Heat consumption of apartment buildings during the heating period

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Abstract. The work is devoted to the search for methods for calculating the heat consumption of multi-apartment residential buildings for heating and hot water supply, which allows obtaining the closest results to the actual ones. Three current methods of calculating heat consumption and one canceled, but often used in heat supply contracts, were used. Based on a comparison of the actual data obtained by the common-house heat energy metering devices and the calculated values, the possible deviations in the heat consumption of multi-apartment residential buildings of different floors, area and year of construction, ranging from 49.73 to 177.77%, were found. An economic assessment of the consequences of using the most inadequate methods has been carried out. It was found that when using methods with extreme error values, payments for the heat supply service from one house can differ by 3.6 times.

1. Introduction

In the period from 2009 to the present, great importance is given to energy conservation issues. Federal laws were adopted in the field of energy conservation, heat supply, water supply and sanitation, and the "Rules for the provision of public services to consumers" were approved. Much attention from the administrations of the constituent entities of the Russian Federation is paid to the quality control of heat supply services to consumers [1,2]. An important issue is the streamlining of the system of payments for consumed thermal energy [3,5].

Currently, in most cases, the calculation of the consumer of thermal energy with the supplier is carried out by metering devices (ODPU). But there are a number of situations in which the calculation method is used. Heat supply agreements usually indicate a specific calculation method. The applied technique should have the property of adequacy, i.e. to obtain results comparable with the instrument [4,6]. The choice of the most appropriate methodology for calculating the consumed thermal energy is an important task, the solution of which allows balancing the interests of the consumer and supplier.

2. Materials and methods

As a calculation method, several techniques can be used. In this paper, the following calculation methods were considered: method 1 - CR 373.1325800.2018; Method 2 - Resolution of the Government of the Russian Federation No. 306 as amended on September 29, 2017; Method 3 - Order of the Department of Housing and Utilities and Energy of the Voronezh Region No. 239 dated 12.12.2014; Method 3 - MDS 41.4.2000. These techniques are often used in the implementation of contractual relations between the consumer and the supplier of thermal energy in the territory of the Voronezh region. The fundamental
similarity of all the considered methods is the use of specific values of the heat flux per unit area or volume. Some methods use corrective (correction) coefficients for the outdoor temperature, infiltration, heat loss of the home heating systems. In all methods, design climatological data (CR 131.13330.2018) and actual, as well as the duration of the heating period, can be used. Obviously, using different combinations of data will lead to different results.

According to the methods presented above, calculations were carried out and heat consumption values were obtained for the heating period 2018-2019 and for the year for 58 residential buildings of various floors located in the city of Voronezh.

3. Results
Table 1 presents the results of calculations of heat consumption for the needs of hot water supply for a building having the following characteristics: commissioning year - 2008; the number of storeys - 16; total area - 12503.7 m²; The design heat consumption for heating according to the technical passport is 0.966 Hcal/h. Figure 1 shows the annual heat consumption of the building for the needs of hot water.

Table 1. Heat consumption of a residential building for the needs of hot water supply, Hcal.

