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CALCULATION OF BUILDING ENERGY EFFICIENCY INDICATORS AND SELECTING THE MOST EFFICIENT DESIGN SOLUTION

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Annotation. In Kazakhstan, over the past decades, there have been changes in regulatory requirements for energy efficiency and energy saving of buildings. A number of regulatory documents have been adopted related to increasing the energy efficiency of existing and newly erected buildings and structures, as well as the development and implementation of new principles and life support systems, i.e. the creation and maintenance of a microclimate. From the analysis of world and domestic experience, it follows that energy-saving engineering systems for the microclimate of buildings are currently being actively developed. However, in terms of the implementation of energy-saving solutions, energy-saving devices and equipment for engineering systems in the construction of buildings and structures, our country lags behind foreign indicators. From the above, the relevance of the issue follows that, in general, it is possible to reduce energy consumption by microclimate systems by combining all engineering devices and technologies to reduce energy consumption to a level at which the required parameters of the microclimate in the room are maintained. This is possible when assessing the energy efficiency of microclimate systems and the presence of an automated control system. As a result of calculating the energy efficiency of the microclimate systems of a five-story residential building in Kyzylorda, the following was determined: annual heat consumption by heating systems; annual heat consumption by ventilation and air conditioning systems; annual heat consumption by hot water supply systems (HWS); annual electricity consumption by the building's power supply systems.

Keywords: energy efficiency, heat consumption, ventilation, heat supply, air conditioning, microclimate, energy saving.

Introduction. Over the last ten years, the construction industry has focused on two issues. The first issue is related to increasing the energy efficiency of newly constructed and operated buildings and structures, and the second issue is related to the development and implementation of new life support systems and principles, i.e. creating a microclimate and maintaining it. Nowadays, a modern home is a complex technical system that must take into account and interconnect not only the energy efficiency requirements of engineering systems, but also the provision of an internal climate for the premises.

When developing design documentation and constructing facilities, it is easier to solve issues of increasing energy efficiency when there is an opportunity to justify and select the best design solutions. Operation of buildings is associated with the consumption of a certain amount of fuel and energy resources. And therefore, all states form and implement their energy conservation policies, which include a variety of scientific and technical measures aimed at reducing energy consumption in newly constructed and operated buildings.

It is possible to reduce energy consumption and increase energy efficiency in buildings by implementing various energy-saving measures aimed at the efficient use of energy in buildings and engineering systems of these buildings.

The purpose of the work: substantiation and selection based on scientific research of optimal energy-saving measures in the design of building microclimate systems. The relevance of the work is associated with the selection of the most optimal ways to improve the energy efficiency of newly erected and operated buildings and structures, including the development of new principles and life support systems and their implementation (creation and maintenance of microclimate).

The scientific novelty of the work lies in the calculation of optimal indicators of energy consumption and energy efficiency of a five-story residential building in Kyzylorda, the selection of the most suitable energy-saving engineering systems of the microclimate of a residential building for a given territory, the justification of optimal technological solutions that allow the implementation of energy-saving measures when designing engineering systems of the microclimate in a five-story residential building in Kyzylorda. Many foreign and Kazakh scientists have studied various measures aimed at increasing the energy conservation of residential, public, industrial and other buildings [1-7].

In a number of the largest cities of Kazakhstan, since 2009, in accordance with [8], work has begun on the modernization of multi-story residential buildings that were built in the 1970s - 1980s. 11 Within the framework of the above-mentioned program, the following works were carried out: replacement of windows, additional insulation of walls, modernization of engineering systems. For a number of reasons (use of the cheapest reconstruction options or the inability to radically improve the heating system in old-style houses, no possibility of installing a metering system, no possibility of organizing a ventilation system), the effect of the above works was very insignificant - it was only possible to reduce specific heating costs by no more than 10 - 15%. Such an effect from the implementation of measures was clearly insufficient. Such results differ significantly from the results of the modernization of similar buildings in other countries with similar climatic conditions [9-13].

It can be concluded that the difference in efficiency is most likely due to a more comprehensive approach of European partners to solving the problem, including more thoughtful solutions for the reconstruction of old buildings and the construction of new buildings. Energy-saving measures in microclimate systems are aimed at providing the specified (necessary) values of the energy indicators of the indoor microclimate with minimal energy consumption. When designing air conditioning systems, preference should first of all be given to rational types of systems, then provide for a set of measures to reduce the load on the systems and reduce energy consumption during operation. The latter can be achieved as a result of using effective control methods.

