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Choice of Ventilation System of Apartment Building

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Abstract:

The air quality in the premises with the presence of people affects the performance and health of a person. In the context of the spread of infections and various respiratory diseases, air exchange in the room, the presence of fresh, clean air become a mandatory requirement to prevent the development of diseases. During the construction of apartment buildings, an important issue is the choice of ventilation systems to ensure comfortable and safe living conditions for people. For many years, natural exhaust ventilation systems have been used in apartment buildings in many countries. Practice and our research show the inefficiency of natural systems, especially when the outside air temperature is above +5 degrees Celsius. In this work, the analysis of mechanical and natural ventilation systems is carried out; their advantages and disadvantages are revealed on the basis of the experience in the construction of apartment buildings of the PIK Group of Companies. Unfortunately, for many developers, the economic component is crucial. A separate economic justification requires a comparison of costs. So with an increase in capital costs (the cost of fans, but a lower consumption of air ducts due to higher air velocity), the area of apartments is freed up due to the smaller size of

the shafts for air ducts.

Keywords: Natural Ventilation, Mechanical Ventilation, Apartment Buildings, Ventilation System, Developer

1. Introduction

Ventilation specialists in Russia have long come to the conclusion that it is necessary to switch to mechanical ventilation for apartment buildings. New equipment and technologies make it possible to provide more comfortable conditions for a person to stay. The introduction of a mandatory requirement in the documents of technical regulation of the construction industry requires justification. The purpose of this study is to obtain a theoretical evidence base and confirmed by the practical experience of a construction company to include a mandatory requirement in technical regulation documents. In Russia, such documents are codes of rules (SP) [13-17].

Over the past twenty years, the problems of energy saving and microclimate quality are at the forefront of the construction industry around the world. Perhaps, at first glance, this will seem strange, but by their nature (essence) both of these problems are twins of the same mother - energy. Indeed, the microclimate of a room is characterized by the temperature of the internal air, the temperature of the internal surfaces of the enclosing structures and the quality of the internal air. The energy content of the first two characteristics of the indoor climate is beyond doubt. The third characteristic (indoor air quality) is determined by the amount of ventilation air exchange, which also has an energy content. Thus, each of the characteristics of the indoor climate is a part of the energy consumed by the building's air conditioning systems.

If we agree with this fact, then specialists should look for the best optimal solution to the following problem: to ensure the specified values of the energy indicators of the indoor microclimate with minimum energy consumption.

The intrigue, however, lies in the fact that the problem of energy saving, which in terms of its impact on the quality of life and human health is significantly less significant than the problem of ensuring the quality of the microclimate, is being deeply. It is fashionable to talk about the problem of energy conservation at all levels of society: from the average person to politicians of the highest rank. The problem of the quality of the indoor microclimate is very

important.

The introduction of a concessional mortgage program with a record low rate of 6.5% supports demand in the market for new buildings and servs as an incentive for higher prices. According to the Analytical Center INKOM-Real Estate, since the beginning of 2020, the average cost of a one-room apartment in Moscow has grown by 27%, in the Troitsky and Novomoskovsky administrative areas the growth was 16%, in the Moscow region - 32.4%, respectively. Two-room housing showed 28.3% growth in the capital, in New Moscow its price increased by 20.6%, in the region - by 26.9%. The average cost of a three-room flat within old Moscow rose by 25.7%, in the Troitsky and Novomoskovsky administrative areas - by 19.8%, in the Moscow region - by 22.4%. Multi-room apartments in Moscow showed an increase of 12.1%, in the annexed territories the average cost increased by 33.4%, and in the region - by 13.1%, respectively.

Developers have begun to actively sell two- and three-room apartments, and tried to sell one-room apartments at a higher price, in order to stimulate buyers' interest in multi-room housing.

70% of medium-sized developers left the market a year after the transition to project financing. In the context of restrictive measures, the market for new buildings continued to adapt to the reform of shared construction, introduced on July 1, 2019. Despite the fact that it did not cause significant changes in the framework of the capital's market for new buildings as a whole, it still did not go without losses. According to the company's specialists, over the year, about 80% of small and medium-sized developers faced difficulties when switching to escrow accounts, and 70% were forced to leave the market.

The construction of apartment buildings in Moscow and the Moscow region is proceeding at a tremendous pace. Most of the houses are being built as commercial housing.

The largest developer in Moscow and the Moscow region is PIK Group of Companies. Since the beginning of its activity (1994), more than 25 million square meters of housing have been built, providing apartments for 1.5 million people. Despite the accelerated pace of construction, houses must be made of high-quality and safe materials in compliance with the requirements of regulatory documents [1, 2].