| Month      | CR 131.13330 | fact. temp. | Methodology 3 | Methodology 1 | Actual readings | Corrected methodology |
|------------|---------------|-------------|---------------|---------------|-----------------|-----------------------|
| April      | 5,293         | 4,058       | 4,992         | 6,758         | 3,981           | 5,011                 | 8,019 | 7,909 |
| May        | 20,215        | 20,215      | 16,733        | 19,035        | 17,205          | 18,917                | 36,873 | 29,877 |
| June       | 17,362        | 17,362      | 16,07         | 18,826        | 14,967          | 18,011                | 37,885 | 29,628 |
| July       | 10,014        | 10,014      | 8,341         | 10,551        | 8,514           | 10,56                | 20,144 | 17,008 |
| August     | 20,006        | 20,006      | 16,578        | 18,209        | 16,057          | 18,991                | 30,996 | 32,15  |
| September  | 18,478        | 18,478      | 15,547        | 18,315        | 16,48           | 19,002                | 37,287 | 29,489 |
| October    | 7,408         | 3,087       | 6,346         | 7,873         | 2,644           | 3,474                 | 5,229  | 5,002  |
| heated     |               |             |               |               |                 |                       |        |       |
| November   | 29,903        | 29,903      | 25,613        | 30,142        | 25,613          | 30,142                | 43,522 | 38,766 |
| December   | 28,938        | 28,938      | 24,787        | 29,170        | 24,787          | 29,170                | 48,026 | 37,516 |
| January    | 29,903        | 29,903      | 25,613        | 30,142        | 25,613          | 30,142                | 48,122 | 38,766 |
| February   | 27,009        | 27,009      | 23,135        | 27,225        | 23,135          | 27,225                | 36,442 | 35,015 |
| March      | 29,903        | 29,903      | 25,613        | 30,142        | 25,613          | 30,142                | 42,166 | 38,766 |
| April      | 19,292        | 21,221      | 16,525        | 19,447        | 18,177          | 21,391                | 29,470 | 27,511 |
| Total      |               |             |               |               |                 |                       |        |       |
| unheated   | 98,776        | 93,220      | 84,607        | 99,567        | 79,848          | 93,966                | 176,433 | 151,063 |
| heated     | 183,276       | 191,957     | 156,985       | 184,744       | 164,422         | 193,495               | 283,169 | 248,853 |

The data presented in table 1 allow us to conclude that when using the calculation method in various combinations of design and actual data, the results are underestimated, on average, only 58% of the actual. The use of the regional standard for the consumption of hot water and the actual climatological data on the number of days in the heating period make it possible to obtain underestimated values on average by 37.9%.
It can be seen from the calculation results that the data using the local standard and actual climatological data are almost identical to those obtained using the specific aggregated indicator of the average heat consumption for hot water supply per consumer and the climatological data for the joint venture (the difference is less than 1 Hcal for the whole year).

The formula for calculating the average heat consumption for the hot water supply of the design procedure for autonomous heat supply sources of the latest edition (2018) contains the old requirement for hot water temperature of 55 °С. The current value is 65 °C. Using the old value leads to underestimated results of the calculation of heat consumption. The heat loss by the risers and heated towel rails of the hot water supply system is estimated by a factor of 1.2 and does not depend on the type of system, place of installation, type of insulation. The previously used methods took into account the "degree of improvement" and the coefficient was taken in the range of 1.1-1.35. The maximum value of the coefficient was related to the case of the presence of hot water networks after the central heating station on the consumer’s balance, which is practically not found in modern systems. The last column of table 1 presents the heat consumption values obtained by the adjusted method taking into account the temperature of 65 °С and the coefficient value of 1.3. Using the proposed recommendations to improve the calculation accuracy leads to a decrease in the difference for the year on average from 37.9 % to 13.08 %. However, the actual value is higher than the estimated value, and the difference is significant.

Table 2 presents the results of calculating the heat consumption of the building under consideration for the needs of heating and hot water supply for the heating period. Figure 2 in the form of a diagram shows the total values of heat consumption for heating and hot water supply.

From figure 2 and the data in table 2, it follows that the closest to the actual results are observed when using method 3 with climatology data adopted by CR. In this case, the difference is -30,501 Hcal for the heating period. The calculation results when using method 3 in any combination of climatological data are not significantly different: with actual climatological data (difference -96,327 Hcal) and taking into account full months (difference -192,646 Hcal). The largest deviations are observed when using method 2 with actual data on climatology (the difference is 708,092 Hcal, i.e. more than two times less) and method 4 with climate data on the joint venture (the difference is 1,605.01 Hcal, more than twice as much).
Table 2. Heat consumption of a residential building for heating needs, Hcal.

