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The algorithm and accuracy of definition of heattechnical indicators of buildings

Алгоритм и точность определения теплотехнических показателей зданий

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Ключевые слова: удельное потребление тепловой энергии на отопление; расчетные условия эксплуатации; измерения; коэффициент удельных теплопотерь; статистические характеристики; классификация зданий

Abstract. The object of the given research is the thermotechnical characteristics of buildings. The problem of thermotechnical indicators measurement arises at the acceptance of the buildings in use and also while performing work on energy classification of buildings in use. The two-level procedure of specific consumption definition of thermal energy for heating is offered: the coefficient of heat losses of the building is defined, and then the specific consumption of thermal energy for heating for settlement conditions is estimated. The given article suggests the optimal algorithm of the coefficient of heat losses determination according to the consumption of thermal energy for the buildings, not depending from the outdoor air temperature and the power of household thermal emissions of the building. There are also the results of the estimation of the coefficient of the coefficient of heat losses and specific consumption of thermal energy for heating for the conditions estimation according to the long-term observation for high-rise buildings. There are also the estimation of the RMS error of determining the coefficient of the coefficient of heat losses and specific thermal energy consumption for heating for the conditions estimation, as well as the 75 % confidence interval for this indicator. The results can be used for the buildings in use energy classification.

Аннотация. Объектом исследования являются теплотехнические характеристики зданий. Проблема измерения теплотехнических показателей возникает при приемке зданий в эксплуатацию, а также при выполнении работ по энергетической классификации зданий в процессе эксплуатации. Предлагается двухступенчатая процедура определения удельного потребления тепловой энергии на отопление: определяется коэффициент теплопотерь здания, затем рассчитывается удельное потребление тепловой энергии на отопление для расчетных условий. Представлен оптимальный алгоритм определения коэффициента теплопотерь по данным потребления тепловой энергии на отопление в здании, не зависящий, от температуры воздуха и мощности бытовых тепловыделений в здании. Определена потенциальная точность определения указанного коэффициента в зависимости от климатических условий и погрешности измерения температуры наружного воздуха. Приведены результаты определения коэффициента теплопотерь и удельного потребление тепловой энергии на отопление для расчетных условий по данным многолетних наблюдений для многоэтажных зданий. Вычислены значения среднеквадратичной погрешности определения коэффициента удельных теплопотерь и удельного потребление тепловой энергии на отопление для расчетных условий, а также 75 % доверительный интервал для этого показателя. Полученные результаты могут быть использованы для выполнения энергетической классификации эксплуатируемых зданий.

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Introduction

The requirements for the heat engineering characteristics of buildings change together with the cost of energy resources. If in [1] the requirements for resistance to heat release of enclosing structures were chosen only for the sake of thermal comfort, in [2, 3] normalized values for the heat resistance for protecting structures was established, and in [3, 4] standardized values for the specific annual heat consumption for heating of buildings was estimated. Specific annual heat consumption for heating is also set in the normative documents of the EU, [5], RF [6] RK [7]. From the regulatory requirements to the mentioned indicator logically follows the need to develop measuring techniques providing the verification of compliance of performance indicator values calculated at the stage of acceptance of the buildings as well as at the other stages of its use.

Currently, to assess the thermal performance of the building in most cases methods of thermal control [8–10] are used. However, its use lets estimate the thermal defects in the exterior building enclosure and do not provide us with the ideas of specific energy characteristics of the building.

In [11] the methodology and results of determination of heat transfer resistance exterior walls of buildings in use are given. The considerable complexity of methods with a small sufficiently result should be noted. It is almost impossible to define thermal resistance of all external fences of the building with the method proposed in [11]. The results are selective with no statistical evaluation of the accuracy and reliability of the results.

Definition and comparative analysis of values of specific heat energy consumption for heating of buildings is, as a rule, made in specific conditions [12], Russia, [13]. However, the indicator "specific annual consumption of thermal energy for heating" refers not to the building as a structural system, and characterizes it with the account of climatic conditions, inhabitation of the building and its operation conditions. Therefore, the value of the indicator of specific consumption of thermal energy for heating measured under the specific climatic conditions and under operating conditions differing from design, may differ significantly from the calculated. It should also be added that the complete inhabitation of the building occurs a few years after putting it in use, therefore, the consumption of thermal energy for heating and ventilation during this period may differ significantly from the design value.

[19] suggests the concept of the specific thermal characteristic of the building which value is equal to the relation of specific power of thermal losses at a difference of temperatures in 1K to building volume. This quantity does not depend on the service conditions and characterizes the building as a thermal power object. For residential buildings it is more convenient to standardize this quantity not to volume, but to the heated area of the building which value can be received from the maintenance organization. In our opinion, the name "Coefficient of heat losses" of the building is more suitable for this quantity. Knowing this indicator, it is possible to calculate quantity of specific consumption of thermal energy on heating of the building for any settlement conditions [20].

