The Evaluation of Household Heat Emissions in Residential Buildings

V Pukhkal

1Saint Petersburg State University of Architecture and Civil Engineering, Vtoraja Krasnoarmejskaja str., 4, St. Petersburg 190005, Russia

E-mail: pva1111@rambler.ru

Abstract. The estimation of household heat emissions in residential buildings, which are taken into account in a design of heating systems, was performed. Utilized calculation methods represented in regulatory documents were reviewed. The necessity of additional studies on sources, values and properties of indoor heat emissions in residential buildings’ flats was established. Heat gains from persons, hot water supply, electrical and cooking equipment were examined. Experimental researches of energy consumption’s actual structure in operated standardized residential houses equipped with electrical ovens and having average floor space per person of 19.2 m² were analyzed. The data on relative changes of average 24-hour specific electrical energy consumption during a year by household appliances in flats was obtained. Specific household heat emissions for different types of families in dependence to a flat’s floor space per person were determined.

1. Introduction

The indicator of heat energy consumption for heating and ventilation of a residential building to be taken into consideration during the stage of documentation designing is the specific characteristic of heat energy consumption that is equal to the consumption of heat energy for 1 m³ of the heated volume of the building per a unit of time with the temperature gradient of 1 °C, \( q_h \), W/(m³·°C) [1].

The rated value of the specific characteristic of heat energy consumption for heating and ventilation \( q_h^r \), W/(m³·°C) depends on the specific characteristic of household heat leaks estimated by the amount of household heat leaks per 1 m² of the area of residential spaces [1, 2].

The amount of household heat leaks per 1 m² of the area of residential spaces is calculated for residential buildings:

- for the rated population density of apartments below 20 m² of the total area per person - \( q_{dom} = 17 \) W/m²;
- for the rated population density of apartments of 45 m² or more of the total area per person - \( q_{dom} = 10 \) W/m²;
- for the rated population density of apartments from 20 m² to 45 m² of the total area per person – by interpolation of the value \( q_{dom} \) between 17 and 10 W/m².

According to [3], the value of the household heat leaks per 1 m² of the area of residential spaces is calculated for residential buildings:
- populated according to the social norm (20 m$^2$ or less of the total area per person) - $q_{dom} = 15$ W/m$^2$;
- without limitations of the area per person (with the rated population density of 45 m$^2$ of the total area and more per person) - $q_{dom} = 5$ W/m$^2$;
- with the rated population density from 20 m$^2$ to 45 m$^2$ of the total area per person – by interpolation of the value $q_{dom}$ between 15 and 5 W/m$^2$.

According to the norms of the Belorussian republic [4] “… for residential building, the heat flow regularly generated by electric devices, lighting, people and other sources per 1 m$^2$ of the area of residential spaces and kitchens, shall be assumed as:

- with the population density 20 m$^2$ or less of the total area of apartments per one person to be assumed equal to 9 W/m$^2$;
- with the population density 45 m$^2$ or more of the total area of apartments per one person to be assumed equal to 3 W/m$^2$;
- with other values of the population density – by interpolation of the values 3 and 9 W/m$^2$.

The above-listed values are presented in Figure 1.

\[
Q_{dom} = Q_e + Q_{st} + Q_{h,w} + Q_p, \text{ W},
\]

where $Q_e$ is the heat inflow from electric equipment in the apartment;

$Q_{st}$ is the heat inflow from the cooking device (stove);

\[
Q_{dom} = Q_e + Q_{st} + Q_{h,w} + Q_p, \text{ W},
\]

Figure 1. Dependence of specific household heat leaks in residential buildings on the population density in apartments

Difference in values of household heat leaks in residential apartments indicates the necessity to carry out additional investigations of sources, values and character of internal heat leaks in apartments.

2. Methods
The values of internal household heat inflow into the apartment

\[
Q_{dom} = Q_e + Q_{st} + Q_{h,w} + Q_p, \text{ W},
\]

where $Q_e$ is the heat inflow from electric equipment in the apartment;

$Q_{st}$ is the heat inflow from the cooking device (stove);
\( Q_{h,w} \) is the heat inflow from hot water supply system; 
\( Q_p \) is the heat inflow from people.

