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РОБОЧА ПРОГРАМА ТА ТЕЗИ ДОПОВІДЕЙ

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КИЇВ
27-29
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2024

МІЖНАРОДНА НАУКОВО-ПРАКТИЧНА КОНФЕРЕНЦІЯ

ЕНЕРГІЯ. РЕСУРСИ. ЕКОЛОГІЯ

БАГАТОФУНКЦІОНАЛЬНІ ЕНЕРГО- ТА РЕСУРСОЕФЕКТИВНІ ЕКОЛОГІЧНО БЕЗПЕЧНІ ТЕХНОЛОГІЇ В АРХІТЕКТУРІ ТА БУДІВНИЦТВІ

КИЇВСЬКИЙ НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ БУДІВНИЦТВА І АРХІТЕКТУРИ
ТЕХНОЛОГІЧНИЙ УНІВЕРСИТЕТ ВАРШАВИ, РЕСПУБЛІКА ПОЛЬЩА
ТЕХНОЛОГІЧНИЙ УНІВЕРСИТЕТ ЛЮБЛІНА, РЕСПУБЛІКА ПОЛЬЩА
ТЕХНОЛОГІЧНИЙ УНІВЕРСИТЕТ ЧЕНСТОХОВА, РЕСПУБЛІКА ПОЛЬЩА

PROGRAM AND ABSTRACTS OF REPORTS

of the 5th INTERNATIONAL SCIENTIFIC AND PRACTICAL CONFERENCE

ENERGY. RESOURCES. ECOLOGY

MULTIFUNCTIONAL ECO- and ENERGY-EFFICIENT, RESOURCE-SAVING TECHNOLOGIES IN ARCHITECTURE, CONSTRUCTION AND RELATED INDUSTRIES

KYIV
November 27-29, 2024

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Oleksandr PRYYMAK, Dean of the Faculty of Engineering Systems and Ecology, KNUBA, Ukraine – Deputy Chairman

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REGULATIONS ON THE CONFERENCE

- **Registration of participants** - 11/23/2022, 9:00 a.m.
- **Conference opening** - 11/27/2024 at 10:00 a.m.
- **Plenary session** - 11/27/2024 from 10:00 to 16:00 with a break at 13:00-14:00
- **Sectional meetings** - November 28 and 29, 2024 from 10:00 a.m.
- Between meetings, there is a coffee break
- **Round table based on the results of the conference** - 11/29/2024 at 1:00 p.m.

PROGRAM

PLENARY SESSION

1. **Borys BASOK,** Corresponding Member of the National Academy of Sciences of Ukraine, Doctor of Technical Sciences, Professor, Institute of Technical Thermophysics of the National Academy of Sciences of Ukraine, Kyiv, Ukraine
   Borys DAVIDENKO, Doctor of Technical Sciences, Professor, Institute of Technical Thermophysics of the National Academy of Sciences of Ukraine, Kyiv, Ukraine

Innovative window structures for the renovation of war-damaged buildings

1. **Mykola KRUPA,** Doctor of Physical and Mathematical Sciences, Institute of Magnetism of the National Academy of Sciences and the Ministry of Education and Science of Ukraine
   Oleksandr PRIYMAK, Doctor of Technical Sciences, Professor, Kyiv National University of Construction and Architecture
   Serhiy KONOPLYUK, Doctor of Physical and Mathematical Sciences
   Institute of Magnetism of the National Academy of Sciences and the Ministry of Education and Science of Ukraine

Thermoelectric sources of energy

2. **Nasrin Arjomand KERMANI** Senior Researcher, Mechanical designer and Energy specialist, Technical University of Denmark

Production and Use of Thermal Energy: Heating and Gas Supply

3. **Oleksandr KRAVCHENKO,** Doctor of Technical Sciences, Kyiv National University of Construction and Architecture, Institute of Communal Infrastructure

New National building norms for water supply and sewerage

4. **Andrzej LANGE**, Doctor of Engineering
   Krzysztof WOŁODKIEWICZ, Master of Science in Environmental Engineering, Instal-Audyt , Poland

Energy transformation of public buildings using high-efficiency cogeneration

5. **Tetyana PRIKHNA**, Doctor of Technical Sciences, Academician of NASU, V. M. Bakul Institute of Superhard Materials of NASU
   Gennadii KOCHETOV, Doctor of Technical Sciences, Professor, Kyiv National University of Construction and Architecture

Comprehensive resource-saving processing of waste from electroplating industries

6. **Valentyn GLYVA,** Doctor of Technical Sciences, Professor, Kyiv National University of Construction and Architecture

Development and research into the protective properties of materials for blocking infrared radiation

7. **Larysa SABLIY,** Doctor of Technical Sciences, Professor, NTUU "Igor Sikorsky Kyiv Polytechnic Institute"

Prospects for the use of immobilized microorganisms on carriers of various types in biological wastewater treatment

8. **Tetiana TKACHENKO,** Doctor of Technical Sciences, Professor, Kyiv National University of Construction and Architecture

Positive effects of green structures in modern construction

9. **Tetiana KRYVOMAZ,** Doctor of Technical Sciences, Professor, Kyiv National University of Construction and Architecture

Diversification of energy supply risks of multi-story residential buildings in war conditions

10. **Viktor MILEIKOVSKYI,** Doctor of Technical Sciences, Professor, Kyiv National University of Construction and Architecture
    Vadym KORBUT, Doctor of Technical Sciences, Professor, Kyiv National University of Construction and Architecture
    Tetiana TKACHENKO, Doctor of Technical Sciences, Professor, Kyiv National University of Construction and Architecture

Evaluation of the effectiveness of air exchange for the formation of a bio-safe and comfortable environment of premises with a massive presence of people

11. **Adam UJMA,** Doctor of Engineering, University of Applied Sciences in Nysa, Poland

Selected examples of the use of AI in architecture and construction

12. **Oleksandr PRIYMAK**, Doctor of Technical Sciences, Professor, Kyiv National University of Construction and Architecture

Achieving resource and energy balances in energy-efficient district heating and cooling systems

Main thematic areas

Use of thermal energy. Non-traditional energy sources

1. ***Mykola Krupa, Oleksandr Priymak, Serhiy Konoplyuk***

Thermoelectric sources of energy

2. ***Borys Basok, Borys Davydenko***

Innovative window structures for the renovation of war-damaged buildings

3. ***Olha Chernousenko, Olha Vlasenko, Oleksandr Nedbailo***

Intensity of heat exchange in the round pipe of the heat exchanger of the biogas plant

4. ***Vitaly Petrash, Vitaly Baryshev, Elina Geraskina, Andriy Golubenko***

Integrated heat supply system based on conventional and steam-compression heat generation according to the two-stage scheme

5. ***Kostiantyn Predun, Oleksii Kushnir, Olha Pochka***

Energy transformation in Ukraine on the basis of biosphore compatibility

6. ***Bohdan Koziachyna***

Methodology for estimation seasonal generation of heat energy by a combined heat source with an air heat pump based on an array of hourly temperature data

7. ***Oleksandr Pohosov***

Research of technological systems of steam supply and possible ways of increasing their energy efficiency on the example of devices for defrosting wagons

8. ***Ivan Kripak***

A window as a high-tech multifunctional transparent enclosure

9. ***Andriy Redko, Maxim Batiuta, Oleg Synilo, Vadym Zadyranov, Yuriy Reznychenko, Timur Lavrynov***

Evaluation of biogas (biomethane) production during anaerobic fermentation of plant biomass

10. ***Bohdan Kutnyi, Iryna Chernetska, Eduard Yevtushenko***

Stagnation as one of the challenges for the development of solar systems

11. ***Stepan Shapoval, Yuriy Pryshlyak, Olena Savchenko***

The research of thermal characteristics of a hybrid solar collector on the base of computer simulation

12. ***Georgy Ratushniak, Yuriy Biks, Andriy Lyalyuk***

Fuzzy fitness functions of key influence parameters for the envelope energy efficiency assessment prediction

13. ***Stepan Mysak, Stepan Shapoval***

Modeling of thermal efficiency of a hybrid solar collector in a system with thermal storage

14.***Yevhen Patrashku, Volodymyr Isaev, Volodymyr Kiosak***

Solar activity and thermal comfort

15.***Yuri Volokh, Mykhailo Kyrychenko***

The feasibility of implementing passive heating and cooling systems in Ukraine

16.***Oleksii Nikitin***

Research on the efficiency of geothermal heat pumps in the construction of multi-apartment residential buildings

17.***Borys Basok, Borys Davydenko, Volodymyr Novikov***

Research of thermal characteristics of window structures with shutters

18.***Pavlo Glamazdin, Natalia Chepurna, Vasyl Savyk***

High-temperature heat supply systems in the elements of oil pipelines

19.**Yevhen Vakulenko**

Enhancing combustion efficiency of non-design fuels through oxygen-enriched combustion air

20.***Kristina Gaba, Pavlo Glamazdin***

Cleaning heating surfaces in the presence of surfactants

21.***Vitaly Bashkir, Pavlo Glamazdin***

Modernization of gas supply systems of district boiler houses and heat supply stations

22.***Darya Omelchenko, Pavlo Glamazdin***

Individual heat station with heat pumps for heat supply systems

Water supply and wastewater. Engineering. Technologies

1. ***Oleksandr Kravchenko, Oksana Nechypor, Tetyana Kuba, Nestan Tavartkiladze***

Building codes for the design of external water supply and sewerage networks in Ukraine: relevance, problems and prospects

2. ***Orest Verbovskiy, Vadym Orel, Oksana Matsiyevska, Nazarii Zheplinskyi***

Electro-dewatering of activated sludge of sewage treatment plants, Ternopol

3. ***Valery Makarenko, Volodymyr Gots, Tetiana Arhatenko***

Experimental studies of bearing capacity of pipe steel of sewage systems

4. ***Anastasia Sosedko, Gennadii Kochetov***

Development of complex wastewater treatment of galvanizing lines

5. ***Stepan Epoyan, Tamara Airapetian, Oleksandr Haiduchok, Vladislav Miroshnyk***