The way of determination of the coefficient of heat losses for the general and separate accounting of thermal energy on heating and hot water supply is investigated in [21–25]. It is offered to determine the value of a specific consumption of thermal energy on heating for settlement conditions by the calculations for this indicator.

The necessity to define the thermal energy specific consumption for heating arises while performing the following tasks:

- At the acceptance in use of new buildings and buildings after thermal modernization;
- While performing energy certification of the buildings in use;
- To estimate the thermal protection design quality of the building and to provide the feedback between the project and the constructed object for the purpose of its iteration.

By now in the well-known literature there is no information which would allow determining the possible accuracy of definition of this indicator, as well as no data on an error of its definition for the buildings in use.

It should also be noted that in normative and scientific literature there is no specific requirements to the accuracy of measurement of a specific indicator expense of thermal energy on heating of the operated buildings.

Requirements to the accuracy of definition of specific consumption of thermal energy on heating for settlement conditions

In the Republic of Belarus the classification of buildings by specific consumption of thermal energy on heating and ventilation for settlement conditions is accepted [3]. While solving the problem of the building in use reference to a certain class, it is necessary to consider the possible accuracy of definition of specific consumption of thermal energy on heating and ventilation.

Buildings of the classes B, A and A⁺ are allowed to design and construction in the Republic of Belarus. The class B for multistoried buildings is characterized with a range of values from 30 to 48 kWh/m² for a heating season. The accuracy of the measurement of this indicator should provide the possibility of a clear classification of the building to a particular class. E.g., the value of an error of measurements of ±4 W / (m2K) allows to range the specified range into 5 intervals of unambiguous reference of the building to the specified class. The increase in accuracy of measurements respectively increases the quantity of the intervals and decreases the uncertainty of its reference for a certain class.

Table 1 presents the number of ranges of intervals depending on the control precision for high-rise buildings of different classes.

Table 1. Quantity of Ranges of Split Intervals depending on the precision of measurements

Classes of buildings with more than 7 levels	Range of values of indicator, kWh/m²	Reasonable range of indicator, kWh/m²	Accuracy of definition of kWh/(m²a)							
			±2		±4		±6		±8	
			Quantity of ranges For two ranges of indicators		Quantity of intervals For two ranges of indicators		Quantity of intervals For two ranges of indicators		Quantity of intervals For two ranges of indicators	
			range 1	range 2						
D	81 - 60	89 - 69	10	10	5	5	3	3	2	2
C	59 - 49	69 - 49	5	10	3	5	2	3	2	2
B	48 - 30	49 -29	10	10	5	5	3	3	2	2
A	29 - 25	29 -19	3	10	2	5	1	3	1	2
A⁺	<25	<19	12	10	6	5	4	3	3	2

From the data shown in Table 1, we can conclude that the choice of division of the ranges into classes is irrational. The above-mentioned ranges of the indicator q_u for classes A and C will lead to an increase of the number of errors in determining the class of the building compared to the others, since the number of measurement intervals in a specified range-tries is twice less than in the others. The appropriate division into ranges proposed in the table does not break the logic of the division into classes, and makes it possible to reduce the uncertainty of attribution of the building to a particular class.

The optimal solution for the coefficient of heat losses

In [26] it is proposed to take into account the energy costs of hot water supply by data out of a heating season for determining the coefficient of heat losses of the building in the case of general energy account for heating and hot water supply. This approach can lead to considerable mistakes while estimating the coefficient. Besides, offered in [26] method of calculating annual energy consumption and value of consumption at zero degrees Celsius is not rational.

In [20–23] the coefficient of heat losses of the building, f_1, is estimated together with the following assumptions:

– Air temperature inside the building is known and equal to some extent to the constant value;

– the power of the household thermal emissions remains constant during the entire measurement period;

– Insolation is negligible in comparison with the other components of thermal balance.

The compliance of the above-stated requirements during one heating season and especially during several heating seasons is problematic. In practice, these requirements are not fulfilled which leads to decrease in accuracy of measurements.