Every year, the requirements for design, in particular engineering systems of apartment buildings, are increasing. The life becomes safer and more comfortable. The increasing competition also affects the quality of housing being built. The number of developers on the market grows rapidly.

Every person needs fresh and clean air to feel good and work well. The ventilation system can provide this requirement. The efficiency of ventilation systems largely depends on the correct implementation of engineering calculations, the use of reliable equipment and operating conditions [3-6].

2. Natural Ventilation

The reason of apathy and accelerated fatigue is carbon dioxide. It is known that we are all sources of it, since it is formed as a result of our metabolic processes and is released with exhalation. In the blood, carbon dioxide, like oxygen, is carried by hemoglobin. The higher the concentration of CO_2 in the air, the more hemoglobin will attach it and the less oxygen it will attach, and, accordingly, the higher the blood acidity (hypercapnia and respiratory acidosis).

The development of respiratory acidosis (a decrease in the blood pH concentration <7.35) leads to a deranged work of organs and systems, which in some cases manifests itself as apathy, depressed mood, headache, instant fatigue and the desire to snore. In this case, the amount of oxygen in the ambient air may not change significantly. Some even call this condition carbon dioxide poisoning, by analogy with carbon monoxide, because the phenomena characteristic of hypoxia occur when the oxygen level in the ambient air is almost normal.

A person feels good at CO_2 levels of 700ppm and below. At the moment, the planet's average air contains 400ppm (ppm = part per million, 0.04% (* fixed)). At a level of 1000ppm, the room becomes stuffy and the first symptoms of oxygen starvation and a feeling of suffocation appear.

If the amount of carbon dioxide exceeds 2000ppm, it will become stuffy even trained and unresponsive persons (while the oxygen concentration changes very slightly, falling from 20 to 19.75%). A further increase in concentration leads to aggravation of the condition and even the development of symptoms characteristic of respiratory failure.

In more than 80% of modern apartments in metropolitan areas, ventilation is poor. Moreover, each person emits 35 grams of carbon dioxide for one hour. For an average room with an area of 20 square meters and a ceiling height of 2.5 meters, this means an hourly increase in the amount of carbon dioxide by 584ppm. In other words, 4 hours using standard ventilation is

enough for the concentration to reach values that not only cause a decrease in performance, but have a detrimental effect on human health.

The work of natural ventilation is based on the difference in the density of the outside and inside (exhaust) air. The system excludes any equipment that could force the air flow to move.

Outside air inflow occurs through open vents of premises or heterogeneity of enclosing structures. Air is removed through exhaust grilles in kitchens, bathrooms, toilets.

Schematic diagrams of natural ventilation are considered in Figure 1.

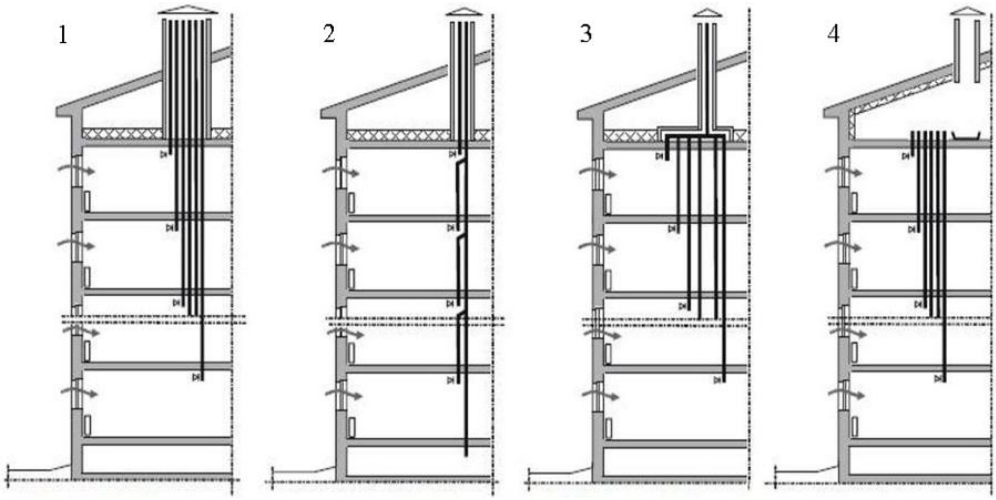

Figure 1. Schematic diagrams of natural ventilation systems: 1 - without collecting channels; 2 - with vertical collecting channels; 3 - with horizontal collecting channels; 4 - with a warm attic.