Intensification of swirl-vortex chamber operation for the formation of flakes and its technological and construction parameters

6. ***Svitlana Velychko, Olena Dupliak, Ruslan Ilkiv***

Simulation of the seepage pressure under the dam by seep/w during engineering education

7. ***Mykola Sytnichenko, Hanna Anatska***

Using the exponential distribution as a synthetic curve volume of runoff to determine the volume of surface runoff

8. ***Yuriy Kopanytsia, Olena Gizha, Oksana Nechypor, Oleksandr Kormiltsyn***

Determination of the force of hydrostatic pressure on the plane surface of an arbitrary non-symmetrical form by the three-command method K123

9. ***Andriy Kravchuk, Oleksandr Kravchuk, Oleksandr Voznyi, Olga Kravchuk***

Operational features of collecting pipelines in the presence of transit and groundwater level slope

10. ***Tetiana Kurbanova, Tetiana Khomutetska***

Prospects for improving technologies of groundwater deironing for local drinking water supply systems

11. ***Ihor Prokopenko, Victor Khoruzhy, Ihor Nedashkovskyi***

Analysis of domestic wastewater disinfection methods using chlorine dioxide and sodium hypochlorite

12.***Vadym Orel**, **Lesya Vovk**, **Volodymyr Femiak, Iryna Balinska***

The potential of alternative water sources for potable water savings in Ukraine's residential areas

13.***Taras Sydor, Vadym Orel***

Influence of geometric parameters of pipe narrowing on pressure losses in a pressure short pipeline

14.***Liubov Kika, Larysa Sabliy***

Influence of technological parameters of biological wastewater treatment using lemnaceae on the degree of antibiotic removal

15.***Larysa Sabliy, Veronika Zhukova, Andriy Hrynevych***

Assessment of the microorganism composition immobilized on carriers of different types

16.***Olena Dupliak**, **Vitaliy Stesenko***

Analysis of existent catalytic filter materials for removal of iron and manganese

17.***Yuriy Kopanytsia, Olena Gizha, Evgen Pavlov, Oleksandr Kushka, Oleksandra Goloborodko, Andriy Gavrylyuk***

Numerical online experiment in the calculation of channels of the hydraulicly most advantageous profile of a trapezeidal form

18.***Oleksandr Kravchenko**, **Oleg Bakunovsky, Tetyana Kuba, Nestan Tavartkiladze***

Modernization of Desnianska water treatment plant: justification of the need and selection of technological solutions based on pilot studies

19.***Tetiana Arhatenko, Olexandra Pestienko***

Use of combined water supply systems to increase the reliability of water supply

20.***Svitlana Potapenko, Oleksandr Kravchenko***

Ensuring the safety of drinking water for all in Ukraine

Heating, ventilation and air conditioning. Engineering. Technologies

1. ***Vadym Korbut, Tetiana Tkachenko, Viktor Mileikovskyi, Volodymyr Vakhula, Yurii Tsiuriupa***

Evaluation of the effectiveness of air exchange for the formation of a bio-safe and comfortable environment of premises with a massive presence of people

2. ***Maksym Mykytenko, Oleksandr Liubarets***

Analysis of the impact of key factors on the dust collection process in scrubbers with disc atomizers

3. ***Bohdan Hulai, Oleh Kuz, Volodymyr Bundzylo***

Analysis of the effectiveness coefficient of decentralized ventilation systems with heat recovery

4. ***Valerii Savin, Vasyl Zhelykh***

Natural ventilation as an energy-efficient solution for thermally modernized buildings

5. ***Ihor Polataiko***

Applications of automation control for commercial gas accounting based on the concept of virtual points

6. ***Yurii Franchuk, Viktoriia Konovaliuk***

Prospects for using gas to balance the electricity supply system

7. ***Anna Moskvitina, Yana Safronova***

Analysis of ways to save energy and increase the energy efficiency of residential buildings

8. ***Anna Moskvitina, Andriy Yakymenko***

Problems of wide-scale introduction of heat pumps in Ukraine

9. ***Anna Moskvitina, Vladyslav Bondarenko***

Secondary energy resources in the energy sector of Ukraine

10. ***Vitalii Voinalovych***

Ground source heat pumps: regulatory framework and environmental impact on subsoil

11. ***Anatolii Moisin***

Natural air pollution technologies in the premises of health care institutions

12. ***Anatoliy Makarov, Andriy Khodos, Mykhailo Kyrienko, Mykhailo Senchuk***

Improving the efficiency and reliability of spray drying equipment for dairy products

13. ***Volodymyr Siredzhuk***

Current challenges and energy-efficient technologies in ukraine's district heating and gas supply systems

14. ***Vasyl Zhelykh, Yuriy Furdas, Volodymyr Shepitchak, Khrystyna Myronyuk***

Passive technologies for maintaining microclimate in modular buildings

15. ***Oleksandr Zadoiannyi, Yuri Evdokimenko***

Evaluation of energy efficiency indicators of elements of central air conditioning systems by the exergy efficiency index

16. ***Pavlo Pasichnyk, Kristina Gaba***

Features of heat supply when establishing civil protection structures in public buildings

17. ***Volodymyr Vakhula, Alexey Dudnikov***

Ensuring optimal microclimate in museum premises using multi-jet air distributors in systems with adjustable air flow

18. ***Serhiy Rybachov***

Energy-efficient ventilation and smoke extraction solutions for multi-level parking lots of large areas

19. ***Borys Basok, Oksana Lysenko, Svitlana Goncharuk, Maryna Moroz, Vitaly Opryshko, Igor Bozhko***

Experimental studies of the thermal regime of the room when it is heated by an electric heating device

Ecosystems and water resources. Engineering. Technologies

1. ***Tetiana Tkachenko, Viktor Mileykovskyi, Adam Ujma, Anna Lis***

Use of military waste in construction

2. ***Olena Kotovenko, Olena Miroshnychenko, Daniil Danylenko***

Oil and gas production and the environment

3. ***Vitaliy Zalozh***

Development of a design solution for the automation system of an experimental ballast water treatment facility

4. ***Andrii Mats, Olena Mitryasova, Viktor Smyrnov***

Google earth engine tools forstudy of the state of the hydroecosystem

5. ***Artem Maksymenko, Iryna Klimova***

Acoustic properties of materials used in the construction of noise barriers

6. ***Viktoriia Sakhnovska***

System model for ensuring ecological safety of municipal water supply and wastewater systems during martial law

7. ***Sergii Kozhevnikov***

The main trends of pvc recycling

8. ***Tetiana Tkachenko, Sofiya Bugayova, Khrystyna Dyachenko***

The problem of plastic pollution of the environment

9. ***Tetiana Tkachenko, Irina Petchenko***

The role of intelligent systems in risk management and improving the efficiency of construction processes

10. ***Tetiana Tkachenko, Kateryna Matviychuk***

Environmental-safe household alternative

11. ***Tetiana Kryvomaz, Roman Hamotskyi, Igor Ilchenko, Artem Tsyba***

Diversification of energy supply risks of multi-story residential buildings in war conditions

Fundamental and applied scientific research. Efficiency. State-of-the-art design and operation

1. ***Boris Basok, Oleksandr Nedbailo***

Explosion resistance of transparent structures

2. ***Grygorii Krasnianskyi, Iryna Aznauryan, Maxim Dovhanovskyi, Oleg Besarab, Vadym Okhrysko***

Evaluation of the effectiveness of infrared radiation shielding with glass fiber

3. ***Vitalii Tarasevych, Oleksandr Hryhorchuk, Darya Tanasienko***

Corrosion-resistant facing material from sulfur-gypsum composite manufactured using sulfur-containing waste

4. ***Nataliia Burdeina, Yaroslav Pidlisnyi***

Identification of critical sources of electromagnetic fields in public buildings and ways to reduce their impact on people

5. ***Yana Biruk, Larysa Zozulya, Andrii Klymchuk***

Means of increasing the efficiency of shielding electromagnetic fields by heterogeneous building materials

6. ***Valentyn Glyva, Serhii Zozulya, Mykhailo Kashlev***

Investigation of the spectral composition of construction machinery noise and development of a methodology for improving the effectiveness of protective equipment

7. ***Valentyn Glyva, Larysa Levchenko, Dmytro Osadchyi***

Investigation of magnetic field levels of electric generators and determination of means of their reduction

8. ***Vadym Lutsenko, Oleksandr Hryhorchuk, Vitalii Tarasevych, Maksym Volchkov, Oleksandr Khodakivskyi***

Experimental equipment for researching thermophysical properties of building materials

9. ***Oksana Berdnyk, Sergiy Vyhovskyi***

Application of waste glass powder as a partial replacement for cement in concrete

ABSTRACTS OF REPORTS

Use of thermal energy. Non-traditional energy sources

***Mykola KRUPA**, Doctor of Physics and Mathematics of Sciences*
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THERMOELECTRIC SOURCES OF ENERGY

The issue of increasing the efficiency of existing energy sources, as well as the search and development of new ecologically clean energy sources is considered one of the most urgent tasks in energy, and today the problem of energy conservation has become extremely important not only economically, but also politically. This report examines the principles and schemes of building thermoelectric converters based on the Seebeck and Nerst effects as basic elements for creating environmentally friendly renewable sources of electrical energy. Thermoelectric converters of this type can use natural heat sources or waste heat from industrial production directly converting it into electricity, which allows you to avoid the release of ozone-depleting substances and CO2. The advantage of energy sources that work on these principles is that the Seebeck and Nerst thermoelectric converters do not contain moving parts, are reliable, fast-acting, silent, thermally stable and have very large lifetime values. Therefore, thermoelectric sources of electrical energy are small-sized, autonomous and can be used for household needs and for powering electronic devices and systems of various purposes.

