Experimental research of the temperature potential of ventilation emissions in apartment buildings

Vasilyev Gregory¹, Gornov Victor¹, Timofeev Nikolay¹, Dmitriev Alexander², Shapkin Pavel³, Kolesova Marina¹

1 JSC “INSOLAR-INVEST” 121433 Bolshaya Filevskaya str. 32-3 Moscow, Russia
2 Plekhanov Russian University of Economics, 117997 Stremyanniy pereulok 36, Moscow, Russia
3 LLC “AVT-KONSALTENERGO”, 121309 Bolshaya Filevskaya str. 22-2, Moscow, Russia
E-mail: eco-insolar@mail.ru

Abstract. Authors of this article presents the results of experimental research of the temperature potential of ventilation emissions in apartment buildings in Moscow. Also this paper offers an analysis and synthesis of technological schemes and technical solutions for natural ventilation systems used in apartment buildings. The systems of natural ventilation of lower-cost multi-storey buildings have been analyzed. The influence of various factors on the parameters of operating modes of natural ventilation systems have been also analyzed. As a result of the analyses it has been found, that the operated apartment buildings largely do not ensure air exchange required according to sanitary regulations, which results in adverse effects for the health, efficiency and life expectancy of population.

1. Introduction
The natural ventilation systems operated today in apartment buildings, include the following main elements: inlet "devices" in the form of windows, air vents, interior and sanitary doors with special slots or overflow grilles to ensure air passage to utility rooms, exhaust grilles and exhaust ducts, which in the most favorable scenario do not provide mandatory air exchange in residential premises for at least half a year.

Table 1. Addresses of apartment buildings used in the study. Photo of the Building

| Address                          | Photo |
|---------------------------------|-------|
| 3rd Filyovskaya str., 6, building 2, Moscow, Russia | ![Photo](image1.jpg) |
| 2nd Filyovskaya str, 8, Moscow, Russia | ![Photo](image2.jpg) |
| 2nd Filyovskaya str., 8, building 1, Moscow, Russia | ![Photo](image3.jpg) |

Estimation of the actual temperature potential of operated apartment buildings is an urgent task for designers of energy efficient equipment in many countries of the world. In the absence of reliable information on the actual temperature potential of ventilation emissions and its variation during the day and year, it is difficult to design an effective system for recuperation or utilization of heat in the vent
emissions of apartment buildings. [1-2] This article offers the results of studies on the field assessment of temperature potential of ventilation emissions from apartment buildings in Moscow. The studies have been conducted during the heating season of 2018/2019 at three apartment buildings, the addresses and photographs of which are given in Table 1.

2. Methods.
Measurements of temperature and relative humidity of exhaust air were carried out at the outlets of ventilation shafts in the automatic mode.
The layout of the sensors and photos of the ventilation shafts are shown in Figures 1 and 2.

Field measurements of exhaust air temperature and relative humidity at the above apartment buildings were carried out within the period from December 2018 to January 2019 with an increments of 5 minutes. In processing the experimental field data on the actual thermal conditions of exhaust air of ventilation systems (ventilation emissions) of the apartment buildings, statistical calculations were based on the Gaussian distribution model. The results of the measurement were grouped and formed into histograms. [3] The number of “n” grouping intervals was calculated using the Sturgess heuristic formula: \( n = 1 + 3.322 \log N \), where N is the number of units of the totality of the data under consideration. Figure 3 shows the average daily exhaust air temperatures over the measurement period with confidence intervals of changes in recorded temperatures, and Figure 4 shows the histogram of distribution of the recorded exhaust air temperatures.
Figure 3. Average daily exhaust air temperatures over the measurement period with confidence intervals, °C

Figure 4. Exhaust air temperature distribution histogram

The histogram is based on 105,717 registered measurements. The average exhaust air temperature is 22.31 °C. The standard deviation is 1.99 °C.

To improve the accuracy of the processing results, the experimental data were divided into groups by sections of ventilation risers, since there was a difference in the temperature of up to 3 °C between different groups of the ventilation risers. This was probably due to the blowing in of external air, but there was no reason to completely discard the data. When the data is processed by a common stream, there is an excess spread. [4]

Therefore, it was decided to separate data processing and, if appropriate, to perform a distribution composition. The results of separate processing of the recorded field data on exhaust air temperatures in December are shown in Table 2 and in Figures 5 and 6, and same data for January are shown in Figures 7-10.[5]

Table 2. Results of the separate processing of the recorded field data on exhaust air temperatures
Month | Average temperature, °C | Standard deviation, °C |
--- | --- | --- |
January 2019 | 21.83 | 1.86 |
December 2018 | 21.82 | 1.763 |
Summarized values for the entire period of measurements | 22.31 | 1.99 |

Figure 5. Exhaust air temperature distribution histogram in December

Figure 6. First ventilation raiser group exhaust air temperature distribution histogram in December

Parameters for the second group of ventilation raisers in December:
- average temperature during the month: 22.96 °C;
- standard deviation: 1.29 °C.