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Energy-saving measures in microclimate systems have a great influence on energy consumption. Architectural planning solutions and thermal protection parameters, which determine the heat load on heating, ventilation and air conditioning systems, have a great influence on energy consumption.

In addition to thermal protection of the building, economic optimization of the structural elements of the building can increase the energy efficiency of providing a microclimate. Heat gain from solar radiation depends on the degree of glazing of the facades, the presence of sun protection devices, as well as the aspect ratio of the building and the orientation of the building facades. An increase in the degree of glazing leads to an increase in heat consumption for heating and cooling the building.

The shape of the buildings affects energy consumption. For buildings with an elongated shape, you can choose an orientation in which the heat consumption for heating will be the lowest.

The area S of the external enclosures and, consequently, the amount of heat loss depend on the ratio of the building height and the sides of the building.

An effective way to reduce heat loads on air conditioning systems is to combine the functions of enclosures and systems. For example, ventilated windows, which utilize the heat of exhaust air in cold weather, and remove the heat absorbed in the window from solar radiation in warm weather.

One of the most commonly used means of increasing energy efficiency is the utilization of exhaust air heat. In the heat exchanger, the heat of the air removed by the exhaust systems is transferred to the supply air, which reduces the heat consumption of the air heaters of the ventilation and air conditioning systems.

In order to increase the potential of secondary renewable energy sources, it is necessary to use heat pumps, which are a reversed refrigeration machine that can extract heat from an environment with a relatively low temperature, i.e. low-potential heat. One of the inexhaustible sources of heat is solar energy, which is used in solar installations.

Energy-efficient operating modes can reduce energy consumption by microclimate systems. This is a periodic operation of heating systems, in which, during the period when the premises are not in use, a lower temperature is maintained in it, with periodic ventilation.

In general, it is possible to reduce energy consumption by microclimate control systems by combining all devices and technologies for reducing energy consumption to a level at which the required indoor microclimate parameters are maintained. This is possible with an automated control system.

The strategy of reducing heat loads by using energy-efficient lighting, enhanced thermal insulation, high-quality roof glazing with a reflective surface, etc. are the main elements of the strategy [14].

The diagram for reducing the capacity of HVAC systems is shown in Figure 1. The results showed that roof insulation provides the greatest effect among energy-saving measures (about 25%). Although the total capacity of HVAC systems was reduced by only 35...45%, depending on the geographic location of the facility.