The most common scheme of natural ventilation in apartment buildings in Moscow and the Moscow region, built during the Soviet era, is the scheme with vertical collecting channels (Figure 1, part 2). Such a scheme is more compact than schemes with individual channels; it is more aerodynamically stable and meets the requirements of fire safety. Further, when comparing natural ventilation with mechanical one, it is this scheme that wakes up as the most widespread and perfect.

A prerequisite for the correct operation of natural ventilation is the outside air temperature not higher than 5 °C and calm weather. As the outside temperature rises, the draft decreases.

In connection with these conditions, when using natural ventilation in Moscow and the region, there is a problem with ensuring the required air exchange. The average outdoor temperature by months during a day and night throughout the year is presented in Figure 2.

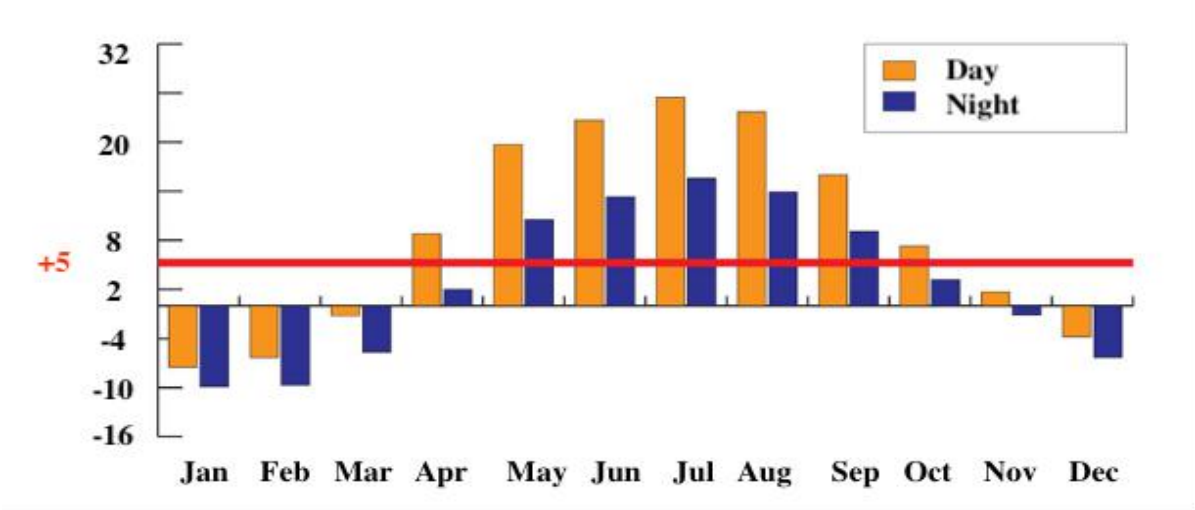

Figure 2. Average outdoor temperature graph in Moscow.

According to Figure 2, more than half a year the required air exchange will not be provided in apartments. In this regard, the use of natural ventilation in apartment buildings in Moscow and the region is not permissible, according to clause 7.1.3 of SP60.13330.2020.

3. Mechanical Ventilation

A "lightweight" solution is often used to reduce the tightness of the building. There are windows with adjustable openings to allow for some air infiltration.

In our opinion, this is primarily an open legal issue, since such a decision violates the requirements for tightness. We install mechanical ventilation to ensure the required air exchange in accordance with current standards. Statistics on how many new buildings have mechanical ventilation is not kept, but according to the statistic, it is about 30... 50% of buildings.

The real problem with this solution is the retrofitting of existing buildings. There are many buildings where the facade has been restored and new sealed windows have been installed. It is often difficult to find the necessary space in such a building for the additional installation of mechanical ventilation. These are technical difficulties. But there are also difficulties of another kind - most users do not want to have mechanical ventilation in their home.

The undoubted advantage of mechanical ventilation is the ability to recover the heat of the exhaust air. The problem with many mechanical systems on the market is that they are often inefficient in terms of air distribution. Formally, they supply the required volume of outside

air, but the ventilation efficiency is low.

Open windows provide air exchange. Disadvantages of this solution are uncomfortable conditions when the outside air is cold; and the occurrence of drafts.

There are no indicators (sensors) for indoor air quality. Some lawyers have already concluded that the space is a product that is sold to the end user, and the product must function without any action on the part of the end user, that is, one cannot require the end user to open or close the window himself thereby exercising control over the ventilation, as it leads to an energy loss.