The algorithm offered in [24] measures the temperature of external air and the energy spent for the hot water preparation on the measuring intervals. But there are still some requirements to the constant temperature values about in the building and the power of household thermal emissions during each heating season. The system of the equations in [24–25] for the definition of f_1 in the heating season *k* consists of the equations like follows:

$$p_i^k = f_1 \cdot (t_{0i}^k - t_i^k) - f_{2i}^k + \widetilde{u_\iota}, \text{ i=1,…,N; k=1, …,K;} \quad (1)$$

where f_1 – coefficient of heat losses of the building of W/(m²K);

f_{2i}^k – the power of the building thermal emissions in a heating season *k,* and the measuring interval *i* which is supposed to be constant during one heating season, W/m²;

t_{0i}^k – air temperature in the building in a heating season *k* and a measuring interval *i* which is also supposed to be constant during one heating season, K;.

t_i^k – the temperature of the outdoor air on the interval *i* of the heating season *k, K*;

p_i^k– a specific power of a source of heating of the building on the interval *i* of the heating season *k*, W/m²;

N – quantity of intervals of measurement in one heating season;

K – quantity of heating seasons, information on which is used for the f_1 value definition.

$\widetilde{u_\iota}$ – an uncorrelated interfering component on the interval *i* which arises from the inaccuracy of temperature and energy measurement, and also owing to the deviation of air temperature and power of thermal emissions in the building from the constant values, W/m².

In order to increase the accuracy of measurements, the algorithm of f_1 value definition is proposed to be changed as follows:

– The electricity meter counters estimate the average power of the thermal energy consumed by the building on heating on several time intervals during one or more heating seasons;
– Duration of the time intervals gets out of a ratio:

$$\tau >> \tau_0,$$

where τ_0 is a constant of loss of heat time of the building, s;

– For the same intervals of time the average temperature of the outdoor air, e.g., according to the hydrometeocenter is estimated.

For the chosen measuring intervals of each heating season we make a system of the equations (1) in which the sequence of the equations in system corresponds to the sequence of the chosen measurement intervals. Then we subtract the next equations systems (1) made for a concrete heating season to get a new system of the equations for each heating season with a quantity of the equations in system, equal to N-1. While subtraction the corresponding coefficients and free members of the equations are subtracted. Then we unite the systems of the equations received for each heating season in the general system and solve it concerning f_1.

The total system of the equations is as follows (2):

$$\begin{aligned} q_1^k &= f_1 \cdot T_1^k + \widetilde{u_1} \\ q_i^k &= f_1 \cdot T_i^k + \widetilde{u_\iota} \\ q_{n-1}^k &= f_1 \cdot T_{n-1}^k + \widetilde{u_{n-1}} \end{aligned} \quad (2)$$

where $q_i^k = p_i^k - p_{i+1}^k T_i^k = t_i^k - t_{i+1}^k$, i=1,…, N; k=1, …, K;

p_i and p_{i+1} - the specific power of a source of heating of the building on *i* and *i+1* intervals of the heating season *k*, W/m².

$t_i^k u\ t_{i+1}^k$- the average temperature of the outdoor air on i and i+1 intervals of heating season k, K.

The total quantity of equations is equal to the system K*(N-1)

Such an approach to the equations system formation allows:

– To reduce labor input of measurements since it is enough to obtain information on average value of temperature of external air and there is no need to take temperature in the building:
– To increase the precision of measurements by the increase of the initial information volume;
– To reduce the measurement uncertainty associated with the violation of the requirement of constant values of temperature, power, domestic heat and intensity of the insolation during each heating season.

Change in parameters in the neighboring time intervals is not abrupt because of the inertia of these quantities in blocks of flats and to a less extent than during the heating season.

The changes in solar activity in the adjacent months of the heating season is also smaller than the dispersion for the season and, especially, for several heating seasons. For example, Table 2 shows the value of the energy of solar radiation coming to the multilevel, designed for Minsk.

Table 2. Energy of Insolation coming to the multilevel dwelling in Minsk

Single-section 19-floors 132-rooms dwelling in a series 111-90 MAPID, Minsk:					
Months of a heating season	November	December	January	February	March
Insolation, W/m^2	0.018	0.015	0.027	0.050	0.074

Using the least squares method [27] to solve the system of equations (2), we obtain a formula for determining the coefficient of the specific heat losses of a building:

$$f_1 = \frac{\sum_{k=1}^{K}\sum_{i=1}^{N} q_i^k T_i^k}{\sum_{k=1}^{K}\sum_{i=1}^{N} (T_i^k)^2} \quad (3)$$

Usage of the method of least squares to solve the system of equations gives the minimum value of f_1 estimate variance [27] and is optimum in sense of providing the minimum mean square error for an objective.

On the known value of coefficient determine specific consumption of thermal energy on heating for settlement service conditions by a formula:

$$q_h = 0.024 \cdot N(\Delta t_{sr} \cdot f_1 - \xi(f_2 + \varsigma \cdot q_s)), \quad (4)$$

where: Δt_{sr}= ($t_{in.}$-$t_{out.}$), K,

q_h – the Specific average annual power of a power source on heating and ventilation for settlement conditions, W / (м^{2}a);

f_1 – specific coefficient of thermal losses of the building, W / (m^{2}K);

f_2 – the specific power of internal thermal emissions in the building accepted for calculations for W/m^2;

t_{in} – settlement air temperature in the building, equal 18 °C;

t_{out} – the average temperature of external air in in a heating season according to climatic conditions of the area on [29];

q_{sr} – the average stream of the solar radiation coming to the building, according to requirements [29];

ζ and ξ – the coefficients considering type of system of regulation and coefficient of assimilation of solar energy in the building, respectively.