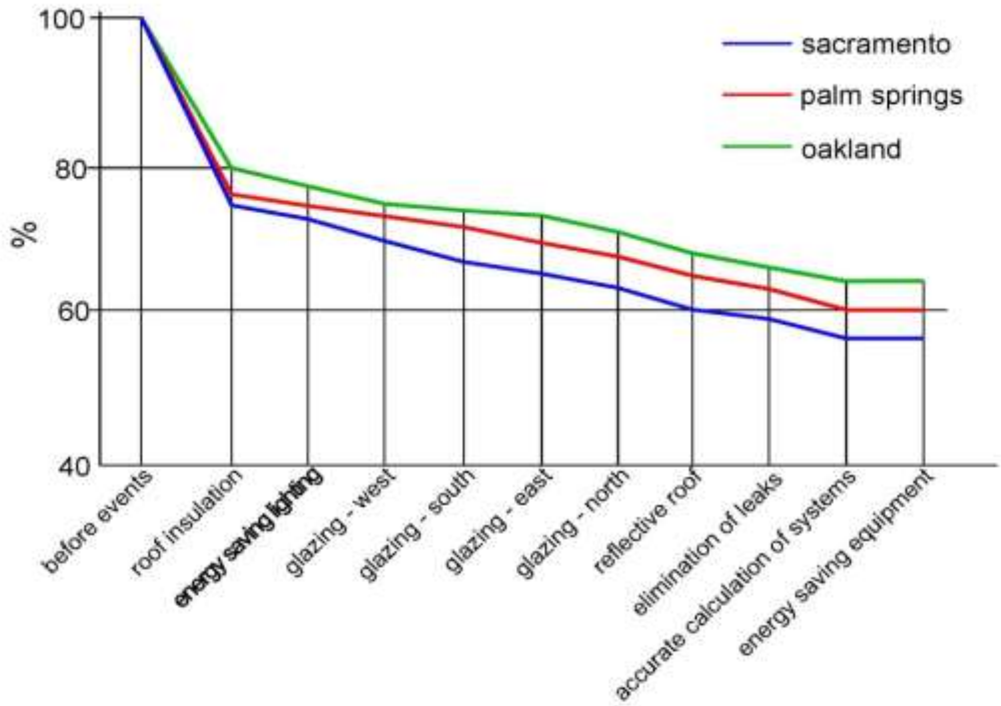

Figure 1 – Reduction in the capacity of HVAC systems as a result of the implementation of energy-saving measures

Materials and methods of the study. For the selection of energy-saving engineering systems of the microclimate of a five-story residential building in Kyzylorda, the software package «POTOK» was used.

The POTOK program [15] is designed to perform a thermal-hydraulic calculation of 1-2 pipe, central water heating with a coolant or collector (skirting, radial) heat and cold supply systems - water or solution, with a constant or sliding temperature difference (in cases of connecting consumers via a single-pipe system) in buildings of any purpose with centralized or separate heat metering. Heat/cold is transferred to the premises by local heating devices, air heaters, fan coils, with organized and unorganized heat metering in the system. Systems with complex configurations (single-pipe, bifilar and double-pipe risers, etc.) can be divided into separate calculation blocks with subsequent automatic unification for the purpose of hydraulic coordination and obtaining a general equipment specification in MS Word and AutoCAD formats.

The program allows calculating heating systems in series - connected by coolant, systems with pre-connected heating devices.

The designed systems can be: heating; warm floors; refrigeration; heat supply (heaters, process equipment); with manual and automatic regulation of heat consumption and hydraulic stability; with the installation of balance valves, thermostatic valves; heating with local devices combined with elements of heat supply, warm floors; intra-site heating networks.

By the method of accounting for heating costs: unorganized heat metering; per-apartment - each apartment (office, store, etc.) has its own heat source and hydraulically the heating systems are not interconnected - count separately without combining; systems with separate heat metering by owners (apartments, offices, stores, etc.) - count separately and combine.

By connection of heating devices when forming risers: single-pipe; double-pipe; bifilar.

By arrangement of main lines: with upper wiring; with lower wiring with conventional and Π-T-shaped risers; with "inverted circulation"; with a single lower main line with sequential connection of Π-shaped risers.

By direction of water movement: vertical or horizontal; with dead-end movement in main lines; with concomitant movement in main lines; radial; collector; with bifilar movement in devices;

By instrument (one-way or two-way) units: flow-through; adjustable; HERZ thermostats; with mixing modules for Oventrop heated floors; flow-through and adjustable; with reducing inserts.

By heat carrier: network superheated water from a thermal power plant (with elevator selection); local heat source; non-freezing solutions.

By the source that causes circulation: pumping; gravity.

The heating system can use heating devices of previous years, manufactured by the CIS industry or supplied by German companies. In addition, the heating system with local heating devices can be combined with heat supply of air heaters and/or electric air heaters of the FC-205C – FC-805C type, heat supply of process equipment. In this case, a joint calculation of the system is carried out, the necessary design materials are prepared. When designing new systems, it is recommended to install thermostats at the devices, and automatic balancing valves on the risers. This will avoid the installation of throttle washers, eliminate design, calculation and installation flaws, ensure heat savings for the entire heating period, which will very quickly offset some increase in capital costs. The use of a two-pipe layout also leads to a significant reduction in operating costs.

Results and Discussion. The heating solution is innovative. A water heating system with forced circulation, with a lower distribution and a closed expansion tank. The heating devices are connected by a two-pipe piping system. The system is designed for a supply pipe temperature of 90°C, and a return pipe temperature of 70°C. Operation occurs without interruptions, but with a decrease in temperature at night using a boiler control controller that receives signals from an external temperature sensor.