The review shows that today the field of practical use of thermoelectric converters for obtaining electrical energy can be narrow, which is due to low coefficients of direct conversion of heat into electrical energy, as well as the high cost of monocrystalline semiconductor materials. However, the results of recent research and development show that the transition to composite nanomaterials makes it possible to create efficient sources of electrical energy based on thermoelectric converters.

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INNOVATIVE WINDOW STRUCTURES FOR THE RENOVATION OF WAR-DAMAGED BUILDINGS

Among energy saving measures in the building industry, an important place is occupied by increasing the energy efficiency of translucent structures. This is not only about reducing heat loss through windows, the heat transfer resistance of which is lower than that of wall structures, but also about using windows as heating devices for heating rooms and heating ventilation air coming from the environment. Therefore, windows, in addition to their main purpose of transmitting sunlight, should also contribute to the creation of a proper microclimate for comfortable living conditions for humans indoors. Therefore, the development of methods for increasing the energy efficiency of window structures is an extremely urgent scientific and applied problem. Another important circumstance that encourages the active creation of innovative windows is the military operations in Ukraine. As a result of the military operations, many residential and public buildings were damaged. Even in cases where the walls of the building survived the explosion, the windows, as a less durable element of the building, crack, collapse or even fly out from the action of the shock wave. It is logical and more expedient to replace the destroyed windows with modern ones that meet the current quality standards and state building codes. In recent years, the *Institute of Engineering Thermophysics of the National Academy of Sciences of Ukraine* has been actively working on solving these problems. To this purpose, relevant theoretical, computational and experimental studies are being carried out.

Among the known methods of increasing the heat transfer resistance of window structures, an important place is occupied by increasing the number of chambers in windows. Today, two-chamber glass units with low-emission coating on the inner surfaces of the glass are most often used in modern buildings. But their heat transfer resistance remains significantly lower than the heat transfer resistance of wall structures with a layer of insulation. Studies have shown that it is advisable to increase the number of chambers in a windows to three. The total heat transfer resistance of these glass units will increase proportionally to the number of chambers. If low-emissivity coatings are used on the inner surfaces of the glass, then even when chambers are filled by air, the heat transfer resistance of a three-chamber glass units with a distance between the glass of 10 mm can be increased to 1.1 m^2 K/W. Further increase in the number of chambers is not very rational due to the increase in the weight of the windows. They become bulky, which causes inconvenience during their installation.

Another direction for increasing the heat transfer resistance of translucent structures is the use of combination of two double-chamber windows. Two double-chamber windows are installed in the window opening parallel to each other at a certain distance. The results of the studies show that compared to the heat transfer resistance of one double-chamber window with a distance between the glass of 10 mm and without low-emissivity coatings, two such double-chamber windows located at a distance of 32 mm…120 mm from each other provide a heat transfer resistance of 0.843…0.87

m^2K/W, which is 2.63...2.8 times greater than the resistance of one double-chamber window.

Increasing the heat transfer resistance of glass units is also possible by replacing the air medium in their chambers with inert gases, which have a lower thermal conductivity than air. This well-known method of increasing the heat transfer resistance is widely used in practice. However, it is necessary to take into account the fact that mainly a larger amount of heat loss through windows occurs by radiation heat transfer. Therefore, reducing the thermal conductivity of the gas will play a more significant role in increasing the heat transfer resistance when the amount of heat transferred by radiation is significantly reduced by applying low-emissivity coatings to the glass surface.

It is also considered promising to increase the heat transfer resistance of windows by vacuuming the glass chambers. This method also proves to be effective when the radiation component of the heat flux is also reduced. However, it should be noted that the effect of vacuuming on the heat transfer resistance of glass units with a distance between the glass of 8...12 mm will be noticeable only when the pressure in the chambers decreases to 10 Pa. At a higher pressure in the chambers, the increase in resistance will not be too significant. The effect of vacuuming the space between the glass becomes more effective when the distance between the glass surfaces becomes less than 1 mm. In this case, we are no longer talking about glass units, but about double-layer vacuum glass.

In addition to inert gases, it is also advisable to fill the space between the glass surfaces in the chambers of a double-glazed window with a porous aerogel, the thermal conductivity of which under certain conditions may be lower than that of air. Calculation and experimental studies show that the value of the heat transfer resistance of a single-chamber glass unit with an interglazed space width of 10 mm when filled with porous aerogel reaches 0.37 m^2K/W. If this space is 20 mm, the heat transfer resistance of that glass unit reaches 0.71 m^2K/W.

The results of the conducted research show that window structures are also advisable to use in room ventilation systems. For this purpose, ventilated glass units are created. They are used as recuperative heat exchangers for heating cold outside air entering the room, as well as for removing air from the room. In both cases, heat losses through the glass surfaces increase slightly compared to the case of a conventional double-chamber window. However, these losses are compensated by an increase in thermal energy entering the room with air from the environment. At the same time, heat consumption for heating the outside air is reduced. When air is removed from the room through a ventilated double-chamber window, part of its thermal energy is returned to the room again, unlike the case when warm air is removed directly into the environment.

A similar result is also achieved when the air from the room is removed through the gap between two double-chamber windows. The results of numerical studies show that this method of removing air from the room is efficient from an energy point of view.

Shutters, which can be installed both on the outside and inside of the window, also contribute to increasing the heat transfer resistance of window structures. The results of numerical studies have shown that shutters of a certain type can almost

double the heat transfer resistance of a window structure, both due to the resistance of the shutter itself and due to the resistance of the air layer between the window and the shutter.

In order to reduce the end heat fluxes from the window into the facade wall of the building, it is advisable to use special thermal insulation inserts between the window and the window opening in the wall structure. Numerical studies have been conducted to indicate the effectiveness of this measure in reducing heat losses through windows. Heat losses from the room also occur through the profiles of the frame in which the window is installed. To determine these losses and to develop measures to reduce them, appropriate calculation and experimental studies were carried out. The dependence of the heat transfer resistance of the frame profiles on the number of chambers in these profiles was found.

Window structures can also be used as heating devices. If an electric current is passed through a layer of low-emission coating applied to the inner surface of the glass, this layer heats up. Part of the heat generated by the current flows from the window into the room, and the other part is removed into the environment. The use of electrically heated windows prevents the formation of condensation or frost on the window glass. Their use is especially important at the beginning of the heating season, when the building has already cooled down somewhat and the heating has not yet been turned on. But such windows with electric heating can be considered effective if the heat entering the premises significantly exceeds that part of it that is transferred to the environment. Numerical and experimental studies showed that for the studied structures 83%...85% of the heat released due to electric heating is transferred to the premises. Accordingly, 15%...17% of the heat is removed to the outside space. That is, such windows are quite efficient from an energy point of view and can contribute to heating premises in the winter period of the year.

Special electrically conductive plates can also be used as heating elements in the window. In this case, part of the window glass is heated. In modern glass units, spacer frames are most often made of aluminum, which is a good conductor of electric current and a source of thermal energy. Numerical studies of heat transfer processes through windows with such heating elements indicate a significant increase in the temperature of the glass surfaces in the edge zones. From this we can conclude that the use of spacer frames as sources of thermal energy eliminates moisture condensation in the edge zones of glass units.

The presented results of theoretical and experimental research indicate the potential for a significant increase in the energy efficiency of window structures. This is especially important for Ukraine, which is in difficult modern conditions.

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INTENSITY OF HEAT EXCHANGE IN THE ROUND PIPE OF THE HEAT EXCHANGER OF THE BIOGAS PLANT

Biogas technologies involve large-scale production. They use significant volumes of the substrate, the thermophysical properties of which are usually unknown.

At the current stage of the development of biogas technologies, problems arise regarding the thermal stabilization of processes and forecasting the parameters of the intensity of heat exchange. In production, a lot of attention is paid to the problems of creating a stable thermal regime of the bioreactor, subject to changes in the ambient temperature. The main factor for the effective functioning of the bioreactor is to maintain the temperature of the substrate in a certain range. Processes of heat and mass transfer during the production of biogas have not been sufficiently studied, because the composition of the substrate is diverse. In addition, it is a multiphase and multicomponent medium at the same time. Commonly known methods of forecasting the intensity of heat exchange are not suitable in this case and require an original, specific approach.

From information sources, a widely used method of calculating heat exchanger parameters using the results of the analysis of the regular thermal regime in the "liquid - solid" system according to the criterion equations of heat exchange for liquids with known thermophysical properties is known.

Given the availability of limited data on the thermophysical properties of liquids, an experimental and computational method is proposed for predicting the values of heat exchange intensity parameters in such environments. According to previous experience, the experimental-calculation method is based on the theory of similarity with studies of only the parameters of individual components that make up the substrates.

The aim of the work is to develop a reliable method for predicting the intensity of heat exchange in a round tube of a natural heat exchanger in various technological regimes that occur in biogas technologies (using the criterion equations of heat exchange, but with limited information on the thermophysical properties of the substrate).

The presented work uses an improved experimental and computational method based on the combined use of the theory of similarity and the analysis of the parameters of the regular thermal regime. During the research, a real substrate from an operating biogas plant was used.

The reason for the high intensity of heat exchange is the direct contact of substances on the boundary surfaces of the phases, which must be supported by the continuous renewal of these surfaces thanks to the constant mixing of the substrate. However, such a process can be implemented only if the viscosity of the substrate allows uniform mixing of liquid, suspended solid particles, as well as bacteria and

bubbles of a mechanical mixture of gases. The upper limit of the concentration of solid particles, at which free mixing of phases is still possible, for a substrate with a finely dispersed suspension of solid substances corresponds to 10...12%. At higher values, gas output decreases significantly. By means of intensive mixing and the appropriate introduction of heat, the influence of the unwanted effect can be significantly reduced.