Summarized values for two groups of ventilation raisers in December:
• average temperature during the month: 21.82 ºC;
• standard deviation: 1.763 ºC.

Figure 7. Exhaust air temperature distribution histogram in January.

Figure 8. First ventilation raiser group exhaust air temperature distribution histogram in January.

• Average monthly value: 20.34 ºC
• Standard deviation: 1.31 ºC.
Figure 9. Second ventilation raiser group exhaust air temperature distribution histogram in January.

- Average temperature during the month: 23.32 °C
- Standard deviation: 1.33 °C

Summarized values are:
- Average temperature during the month: 21.83 °C;
- Standard deviation: 1.86 °C.

3. Results and Discussion.

The studies have shown that when theoretical or design energy consumption of an apartment building is considered, is always about some rated consumption, which presumes certain rated temperature and relative humidity of the indoor air in the rooms in the building, certain standard air exchange rate, rated density of accommodation, etc. Practically, some standardized behavior of inhabitants is always considered. However, in reality the behavior of homeowners significantly differs from standardized scenarios, which ultimately determines the difference between the actual energy consumption of an apartment building and the calculated values. [6]

An important component of the subjective factors affecting the actual energy consumption is the individual comfort of living. From life experience we all know that the feeling of comfort is very individual and depends on a variety of individual features of a person, his or her age, physiological characteristics, state of health, etc. Unfortunately, the comfortable conditions of the internal microclimate in an apartment in the apartment buildings in the normalized, standardized conditions, that determine the energy efficiency of the building, are not yet taken into account. As a result, as shown by the studies conducted by the authors of this article, while the standard temperature of air in apartments is 20 °C, Muscovites prefer a temperature of 22.5 °C. [7-8]

As a result, according to the results of processing of the conducted field measurements, the actual exhaust air temperature of the ventilation systems of apartment buildings was assumed to be 22.5 °C. At the same time, the average relative humidity of exhaust air during the heating period was about 38%.
4. References

[1] Vasilyev G.P., Leskov V.A., Mitrofanova N.V., Gornov V.F., Kolesova M.V., Yurchenko I.A., Filippov M.D. Atmospheric air - the effective source of low-grade thermal energy for heat pump snow melting systems under climatic conditions of Moscow. MATEC Web of Conferences. No4 p.05001. (2015)

[2] Malakhov M. A., Savenkov A. E. Experience in designing natural mechanical ventilation in residential buildings with warm attics. AVOK. No. 6. (2008)

[3] Vasilyev G.P., Leskov V.A., Mitrofanova N.V., Gornov V.F., Timofeev N.A., Tabunshchikov I.A., Brodach M.M., Esaulov G.V. Modeling moisture condensation in humid air flow in the course of cooling and heat recovery. Energy and Buildings. Vol. 112. Pp. 93-100. (2016)

[4] Lei Wang, Guoyuan Ma, Anna Ma, Feng Zhou, Fuping Lib Experimental study on the characteristics of triplex loop heat pump for exhaust air heat recovery in winter. Energy Conversion and Management. 176 Pp. 384–392. (2018)

[5] SP 131.13330.2012 Construction Climatology

[6] Zi-Yang Zhang, Chun-Lu Zhang, Mei-Cai Ge, Yue Yu A frost-free dedicated outdoor air system with exhaust air heat recovery. Applied Thermal Engineering. Volume 128, 5 January 2018, Pp. 1041-1050

[7] Vasiliev G. P., Timofeev N. Ah. Kolesova M. V. Utilization of heat of ventilation emissions of buildings - an effective technology to improve the energy efficiency of residential buildings. Energetic. No. 8. Pp. 35-37.(2012)

[8] Vuksanovic D., Murgul V., Vatin N., Pukhkal V. Optimization of microclimate in residential buildings. Applied Mechanics and Materials. 2014. Vol. 680. Pp. 459-466.

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