The low-temperature part of the heating system of a residential building includes heating circuits located in the walls and floors. The conventional placement of warm floors and warm walls in a residential building is shown in (Figure 2). The power supply to individual circuits is carried out through collectors located under the plaster, and regulation is carried out using zone regulators. The parameters of the internal microclimate in the building are accepted according to the existing sanitary and hygienic standards depending on the category of the main functional premises or their groups and the customer's requirements for the quality of microclimate provision while meeting the sanitary and hygienic safety conditions. When assessing an already adopted design solution, these parameters are accepted according to the working project; when calculating energy efficiency at the design stage and (or) in preliminary multi-variant calculations, it is allowed to select uniform values for a typical (representative) room. The object for calculation is a five-story residential building in Kyzylorda.

We calculate the total specific annual energy consumption of the building per 1 m^3 of heated volume V_{heated}, kW·h/(m^3·g) using the formula

$$q^{р}_{general} = \left(Q^{г}_{general} + Q^{г}_{vent(rv)} + Q^{г}_{hv} + \text{E}\right) \cdot 10^3 / V_{от} \qquad (1)$$

$$q^{р}_{general} = (394 + 272 + 81{,}8 + 43{,}14) \cdot 10^3 / 7925{,}4 = 99{,}8 \text{ kW·h/(m}^3\text{·g)}$$

Next comes the calculation of the building's energy efficiency coefficient using the formula

$$\eta_{bild} = [Q^{г}_{heat} + Q^{г}_{perm} + Q_{vent(rv)} / (1 - k_{ef}) + Q_{\Sigma\, hv} \cdot \frac{55}{\Delta t} + \text{E}] \;/\; Q_{prim.fuel} \qquad (2)$$

where $Q_{prim.fuel} = (Q^{г}_{heat} + Q^{г}_{vent(rv)} + Q^{г}_{hv}) / \eta_{thermal} + \text{E}/\eta_{elect}$ is the energy consumption of the building per year in terms of primary fuel, MW·h/g.

$$Q_{bild} = \frac{(394+272+81{,}8)}{0{,}9} + \frac{43{,}14}{0{,}9} = 879 \text{ MW·h/g.}$$

Where η_{ther} and η_{elect} are the efficiency factors of the sources of thermal and electrical energy, respectively, servicing the building, using the accepted methods of producing these types of energy. When connecting to sources that do not use primary organic fuel (hydro- and nuclear power plants, solar, wind and other installations), the corresponding term in the brackets of formula (2) is ignored.

$$\eta_{bild} = [394 + 59{,}5 + 272/(1 - 0) + 81{,}8 \cdot 55/55 + 43{,}14] \,/\, 879 = 0{,}88$$

The results of calculating the annual energy consumption may be used in the technical and economic comparison of design solution options and the selection of the optimal option.

To determine the actual energy consumption of the building and to verify the fulfillment of design indicators 1–2 years after its commissioning, an inspection is carried out based on the readings of heat and electric energy meters at the building inputs.

The readings of the meter $(Q^{г}_{heat} + Q^{г}_{vent(rv)} + Q^{г}_{hv}$ of thermal energy Q', MW·h/g, are compared with the sum from vent (kV) gv for the final version of the project, reduced to the actual value of the outside air temperature by recalculation using the formula

$$(Q^{г}_{heat} + Q^{г}_{vent(rv)} + Q^{г}_{hv}) = Q^{г}_{heat} + Q^{г}_{vent(rv)}) \cdot \left(\frac{t_{в} - t'_{h.s}}{t_{в} - t_{h.s}}\right) + Q^{г}_{hv} \qquad (3)$$

where $t_{heat.season}$ is the actual average outdoor air temperature for the heating period in question, °C, taken from the meteorological station data. In buildings where a lower temperature is maintained during non-working hours, the conventional internal temperature t should be taken instead of $t_{int.temp}$.

The readings of the electric energy meter E' are compared with the value of E, MW·h/g, for the final version. In case the actual values of Q' and E' exceed the design values, recommendations are developed for additional reduction of energy consumption. The bathrooms and kitchens are equipped with heated floors, and the living rooms are equipped with radiators.

Figure 2 – Water wall heating system

The idea of such a solution is based on the following provisions:

– absence of heating devices and elimination of the effect of local heating of walls;

– improvement of thermal comfort, creation of a healthy microclimate in the premises;

– energy savings due to a high share of radiant heat exchange;

– an optimal solution for a condensing boiler due to a lower supply temperature (45–55°C);

– the possibility of using the system for cooling in the summer.

