

## Calculation method of heat consumption for buildings life support systems

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**Abstract.** The methodology used for calculating annual values of heat consumption four life supporting systems of buildings: heating, mechanical ventilation; air-conditioning and hot water system. It has become an actual issue. Currently, the last two engineering systems in the regulations either not considered at all or are divided on various departmental standards and different from each other. This leads to the fragmentation and incorrect reporting of information at different levels. Therefore, it was necessary to create a uniform technique of calculation of heat consumption for all four systems in the classic concepts which developed by previous generations of researchers. The classic concept of specific heat characteristics of the building, shows specific capacity of the heating system, the author applied to three other life-supporting systems that consume heat power. The result formed a logical chain of calculation formulas. In the suggested method first of all it determines annual unit costs of heat energy for each of these systems. This procedure uses "specific heat characteristics of the building." This and other values apply to 1 m<sup>3</sup> of building volume of the building to the volume counted according to his measurements from the outside heat-transfer surfaces. Also, it introduced the average ratio of the daily load of the system. Because of the fact that the value of specific consumption of heat in this systems in the suggested method has the property of additivity, it is possible to correctly identify a single specific indicator of heat for all life-supporting systems of the building. The final step is the determination of the absolute total heat consumption for the four systems for this building for a year. This is done by simply multiplying the specific heat consumption of the building volume to the outside measurement. Moreover, the same result can be obtained as the sum of the individual systems and by finding and applying the combined specific energy consumption for the building in general. The advantage of the obtained results consists in a universal method to the calculation of heat consumption of the various life support systems which emanating from the development of the classical method V. M. Chaplin's modern construction. It is recommended to use these results in the academic and design practice and as a theoretical base in developing standards. Besides, it will allow us to find reserves for energy saving and the sequence of their implementation. The method is also open to development, so it can be complement in a similar way with the values of new building systems. For example, a central dust cleaning systems.

**Keywords:** the annual heat consumption; life support systems of buildings; specific heat characteristics of the building; heat consumption of systems in buildings; specific heat consumption; the building volume by outside measurement; the classical meaning.



## Introduction

Annual heat consumption of the building is necessary for the following main purposes:

1. The calculation of fuel which consumed in the heat generating units;
2. Improvement and optimization the thermal performance of external building envelope in national climatic and economic requirements;
3. Identification of priority measures to improve technical and economic indicators of thermal engineering equipment and life-support systems of buildings;
4. Preparation of energy passport for each building with finding its nominal value (class) of performance;
5. The development of heat-and-power balances in different levels.

Calculations of heat consumption in buildings has been done by scientists which worked since the inception of heating systems and continue it in our days with the development and increasing complexity of engineering equipment in buildings, with a corresponding change in their construction and technical maintenance.

At each stage of development, scientists have created their own methods of calculating the heat consumption of buildings and individual systems with climatic conditions and definition of objectives requirements. So from the second half of the 19th and early 20th centuries in Russia with “Imperial Moscow higher technical school” (IMHTS)\* worked “Heat Committee”, which consisted of important scientists, whose task was to develop recommendations to ensure the country's fuel on the basis of balance of heat consumption, heat generation and fuel resource base.

In the above-mentioned “Heat Committee” was part of an outstanding scientist and engineer, Professor IMHTS K. V. Kirsch [1]. In the works of K. V. Kirsch participated and continued them his disciples who later became a famous Professors L. K. Ramzin and M. M. Shchegolev [1,2].

Already at that time it was offered a relatively simple, but in some ways different from other engineering techniques, which are further developed separately and in part of calculation of fuel consumption generators [1-4], heating systems (GOST 54860-2011), and the optimization of heat-insulating properties in the building envelope [5-9], and the efficiency of equipment and systems for heating, mechanical ventilation, air-conditioning and hot water systems [7-15].

This is reflected in the number of legal documents according to departmental affiliation and scientific statement of the developers (SP. 118.13330.2012, SP 50.13330.2012, SP 60.13330.2012 allowance of 9.9 (SNiP 2.04.05.91 and others)). However, they were not always coordinated. Some documents have failed to avoid contradictions and even incorrect positions.