The heat inflow from electric equipment and electric stoves (\( Q_e + Q_{st} \), W) is calculated depending on the number of people living in the apartment (\( N \), ppl/sq.m) [3]

\[
Q_e + Q_{st} = q_e + q_{st} \cdot N, \text{ W},
\]

where \( q_e + q_{st} \) is the specific heat inflow from electric equipment per one person for residential buildings with electric cooking stoves

\[
q_e + q_{st} = 0.566 \cdot N^4 - 10.216 \cdot N^3 + 68.844 \cdot N^2 - 212.12 \cdot N + 328.84, \text{ W/person.}
\]

The heat inflow from hot water supply system by the data [6] shall not be taken into consideration as a significant part of heat from linen-driers is carried away with the air of suction ventilation systems, and 30% of the rest is consumed for evaporation of moisture and does not participate in heating of the residential spaces [6] - \( Q_{h,w} = 0 \text{ W}. \)

The heat inflow from people \( Q_p \) is estimated as apparent heat leaks from a person in a calm state for the following data:

- the first variant (for the minimum population density):
  - in a one-room flat - 1 person (adult);
  - in a two-room flat - 2 persons (adult);
  - in a three-room flat - 3 persons (2 adults and 1 child);
- the second variant:
  - in a one-room flat - 2 persons (2 adults);
  - in a two-room flat - 3 persons (2 adults and 1 child);
  - in a three-room flat - 4 persons (2 adults and 2 children).

Apparent heat leaks from people under the temperature of internal air plus 20 °C are assumed [6] as follows: 90 W per man, 76.54 W per woman and 67.5 W per child if 12 ppl/day are present in the apartment and with consideration of decreased heat generation during evening and night time by the factor of 0.75. For the first variant of calculation, the apparent heat leak from people is estimated as follows:

- for a one-room apartment - \( Q_p = 90 \cdot 0.5 \cdot 0.75 = 34 \text{ W}; \)
- for a two-room apartment - \( Q_p = 90 + 76.5 \cdot 0.5 \cdot 0.75 = 62 \text{ W}; \)
- for a three-room apartment - \( Q_p = 90 + 76.5 + 67.5 \cdot 0.5 \cdot 0.75 = 88 \text{ W}. \)

The value the household heat inflows shall be considered for heated spaces of the apartment (building)

\[
Q_{dom} = Q \cdot F_{res} + F_{kit}, \text{ W};
\]

where \( Q \) is the specific value of household heat inflows (per 1 m\(^2\) of the heated area), W/m\(^2\);

\( F_{res} \) is the floor area of residential rooms, m\(^2\);

\( F_{kit} \) is the floor area of the kitchen, m\(^2\).

3. Results
We analyzed the energy consumption data of the existing residential building of the standard type 111-355.МО [5]. The buildings are located in the town of Balashikha (micro-district Gagarin, houses Nos. 19, 21, 24). These are 16-storey panel multi-section buildings with electric cooking stoves; the average population density is 19.2 m\(^2\)/person (3.35 persons per 1 apartment).

We selected these buildings as objects for investigation because their energy consumption values are close to the average values for the total residential area for Moscow.
The investigation was conducted during the period from 1.05.09 till 26.04.11. The specific heat inflow from electric equipment and electric cooking stoves during the heating period was as follows:
- per 1 m$^2$ – 5.63 W/m$^2$;
- per one person – $q_e + q_{st} = 108$ W/person

The specific heat inflow from electric equipment per one person for residential buildings with electric cooking stoves, as estimated by the dependence (2) – $q_e + q_{st} = 88$ W/person. Difference between the actual values and the rated ones for the same value of the population density per one apartment was 19%. The preliminary estimation (until more accurate data are obtained) for the dependence (3) has the increasing factor, so the dependence is transformed as

$$ q_e + q_{st} = 1.385 \cdot 0.566 \cdot N^4 - 10.216 \cdot N^3 + 68.844 \cdot N^2 - 212.12 \cdot N + 328.84 , \text{ W/person.} \quad (4) $$

For standard-type multi-apartment residential buildings in Moscow, the specific household heat leak values were estimated for different types of families depending on the heated area of apartments (residential rooms and kitchens) per one person. The calculated results are shown in Figure 2.

![Figure 2. Dependence of the specific household heat leaks value in residential buildings on the population density in the apartment (per 1 m$^2$ of the heated area)](image)

4. Discussion

As the result of calculations, it was estimated that the actual household heat leaks value in multi-apartment residential buildings is significantly higher (~2 times) than the values specified in normative documents [1-3].

The value of household heat leaks depends on the population density in the apartment – the heated area per one person, as well as the number of people living in the apartment (Figure 2).
The household heat leaks need to be considered for residential rooms, kitchens and other spaces with heating devices. Respectively, these values need to be calculated as specific heat leaks per 1 m² of the heated area.

Conclusions

1. The household heat leaks are not currently calculated by the specific characteristic of household heat leaks per 1 m² of the residential spaces and kitchens. Depending on the rated population density in the apartment, the calculated data according to the normative documents in Russia differ by 1.13 ± 2 times, which causes errors in designing of heating systems.

2. We proposed methods for detecting household heat leaks in heated spaces of the apartments, with consideration of the population density in the apartment.

References

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