Controlled mechanical windows can be an engineering solution of the problem, but it will be commensurate with the cost of mechanical ventilation.

According to the authors, only mechanical ventilation can solve the problem, but it is not widely used due to a number of problems.

According to the new edition of SP 60 of 2020, in the design and construction of multi-apartment residential buildings, only mechanical ventilation is admissible.

The principle of operation of mechanical ventilation is based on the use of equipment for air injection (fans).

In contrast to the previously considered natural ventilation, the performance of the system is not affected by the outside temperature and wind speed.

Mechanical ventilation is divided into supply and exhaust.

The purpose of supply ventilation is to ensure the supply of clean air to the room. It is also possible to change the air parameters with the help of the supply unit.

At present, the air permeability of the enclosing structures has become lower due to sealed plastic windows and high density of external fences. Therefore, to ensure the required infiltration, it is necessary to provide forced ventilation.

When designing residential buildings, PIK Group of Companies does not provide for mechanical ventilation in apartments, which makes it possible to reduce equipment costs and increase the usable area of premises. Air inflow into the apartments is carried out through adjustable supply valves, built-in external fencing of the room. The supply valves are equipped with silencers and filter elements (Figure 3).

Currently, the tightness of buildings is increasing; therefore, to ensure the required infiltration,

it is necessary to provide for supply ventilation.

Exhaust ventilation removes air through ventilation grilles in kitchens and bathrooms on ventilation channels - satellites connected to prefabricated vertical ventilation channels through an air lock. The apartments on the top floor have a separate axial fan for air removal.

Figure 4 gives a mechanical ventilation scheme used in the design of multi-apartment residential buildings of the PIK Group of Companies.

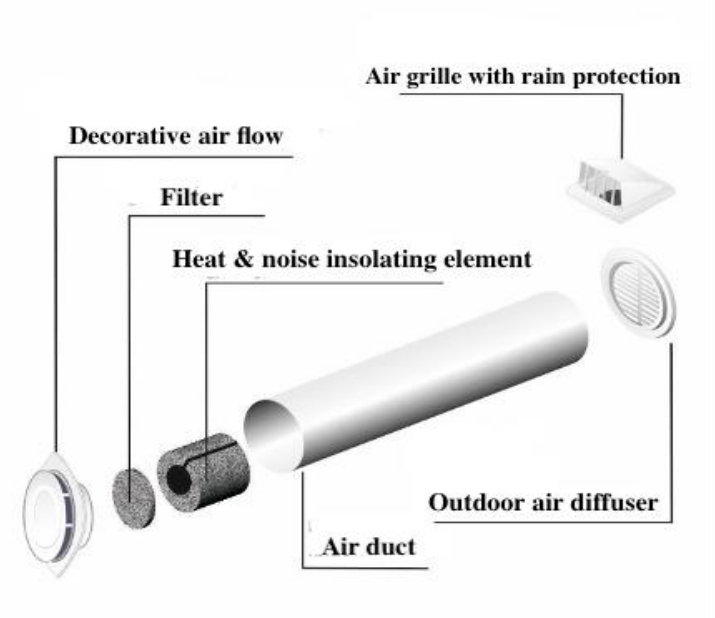

Figure 3. Supply valves.