The main of them is the choice of the boundaries consideration [16], which should remain unchanged main subject of assignment – the building in general which has built in some of the boundaries in the environment. Here are revealed two contradictions: 1) Instead of using the outside volume of the building, it has to be used the inside volume of its each premises (which called heated volume) in calculating of building heat power performance in general.

2) Unjustified reductions necessary and sufficient set of life-support systems, consume thermal energy. Discussion is also in used (in the article [17] and in SP 50.13330.2012) terminology. Developments of previous generations of researchers [5-11,15], SNiP 2.3.79 etc. convinced of the scientific validity, physical objectivity and in general at the classical nature of concepts and terms V. M. Chaplins about the specific heat characteristics of the building. The key of this concept and its development the author of this work has been formulated and applied a method of calculating “specific thermal characteristics of the building” [“specific power”] not for the one as it was before but for all four heat consumption life-support systems of buildings [18,19].

The author in his research articles protects of the that necessary structure which consist of the four systems since 2002 (Academic readings RAASN 2002 y, col. reports, ed. NIISF, publishing “Building expert” 2002 No. 12,13,16; [18])

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After the order of the Ministry of construction of Russia №399 from 06.06.2016 it has become required. In the article [20] provides information about the positive results of that action. But it doesn't have too much specific methodological study. The following is a continuation of the methodical research of the author has already applied to the annual consumption of heat, which is universal for all heat consumption systems.

### The method of calculation of the annual heat consumption

The beginning of the calculating is the calculation of the annual specific consumption of heat energy (ASC) for each of the four systems. It is displayed using the subscript "ASC" in the formulas. In calculations it has been used the values of the specific thermal characteristics of buildings (specific heat power) for all the considered systems [18]. But each of them will need to use the normalizing functions and the factors which includes seasonal (climatic) daily (technological) variation of their work.

#### Heating system

$$q_{ASR}^h = 0,024 \cdot DDHP \cdot K_o \cdot q_h^d, KWh / m^3 \cdot year; \quad (1)$$

Where: 0,024 - conversion coefficient for days to hours and watts to kilowatts (often used in the literature on thermal physics of buildings, works, V. G. Gagarin, etc.);

DDHP – degree-days of the heating period;

$K_o$  - average coefficient of the daily load of the heating system, with the average number of working hours of the heating system in a day (no)

$$K_o = \frac{n_o}{24}; \quad (2)$$

$q_h^d$  - specific heat characteristics of the building in a design mode for heating system (specific heat capacity of the heating system),  $W / m^3 \cdot ^\circ C$ ;

#### Mechanical ventilation systems

The calculated value of specific consumption of heat building ventilation during winter period (annual, in contrast to energy costs):

$$q_{ASR}^v = 0,024 \cdot DDHP \cdot K_v^a \cdot q_v^d, KWh / m^3 \cdot year; \quad (3)$$

Where:  $K_v^a$  – coefficient taking into account the shift work systems of mechanical ventilation with heat consumption over the year, we Express the average number of hours per day  $n_v$  (determined by technological requirements of the legal document on the design of buildings of this type).

$$K_v^a = \frac{n_v}{24}; \quad (4)$$

#### The air conditioning system

Calculated value of annual specific heat consumption in the building by the air conditioning system is defined as the average number of the sum of winter and summer used heat:

$$q_{ASR}^{ac} = q_{ASR}^{ac.w} \cdot K_{ac}^w + q_{ASR}^{ac.s} \cdot K_{ac}^s, KWh / m^3 \cdot year; \quad (5)$$

$$K_{ac}^w = \frac{n_{ac}^w}{24}; \quad (6)$$

and

$$K_{ac}^s = \frac{n_{ac}^s}{24}; \quad (7)$$

$K_{ac}^w$  and  $K_{ac}^s$  - the coefficients of daily load of air conditioning in summer and winter, depending on the number of hours of consumption per day, respectively, meaning that as the technological requirements and climatic conditions.

$$q_{ASR}^{ac.w} = 0,024 \cdot DDHP \cdot K_{ac}^w \cdot q_{ac}^{d.w}, KWh / m^3 \cdot year; \quad (Winter) \quad (8)$$

and

$$q_{ASR}^{ac.s} = 0,024 \cdot (t_i - t_o) \cdot z_{s.p} \cdot K_{ac}^s \cdot q_{ac}^{d.s}, KWh / m^3 \cdot year; \quad (Summer) \quad (9)$$

