ЕНЕРГЕТИКА ТА ЕНЕРГОЗБЕРЕЖЕННЯ

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Research and rational choice of modern microclimate provision systems

***Viktoriia Kryvda*[1✉], *Galina Diachenko*[2], *Yurii Bessatyan*[3], *Oleksandr Tarasiuk*[4], *Dmytro Ihnatenko*[5]**
[1-5]National University "Odesa Polytechnic", 1 Shevchenko Ave., Odesa, 65044, Ukraine
✉ e-mail: [1]Kryvda@op.edu.ua
ORCID: [1]http://orcid.org/0000-0002-0930-1163; [2]https://orcid.org/0000-0002-1657-1698; [3]https://orcid.org/0009-0008-2445-365X; [4]https://orcid.org/0009-0004-6552-6932; [5]https://orcid.org/0009-0005-9587-9285

One of the most pressing nowadays problems is the reduction of energy costs for heat supply systems in residential buildings and various purpose building structures. This study analyzes modern trends in ensuring the specified microclimate parameters by various types heating systems using different types of heating devices. Special accent is posed on the necessary correspondence between different types heating systems and the building's purposed use as well as its engineering systems' operating modes for ensuring the microclimate. Demonstrated is the impossibility of energy saving problems analysis without the heat supply consideration from the viewpoint of special approach to systems operating at different levels. The importance of the need for a rational choice of heating systems and devices type in the newest approaches implementation is proven. The main criteria of heating systems classification and each heating devices type main advantages for different operating conditions are given with the account to the housing-communal sector buildings' sanitary and technical systems operation modes. The article exposes main external and internal climatic factors that affect the modes of microclimate systems operation in the premises. Revealed is the external temperature influence on the heat supply systems operation at buildings of various inertia degrees. In a specialized laboratory, a study of the operation of heterogeneous heating systems has been conducted to analyze the premises heating dynamics when bringing systems to operating mode when using a two-period mode of buildings operation. To illustrate the data resulting, the involved laboratory equipment main characteristics are given. According to the research results, there were elaborated general recommendations for the use of various types heating systems for different types of buildings in the housing and communal sector of cities and towns.
Keywords: *Heat supply systems; Operating modes of heat supply systems; Heating systems; Heating devices*

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1. Introduction

One of the most pressing nowadays problems is the reduction of energy costs for heat supply systems in residential buildings and various purpose building structures, while the share of heat consumption in housing and communal services accounts for about 50% of the total amount of heat energy produced [1].

Currently, insufficient attention is paid to justifying the need for energy saving from the standpoint of municipal energy sector innovative development, where the most important tasks are to ensure the lowest possible losses in energy consumption while maintaining the main microclimate parameters in various types premises at the required level. This task solution must meet the requirements of modern trends in energy-efficient technologies maintaining safe and comfortable conditions for consumers' activity at the proper level.

The energy saving problems analysis is impossible without considering heat consumption from the standpoint of a systems approach to devices operating at different levels. Coordination of these parts has a significant impact on increasing the energy efficiency in the municipal heat power sector and on the innovative investment activities embodiment in energy-efficient technologies in the municipal housing and residential sector. This is manifested as a result of the difference in interests of the parties involved in the innovative process of the heat supply systems energy-efficient technologies introducing (equipment manufacturers, companies implementing the project, service consumers, energy service services) that involves the rejection of outdated forms and methods of engineering systems operation, as well as the formation and implementation of new approaches taking into account the various purpose type buildings' operation modes [2].

One of the links in the newest approaches implementation is the rational choice of the heating systems and devices type. In recent years, various solutions for energy-efficient microclimate provision (primarily in the cold season) using various types of local devices have become increasingly widespread. A rational choice of a heating device can ensure not only the necessary microclimate parameters maintenance, but also reduce the costs primary energy carrier and maintain work in accordance with the building operation modes.