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INTEGRATED HEAT SUPPLY SYSTEM BASED ON CONVENTIONAL AND STEAM-COMPRESSION HEAT GENERATION ACCORDING TO THE TWO-STAGE SCHEME

Introduction. The research is devoted to the solution of topical issues of increasing the efficiency of decentralised heat supply of public buildings and industrial enterprises by typical municipal and industrial heat generators on the basis of steam-compression energy conversion of pre-cooling of heat flows of waste energy carrier from the heat network, initial cold water and flue gases.

The aim of the work is to substantiate the conditions for expanding the total amount of generated heat and increasing the efficiency of an improved integrated heat supply system and the environmental friendliness of primary fuel energy use. The proposed approach involves increasing the energy performance of heat sources with the regulation of the reasonable temperature of the waste energy carrier in accordance with the normalized temperature schedule.

The objectives of the study were to evaluate and substantiate the rational structure for the effective functioning of the proposed system for two-stage heat generation with increased energy and technological efficiency and operational control while coordinating the temperature regimes of the processes of combined heat generation based on the above-mentioned low-temperature sources.

Research methods. The solution of the problem is based on the analytical substantiation of the rational structural and functional structure and highly efficient operation of heat pump heat supply systems with the search for rational operating conditions based on an improved temperature schedule of heat supply using the integrated aftercooling potential of these low-temperature sources.

Research results.

1. For the integrated decentralised heat supply system the generalised dependence for definition of actual conversion coefficient of the heat pumping unit on the basis of integral potential of aftercooling of the waste energy carrier from a heat network, initial cold water and flue gases is established. This allows a qualitative analysis of the energy efficiency of the heat supply system. For this purpose, the temperature changes of the analysed low-temperature sources, the coefficient of relative water consumption and the influence of the regime distribution of cold water for municipal and industrial-technological needs were studied.

2. For the proposed system it is established that the change in the actual conversion coefficient is significantly influenced by the value of the intermediate temperature of the exhaust energy carrier from the heat network after the condenser at the inlet to the heat generator. It follows from the results of the analytical study that the calculated value of the temperature of the waste energy carrier from the heat network after the condenser at the inlet to the heat generator should be based on the thermal and economic optimisation of the calculated difference in the condensation temperature when heating the heat carrier of the consumer and boiling of the working fluid in the evaporator of the heat pumping unit on the basis.

3. The system operation provides increase of the total capacity of the generated heat in 2,1÷3,7 times, depending on the actual ratio of the initial common cold water consumption in the considered range and its consumption for hot water supply in the range of 0,1÷0,3. It is obvious that in the specified range of change of water consumption for hot water supply it is possible to increase (20 ÷ 30)% of the heat-generating component and less significant influence of the ambient temperature change on it.

4. The research results of the improved decentralised heat supply system create a basis for its further development with justification of rational intermediate temperature of the heat carrier.

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ENERGY TRANSFORMATION IN UKRAINE ON THE BASIS OF BIOSPHORE COMPATIBILITY

The technological level of development of any country is indirectly characterized by the indicator of electricity consumption by one person during the year. In Ukraine in 1990, at the peak of the development of the fuel and energy complex, it was 5198 kWh/person, which was close to the average value in the European Union at that time of 5468 kWh/person. However, it should be noted that the energy intensity of the economy at that time exceeded the similar indicator both in the EU and in the world. Thermal generation was dominant with a share of more than 70%. Alternative energy was in its infancy: due to low domestic prices for traditional fuels, as well as the social orientation of state policy. The transition to market principles of management with a simultaneous reduction in electricity consumption by domestic industry and agriculture, respectively, reduced the need for electricity generation.

In 2021, before the start of a full-scale war with the russian federation, electricity production in Ukraine amounted to 158.4 billion kWh. More than half of the electricity in the country was and continues to be produced by nuclear power generation (NPP) - 54.4%. The share of thermal power plants (TPP) was 23.5% of the total volume of production, renewable energy -7.9%. Thermal power plants (CHP) produced 6.4%, hydroelectric power stations (HPP) - 5.8% of electricity, another 0.8% was accounted for by hydro-accumulating stations. A little more than 1% of the total amount of

generation was taken by other sources. In March 2022, the energy system of Ukraine was fully synchronized with the energy grid of continental Europe ENTSO-E.

A full-scale war with russia caused significant destruction of the state's infrastructure. Of the 4 operating nuclear power plants, 3 are currently operating (the largest in Europe, Zaporizhzhya LES is located in the temporarily occupied territory and does not produce electricity). All Ukrainian TPPs were partially damaged/completely destroyed (there were 15 of them in Ukraine). In the pre-war years, the stations were used, including for balancing the energy market. Built in the 60s and 70s of the last century, they were almost the biggest polluters of the environment in Europe (out of the first ten, eight were Ukrainian). Currently, the share of thermal generation in electricity production barely reaches 5%. Out of 43 thermal power stations, 80% of the stations were destroyed as a result of the attacks. All large hydroelectric power plants, in particular Dniprovska, were damaged, and Kakhovska was completely destroyed. As a result of the invasion of the russian federation, Ukraine lost 80% of wind and 20% of solar power plants Thus, russia destroyed 9.2 GW of Ukrainian generation.

Started with the signing of the Association Agreement with the EU, the reform of the energy sector continues today: from the adoption of normative legal acts, harmonized by 3 relevant documents of the European Parliament and the Council, to the implementation of technical solutions that contribute to the reduction of the use of traditional fuels and, accordingly, "thermal" pollution of the environment. Significant changes are taking place in the tariff policy, primarily for housing and communal services.

Since 2019, the Ukrainian electricity market functions according to the European model. The National Commission, which carries out state regulation in the spheres of energy and communal services, takes care of the Ukrainian consumer. The single fixed price for household consumers for the period from June 1, 2024 to April 30, 2025 is fixed at UAH 4.32. or 0.1 euro per kWh.

Among European consumers, electricity is the most expensive in Germany, where the cost of 1 kWh currently is 0.39 euro. In Sweden and Finland - 0.17, and in Moldova - 0.14 euro. The cheapest electricity in Serbia and Hungary is 0.10 euro, and the cheapest: 0.09 euro in Bulgaria and 0.07 euro in Norway.

To compensate for the volume of electricity that was lost both for domestic consumption and for export due to wear and tear infrastructure on fossil fuels and its practical destruction, in the near future only power plants based on renewable energy sources will be able to. By receiving electricity from the wind and the sun, consumers do not depend on the quantity and finiteness of traditional fuels, the terms of their extraction or delivery, the availability of places for storage and disposal of waste.

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METHODOLOGY FOR ESTIMATION SEASONAL GENERATION OF HEAT ENERGY BY A COMBINED HEAT SOURCE WITH AN AIR HEAT PUMP BASED ON AN ARRAY OF HOURLY TEMPERATURE DATA

The constant growth in demand for heat sources with heat pumps causes the need to develop effective schematic solutions and algorithms for their operation, and also requires a thorough economic analysis, including an approximate calculation of the payback period and proof of the economic feasibility of implementation. In particular, this applies to heat pumps that use as a low-potential heat source those sources whose heat energy potential is significantly dependent on changes in seasonal and climatic factors, such as outdoor air. The variability of the outdoor temperature has a crucial impact on the thermal capacity and the coefficient of performance of an air source heat pump. Therefore, it is usually not appropriate to install an air source heat pump to cover the heat loads during the heating season in monovalent mode. Thus, in most cases, combined heat sources that combine the operation of an air source heat pump with a traditional heat source are developed. The traditional heat source can be auxiliary and cover the residual heat load during peak periods, or an alternative heat source that can take over the entire heat load after reaching a certain outdoor temperature, depending on the algorithm of the combined heat source, which is laid down during the design. The task of determining this temperature, up to which the heat pump is considered efficient, is key in determining the ratio of the heat pump and the traditional heat source in the combination. To solve this problem, a number of calculations are carried out, usually based on data on the average duration of certain intervals of outdoor air temperatures during the heating period in the geographical conditions of the future heat source. These data are developed by analyzing the repeatability of outdoor temperatures over a long time period, so they are rarely updated. In general, the calculation methodology based on the average duration of standing temperatures is not flexible enough and does not allow to include a large number of important factors. The use of hourly outdoor temperatures in the calculation of the seasonal amount of heat energy to be produced and the amount of energy consumed by the sources as part of the combined heat source allows to increase the accuracy of the calculation.

In this study, a methodology for calculating the distribution of heat generation and electricity consumption by sources in a combined heat source with an air heat pump was developed based on an array of hourly temperature data. This methodology allows to take into account various bivalent operation modes, variable operation of the heating system and the division of day and night electricity tariffs into periods. Using the developed algorithm, a calculation program was built based on an array of hourly outdoor air temperatures for the last 50 heating periods for the city of Kyiv. The calculation results are presented for three variants of bivalent modes and several variants of temperature graphs of the heating system.

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RESEARCH OF TECHNOLOGICAL SYSTEMS OF STEAM SUPPLY AND POSSIBLE WAYS OF INCREASING THEIR ENERGY EFFICIENCY ON THE EXAMPLE OF DEVICES FOR DEFROSTING WAGONS

Steam supply systems of industrial enterprises in various fields of activity remain relevant primarily due to the thermophysical features of the use of phase transition energy of water vapor in the process of its condensation. In addition, in the countries of Eastern Europe, traditionally a significant number of existing boiler houses are steam and the choice of energy carrier is determined precisely by the presence of a characteristic source. At the same time, cargo logistics processes are provided today largely by sea transport, and delivery to ports is traditionally carried out by rail, which in turn requires the use of a defrosting system and transshipment of bulk products.