Here:  $Z_{s.p.}$  – the number of days in the summer season;

$$Z_{s.p.} = 365 - Z_{h.p.}; \quad (10)$$

Where:  $Z_{h.p.}$  – the number of days in the heating season (“winter”);

$(t_i - t_o)$  the temperature potential of the “second heating” (temperature difference of the air flow on the inflow  $t_i$  and after the evaporator  $t_o$ , °C) [18]. The magnitude of this difference a small change in air temperature affects slightly.

$q_{ac}^{d.w.}$  and  $q_{ac}^{d.s.}$  – specific heat characteristics of the building for air conditioning systems for winter and summer modes,  $W / m^3 \cdot ^\circ C$

In General, the “second heating” is the technological needs of the air conditioner, and most importantly the impact it has relatively stable temperature and humidity parameters of the air after cooling and drying.

However, the temperature and humidity of the outside air, of course, affect the capacity of the refrigeration unit, which should be reflected in the calculation of the energy consumption of the air conditioner.

It is also necessary in calculations and when programming, note that the expression  $q_{ac}^{d.w.}$  and  $q_{ac}^{d.s.}$  represent fractions with different denominators [18]

### Hot water system

Calculated value of annual specific heat consumption in the building on hot water system

$$q_{ASR}^{hws} = q_{ASR}^{hws.w.} \cdot K_{hws}^w + q_{ASR}^{hws.s.} \cdot K_{hws}^s, KWh / m^3 \cdot year; \quad (11)$$

Where:  $K_{hw}^w$  and  $K_{hw}^s$  – normalizing the coefficients, the average heat consumption in hot water systems for winter and summer seasons respectively the notation.

$$K_{hws}^w = \frac{n_{hws}^w}{24}; \quad (12)$$

and

$$K_{hws}^s = \frac{n_{hws}^s}{24}; \quad (13)$$

In the numerators of formulas (11) and (12) – the average daily number of hours of operation of hot water systems for winter and summer modes.

Summands in the formula (10) are calculated by the formulas:

$$q_{ASR}^{hws.w} = 0,024 \cdot (60 * -t_{cw}^w) \cdot Z_{hp} \cdot q_{hws}^{d.w.}, KWh / m^3 \cdot year; \quad (Winter) \quad (14)$$

and

$$q_{ASR}^{hws.s} = 0,024 \cdot (60 * -t_{cw}^s) \cdot Z_{hp} \cdot q_{hws}^{d.s.}, KWh / m^3 \cdot year; \quad (Summer) \quad (15)$$

The value of  $60 \text{ }^\circ C$  is adopted in the latest 2017 edition of the SP 30.13330.2012

Previously, the temperature of the hot water “at the tap” was taken  $55 \text{ }^\circ C$ , which should be considered when negotiating formula [18].

In formulas (14,15):  $q_{hws}^{d.w.}$  and  $q_{hws}^{ds.}$  – specific heat characteristics of the building (specific heat capacity) for hot water systems in winter and summer design modes,  $W / m^3 \cdot ^\circ C$ .

In General, the total calculated value of annual specific consumption of heat energy in the building for heating, mechanical ventilation, air-conditioning and hot water will be:

$$q_{\sum ASR} = q_{ASR}^h + q_{ASR}^v + q_{ASR}^{ac} + q_{ASR}^{hws}, KWh / m^3 \cdot year; \quad (16)$$

Equity contribution of the systems considered in the heat load of the building for the year can be calculated by the relation:

$$100\% = \frac{q_{ASR}^h}{q_{\sum ASR}} + \frac{q_{ASR}^v}{q_{\sum ASR}} + \frac{q_{ASR}^{ac}}{q_{\sum ASR}} + \frac{q_{ASR}^{hws}}{q_{\sum ASR}}; \quad (17)$$

After solving expression (17) becomes clear in some of the systems over the most promising reserves of energy savings.

The value of  $60^\circ C$  is adopted in the latest 2017 edition of the SP 30.13330.2012

Previously, the temperature of the hot water “at the tap” was taken to be  $55^\circ C$ , which should be considered when negotiating formula [18].