Thus, research aimed at developing recommendations for the use of various types heating systems with modern heating devices that take into account the specifics of various purpose buildings operation is relevant and corresponds to modern trends in the development of energy-efficient technologies.

2. Literature review

A number of scientific papers are devoted to the modern heat supply systems energy efficiency increasing. Most of those studies conduct research in a narrow-specialized sector of municipal heat power engineering sector, focusing on specific systems and buildings that they serve.

In the municipal sector, there are three main types of heat load: heating systems; heat supply of ventilation systems; hot water supply. The heat load on each of the listed systems depends on the type of systems and the purpose of the building. The main tool ensuring microclimate parameters in the cold season are various heating systems. They account for the main share of heat loads in buildings [3].

Modern heating systems can be implemented in a fairly wide sector of technical solutions. The heating systems efficiency analysis is usually carried out according to the following criteria: by type of coolant (water; air; electricity); by priority type of heat transfer (convective; radiation); by schematic solutions (single-pipe; two-pipe; radiant); by type of convection (natural; forced); by type of heating devices (radiators; convectors; fan coils; underfloor heating; radiant panels.

The main important characteristics of the heating system in variable operating modes are inertia, decentralization and power reserve. According to these features, it is possible to analyze the effective operation of various types heating systems and various heating devices.

The least inertial system from the heat carrier viewpoint is the central air conditioning system using air as a heat carrier. These systems are able to quickly heat the air inside the premises, but due to the low specific heat capacity, they require the installation of large air ducts. These systems are much convenient in large rooms of public buildings.

Electric heating systems usually come in the form of electric convectors and thermal radiation panels. The convectors are quite inertial compared to panels, but more evenly distribute the temperature inside the room. Thermal radiation panels have found wide application in industrial workshops, where it is necessary to maintain the temperature in the workplace. Electric convectors are usually installed in small rooms to maintain the required temperature, or to maintain the operating temperature in the absence of other heat sources [4].

Water heating systems are the most common and have a large range of inertia depending on the heating device. They are safer, have versatility in terms of energy sources used, and can be implemented in a wide range of heating devices [5].

One of the most inertial types of heating devices are convectors with natural air circulation. These devices performance depends greatly on the coolant temperature. The least inertial among them are the fan coil type heaters. This heating device includes a fan and special automation unit. This device can respond quickly enough to changes in the thermal regime of the building and clearly maintain the temperature in the room.

The "warm floor" type system is a rather desirable heating system in many cases. It has significant advantages:

– uniformity of room heating;

– this system corresponds to the design solution;

– ability to maintain a low temperature in the room to achieve a sense of comfort;

– accumulation capacity.

But at the same time, this system also has certain disadvantages:

– selectivity to floor covering;

– high inertia;

– inability to fully cover heating needs in some rooms.

The heating system effective operation is also associated with the ability to precisely control temperatures in different rooms. In this case, it is necessary to minimize the human influence on temperature balance control. The most suitable from this viewpoint are systems with a radial connection of heating devices' groups in the rooms served. Such a circuit solution provides the possibility to remotely organize the heat loads regulation in different rooms depending on the operating mode and to carry out a clear balancing of hydraulics at the control adjustment stage. Another advantage is the possibility to install heat energy meters in a separate place [6].

The use of two-pipe systems can also provide the possibility of regulation and a precise temperature balance, but usually the regulation and balancing systems elements can be accessed by users. As practice shows, in such a case, human intervention should be taken into account.

The issue of implementing some specific heating system with specific types of devices is quite complex and depends on a number of factors.

3.This study purpose and objectives

This study main goal is to determine the rational areas of different types o heating systems of application and the use therein of different types heating devices for buildings of various purposes.

To achieve the goal, it is necessary to solve the following tasks:

– analyze the operation of heating systems at buildings of various purposes;

– investigate the operating conditions of various heating systems in buildings with different operation modes.