| Month | Methodology 1 | Methodology 2 | Methodology 3 | Methodology 4 |
|-------|---------------|---------------|---------------|---------------|
|       | CR 131.1 | actual temperatures | CR 131.13 | actual temperatures | CR 131.13 | actual temperatures | for full months | CR 131.13 | actual temperatures |
|       | 1330 |              | 330 |              | 330 |              | Actual readings |
| 10    | 56,849 | 34,365 | 45,586 | 27,556 | 120,612 | 72,908 | 137,944 | 188,766 | 225,067 | 173,209 | 104,702 | 125,934 |
| 11    | 145,987 | 157,279 | 117,064 | 126,119 | 309,727 | 333,684 | 225,067 | 225,067 | 225,067 | 225,067 | 444,794 | 479,197 | 204,540 |
| 12    | 181,085 | 176,870 | 145,209 | 141,829 | 384,192 | 375,250 | 225,067 | 225,067 | 225,067 | 225,067 | 551,721 | 538,809 | 259,045 |
|       | 205,672 | 201,075 | 164,925 | 161,238 | 436,356 | 426,602 | 225,067 | 225,067 | 225,067 | 225,067 | 626,643 | 612,635 | 264,071 |
| 2     | 183,583 | 154,079 | 147,212 | 133,553 | 389,491 | 326,894 | 225,067 | 225,067 | 225,067 | 225,067 | 559,341 | 469,447 | 220,631 |
| 3     | 156,472 | 115,419 | 125,472 | 92,552 | 331,973 | 244,873 | 225,067 | 225,067 | 225,067 | 225,067 | 476,740 | 351,657 | 216,062 |
| 4     | 50,995 | 2,347 | 40,892 | 1,882 | 108,192 | 4,979 | 150,044 | 165,049 | 225,067 | 155,373 | 7,150 | 92,550 |

Figure 2. Heat consumption for heating.

According to the results of calculations for all considered buildings, the following can be indicated. Method 1 in any combination of climatological data gives underestimated results, and significantly. Method 4 (currently canceled) gives, as a rule, significantly overestimated results. The maximum discrepancies ranged from 0.452 to 2.16. When using different methods, the calculation results in comparison with the actual heat consumption can differ by more than two times, both smaller and larger.

Of the currently existing methods, 3, in combination with climatology data for CR, gives in most cases the most adequate results.

Table 3 presents the results of calculating the cost of heat consumed for a building with the maximum deviations of the calculation methods for heating and hot water supply for the heating period 2018-2019.
and for the year, taking into account the heat energy tariff for extreme values of the possible ranges. The values of the difference between the received value of each method and the actual value are also given.

Table 3. Cost of consumed thermal energy, rub.

|               | min       | methodology 3 | max       | Metering device | difference, million rubles |
|---------------|-----------|---------------|-----------|-----------------|----------------------------|
|               |           |               |           |                 | min | methodology 3 | max |
| for the heating period | 1,408963 | 2,704715       | 5,389323  | 2,822268 | 1,413 | 0,118 | -2,567 |
| in a year     | 1,552292  | 2,872045       | 5,548507  | 3,121155 | 1,569 | 0,249 | -2,427 |

The use of inadequate methods for calculating heat consumption can lead to significant losses for both the consumer and the supplier in monetary terms. Using an example of a building with a maximum difference in results (see table 3) obtained by calculation methods, it can be seen that using the minimum heat consumption will result in the supplier losing 1.191 million rubles, and using a method that receives the most overstated results will result in an overpayment of 2.567 million rubles for one heating period. Using the most appropriate methodology, as follows from table 4, can also lead to a shortfall in profit by the supplier.

4. Conclusions

Existing methods for determining the heat consumption of residential buildings for heating and hot water supply using the calculation method are considered. The calculations of the total heat consumption of multi-unit residential buildings for heating and hot water supply for the heating period 2018-2019 were carried out. and for the whole year. Based on a comparison of the actual data obtained from common-use heat energy metering devices and calculated values, the possible deviations in the heat consumption of multi-unit residential buildings of different floors, area and year of construction, ranging from 49.73 to 177.77%, were found. It has been established that the methodology for calculating the consumed heat, taking into account local specific standards for heat consumption for heating and hot water supply in combination with climatology data according to CR 131.13330.2018, allows you to get the closest values to the actual ones, but the results are underestimated by an average of 11.8%. The calculation of the possible economic consequences of errors in the values of heat consumption obtained by the calculation method is carried out. When using a methodology that obtains minimal results, it is possible to receive payments from one residential building in the amount of 1.191 million rubles. For the heating period, and the maximum - an overpayment of 2.567 million rubles.

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