There are few studies devoted to the rather narrow and geographically limited topic of energy efficiency of steam supply systems for defrosting wagons. First of all, this is due to the fact that defrosting houses with steam heating devices were actively used only in Eastern Europe, and the geography of research is mainly limited to the northern countries of this region. At the same time, the growth of shipping is an inherent process for actively developing and consuming humanity. Accordingly, the importance of the energy efficiency of all processes at all stages of shipping is difficult to deny. At the same time, the delivery of goods by rail to ports remains an integral part of the logistics process.

The object of this study was one of the ports of Ukraine, located on the Black Sea coast. In the total energy balance of the facility, the largest share is occupied by the central boiler house, represented by a combination of steam and hot water boilers with a total installed capacity of about 45 MW, of which 9 MW is the installed capacity of hot water boilers. At the same time, the share of the installed capacity of two devices for defrosting wagons (hereinafter, technological defrosting house) is up to 8.8 MW in full load mode (according to the enterprise). One of the largest technological consumers of water vapor at the enterprise are two devices for defrosting wagons (loading one device - 20 wagons). Side and ceiling smooth pipe steam registers are used as heating elements.

The paper presents the results of studies of energy consumption of devices for defrosting wagons of port infrastructure and proposes circuit thermal and mechanical solutions for the modernization of the steam supply system of defrosting house. According to the results of the study, the values of heat energy consumption per unit of output in the existing scenario and after modernization are given. The characteristic technological and thermotechnical features of the existing scheme of devices for defrosting wagons of the port infrastructure of Ukraine and measures for the modernization of such systems, the introduction of which will achieve a significant reduction in the consumption of thermal energy in shunting non-stationary modes of operation of defrosting houses, are given. The feasibility of using an infrared wagon heating system using steam registers is substantiated.

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A WINDOW AS A HIGH-TECH MULTIFUNCTIONAL TRANSPARENT ENCLOSURE

Any building in the cold period of the year constantly loses internal thermal energy due to the flow of heat from the heated internal environment of the premises to the colder external air. Heat losses and negative contribution of each of the enclosing structures are individual for each building. However, in the vast majority of cases, the largest losses of thermal energy occur on translucent enclosing structures. It is these elements that most need attention and the constant search for ways of improvement. Simultaneously with the constant increase in the requirements for thermal insulation of buildings (including due to the improvement of the thermal insulation properties of windows), there is a constant demand for an increase in the percentage of areas of transparent enclosing structures relative to the total area of the surfaces of external enclosures of buildings. In the case of office buildings, it is often possible to observe the absolute absence of external walls: the entire area of vertical fences is occupied by windows. Having such large areas of glazing, inventors are constantly searching for solutions that would increase the functionality of translucent enclosing structures.

For ordinary consumers, the term "multifunctional window" means that its construction uses glass with energy-saving and sun-shielding properties: this allows you to save on heating in winter and air conditioning in summer. However, to date, many elements of transparent fencing structures have been developed and patented, which provide additional opportunities for increasing the functionality of glazed areas. Inventions that help to change the shading coefficients of transparent fences are considered in the work: external/internal grids; electrochromic film devices capable of changing the coefficient of light transmission, or the color of windows, have the property of making the window opaque, or even mirror-like; liquid crystal coating, which allows the necessary information to be transmitted on a transparent structure. The existing transparent enclosures, which are capable of performing the functions of heating devices, have been analyzed: heating devices due to electric energy, with different constructions; and heating due to circulating heated air between glazing sheets. The existing options for the use of photovoltaic surfaces (PEPs) over the areas of transparent enclosing structures are analyzed and new options are proposed: placement of flexible film PEPs on elements with uneven surfaces (on window frames); the use of transparent, film elements of FEP directly on glazing areas.

Based on the presence of a large number of inventions aimed at increasing the multifunctionality of translucent enclosing structures, we can conclude that over time, windows will acquire new properties and criteria for ensuring comfort, which will gradually become familiar and indispensable for consumers.

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EVALUATION OF BIOGAS (BIOMETHANE) PRODUCTION DURING ANAEROBIC FERMENTATION OF PLANT BIOMASS

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At present, about 10% of the world's energy production comes from biofuels obtained as a result of plant biomass fermentation. Biofuels from biomass have been widely used: ethanol from sugarcane in Brazil and ethanol from corn in the USA. Anaerobic digestion is a sustainable technology used in waste processing and energy production.

First-generation biofuels are produced from dedicated feedstocks using conversion technology for bioenergy crops. Second-generation biofuels are bio-based products from non-food feedstock, such as agricultural and forestry residues. Third-generation biofuels are produced from aquatic cultivated feedstocks.

To evaluate biogas yield from biomass, calculations of anaerobic fermentation processes must be performed. The well-known Buswell model allows for the theoretical determination of the amount of biomethane from organic matter substrates. The model integrates chemical, biochemical, and thermodynamic processes occurring in the biosystem. The Buswell method estimates the output of anaerobic fermentation products based on a theoretical stoichiometric assessment.

The stoichiometric Buswell equation (BEq) plays a crucial role in calculating the quantity of biomethane either from pure or mixed organic matter. Theoretical biochemical methane potential (TBMP) assumes that all organic matter is biodegradable. The quantity of biomethane (nCH_4) is a parameter that depends on the elemental composition of the organic matter.

To determine nCH_4, measurements and calculations are required. Based on elemental analysis, the empirical formula of organic matter can be determined using the stoichiometric BEq.

Calculation results show that the biogas yield from poultry litter and cattle manure ranges from 541 to 542 L/kg. Higher values were obtained for grains and lignin, ranging from 698.6 to 705.4 L/kg, while wood and straw yield ranged from 476.5 to 514.2 L/kg. Sewage sludge yields around 570 L/kg of biogas.

The coefficients of the BEq are refined during experimental testing, as they are based on assumptions such as: all carbon atoms in the biomass are fully converted into CH_4 and CO_2, and nitrogen, sulfur, and halogen atoms in organic matter are fully converted into NH_3 and H_2S, with no other side reactions.

The calculation process is as follows: for most organic matter, their C/H/N/S contents are analyzed by elemental analysis. The mass percentages of the sample's

elements are determined experimentally. These percentages are then used to determine the empirical formula, which leads to the stoichiometric coefficients in the BEq.

The calculation results showed that the nbiomethane content in nbiogas ranges from 49.03% to 56.3%.

Thermophilic (55°C) and mesophilic (37°C) temperatures are used during anaerobic digestion. The optimal anaerobic digestion parameters were: pretreatment temperature of 38°C, stalk particle size of 0.5 mm, and pretreatment time of 169.03 hours. The validation experiment showed an exergy efficiency of 19.25%. The heat of combustion varies from 4 to 11 MJ/kg.

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THE RESEARCH OF THERMAL CHARACTERISTICS OF A HYBRID SOLAR COLLECTOR ON THE BASE OF COMPUTER SIMULATION

Nowadays due to the deterioration of the environmental situations and depletion of natural resources, there is an urgent need for the development and implementation of renewable energy sources. Traditional energy sources pollute the environment and contribute to climate change, making the demand for environmentally friendly technologies increasingly relevant. One promising solution is the use of solar collectors, which can convert solar energy into electrical and thermal energy. Hybrid solar collectors, which combine both of these functions, can significantly enhance the efficiency of solar energy utilization.

The authors have developed a model of a hybrid thermal solar collector that operates together with a thermal storage system. Using the SolidWorks software, thermal processes were simulated, and the change of temperature indicators at constant solar intensity in the solar collector and storage tank was investigated. The impact of various parameters on heat transfer efficiency was studied, and the optimal design solutions were identified for further implementation. This opens up possibilities for the advancement of more efficient solar collectors, which will contribute to the expanded use of renewable energy within the global energy system.

The relevance of researching hybrid thermal-photovoltaic solar collectors is driven by global environmental and energy challenges, as well as the growing need to increase the efficiency of renewable energy sources. Since hybrid solar collectors can simultaneously generate both thermal and electrical energy from a single installation, they are more efficient compared to separate thermal or photovoltaic systems. This integration improves the coefficient of performance and ensures better return on investment, which is particularly significant. The development and enhancement of hybrid solar collectors hold substantial potential for addressing energy efficiency and sustainable development goals, underscoring the importance of studying and implementing these technologies in in modern energy systems.

The aim of the research is to improve the design of a hybrid solar collector, investigate thermal processes using SolidWorks software, develop and implement a computer model for further analysis and optimization of its design.

To solve the given task, a design of a hybrid solar collector (HSC) has been proposed, which combines elements of a solar collector and a window. The main components of the experimental setup include a casing, a finned heat exchanger with transparent protection, a thermal accumulator, a circulation pump, and a piping system. The modeling was conducted under a constant solar radiation intensity of Iv=600 W/m2 at a constant consumption G=0.00113 g/s.

During the simulation, a temperature increase up to 23,4°C was observed in the side and upper parts of the frame. Convective flows around the window structure were absent due to the transparent protection. Throughout the experiment, the upper part of the accumulator tank warmed from 19°C to 22°C, and a characteristic stratification of the water-heat carrier developed along the height of the coolant-water. At the outlet of the solar collector, the temperature increased from 19°C to 21,6°C from the 5th to the 40th minute of modeling, with minimal changes afterward. During the simulation, the instantaneous power of the solar collector increased in the first half of the experiment and then stabilized. Additionally, the efficiency ratio of HCV increased from 42% to 0,66%. In general, the core efficiency of the studied solar collector was 0,60.

The experimental results confirm the effectiveness of computer modeling for analyzing and optimizing the thermal characteristics of a hybrid solar collector. The use of SolidWorks software made it possible to simulate parameter changes within the system containing the solar collector and thermal accumulator, making it possible to predict its performance under variable solar radiation intensity. The model demonstrated that selecting the right design parameters can significantly reduce thermal losses and improve heat transfer efficiency.

