters for indoor enclosures” [2]. For a library, the minimum temperature from the permissible range of indoor air temperature according to [2] is equal to $t_{in}$ = 18 °C.

The relative humidity of indoor air in accordance with clause 5.7 [1] in heat engineering calculations for a public building is taken to be equal to $\varphi_{in}$ = 50 %.

External conditions of the cold period of the year are determined according to SP 131.13330.2020 “Building climatology” [4] for the construction area:

$t_{in}$ – the calculated temperature of the outside air of the room during the cold period of the year, °C, taken as equal to the average temperature of the coldest five-day period with a probability of 0.92, that is, for the city of Irkutsk according to table 3.1 [4] is equal to $t_{in}$ = –33 °C.

$t_{hp}$, $z_{hp}$ – average outside air temperature, °C, and duration, day/year, of the heating period, adopted according to SP 131.13330.2020 "Building climatology" [4] for residential and public buildings for the period with an average daily temperature of no more than 8 °C, and when designing medical and preventive, children's institutions and nursing homes for the elderly no more than 10 °C.

In accordance with paragraph 5.2 [1], the boundary of the heating period in a public building is the average daily outside air temperature of +8 °C. For the city of Irkutsk, according to Table 3.1 [4], the average temperature of the heating period is $t_{hp}$ = –7.1 °C, and its duration is $z_{hp}$ = 230 days.

## 1.4. Calculation of required heat transfer resistance of external enclosing structures

According to the requirements of paragraph 5.2 [1], the required heat transfer resistance of all enclosing structures of public buildings, except for the entrance doors to the building, lies between the basic values and the standardized ones. The basic values for all external enclosing structures of the library building are determined according to Table 3 [1]. They depend on the number of degree-days of the heating period (*HDHP*), °C.day, which is calculated using formula (5.2) [1]:

$$HDHP = (t_{in} - t_{hp})\, z_{hp}, \tag{1.1}$$

where $t_{in}$, $t_{hp}$, $z_{hp}$ – the same as in section 1.3,

$$HDHP = [19 - (-7.1)]\ 230 = 6003\ °C \cdot \text{day}.$$

### 1.4.1. Calculation of basic heat transfer resistances of external enclosing structures

For the library building, the values of the basic heat transfer resistances are taken from Table 3 [1] depending on the functional purpose of the building, the degree-days of the heating period of the *HDHP* and the purpose of the enclosing structure. The basic values of heat transfer resistance are given in Table 3 [1] for *HDHP* values through 2000 °C·day/year. The actual value of the basic heat transfer resistance of the enclosing structures should be determined by interpolation between the table values. For massive enclosures of the library building, interpolation can be performed using the coefficients a and b given in Table 3 [1] for public buildings of group 2:

– for external walls: $R_o^{bas} = a \cdot HDHP + b = 0.0003 \cdot 6003 + 1.2 = 3.06$ m$^2 \cdot$°C/W;

– for coatings: $R_o^{bas} = 3.4$ m$^2 \cdot$°C/W;

– for covering over an unheated basement: $R_o^{bas} = 2.7$ m$^2 \cdot$°C/W;

– for windows, the value of the basic heat transfer resistance is calculated by interpolation between the values specified in Table 3 [1], for the *HDHP* below and above the actual *HDHP* value:

$R_o^{bas} = R_o^{bas}(6000) + [R_o^{bas}(8000) - R_o^{bas}(6000)] \cdot [HDHP - 6000]/2000 = 0.73 + (0.75 - 0.73) \cdot$ $\cdot (6003 - 6000)/2000 = 0.73$ m$^2 \cdot$°C/W.

The basic heat transfer resistance for entrance doors to the building in Table 3 [1] is not standardized.