4. Methodology for research conducting and the obtained data processing.

The thermal energy consumption in municipal heat and power engineering sector is uneven during the day, week and year. The unevenness of thermal energy consumption is influenced by the following factors:

– outdoor air temperature;

– types of thermal load (heating, hot water supply, ventilation, technological needs);

– building purpose;

– operating modes of heat supply systems;

– power regulation at heat control rooms.

Outdoor air temperature. To calculate the load on heating systems for different types of buildings, different values of calculated external temperatures are accepted. In general, in building thermal physics, there are the following types of external calculated temperature:

– average calculated temperature of cold thirty days (parameter A);

– average calculated temperature of cold five days (parameter B);

– average calculated temperature of the coldest day (parameter B).

Depending on the purpose of the building, as well as the type of thermal load, in accordance with regulatory documentation, the temperature criterion is selected among the above. For example, to calculate the heat load on the heating systems of residential buildings, the outdoor air temperature is taken into account according to the parameter "B". To calculate the heat load of the ventilation systems of shopping complexes, the outdoor air temperature is taken into account according to the parameter "A". For the heating systems of maternity hospitals, the outdoor air temperature is taken into account according to the parameter "B" [7].

The outdoor air temperature varies throughout the year. Climatological data are used to determine the total energy demand throughout the year (Table 1.).

In addition to temperature changes during the cold season, there is also a change in temperature during the day. The minimum air temperature at a height of 2 m is observed before sunrise. As soon as the sun appears above the horizon and begins to rise during this period, the temperature increases rapidly, then the temperature increase decreases and at the end at 14-15 hours the maximum occurs. Then the process of temperature decrease begins – at first weak, and then faster and faster. During the day, the amplitude depends on a number of reasons: geographical latitude of the place, season and other reasons. Over the water surface, the daily amplitude is less than over the ground by 2-3 ° C.

***Table 1** – Climatological data for calculating heating systems of a number of cities in Ukraine*

№	City	-29,9÷-25 °C	-24,9÷-20 °C	-19,9÷-15 °C	-14,9÷-10 °C	-9,9÷-5 °C	-4,9÷+0 °C	+0,1÷+5 °C	+5,1÷+8 °C
1	Dnipro	9	37	127	235	457	1152	1514	669
2	Kyiv	5	31	130	336	627	1225	1480	654
3	Lviv		2	20	62	458	1039	1678	1133
4	Odesa		5	22	134	399	975	1781	644
5	Rivne	5	22	102	307	613	1231	1546	758
6	Sumy	11	40	130	330	662	1263	1542	702

The outdoor air temperature is one of the main factors influencing the thermal load of buildings. The effect of temperature changes on the power of heating systems depends on the design of the building and the load control system for heat supply systems [8].

Fluctuations in outdoor air temperature affect the main types of heat supply of buildings in different ways. Ventilation is such a noticeable fluctuation in outdoor temperature. A change in outdoor air temperature immediately affects the power of heat supply for ventilation needs.

The heating system is less noticeable. It takes from several hours to a day to change the heat load on the needs of the heating system, depending on the design of the building. This is due to the fact that the building's storage capacity reduces the sensitivity to external factors of the heating system. For example, for well-insulated massive buildings with a minimum number of windows, it takes about a day to significantly feel a change in the external temperature of up to 5°C. For office centers with facade glass systems, a change in the external temperature of 5°C will become significantly noticeable after just a few hours.

Heat losses from the building to the environment are determined by the process of heat exchange between the internal and external air in the form of heat transfer. Building enclosures of the premises are used as a dividing wall. The fulfillment of the target task by the heating system is ensured by compensating for the lost heat from the heated room to the environment by the thermal capabilities of the systems, i.e. maintaining a balance between heat losses from the room and heat gain to the room. The heat balance equation – between heat gain and heat loss – for a room has the form of the equation [9]:

$$Q_h = Q_w + Q_{inf} + Q_c - \sum Q_r, \qquad (1)$$

where: Q_h – heat supplied to the room by the heating system, kW; Q_w – heat loss by heat transfer through external enclosures, kW; Q_{inf} – heat loss by infiltration due to cold air entering the room due to leaks in external enclosures, kW; Q_c – heat consumption for heating cold objects, kW; $\sum Q_r$ – internal heat release in the room, kW.