The potential accuracy of coefficient of heat losses determination

Assuming the values q_i^k and T_i^k - uncorrelated random variables, in accordance with the principles of the transfer of errors for independent variables in [27], we receive:

$$\sigma_f^2 = \left(\frac{\partial f_1}{\partial T}\right)^2 \cdot \sigma_T^2 + \left(\frac{\partial f_1}{\partial q}\right)^2 \cdot \sigma_q^2, \quad (5)$$

From (3) we receive the derivatives:

$$\frac{\partial f_1}{\partial T} = \frac{\overline{q} \cdot \overline{T^2} - 2 \cdot \overline{qT} \cdot \overline{T}}{\left(\overline{T^2}\right)^2}, \quad (6)$$

$$\frac{\partial f_1}{\partial q} = \frac{\overline{T}}{\overline{T^2}}, \quad (7)$$

With the following designations:

$$\overline{T} = \sum_{k=1}^{K} \sum_{i=1}^{N} T_i^k \quad ; \overline{T^2} = \sum_{k=1}^{K} \sum_{i=1}^{N} (T_i^k)^2;$$
$$\overline{q} = \sum_{k=1}^{K} \sum_{i=1}^{N} q_i^k; \ \overline{(qT)} = \sum_{k=1}^{K} \sum_{i=1}^{N} q_i^k T_i^k \quad (8)$$

Substituting (6) and (7) in (5), and taking into account (8) we get the dependence of the standard square deviation for f_1 value from the error of determination of temperature and power:

$$\sigma_f = \frac{\sqrt{\left(\overline{q}^2 + 4 \cdot (f_1)^2 \cdot \overline{T}^2 + 4 \cdot \overline{q} \cdot \overline{T} \cdot f_1\right) \cdot \sigma_T^2 + \overline{T}^2 \cdot \sigma_q^2}}{\overline{T^2}} \quad (9)$$

From (9) it is possible to obtain the minimum value of an error of dispersion estimation coefficient of heat losses of the building for the known values of uncertainty of determination of power and temperature of the outdoor air.

From (9) we can conclude that besides the values of σ_q and σ_T the accuracy of f_1 determination also depends on the condition of the changes. The decrease in the value of $\overline{T^2}$, i.e., reducing the difference between the outdoor air temperatures at various measurement intervals leads to an increase of the estimation of σ_f uncertainty.

The real uncertainty of measurement of f_1 may exceed the obtained value, since the initial formula does not take into account outcome all possible changes in solar activity, the capacity of the internal heat sources and the temperature of the air inside the building. The measurement accuracy could also depend on the number and duration of measurement intervals, the quality controller of a heat supply, etc.

Results and Discussion

We should determine the potential accuracy of measurements of coefficient of heat losses for average climatic conditions of the cities of Republic of Belarus [28] and the Russian Federation [29]. With this purpose we calculate on a formula (8) for given values of f_1 the range of possible variations of σ_f. In Figure 1 there is a graph of dependence of size σ_f for the range of f_1 values, from 0.4 to 1.8, and climatic conditions of various cities. Calculations are performed for N = 5 (November, December, January, February, March).

σ_T=1K; σ_q=1W/m^2;

From the data provided on Figure 1 it is possible to conclude that the value of the RMS-deviation increases together with the increase of f_1 value and for softer climatic conditions.