For entrance doors to a building, in accordance with clause 5.2 of SP 50.13330.2012 "Thermal protection of buildings" [1], the standardized heat transfer resistance must be no less than $0.6 \cdot R_o^{norm}$ of the building walls, determined by formula (5.4) [1], related to sanitary and hygienic requirements:

$$R_o^{norm} = \frac{t_{in} - t_{out}}{\Delta t^{norm} \cdot \alpha_{in}}, \tag{1.2}$$

where $t_{in}$, $t_{out}$ – same as in paragraph 1.1;

$\Delta t^{norm}$ – the standardized temperature difference between the temperature of the internal air $t_{in}$ and the temperature of the internal surface of the external wall $\tau_{in}$, °C, taken according to Table 5 of SP 50.13330.2012 "Thermal protection of buildings" [1]. For public buildings, according to position 2, it is equal to $\Delta t^{norm}$ = 4.5 °C;

$\alpha_{in}$ – heat transfer coefficient of the internal surface of the enclosing structure, W/(m$^2 \cdot$°C), taken according to Table 4 of SP 50.13330.2012 "Thermal protection of buildings" [1], for walls, equal to 8.7 W/(m$^2 \cdot$°C).

The standardized heat transfer resistance of the entrance doors to the library building is equal to:

$$R_0^{norm} = 0.6 \frac{19 - (-33)}{4.5 \cdot 8.7} = 0.797 \text{ m}^2 \cdot \text{°C/W}.$$

## 1.5. Calculation of the specific thermal protection characteristics of the library building

The specific heat-protective characteristic of a building $k_{shell}$, W/(m$^3 \cdot$°C), is an indicator of a complex requirement for the thermal performance of a building. In accordance with paragraph 3.31 of Section 3 "Terms and Definitions" [1], the specific heat-protective characteristic of a building is the amount of heat equal to the loss of thermal energy through the heat-protective shell of a building per unit of heated volume per unit of time with a temperature difference of 1 °C. It is determined by formula (Zh. 1) [1]:

$$k_{shell} = \frac{1}{V_{heat}} \sum \left( n_{t,i} \frac{A_{f,i}}{R_{o,i}^r} \right) = K_{komp} \, K_{overall}, \quad (1.3)$$

where $R_{o,i}^r$ – reduced heat transfer resistance of the $i$-th external enclosing structure of the building, m$^2$·°C/W, taken equal to the required heat transfer resistance for all external enclosing structures;

$A_{f,i}$ – area of external enclosing structures: external wall 799.44 m$^2$, roof 756 m$^2$, ceiling above the basement 756 m$^2$, windows 163.75 m$^2$, entrance door to the building 3.77 m$^2$;

$V_{heat}$ – heated volume of the building, m$^3$, equal to 5329.8 m$^3$;

$n_{t,i}$ – coefficient taking into account the difference between the internal and external temperatures of the structure from those adopted in the calculation of the *HDHP*; in the example for all enclosing structures, except for the ceiling over the unheated basement, $n_{t,i}$ = 1 is taken. In the basement, in accordance with paragraph 9 [5], the internal air temperature is taken to be equal to $t_{heat}^*$ = 2 °C, not less than which it should be (in real projects, this temperature should be checked against the heat balance of the basement). Then, according to formula (5.3) [1], the coefficient of the position of the ceiling relative to the external air is equal to:

$$n_t = \frac{t_{in} - t_{heat}^*}{t_{in} - t_{out}}, \quad (1.4)$$

$$n_t = \frac{19 - 2}{19 - (-7.1)} = 0.651.$$

$K_{komp}$ – building compactness coefficient, determined by the formula (Zh. 3) [1]:

$$K_{komp} = \frac{A_{out}^{sum}}{V_{heat}}, \quad (1.5)$$

$A_{out}^{sum}$ – the sum of the areas (according to internal measurements) of all external enclosures of the thermal protective shell of the building, m$^2$, in the example under consideration $A_{out}^{sum}$ = 799.44 + + 756 + 756 + 163.75 + 3.77 = 2478.96 m$^2$.

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