The heating modules, appropriately selected in terms of power and dimensions, connected according to the Tichelman system, were primarily placed in the partitions between the windows, and the rest of them – on the internal walls.

The high-temperature part of the system consists of heated towel rails in the bathrooms. The same circuit supplies the heating devices in the stairwell. All devices are equipped with thermostatic head valves and air release valves.

The problem of temperature regulation is solved by installing a weekly room programmer in each apartment, which controls the zone regulators of the heating circuits in the walls and floors of this room.

Ventilation systems. Scientific research and calculations of the air regime of the building made it possible to identify general trends in the change of air balance components with changing weather conditions for different buildings.

An increase in wind speed does not affect the flow rate of air removed from the apartment on the windward façade, but with poor entrance doors, the inflow into them decreases through the windows and increases through the entrance doors. Due to the installation of tight windows in the building, the installation of only an exhaust system turns out to be ineffective. Therefore, to supply the inflow to the residential building, ventilated windows with a valve are used, which have a fairly high aerodynamic resistance and do not let in street noise, and supply valves in the external walls, and mechanical recuperative ventilation is also provided. The conditional placement of ventilation valves in the windows and walls of the residential building is shown in (Figure 3).

The window areas and their air permeability in the building correspond to the standards, as does the air permeability of the doors (the air permeability of the windows on the 1st floor was 6 $kg/h{\cdot}m^2$, and of the doors 1,5 $kg/h{\cdot}m^2$). The main channels are provided with the same diameter along the height, made of metal. The diameters of the side branches are also made the same. Throttle valves were selected for the side branches, equalizing the exhaust air flow rates by floors.

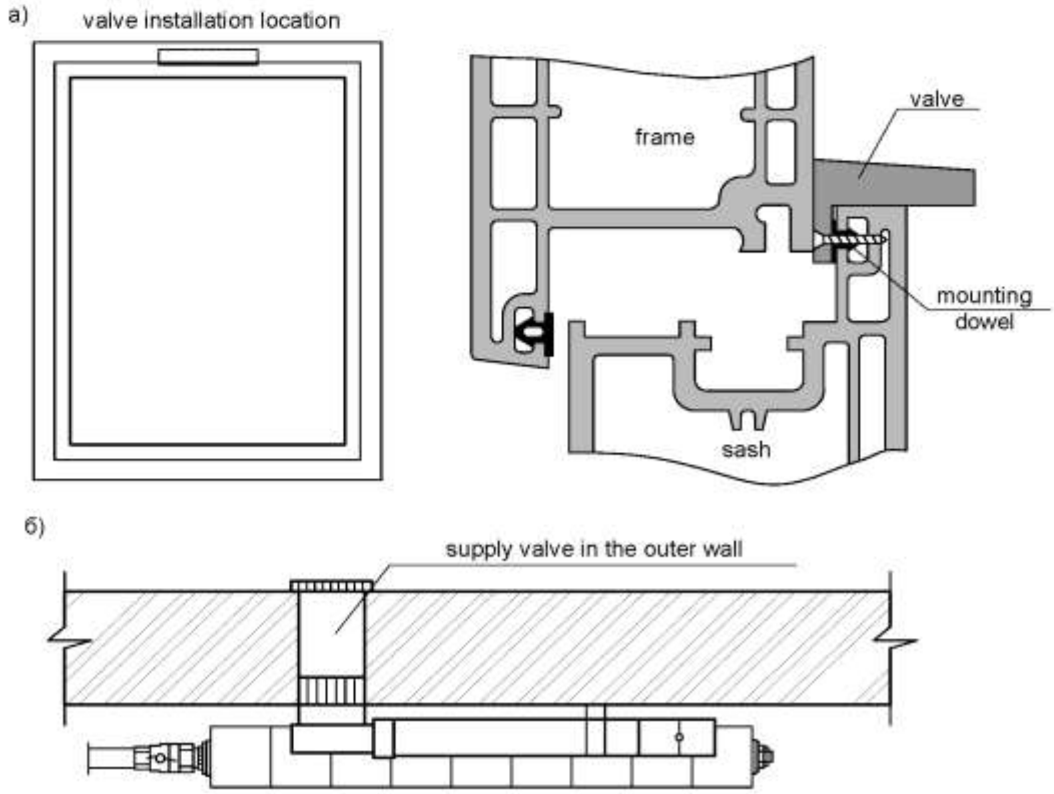

Figure 3 – Conventional placement of ventilation valves in windows (a) and walls (b) of a residential building