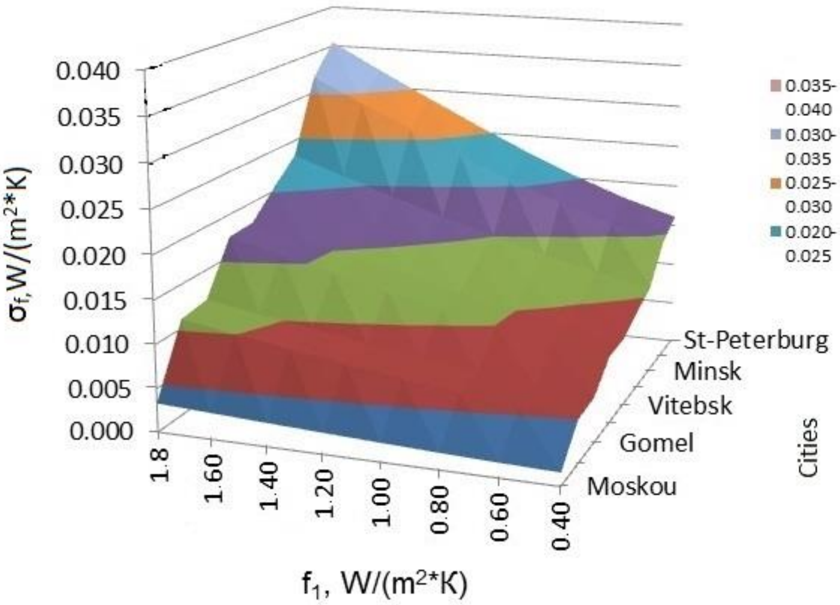

Figure 1. Dependence of the value of σ_f for the range of f_1 values and climatic conditions of various cities

Table 3 shows the average values of dispersion of coefficient estimation of the coefficient of heat losses calculated for the regional centers of the Republic of Belarus.

Table 3. An average error of determination of coefficient of heat losses for the RB regional centers. σ_T=1K; σ_q=1 W / (m^2)

f_1 ,w/(m^{2}K)	1.8	1.6	1.4	1.2	1	0.8	0.6	0.4
σ_f, w/(m^{2}K)	0.042	0.039	0.035	0.032	0.029	0.026	0.024	0.022

Figures 2 and 3 show the dependence of the value of *σf* for a range of changes to the RMS error σT and σq for Minsk and Krasnoyarsk. In both graphs the increases in the values of σ_T and σ_q lead to an increase in the error of determining the coefficient of the coefficient of heat losses, σ_f. However, on the graph for Minsk the range of values of σf are from 0.003 to 0.03 W/(m^{2}K), but for Krasnoyarsk values of σ_f are in the range from 0.0015 to 0.014. Therefore, the accuracy of determining the values of the coefficient of the coefficient of heat losses increases for the more severe climatic conditions.

Recalculation of the RMS deviation σ_f for coefficient of heat losses definition in an error of definition of specific consumption of thermal energy on heating is carried out on a formula:

$$\sigma_q = \sigma_f \cdot \mathrm{G} * 0.024, \quad (10)$$

where σ_q – a the RMS deviation of definition of specific consumption of thermal energy on heating, kWh / (m^2 year);

G – quantity of the degree – days of a heating season, K*d.

According to (10), to value $\sigma_f = 0.01$ W / (m^2*K) corresponds $\sigma_q = 0.9$ to kWh / (m^2 a) for Minsk, and $\sigma_q = 1.6$ kWh / (m^2 a) for Krasnoyarsk.

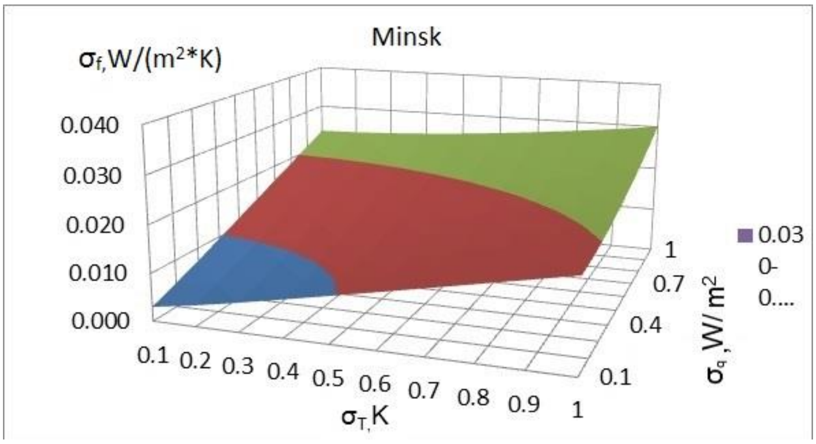

Figure 2. Schedule of Dependence of σf for the range of changes of the RMS deviation σT and σq for Minsk

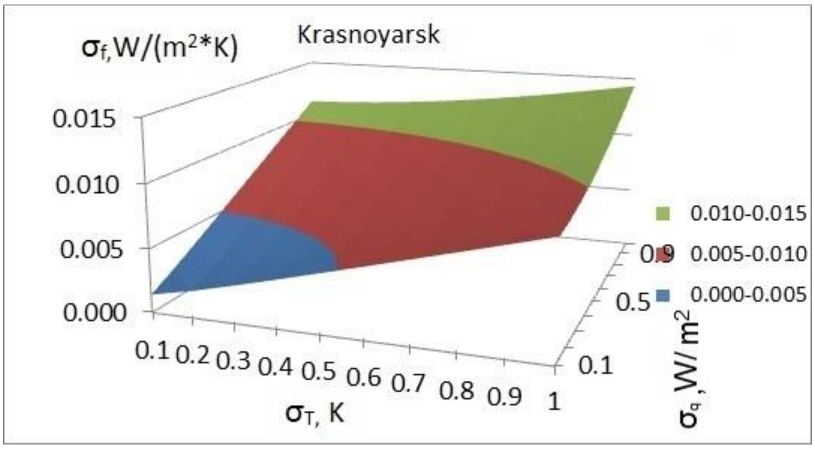

Figure 3. Schedule of Dependence of σf for the range of changes of the RMS deviation σT and σq for Krasnoyarsk