4. Research results

The research was carried out for the specified heating systems in buildings of various types of purpose, namely:
- residential building;
- office center;
- educational institution building;
- shopping center;
- sports ground.

Each of the specified buildings is specific with its own operating mode with unevenness during the day and week. Each of the buildings is characterized by its own thermal inertia, which depends on the material of the external enclosures and affects the operating modes of the heating systems (Table 2).

In addition to the building's inertia another factor affecting maintenance of the required temperatures in the room is the heating systems inertia. The particular influence of heating systems inertia is felt in buildings with variable operating modes of heat supply systems, primarily this is characteristic of public buildings.

To study the inertia of different types heating devices, a specialized laboratory was used in which the dynamics of the operation of different types of systems over a certain period of time was studied (Fig. 1-3).

Table 2 – Dependence of the operating mode of heating systems on the material of the external enclosures

Building type	Heating
A brick house without thermal insulation with a glazing ratio of less than 25%	The effect of a change in the external temperature on the internal one is felt after 8-10 hours
A house made of foam concrete with energy-efficient windows with a glazing area of up to 50%	The effect of a change in the external temperature on the internal one is felt after 10-12 hours
House with facade glazing.	The effect of a change in the external temperature on the internal one is felt after 4-5 hours

Figure 1 *– General view of the EVNA electrode boiler with a capacity of 4.5 kW in a scheme with a tank-accumulator*

Figure 2 *– Wall-mounted Vita fan coil with a capacity of 5 kW with a software control unit (left) and a climatic radiation panel produced by Effi*

Figure 3 *– Jaga wall-mounted convector and two steel wall-mounted Korado radiators (from left to right) and a programmable remote control for intermittent electric underfloor heating from Teplolux with a capacity of 3 kW in one of the classrooms*

The following measuring instruments were used:

– eight-channel Oven meter;

– digital bimetallic thermometer.

Over a certain period, measurements of the heating dynamics of different types of heating systems for similar climatic conditions and internal factors were carried out. The results were generalized for all types of systems (Fig. 4)

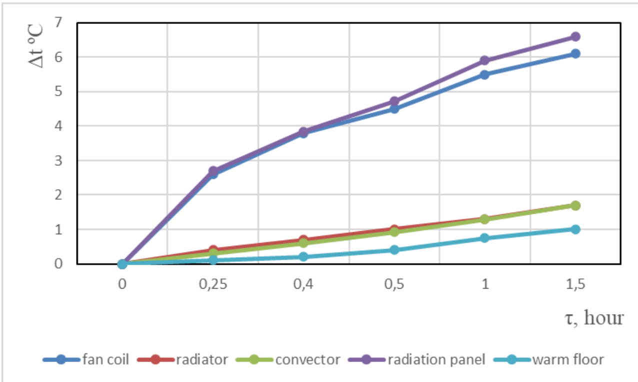

Figure 4 *– Dynamics of temperature increase in the room during initial warming up using different types of heating devices*

As can be seen from the research (Fig. 4), the most effective heating system for use in changing operating modes of public buildings is the fan coil system (forced convection) and radiation panels. The least effective in changing operating modes of engineering systems is the “warm floor” (radiation-convective with free convection). This is explained by the low inertia of the specified systems and the high inertia of the “warm floor” system. Radiator heating systems and wall convectors almost do not differ in the dynamics of heating the premises.

Analyzing the operating conditions of different purpose type buildings and the peculiarities of the operation of various heating systems, as well as the possibility of installing the specified devices, recommendations can be given on the implementation of different types of heating systems (Table 3).