The calculation determined the air flow rates that make up the air balance of each room of the frail house at different outside temperatures, wind speeds and with open and closed vents. In addition to the adjustable natural ventilation system, mechanical heat recovery of the exhaust air is used. The points of fresh heated air inflow are located in the rooms of long-term stay: in bedrooms, private rooms. The points of exhaust of used warm air are located in the kitchen (independently of the local exhaust above the electric stove). The diffusers are placed in the ceiling structures. The spiral recuperator together with the fans, collector and system of control dampers is mounted in the attic. The supply shaft passes through one of the end walls, and a free vertical ventilation duct is used as an exhaust shaft.

In order to ensure general air exchange between the rooms of the apartment of the residential building, 7 mm gaps were left between the door leaf and the floor.

In accordance with the purpose and parameters of the ventilation and recuperative system, the following elements were selected:

– a recuperator with a spiral heat exchanger with a capacity of 1000 m^3/h, with an efficiency of 85–92%;
– one supply and one exhaust fan;
– a speed controller for fan electric motors;
– flexible insulated air ducts;
– rotary and deflecting dampers according to the number of supply channels;
– supply and exhaust diffusers.

The ventilation and recuperative system control provides for equipping the exhaust air secondary heat utilization system with a standard speed controller that controls the performance of the exhaust and supply fans. A programmable temperature controller is provided for the purpose of additional optimization of the residential building ventilation process.

Hot water supply (HWS) systems. The control of the entire residential building heat supply system is designed based on its ease of operation. Widely available microprocessor temperature controllers and time-programmable controllers are used as control elements.

The control of the heat generation and accumulation system is based on the standard boiler automation system, which regulates the coolant temperature and controls the heating of water for HWS. Microprocessor temperature controllers successfully interact with this main system.

The automation of the heating circuit power supply system is combined. Water heating in the HWS water heater is controlled by a thermostat and a programmable controller installed on it. The hot water circulation circuit is equipped with a threshold temperature regulator and a programmable controller. The heating circuit with heating devices receives the coolant directly from the heat accumulator and is controlled by a programmable controller. Heat distribution between individual rooms is regulated by valves with thermostatic heads installed on the devices. The wall heating circuit and warm floors, taking into account the technological temperature limitation up to 55°C, are equipped with a pump group with a mixing unit, which is controlled by a temperature regulator.

Conclusion. The selection of microclimate engineering systems for a five-story frail building in Kyzylorda and energy-saving measures with their optimal combination was made. The following technological solutions were adopted in the work:

– wall heating and warm floors, which, in addition to saving energy, create a healthy microclimate in the premises and a comfortable feeling of radiant heat;

– use of a wall heating system and warm floors for cooling premises in the warm season;

– use of individual temperature regulators of heating circuits in each living space;

– use of programmable controllers, increasing the efficiency of the system, due to the ability to regulate the operating time of the systems (gaps);

– ventilated windows with a valve and supply valves in the external walls were used to supply natural air to the residential building;

– a recuperation system, which, in addition to saving energy, allows for the delivery of cool fresh air in the summer through a supply shaft located in the shade;

– water heating in the DHW water heater is controlled by a thermostat and a programmable controller installed on it;

– the hot water circulation circuit is equipped with a threshold temperature regulator and a programmable controller.

The theoretical and practical significance of the obtained results is intended for scientific, engineering and technical workers, postgraduate and master's students involved in the development and creation of energy-saving measures. Summing up, it can be said that the obtained results of scientific research of the dissertation work contribute to the expansion of knowledge and their application in the design of energy-saving microclimate systems of buildings, expressed on the example of a five-story residential building in Kyzylorda.