The analysis of temperature fluctuations in the thermal accumulator proved that using a finned heat exchanger ensures more uniform heating of the heat transfer fluid within the system. The data obtained helped identify optimal design solutions that enhance the efficiency of the collector. Specifically, an increase in specific thermal power was achieved during periods of high solar radiation, making this type of hybrid collector promising for use in energy-efficient buildings. The model analysis also highlighted the importance of the combined use of a solar collector with a thermal accumulator to stabilize heat supply during evening and nighttime hours.

The research confirmed that the development and implementation of mathematical and computer models are crucial stages in the design of solar collectors, as they enable detailed analysis and identification of optimal parameters without the need for costly experiments. This approach opens up opportunities for developing new solutions in the field of renewable energy, particularly in reducing the consumption of traditional energy resources and decreasing greenhouse gas emissions.

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FUZZY FITNESS FUNCTIONS OF KEY INFLUENCE PARAMETERS FOR THE ENVELOPE ENERGY EFFICIENCY ASSESSMENT PREDICTION

To maintain optimal microclimate parameters in the premises of buildings, approximately 30-40% of Ukraine's energy resources are consumed from their total amount, which significantly exceeds similar costs in European countries. The current legislation of Ukraine [1, 2] provides ways to solve the energy efficiency problem in the construction, housing and communal services sectors. One of the solution's components of this issue is the optimisation of total energy consumption to ensure the functioning of the thermal insulation shell during the building's life cycle, which involves increasing the energy efficiency of envelope structures [3, 4]. Further improvement of the intelligent support tool for adopting managerial, organisational and technological decisions regarding the energy efficiency prediction for the envelope structures of buildings requires the improvement of a mathematical model for assessing the influence of such crucial parameters on the goal function [5]. Thus, further research development, which provides ways to optimise innovative organisational and technological solutions to increase the energy efficiency of the building's envelopes during their life cycle, is an urgent, ambiguous and unsolved task.

The current paper aims to develop the elements of a mathematical model of intelligent support for organizational and technological decision-making to increase the energy efficiency prediction of building envelopes by the usage of fuzzy fitness function to assess the influence of critical parameters on the goal function.

According to the analysis of the latest research and publications of existing methods for forecasting the minimisation of total energy costs for ensuring the building's life cycle, a hypothesis is defined based on the assumption of the need and possibility of improving the envelope energy. Further development of the toolkit for forecasting the energy efficiency of a building's envelope during its life cycle requires a key impact parameters assessment characterised by quantitative and qualitative values. Determining the values of these parameters experimentally is quite expensive and, in the vast majority of cases, is impossible with predicted reliability. As a source of the necessary information, it is advisable to use expert assessments of the impact of determining parameters on the predicted energy efficiency of the thermal insulation envelope of buildings.

To develop an expert modelling system of intelligent support for organisational and technological decision-making regarding improving the energy efficiency of building envelopes, a mathematical fuzzy logic-based apparatus was used, namely, the membership function designing method of fuzzy sets that determines the value of the goal function. The method is based on the membership degree distribution of the universal set, which defines the fuzzy set according to their ranks. The degrees of the parameters belonging to the fuzzy set, denoted by the corresponding term, are calculated according to known formulas by compiling the corresponding matrices. Fuzzy

sets for various linguistic variables determining parameters of impact on the predicted energy efficiency of building envelope structures are presented graphically as output membership functions, namely, the energy consumption for construction, reconstruction, operation or recycling purposes.

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MODELING OF THERMAL EFFICIENCY OF A HYBRID SOLAR COLLECTOR IN A SYSTEM WITH THERMAL STORAGE

The rising cost of traditional energy sources, competition for their deposits and wars, environmental pollution, encourage broader use of non-traditional energy sources. Therefore, improving existing and developing new systems capable of obtaining energy from alternative sources is relevant today. There are now various devices for converting solar energy into thermal or electrical energy, however hybrid systems that allow simultaneous generation of thermal and electrical energy from a single installation are becoming increasingly widespread. Therefore, the research objective is to develop an improved hybrid thermal photovoltaic solar collector and study its thermophysical characteristics.

Mathematical methods of planning a multifactor experiment and processing its data using software for modeling and computer research in the SolidWorks environment.

The computer model of the developed design of the combined energy supply system (CESS) with a hybrid thermal photovoltaic solar collector (HTPSC) consists of two separate blocks - a thermal accumulator and HTPSC, which consists of a photovoltaic panel and thermal solar collector, and is designed to produce thermal and electrical energy. The incident solar radiation on the thermal solar collector is focused in seven concentrators, which are adjacent aluminum parabolic-shaped plates that concentrate solar rays reflected from their walls onto copper tubes 21 placed along their axes at a distance from each other, with diameter and wall thickness, extending along the coolant flow.

The research was conducted in SolidWorks 2022 using the Flow Simulation module under steady-state conditions: at ambient temperature and solar radiation intensity, taking into account the HTPSC tilt angle to the horizon and the azimuthal angle of solar rays incidence on the HTPSC plane.

Based on the analysis of computer modeling results of the CESS with HTPSC operation, the following were calculated: instantaneous specific power values of HTPSC; change in thermal efficiency of HTPSC during the experiment; instantaneous specific power of CESS with HTPSC; thermal efficiency of CESS with HTPSC during the experiment.

The average efficiency coefficient (0.6, or 60%) and its change over time during the experiment were also determined. The change in instantaneous specific thermal power of the system with hybrid thermal photovoltaic solar collector was analyzed. The pattern of change in thermal efficiency of the entire system with hybrid thermal

photovoltaic solar collector, which was 450 W/m2, as well as its efficiency in thermal energy accumulation in the thermal storage, which was 0.5 or 50%, was also studied. The obtained results are used to develop calculation methodology for this system and can be used for system implementation in real conditions to provide energy to various facilities.

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SOLAR ACTIVITY AND THERMAL COMFORT

In Ukraine and the European Union, indoor lighting design—especially concerning direct and diffused solar radiation—is governed by different regulatory approaches. The European Union employs several standards to regulate indoor illumination levels, mainly EN 17037, which establishes lighting requirements across all EU countries. Luminous flux, measured in lumens, defines the total amount of light emitted by a source in all directions. Another important measure is the daylight factor, which expresses the ratio of indoor illumination to outdoor illumination as a percentage. The basis of EN 17037 lies in the spatial daylight autonomy method, a concept proposed by the Swiss Association of Electricians in 1989. This method emphasizes the effective use of daylight to achieve sustainable lighting within buildings, prioritizing natural over artificial light wherever possible.

Ukrainian building codes regulate the insolation of premises from a sanitary and hygienic point of view. Insolation is the amount of solar radiation flux calculated in calories per unit area of a horizontal surface per unit time. In order to harmonize the standards of Ukraine and the European Union, it is necessary to conduct a comparative analysis and find points of convergence that bring the relevant standards closer and allow for the construction of premises with high-quality thermal comfort.

Thermal comfort is a statistical indicator that takes into account individual human characteristics. To assess thermal comfort, EN ISO 7730 uses the PMV (Predicted Mean Vote) value, which is acceptable to the majority of people in a given room. There is also a PPD value (Predicted Percentage of Dissatisfied, i.e. the expected percentage of people who are dissatisfied with the comfort level). The PMV and PPD values serve as indicators of thermal comfort for a person in a room.

Ukrainian standards regulate the microclimate in buildings and indoor comfort through recommendations that are given in the form of examples for the design of buildings with mechanical heating and cooling (DSTU B EN 15251:2011). This standard distinguishes between four categories of buildings that depend on PMV values. The standard justifies the areas of application of these categories, depending on the level of expectations and the duration of a person's stay in the building. Ukraine also applies the standards DSTU B EN 15261:2012 (for calculating microclimate parameters) and DSTU B EN ISO 7730:2011 (defines the ergonomics of the thermal environment).

In construction, all three types of sunlight (infrared radiation, ultraviolet radiation and visible light) are taken into account when designing residential and industrial

premises. Each type of solar radiation has a different impact on various aspects, including indoor comfort, energy saving, and sanitary and hygienic standards.

Different approaches to assessing the parameters regulated by these standards require harmonization and development of common principles and calculation methods.

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STAGNATION AS ONE OF THE CHALLENGES FOR THE DEVELOPMENT OF SOLAR SYSTEMS

Solar energy is becoming increasingly important as one of the key solutions for reducing dependence on fossil fuels. Solar systems that convert solar radiation into heat to supply heating and hot water are becoming popular in the private sector, industry and agriculture. Along with economic factors, important advantages of solar installations include the rational use of natural resources and minimisation of the technogenic impact on the environment.

Despite the great potential of solar installations, their operation often faces serious challenges, in particular, the phenomenon of stagnation, which is one of the factors hindering their spread. The increase in the efficiency of solar systems in the process of their evolution has led to problems with the inability to remove excess heat, which leads to overheating of the heat carrier, the formation of high pressure in the collectors and, as a result, a decrease in efficiency. The technical problems that appear in this case limit the durability of the system, and therefore require analysis and search for solutions to overcome them.

Stagnation of solar systems is most commonly observed in summer due to excess heat energy at high insolation, which is especially typical for combined solar systems used for hot water and heating. Stagnation also occurs in other solar installations when the power is cut off and the heat transfer fluid stops circulating, as well as in the absence of consumption.