Table 3 *– Implementation of different types of heating systems*

Building type	High inertia	Average inertia	Low inertia
Residential	Radiators, convectors, underfloor heating	Radiators, convectors, underfloor heating	Radiators, convectors, underfloor heating, fan coils
Office center	Radiators, convectors, fan coils	Radiators, convectors, fan coils	Convectors, fan coils
Shopping center	Radiators, fan coils, radiation panels	Fan coils, radiation panels	Fan coils, convectors
Educational institution	Radiators	Radiators, convectors	Fan coils, radiators
Playground	Radiators, convectors	Radiators, fan coils	Fan coils, radiation panels

5. Conclusions

The work analyzes the operating modes of different types heating systems considering the operating conditions of cities and towns’ municipal complex buildings.

On the specialized laboratory basis, a study of the efficiency of different types heating systems’ operation for variable operating modes of public buildings was conducted.

Based on the analysis and research carried out, recommendations are given concerning the implementation of different types of heating systems for municipal buildings with different inertial characteristics of the specified buildings.

CRediT author statement

Viktoriia Kryvda: Research problem statement, analysis of existing modern systems. **Galina Diachenko:** A review of modern European sources on the research topic. Translation of research materials into English. **Yurii Bessatyan:** Conducting research in accordance with the tasks. **Oleksandr Tarasiuk:** Processing the obtained research results. **Dmytro Ihnatenko:** Review of modern Ukrainian sources on the topic of research, generalization of research results.

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Дослідження та раціональний вибір сучасних систем забезпечення мікроклімату

В. Кривда[1]✉, Г. Дьяченко[2], Ю. Бессатьян[3], О. Тарасюк[4], Д. Ігнатенко[5]
[1-5]Національний університет «Одеська політехніка», просп. Шевченка, 1, Одеса, 65044, Україна
✉ e-mail: [1]Kryvda@op.edu.ua
ORCID: [1]http://orcid.org/0000-0002-0930-1163; [2]https://orcid.org/0000-0002-1657-1698; [3]https://orcid.org/0009-0008-2445-365X; [4]https://orcid.org/0009-0004-6552-6932; [5]https://orcid.org/0009-0005-9587-9285

Однією з найактуальніших проблем сьогодення є зниження енерговитрат на системи теплопостачання житлових будинків та будівельних конструкцій різного призначення, при цьому частка споживання тепла в житлово-комунальному господарстві становить близько 50% від загального обсягу виробленої теплової енергії. В роботі проведено аналіз сучасних тенденцій забезпечення заданих параметрів мікроклімату різними видами опалювальних систем із застосуванням різного типу опалювальних пристроїв. Вказано на необхідну відповідність різних типів опалювальних систем до призначення споруди та режимів експлуатації її інженерних систем забезпечення мікроклімату. Показано неможливість аналізу проблем енергозбереження без розгляду теплопостачання з позиції системного підходу. функціонуючих на різних рівнях. Доведено важливість у реалізації новітніх підходів потреба раціонального вибору типу опалювальних систем та приборів. Наведено основні пункти класифікації опалювальних систем та основні переваги кожного типу опалювальних пристроїв для різних умов експлуатації із врахуванням режимів роботи санітарно-технічних систем будівель житлово-комунального сектору. В роботі показані основні зовнішні та внутрішні кліматичні чинники, що впливають на режими роботи систем забезпечення мікроклімату в приміщеннях. Для будівель різної інерційності наведено вплив зовнішньої температури на роботу систем теплопостачання. В спеціалізованій лабораторії проведено дослідження роботи різнорідних систем опалювання для аналізу динаміки прогріву приміщень для виводу останніх на робочий режим при застосуванні двоперіодного режиму експлуатації будівель. Наведено основні характеристики обладнання лабораторії. За результатами досліджень визначені загальні рекомендації щодо застосування різних видів опалювальних систем для різного типу будівель житлово-комунального сектора міст та селищ.

Ключові слова: *Системи теплопостачання; Режими роботи систем теплопостачання; Опалювальні системи; Опалювальні прилади.*

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