## Results

1. The presented technique allows you to more fully, more accurately than in existing regulations and universally define the specific consumption of thermal energy to all 4 life support system separately and in the whole building. Absolute energy consumption is calculated by multiplying the volume of the building outside measurement (building volume).
2. On the basis of a comparative procedure, there is the opportunity to find priority areas for energy efficiency in the building.
3. The methodology for the universality, is open to the possibility of additions in a similar way other new systems.
4. It is recommended to use the results in educational and design practice and as a theoretical basis for further development of standards.

## References

- [1] K. V. Kirsch. *Atlas boilers, 85 tables, first edition, 37 new tables*. Posthumous edition. M. Edition Thermal engineering Institute in the name of Professor V. I. Grinevetsky and K. V. Kirsch, edited by students of K. V. Kirsch, 1923.
- [2] Clinger - Ritter. *Handbook for Central heating, water supply and ventilation*. Publications under the editorship of Professor L. P. Shishko – Unistat, 1928.
- [3] Harding and Willard. *Mechanical Equipment of Buildings*. Second edition, 1929 by John Wiley and Sons. New-York.
- [4] Shchegolev, M. M., *Fuel, furnaces, and boilers*. M. Gosstroizdat, 1953.
- [5] Jedinak Richard. *Energy Efficiency of Building Envelopes // Advanced Materials Research*. Vol. 855.2013. P 39-42.
- [6] Fokin K. F. *Stroitel'naya teplotekhnika envelope of the building / Under the editorship of J. A. Tabunschikov, V. G. Gagarin. – 5th ed. revised M. ABOK PRESS, 2006. 256 p.*
- [7] Chaplin V. I. *Heating and ventilation. Part 1. Heating*. M. State Publishing House, 1923.

- [8] G. A. Maksimov *The Approximate method of calculating heat loss factory buildings*. The research work of Giprometz, vol.1, 1928. Edition Giprometz.
- [9] Ashe B. M. *Heating and ventilation*. Vol.1.M. –L., Stroiizdat, 1939.
- [10] Ermolaev N. With. *Problems of heat supply and heating of high-rise buildings*. – M., Gosstroizdat, 1949.
- [11] P. N. Kamenev, A. N. Skanavi, Vladimir N. Bogoslovsky, A. G. Egiazarov, V. P. Shcheglov. *“Heating and ventilation”*, part I, M. Stroyizdat, 1975.
- [12] B. V. Barkalov, E. E. Karpis *Air-Conditioning in industrial, public and residential buildings*. Ed. 2nd, revised and enlarged. M. Stroyizdat, 1982.
- [13] N. N. Chistyakov, M. Grudzinsky, Livchak V. I., E. I. Prokhorov. *The efficiency of the hot water system*. M. Stroyizdat 1980.
- [14] A. A. Polyakov, V. A. Cannavo. *Heat and mass transfer devices in engineering equipment of buildings and structures*. M. Stroyizdat, 1989.
- [15] L. D. Boguslavskiy. *The reduced energy consumption during operations of systems of heating and ventilation*. M. Stroyizdat, 1985.
- [16] V. I. Prokhorov *Border consideration in the tasks of thermal insulation and heating of buildings*. Volgas. Ser.: Polytechnic. 2014. Vol. 2. (33). St.17. Mode of access: <http://www.restnik.vgasu.ru/>
- [17] Salomatov A. S. *The origin and development of the terms of the specific thermal characteristics of the building*. The collection of reports of scientific-technical conference on the results of scientific research works of students of IISM for the 2015-2016 academic year. NIU MGSU, 2016. ISBN978-5-7264-1304-4.
- [18] Prokhorov V. I. *Method of systematic determination of the specific thermal characteristics of the building*. Online resource \*\*\* (2016) MATEC WEB OF Conferences, 86, art.no.04068.
- [19] V. I. Prokhorov, M. A. Razakov. *Power life-support systems of buildings, calculated according to two methods*. Industrial and civil construction, 2016, no. 12, p. 97-100.
- [20] S. V. Kornienko. *Evaluation of energy efficiency of buildings in Russian norms*. NBT No. 6, 2017, p. 46-49.