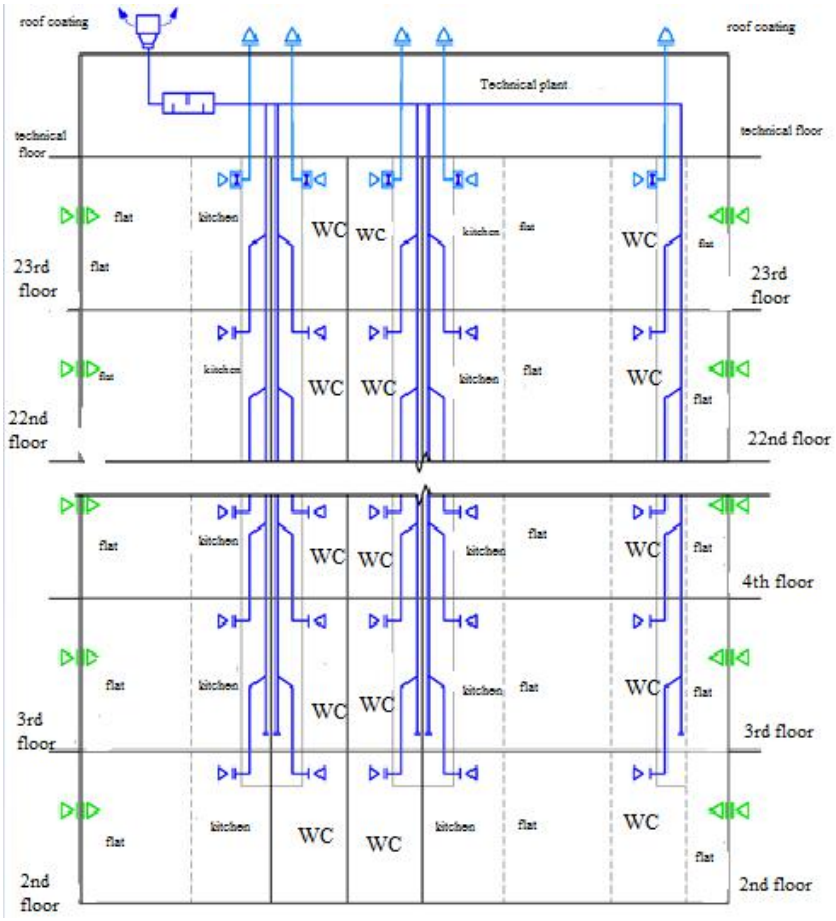

Figure 4. Schematic diagram of ventilation in the apartments of the PIK Group of Companies.

4. Comparison of Natural and Mechanical Ventilation

In theory, mechanical ventilation has many advantages over natural and mixed systems, both in terms of comfort and in terms of impact on human health. For example, the risk of drafts during the cold period of the year is much less than in a system with a natural inflow (hereinafter referred to as a supply valve), since in a mechanical system, as a rule, it is possible to heat the supply air to room temperature, including due to the recovery of waste heat. Besides, the supply air flow rate in the mechanical system is stable and does not depend on external factors (wind and gravitational pressure).

A huge number of projects that we managed to study have one thing in common: problems with mechanical ventilation are always caused not by one mistake, but by a whole range of errors and shortcomings at different stages of the process. Here are the summarized results of studies of "problem" households:

a. Detailed studies and measurements of microclimate quality parameters almost always

confirm that user complaints are not unfounded.

b. Errors are usually made both at the design stage and at the installation stage. The most common mistakes are the lack of silencers in the design, and the wrong choice of installation locations for air intake and exhaust devices.

c. Most ventilation systems are not simple and easy to use. Many systems are designed and installed in such a way that the process of replacing the filter is a hard work. Also, there are often no differential pressure sensors on the filter and a system for informing the user about the need to replace the filter.

d. When designing, the technical assignment for the ventilation system does not include data on the requirements for the microclimate and parameters of acoustic comfort. All project participants mistakenly believe that compliance with the basic requirements of the Dutch building codes guarantees a comfortable and healthy microclimate.

e. The budget for the ventilation system in the early stages of design and construction is too low to create a truly high-quality solution. A recent project with a total construction budget of € 360.000 included only € 2.500 for a mechanical ventilation system.

f. At the stage of acceptance of construction work, attention is paid only to the quality of the enclosing structures and details of the interior decoration. No measurements (air flow, temperature, mobility, noise, etc.), which would allow checking the compliance of the assembled system with design solutions, are not carried out.

g. The contract for the maintenance of the ventilation system is not concluded; as a result, the filters are either changed with a significant delay, or they are not changed at all until the system stops completely.

h. The end user does not have an operating manual and / or some kind of executive documentation.

To produce really high-quality ventilation system that provides comfortable microclimate parameters is a completely realistic task. It is necessary to make a choice in favor of quality, think about the convenience of subsequent operation and make a project based on calculations for this particular building, and not on the minimum requirements of regulatory documents. The regulatory documents of the Kingdom of the Netherlands on the requirements for ventilation systems of individual residential buildings contain “limit minima”, which should not be guided by when designing the technical assignment.

It is very important to take into account the need of the end user. According to the authors, the main preferences of end users are as follows:

1. the system must ensure the design parameters of the microclimate;
2. the system should be simple and easy to use;
3. there should be enough fresh air, preferably in excess;
4. there should be no drafts in winter, no overheated air supply in summer, and no loud noise from the operating system.