Statistical characteristics of f_1 value estimation on long-term observations

If for the preliminary estimations of the potential accuracy of determining the values of σ_f we used the principles of errors transfer for the independent variables from [27], for processing experimental data to determine the values of of the coefficient of heat losses by the results of many years of observations we use the methods of experimental data processing [30].

We should consider statistical characteristics of estimation of f_1 *value* on long-term observations. We should introduce some designations:

$$S^2 = \frac{1}{(N-1)} \sum_{k=1}^{K} \sum_{i=1}^{N} (q_i^k - f_1 \cdot T_i^k)^2 \quad (11)$$

Then the sample variance, σ_f, is equal [25]:

$$\sigma_f = \frac{S}{\sqrt{T^2}} \quad (12)$$

According to [30] 100(1-γ) % confidential range of estimation of f_1 is determined by a formula (3) and is in range:

$$f_1 - \frac{t_{N-1;1-\gamma/2} \cdot S}{\sqrt{T^2}} \le f_{10} \le f_1 + \frac{t_{N-1;1-\gamma/2} \cdot S}{\sqrt{T^2}} \quad (13)$$

where $t_{N-1;1-\gamma/2}$ – the corresponding value of the Student's t-test [30].

Figure 4 shows f_1 values for the multilevel Minsk buildings determined by the values of heat consumption in three heating seasons, 2011–2012, 2012–2013 and 2013–2014. On axis of abscissa there is the conditional number of buildings. To calculate the coefficients the monthly data on consumption of thermal energy from November to March inclusive were chosen. I.e., the processing was performed at 15 months in the three heating seasons, in accordance with the algorithm described in this article. The range of variation of the obtained values of the conversion factor of the coefficient of heat losses in the range from 0.6 to 1.4, which corresponds to the measurable implementation of specific consumption of thermal energy on heating for the calculation of the conditions of Minsk from 55 to 125 kWh/(m²*year), as shown in Figure 5.

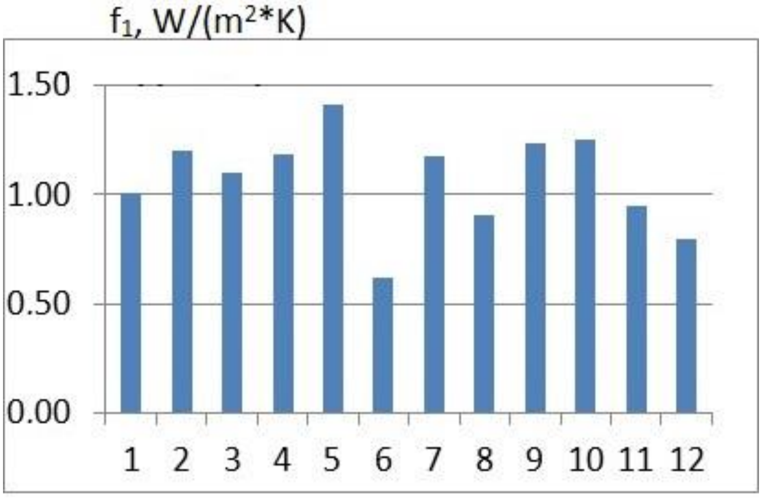

Figure 4. Values of coefficient of the coefficient of heat losses, f_1, for multilevel buildings in Minsk

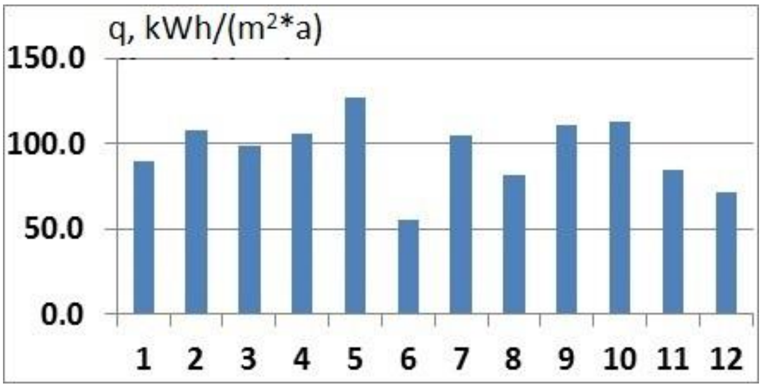

Figure 5. Values of specific consumption of thermal energy for calculated conditions of Minsk (f_1 values of fig. 4)