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ҒИМАРАТТЫҢ ЭНЕРГИЯ ТИІМДІЛІГІ КӨРСЕТКІШТЕРІН ЕСЕПТЕУ ЖӘНЕ ЕҢ ТИІМДІ ЖОБАЛЫҚ ШЕШІМДІ ТАҢДАУ

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Аңдатпа. Қазақстанда соңғы онжылдықтарда ғимараттардың энергия тиімділігі мен энергияны үнемдеуіне қатысты нормативтік талаптарға өзгерістер енгізілді. Қолданыстағы және жаңадан тұрғызылатын ғимараттар мен құрылыстардың энергия тиімділігін арттыруға, сондай-ақ тіршілікті қамтамасыз етудің жаңа принциптері мен жүйелерін әзірлеуге және енгізуге, яғни микроклиматты құру мен қолдауға қатысты бірқатар нормативтік құжаттар қабылданды.

Әлемдік және отандық тәжірибені талдау нәтижесінде қазіргі уақытта ғимараттардың микроклиматына арналған энергияны үнемдейтін инженерлік жүйелер белсенді түрде әзірленуде. Дегенмен, ғимараттар мен құрылыстарды салуда инженерлік жүйелерге арналған энергия үнемдейтін шешімдерді, энергия үнемдейтін құрылғылар мен жабдықтарды енгізу бойынша еліміз шетелдік көрсеткіштерден артта қалып отыр. Жоғарыда айтылғандардан мәселенің өзектілігі, тұтастай алғанда, бөлмедегі микроклиматтың қажетті параметрлері сақтай отырып, энергия тұтынуды азайту үшін барлық инженерлік құрылғылар мен технологияларды біріктіру арқылы микроклимат жүйелері арқылы энергияны тұтынуды азайтуға болатынын көрсетеді. Бұл микроклимат жүйелерінің энергия тиімділігін және автоматтандырылған басқару жүйесінің болуын бағалау кезінде мүмкін болады.

Қызылорда қаласындағы бес қабатты тұрғын үйдің микроклимат жүйелерінің энергия тиімділігін есептеу нәтижесінде мыналар анықталды: жылу жүйелері бойынша жылдық жылу шығыны; желдету және ауа баптау жүйелері бойынша жыл сайынғы жылу шығыны; ыстық сумен жабдықтау жүйелерімен (СЖЖ) жылдық жылуды тұтыну; ғимараттың электрмен жабдықтау жүйелерінің жылдық электр энергиясын тұтынуы.

Тірек сөздер: энергия тиімділігі, жылуды тұтыну, желдету жүйелері, жылумен жабдықтау, ауа баптау, микроклимат, энергия үнемдеу.

РАСЧЕТ ПОКАЗАТЕЛЕЙ ЭНЕРГОЭФФЕКТИВНОСТИ ЗДАНИЯ И ВЫБОР НАИБОЛЕЕ ЭФФЕКТИВНОГО ПРОЕКТНОГО РЕШЕНИЯ

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Аннотация. В Казахстане за последние десятилетия произошли изменения в нормативных требованиях к энергоэффективности и энергосбережению зданий. Принято ряд нормативных документов связанных с повышением энергетической эффективности эксплуатируемых и вновь возводимых зданий и сооружений, а также с разработкой и внедрением новых принципов и систем жизнеобеспечения, т.е. создания и поддержания микроклимата.

Из анализа мирового и отечественного опыта следует, что в настоящее время происходит активное развитие энергосберегающих инженерных систем микроклимата зданий. Однако по внедрению энергосберегающих решений, энергосберегающих устройств и оборудования инженерных систем в строительство зданий и сооружений наша страна отстает от зарубежных показателей. Из изложенного вытекает актуальность вопроса, что в целом энергопотребление системами обеспечения микроклимата можноснизить, объединив в комплексе все инженерные устройства и технологии по снижению энергопотребления до уровня, при котором сохраняются требуемые параметры микроклимата в помещении. Это возможно при оценке энергетической эффективности систем обеспечения микроклимата и наличии системы автоматизированного управления.

В результате расчета оценки энергетической эффективности систем обеспечения микроклимата пятиэтажного жилого дома в г. Кызылорде определено: годовое теплопотребление системами отопления; годовое теплопотребление систем вентиляции и кондиционирования воздуха; годовое теплопотребление системами горячего водоснабжения (ГВС); годовое электропотребление системами электроснабжения здания.

Ключевые слова: энергетическая эффективность, теплопотребление, вентиляция, теплоснабжение, кондиционирование воздуха, микроклимат, энергосбережение.