The main element of solar thermal systems is a solar collector, which determines the cost of the installation, its service life, the efficiency of converting solar radiation into heat and the costs of the hot water produced. The main component of the collector is an absorber that absorbs the infrared component of solar radiation. The liquid heat carrier is pumped through the absorber channels and heated. Currently, there are several types of solar collectors, the main of which are flat and vacuum. Flat-type collectors have the simplest structure and lower cost, but they have high heat losses and practically do not work in cold weather. Along with a number of advantages of vacuum tube collectors and their greater efficiency, there is the problem of frequent stagnation. During almost the entire summer period of the system's operation, the amount of heat received from the vacuum tubes of the solar collector exceeds the amount needed to heat the water in the storage tank to the required temperature of 55 °C. The system periodically enters a stagnation mode and operates at 50% idle. The temperature of the heat transfer liquid reaches 180-220 °C and it boils. Most often, the heat transfer fluid is aqueous solutions of propylene

glycol, which does not freeze in winter but degrades at high temperatures, i.e., oxidises to form acids, leading to internal corrosion. Evaporation during boiling significantly increases the pressure, which is a challenge for the expansion tank membrane and the shut-off and control valves.

Today, the following methods are used to combat stagnation in solar collectors: optimising the number of vacuum tubes and the angle of inclination, adapting the solar system control automatics, introducing an additional consumer or additional heat exchangers to cool the heat carrier. Existing methods do not completely avoid the phenomenon of stagnation, so measures to minimise damage to the system in this mode are recommended, including periodic replacement of the coolant, increasing the volume of the expansion tank to 50% of the total coolant volume and installing it as far as possible from the solar collector on a cold pipeline. Some models of solar collectors are equipped with an anti-boiling system, i.e. an additional tank where the liquid is completely drained in case of pump shutdown. A very promising solution is the use of high-temperature organic coolants with boiling points of up to 300-400 °C, which will not only avoid stagnation but also reduce the size of collectors and heat storage devices, but this approach has not been studied sufficiently and is not currently used.

Consequently, the problem of stagnation of solar systems is relevant, still unresolved and requires further research. Its solution lies in the introduction of automated cooling systems, the search for better materials for absorbers and better coolants. To reduce the risk of stagnation and increase the efficiency of solar systems, it is important to further study heat transfer in solar collectors and optimise their design. An integrated approach to solving this problem will lead to more reliable operation of solar installations and increase their contribution to sustainable energy supply, which is especially important in the current context of energy and environmental challenges.

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THE FEASIBILITY OF IMPLEMENTING PASSIVE HEATING AND COOLING SYSTEMS IN UKRAINE

Passive (radiant) heating and even cooling systems have already become an integral part of today's reality. Apartment buildings with underfloor heating, hotels where rooms are heated/cooled only by ceiling systems. Logistics centers, airports, and other industrial facilities have long been heated and cooled by floors. However, all this has become commonplace in Europe, but not in Ukraine.

In Ukraine, according to 2021 data, 80% of all new construction projects (apartment buildings and private houses, commercial and industrial buildings) are commissioned using convection heating and cooling systems. Why is this? Maybe due to insufficient efficiency of passive systems? No, there are already many not only theoretical but also statistical studies confirming the better efficiency of surface systems

compared to convection ones. Perhaps Ukraine has its own view on this? Also no, besides research, even the State Building Code (DBN) indicates the efficiency:

DBN V.2.5-67:2013 "Heating, ventilation and air conditioning"

Section 7.1: "For rooms with low-temperature heating systems, such as underfloor heating, lower air temperature is permitted, as the system provides comfortable feeling through radiant heat from the floor surface."

What is the practical essence of this section? The DBN directly indicates that with radiant systems, the temperature perception by humans changes and we feel comfortable even at lower air temperatures, and reducing the design temperature in the room is a significant potential for savings.

Why isn't Ukraine rushing to switch to more economical and health-friendly heating and cooling systems?

Most scientists in Ukraine focus on improving calculations of temperature fields in rooms and heat-mass exchange between objects, but they miss the obvious: a human is not an object. It's a living organism that has its own complex thermoregulation, therefore perceiving different types of heat transfer differently. We normally accept weather forecasts indicating that perceived and air temperatures can be different. The same is possible in enclosed spaces. We always feel cool when descending into underground passages on hot days because we feel the impact of cooled structures in the ground. Air circulation in the case of a direct passage is not limited, so the air temperature remains consistently high. It turns out we can feel comfortable in summer even at high air temperatures.

The impact of different combinations of surface and air temperatures on human perception in Ukraine is still poorly researched, although in developed countries, modern heating and cooling systems are based on this.

In Ukraine, we need not only to adopt global experience of such research but also to conduct extensive educational activities among people who make decisions about heating and cooling system concepts in construction. Until everyone involved in this process understands how passive heating/cooling works and why it is more efficient, such solutions will not be implemented.

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RESEARCH ON THE EFFICIENCY OF GEOTHERMAL HEAT PUMPS IN THE CONSTRUCTION OF MULTI-APARTMENT RESIDENTIAL BUILDINGS

Designing a geothermal heat pump of the required capacity at the initial stage of construction and its installation - allows the Developer to:

- minimize costs in the cold period and transfer apartments to residents in a planned manner;
- complete the so-called "wet processes" of finishing, if necessary;
- perform adjustment and start-up of elevator equipment that requires positive temperatures;
- conduct hydraulic tests of heat and water supply networks, pump rotation;
- ensure smooth heating of newly constructed structures.

When constructing a multi-apartment residential building, the required area for heating common areas and necessary technical premises does not exceed 600m2 for a single-entrance twenty-four-story building with a total area of apartments of 14,000m2. The cost of building a heat pump for such an area is:

600m2 x 90W x 2.4 euros/W = 129,600 euros

This adds only

129,600 euros / 14,000 m2 = 9.26 euros/m2 to the cost of a square meter of housing.

Which is less than 1% of the cost of 1m2 of housing.

In turn, the use of heat and cold from geothermal heat pumps for gentle maintenance of the microclimate in common areas (entrance hall, lobby, concierge, elevator machine room, water supply riser niches, etc.) leads to a reduction in residents' expenses in payments for heating and cooling common areas. As a result, it makes it more independent of external factors and more predictable and planned.

In addition, the electricity for the system can be obtained from a combination with a solar station, since the inverter system of the heat pump of leading manufacturers is already designed and adapted for power supply from solar panels. Moreover, the automation allows you to predict the weather and start heating-cooling of certain zones a little earlier in advance, due to a decrease or increase in the amount of sun.

The principle of operation of a geothermal heat pump is to transfer and use low-potential heat of the soil for its sequential conversion into thermal energy, which will be used to heat the coolant in the heating system or hot water supply. [4]

Due to the constant temperature in the soil (on average, the wells of the field are located in a layer with a constant temperature of +10℃), heat is transferred by the coolant and heated-cooled or accumulated, if necessary, by a buffer tank and used in the selected heating system. Due to the small difference between the temperature of the ground and the room, heating and cooling occurs slowly, almost under stationary conditions, and allows you to smoothly, thanks to automation, maintain a given microclimate. At times when the need for heating the premises has decreased, and the need for cooling has not yet arisen, then the heat from heat pumps can be used to preheat ordinary hot water.

The main indicator of the efficiency of a geothermal heat pump is the so-called COP conversion coefficient, and in modern GHP systems it exceeds 4, i.e. compared to electric boilers that consume 4 kW of electricity for heating, a geothermal heat pump will consume less than 1 kW to produce the same amount of heat.

In Ukraine, there is also a trend towards energy-efficient and energy-independent methods of building residential buildings with an emphasis on reducing the consumption of non-renewable energy sources while reducing CO2 emissions. By 2050, Ukraine must switch to 100% use of renewable energy sources. To make this happen, each of us can also get involved - implement energy efficiency here and now!

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RESEARCH OF THERMAL CHARACTERISTICS OF WINDOW STRUCTURES WITH SHUTTERS

Simultaneously with the appearance of window openings in the facades of buildings and structures, structural elements also appeared that covered these openings, providing protection for internal premises from undesirable natural conditions. Such devices began to be called shutters. Even after glass appeared in window openings at the end of the seventeenth and during the eighteenth centuries, which began to perform the same functions as shutters, they still continued to be used in the construction of building facades. They were also an element of a certain architectural style and largely determined the appearance of the building. Today, shutters, as before, retain many functions of protecting interior spaces. In addition to those listed above, there is another function of shutters. Shutters can significantly reduce the amount of heat lost through windows. A window design with shutters can have a heat transfer resistance that significantly exceeds the resistance of a window without shutters. Shutters help reduce energy loss through the window opening, especially at night when the house does not receive heat from solar radiation. Currently, there are many different types of shutters, which differ in shape and installation location.

This paper presents the results of 3D CFD modeling of heat fluxes through a double-glazed window located in the window opening of the building facade. Three window design options were considered: 1 - without shutters; 2 - shutters on the outside of the building; 3 - shutters on the inside of the wall. The study was conducted to substantiate a method for increasing the heat transfer resistance of the window structure by installing shutters. Shutters in the window structure form an additional layer of air between the glass unit and the shutters, which significantly affects the heat transfer from the room to the environment. The effect of shutters on heat transfer through a translucent structure was determined by numerically solving a system of equations consisting of the continuity equation; momentum transfer equations; energy equation (for a gaseous medium) and thermal conductivity equation for solid elements. On the solid-gas interface, boundary conditions of the fourth kind are set, which take into account the radiation and conduction components of the total heat flux coming from the interior of the building. The results of modeling heat transfer through glass unit with and without shutters show that shutters increase the heat transfer resistance of the structure as a whole by 94% compared to the structure without shutters. Therefore, the use of shutters in any form is an effective measure to increase the energy efficiency of the building as a whole.