It should be noted that the cost of a supply and exhaust ventilation device with mechanical induction and heat recovery from the exhaust air pays off by saving heat consumption in the first year or two, and then makes a profit for the management company. In addition, the heat consumption for heating and ventilation in the annual cycle, as mentioned above, decreases by about 40%. If this scheme is developed for a city such as Moscow, then with the utilization of at least 50% of the waste heat of ventilation emissions from the housing stock in Moscow by 2030, it will be possible to reduce the consumption of thermal energy by about 10 billion kWh per year, which is about 20% of the projected energy costs for heat supply of the city's housing stock in 2030.

From the point of view of the investor's costs, the option with apartment systems, when purchased by residents, may also be attractive, since here, in addition to the already described savings in thermal energy, significant savings in the costs of installing ventilation systems will be achieved.

In most buildings under construction, ventilation with natural induction is still used (and its operation is calculated based on an external temperature of 5 °C). The need to switch to ventilation with mechanical induction is an urgent task.

It is enough just to analyze the graph of the period of standing outside temperatures to make sure that natural ventilation in such buildings simply does not work during 6-7 months in the year.

Let's outline the main advantages and disadvantages of mechanical and natural ventilation.

The advantages of mechanical ventilation:

1. Ensuring the required air exchange regardless of the outside temperature and wind speed.
2. Reducing the area of air ducts by increasing the air speed, thereby increasing the useful

area of an apartment.

3. Air dragging from neighbouring apartments is excluded (this process can take place in apartments with natural ventilation, if a local exhaust unit is installed in some apartments).

Disadvantages of mechanical ventilation:

1. Increased investment costs for equipment and installation.
2. Costs for electricity and periodic maintenance of equipment during operation.
3. The need to provide for noise protection measures (installation of sound attenuators).

5. Conclusion

In order to justify the decision, it would be useful for developers, in addition to theoretical justification, to carry out calculations on the economic justification of the use of mechanical ventilation.

Despite the possible economic advantages of natural ventilation (in some cases, the use of mechanical ventilation will be more profitable by reducing the area of air ducts), only mechanical ventilation can provide the required air exchange in apartments in Moscow and the Moscow region. Violation of air exchange in a room with a constant presence of people can lead to diseases of a different nature, constant fatigue and malfunctioning of the body's thermoregulation mechanisms.

The issue of organizing air exchange is complex, therefore it is important not only to correctly design the system, but also to correctly install and operate it.

When designing multi-apartment residential buildings, PIK Group of Companies used exhaust mechanical ventilation even before the entry into force of SP(codes of rules) 60 by the edition of 2020, since the main design criterion is to ensure comfortable living for people.

References

[1] SP 60.13330-2020 “Heating, Ventilation and Air Conditioning” (Moscow, 2020).

[2] SP 131.13330.2020 Building climatology (Moscow, 2012).

[3] E. I. Tertichnik, Ventilation (Moscow, 2015).

[4] Designer handbook. Internal sanitary facilities. Part 3. Ventilation and air conditioning.

Book 2 / Ed. N. N. Pavlov, and Y. I. Shiller (Moscow, 1992).

[5] Natural ventilation of residential buildings. URL: https://www.abok.ru/for_spec/articles.php?nid=67

[6] SP 54.13330.2021 “Multicompartment residential buildings” (Mjscow,2020).

[7] O. Ya. Kokorin, *Modern air conditioning systems* (Moscow, 2003).

[8] A. A. Rymkevich, *System analysis of optimization of general ventilation and air conditioning* (Saint Petersburg, 2003).

[9] V. K. Savin, *Building Physics: Energy Transfer, Energy Efficiency, Energy Saving* (Moscow, 2005).

[10] GOST 22270-2018 Heating, ventilation and air conditioning systems. Terms and definitions.

[11] V. A. Zhila, E. A. Gusarova, D. M. Gulukin, Scientific review 20, 38-44 (2017).

[12] V. A. Zhila, E. B. Solovieva, D. M. Gulyukin, Scientific Review 22, 27-32 (2016).

[13] Federal Law of the Russian Federation "On TECHNICAL REGULATION" No. 184-FZ dated 27.12.02.

[14] TECHNICAL REGULATIONS ON THE SAFETY OF BUILDINGS AND STRUCTURES No. 384-FZ DATED 30.12.09.

[15] Federal Law of the Russian Federation No. 261-FZ of November 23, 2009 "On Energy Saving and on Increasing Energy Efficiency"

[16] Federal Law No. 190 of 29.12.2004 Town-Planning Code of the Russian Federation.

[17] SanPiN 1.2.3685-21 "Hygienic standards and requirements for ensuring the safety and (or) harmlessness of environmental factors for humans"