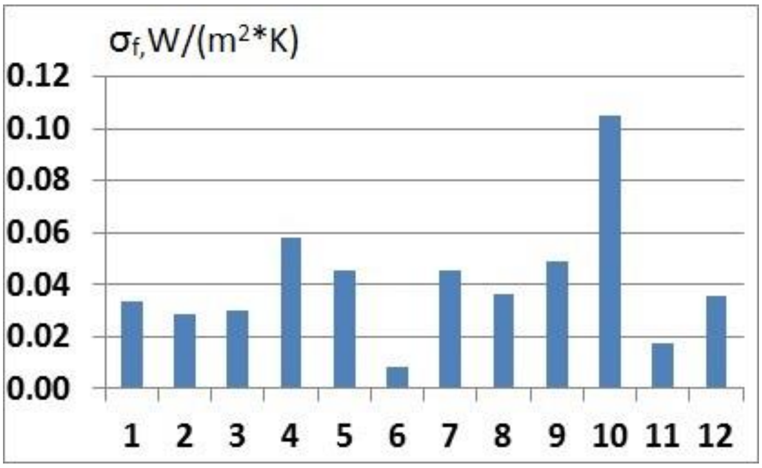

Figure 6. The values of the RMS deviation of determination of the coefficient of heat losses, σ_f (f_1 values of fig. 4)

Figure 6 shows the value of the RMS deviation of determination of coefficient of specific-value, σ_f, calculated according to expression (14). The values are in range from 0.01 to 0.04 W/(m^{2}K) with an average of 0.03 W/(m^{2}K). For buildings # 4 and #10 significantly exceed this value that demands an additional research of the reasons of excess.

Figure 7 shows the values of the RMS deviation of determination of specific consumption of thermal energy for heating $\boldsymbol{\sigma_q}$ and a confidence range of determination of this value for 75 % of probability. The values of the RMS deviation of determination of specific consumption of thermal energy for heating are mostly in the range from 1 to 4 kWh/(m^2), and confidence interval of 3 to 6 kWh/(m^2).

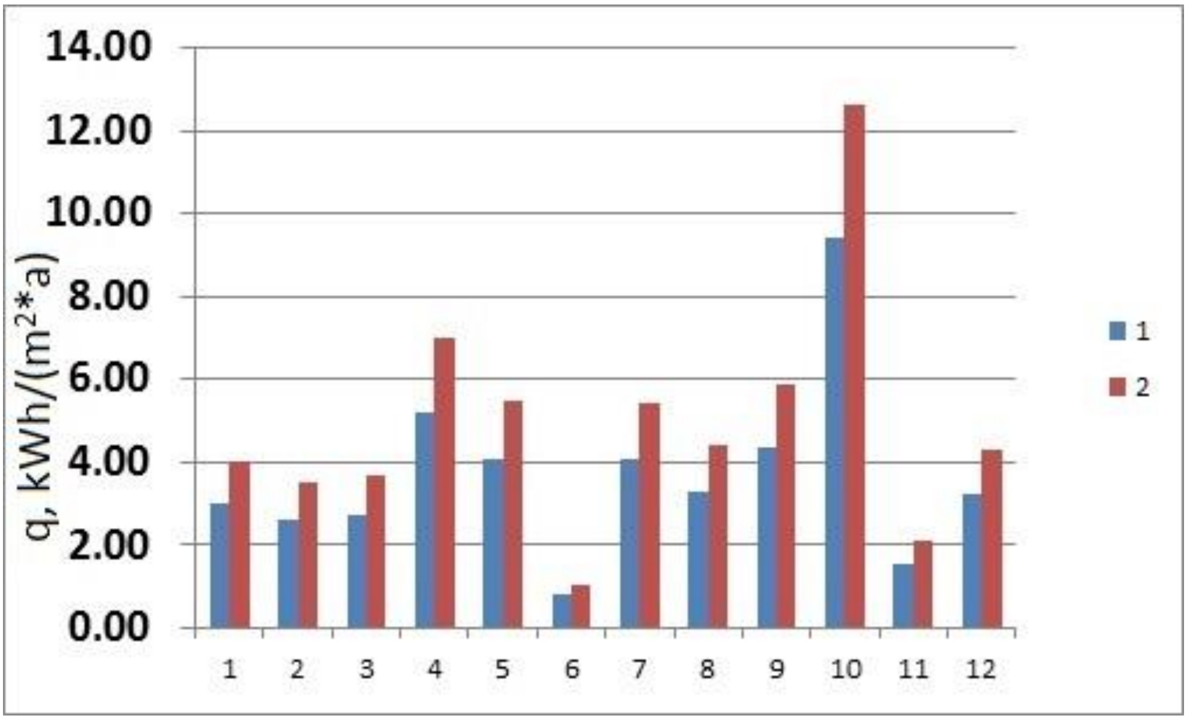

Figure 7. The values of the RMS deviation of determination of specific consumption of thermal energy on heating σ_q – row 1 and a confidential interval of determination of this size for 75 % of probability, row 2 (f_1 values of fig. 3)

Comparison of the received accuracy of measurements with data from Table 1 shows that the values of an deviation received at measurements give the chance of splitting ranges for each of classes of buildings on consumption of thermal energy on heating (at the offered adjustment of ranges) on 5–10 intervals. Such quantity of intervals will give 80–90 % of cases of errorless classification of buildings to a particular class.

The comparative analysis of sample variance of definition of values of coefficient of coefficient of heat losses of the building and specific consumption of thermal energy for settlement conditions and potential accuracy of measurements confirmed their practical coincidence for the potential accuracy of measurements corresponding to values 6_q = 1 W/m^2 and 6_T = 1K. This circumstance gives an opportunity to switch from Student's distribution to normal distribution with use of integral of mistakes [25] during the processing of experimental data and assessment of confidential intervals.

Conclusions

The article investigates a new method of determination of specific consumption of thermal energy for heating and ventilation of the buildings in use with in order to provide their classification. Besides, it contains a research of dependence of a statistical error of determining the rate of accuracy of measurement baseline information for different climatic conditions.

In contrast to the known methods, the method proposed provides the possibility of joint processing of information for the consumption of thermal energy on heating for several heating seasons, which significantly increases the reliability and the accuracy of the measurements. At the same time there is a decrease in the deviation connected with the change of the air temperature, in the power of the household heat emissions and in the intensity of the solar energy into the building during each heating season and from season to season.

The following tasks were solved:

- We developed the optimal by the criterion of minimizing the RMS deviation algorithm, determining the coefficient of the specific heat according to long-term monitoring of heat consumption for heating of the building, independent, in contrast to the already known, from changes in air temperature, the power of the household releases and intensity of the solar energy into the building during the period of measurement (collecting measurement data);
- We developed a mathematical model of dependence of potential accuracy of determination of the specified coefficient depending on the accuracy of determination of air temperature and power of system of heating in the building for various climatic conditions;
- We offered a new principle of the buildings in use classification by consumption of thermal energy on heating in which ranges of classes of buildings are coordinated to the accuracy of measurement of an indicator of classification that provides a possibility of unambiguous reference of the building to a certain class at a use stage;
- We defined the coefficient of the coefficient of heat losses according to long-term observations for a number of buildings in use via the algorithm proposed in the article, besides, the specific thermal energy consumption for heating for the calculated conditions was determined with the known value of the coefficient;
- For the considered buildings we estimated the values of a mean square error of determination of coefficient of the coefficient of heat losses, the specific thermal energy consumption on heating for settlement conditions and 75% confidential interval for this indicator.

According to the comparative analysis of sample variance value and the confidence interval of specific consumption estimation of thermal energy on heating of buildings in use for the calculated conditions, together with the theoretical values of potential accuracy of the measurements we can draw the following conclusions:

- The general tendencies in the change of the RMS deviation of determining the coefficient of the coefficient of heat losses of buildings in use are consistent with the results of the calculation of the potential accuracy of measurements by the offered mathematical model;
- The range of values of σ_f in the experimental studies corresponds with the calculation of the potential measurement accuracy for deviation values to determine the power and temperature, and is: $\sigma_q = 1$ W/m^2 and $\sigma_t = 1$K which corresponds to the possible accuracy of obtaining the initial information.

The statistical analysis of the results of determining the coefficient of the coefficient of heat losses and the specific thermal energy consumption on heating for the buildings in use for the calculated conditions via the method proposed demonstrated the feasibility of its use and allowed us to estimate the metrological characteristics depending on the accuracy of the measurements of the initial variables: temperatures of the outdoor air and energy consumed for heating.

The article suggests the decomposition of the ranges of classes of buildings by their consumption of thermal energy on heating, which provides 80–90% cases of errorless classification to a certain class when performing measurements for the buildings in use.

On the basis of the obtained results we can conclude that during the processing of experimental data and the estimation of confidence intervals on the potential accuracy of measurements and confirmed with experimental results allow us to switch from Student's t-test distribution to the standard distribution with use of the error integral.

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