The work was carried out under project No 2022.01/0172 “Aerodynamics, heat transfer and innovations for increasing the energy efficiency of window structures and their use for the restoration of war-damaged buildings in Ukraine” with the support of the National Research Foundation of Ukraine, the competition “Science for the reconstruction of Ukraine in the war and post-war periods”

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HIGH-TEMPERATURE HEAT SUPPLY SYSTEMS IN THE ELEMENTS OF OIL PIPELINES

Transportation of oil and petroleum products can take place in two ways – with the help of pipelines or using tanks of various sizes – from relatively low-volume cars and railway tanks (up to 60-100 tons) to huge sea tankers. The process of moving oil in pipelines can be complicated due to the high density and viscosity of some types of oil. Heavy oil sometimes needs to be heated to reduce the density and viscosity of heavy oil, because these thermophysical properties are highly temperature-dependent - they decrease significantly as the temperature of the oil rises. To maintain the required temperature of oil in the pipes at oil consumption enterprises and oil refineries, the pipes are heated with saturated water vapor or an electric cable. This, of course, complicates the operation of the pipeline system and increases the cost of enterprises' products. For main oil pipelines, this method is generally economically unacceptable. In this fiction, oil is heated at pumping stations at the beginning of the oil pipeline and step-up pumping stations determined by calculations. On the way between the booster stations, the oil cools down, so before starting to move, it is heated to a temperature that exceeds the required one. And so it is at every station.

When transporting oil in tanks, its viscosity and density become a problem only when the tanks are filled and emptied. Therefore, water vapor is traditionally used to heat oil and the heaviest product of its refining - fuel oil. But the use of water vapor for these purposes has a number of negative consequences and common problems. Condensate is a corrosive liquid, which leads to a shorter life cycle of equipment. It is polluted and cannot be reused to produce water vapor in boilers, which necessitates large amounts of water for the operation of the boiler house and systems of waste condensate and mineralized water from the continuous blowing of steam boilers. Such conditions for the functioning of the steam heat supply system for the elements of transportation of oil and heavy oil products can not always be ensured.

An alternative to steam heating systems is still direct oil heating furnaces. But this is a fire-hazardous equipment. The site with such furnaces must be embanked. In addition, like all stoves, they have low efficiency and are poorly regulated. At the same time, there are heat supply systems in which high-temperature organic heat carriers act as a heat carrier. These are effective mixtures of some organic substances. Their main difference from water is that it is low, the saturation pressure depends on the temperature. This means that when boiling, for example, at 300°C, they have a saturation pressure of 0.2 MPa (2 bar). In addition, they not only do not cause corrosion of metals, but, on the contrary, provide protection against corrosion. Heat-generating equipment for heating them is quite simple, it is more reliable in operation than a steam boiler and much cheaper. Although these coolants also have disadvantages –

significant thermal expansion and the possibility of oxidation in direct contact with air. But these flaws can be easily corrected by design solutions.

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ENHANCING COMBUSTION EFFICIENCY OF NON-DESIGN FUELS THROUGH OXYGEN-ENRICHED COMBUSTION AIR

Currently, the global transition toward a complete phase-out of fossil fuels has slowed down due to numerous negative factors affecting renewable energy sources. Alternative energy sources such as wind, solar, hydro, geothermal, wave, and tidal energy hold great potential for reducing dependence on fossil fuels but are not without drawbacks. Many of these sources depend on weather conditions or exhibit low energy density, reducing the stability of energy supply. Furthermore, they can adversely affect ecosystems. For example, dam construction for hydropower disrupts natural water balance, wind turbines pose risks to birds and bats, and alterations in wind flow can influence regional climates.

This underscores the need for alternative solutions to improve the environmental and economic performance of existing fossil-fuel-based enterprises. One of the most advanced technologies in this regard is «oxyfuel combustion», but it requires entirely new equipment, making it economically unviable, particularly as the long-term goal of the energy sector is to eliminate fossil fuel use rather than replace equipment with more efficient versions. Another commonly employed method involves preheating coal dust en route to the furnace, but this demands strict monitoring of pipeline integrity and increases the risk of premature fuel ignition. Prolonged experimentation with improving solid fuel grinding has not yielded significant enhancements in steam generator performance.

Thus, a practical and cost-effective approach to improving the performance of steam boiler units operating on fossil fuels, particularly coal, is needed. One such method is enriching combustion air with oxygen.

Analyzing modern oxygen-enrichment methods reveals that membrane technology is the most suitable. It requires minimal installation space and provides an adequate oxygen concentration in the air. Oxygen-enriched combustion air is particularly beneficial for coal combustion, as pulverized coal combustion often requires "flame stabilization" using natural gas to maintain the necessary combustion temperature for effective coal burnout. When switching from design fuels to low-reactivity analogs, natural gas consumption for flame stabilization also increases. Adding oxygen to the combustion air raises the flame temperature, potentially allowing partial or complete elimination of natural gas use for stabilization. Furthermore, oxygen enrichment positively impacts all types of coal.

To assess the feasibility of oxygen-enriched combustion air, a thermal calculation was performed for a TP-170 steam boiler producing 170 tons per hour of superheated steam at 10 MPa. The calculations were based on gas-grade coal ("G" brand) with the following composition: Cp - 55.2%; Hp - 3.8%; Op - 5.8%; Np - 1%; Sp - 2%; Ap - 22.6%; Wp - 9.6%. Data for the calculations were sourced from an operational boiler at the

Darnytsia Combined Heat and Power Plant in Kyiv. The analysis also included design fuel ("Ash" grade) and an alternative coal ("B" grade) available for combustion.

Research into the outcomes of using oxygen-enriched combustion air demonstrated a minimum 3% increase in the thermal efficiency of the heat-generating unit. This efficiency improvement directly reduces specific coal consumption and, consequently, emissions of carbon and nitrogen oxides. Enhanced coal burnout depth also reduces slag formation, minimizing its environmental impact. Numerical modeling of combustion processes in the boiler's furnace revealed that oxygen enrichment increases flame temperature, resulting in more complete carbon oxidation and lower CO concentrations. The increased presence of triatomic gases and water vapor in the furnace enhances radiative heat transfer within the furnace and the convective sections of the boiler. Consequently, exhaust gas temperature and heat losses with combustion products decrease.

Additionally, reducing the high-temperature combustion zone diminishes the residence time of nitrogen in this zone, curbing the formation of thermal nitrogen oxides. Lower nitrogen content in combustion air also leads to decreased atmospheric nitrogen oxide generation. These effects were consistent across all tested coal types, exhibiting similar trends with increased oxygen concentration in the combustion air.

The proposed method does not require modifications to steam generator designs and positively impacts the environment by reducing CO and NOx emissions into the atmosphere. It also improves economic performance by decreasing fuel consumption and increasing boiler efficiency, significantly lowering the cost of generated electricity. Furthermore, this method is versatile and suitable for all types of coal and natural gas.

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CLEANING OF HEATING SURFACES IN THE PRESENCE OF SURFACTANTS

Decommissioning heat exchange equipment, in particular boiler units and heat exchangers, due to exceeding the allowable hydraulic resistance is a common forced practice of heat generating enterprises. Hydraulic resistance increases as a result of the narrowing of the passage sections of the pipelines or the gaps of the heat exchanger plates. This happens as a result of the formation of scale deposits of hardness salts, or boiler scale, on the internal surfaces of the equipment. However, until the limit value of the hydraulic resistance is reached, the boiler unit is operated for a long time. During this operational period, there is an overconsumption of electrical energy to drive the pumps, a gradual increase in the temperature of exhaust gases, a decrease in the efficiency of the equipment, and an overconsumption of fuel. As you know, cleaning of surfaces from boiler scale is usually carried out with the use of acids, in particular citric, oxalic and aggressive sulfuric. At the same time, the passport value of the hydraulic resistance after washing is not reached due to the destructive chemical reactions of the metal of the walls and acid.

The use of surface-active substances (surfactants) to destroy scale deposits is a possible safe way of cleaning heating surfaces. Surfactants are fairly large molecules

with a polar head and a nonpolar tail. The adsorption of surfactant molecules causes a decrease in the surface tension on the surface of the deposits. The liquid penetrates into the mouth of the microcrack under the influence of capillary pressure. At the same time, molecules of the most surface-active component are released from the meniscus of the droplet, which migrate forward and cover the surface of the gap at a much higher speed than the liquid absorption in general due to viscous resistance. In the liquid-filled part of microcracks, a thin film of liquid can cause additional wedging pressure.

Solid bodies are destroyed first of all in places of strength defects (macro- and microcracks – defects in the crystal lattice). The phenomenon of reducing the resistance of solid bodies to elastic and lamellar deformations, and as a result, the destruction of bodies under the action of adsorption of surfactants from the external environment is called the Rebinder effect. Its mechanism consists in facilitating the development of microcracks due to a decrease in surface energy in the presence of surfactants, resulting in deformation and destruction of the solid body.

Stretching contributes to the development of such cracks. In heat supply systems, such expansions serve as thermal expansion due to changes in the temperature of the heat carrier and outside air during the heating season.

Numerous experimental studies were conducted to clean heating surfaces from deposits in the presence of surfactants. Complete cleaning of elements of heat supply systems was achieved in laboratory conditions at temperatures of about 100 °C. Express washing of boiler units for two days at pressures up to 0.2 MPa and temperatures of 95 °C. gave a decrease in hydraulic resistance by 70%. Cleaning the internal surfaces of boiler units on the go gave positive results, passport hydraulic resistance values were reached, however, over a long period of time - about three months. Thus, for the surface cleaning process, the parameters of the heat carrier and the time of action of the surfactant solution on the deposit are the determining parameters.

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MODERNIZATION OF GAS SUPPLY SYSTEMS OF DISTRICT BOILER HOUSES AND HEAT SUPPLY STATIONS

The main trend of the European energy industry is to combat the negative impact of burning organic fuels on global warming by phasing them out by 2050 and transitioning completely to renewable energy sources, in particular thermal energy.

However, on the way to the set goal, various problems have already made themselves known and it is possible to predict the appearance of new ones. Even if all problems are solved by the date specified by the European Commission, industry and large power generation will work with the use of fossil fuels. At the same time, the struggle to abandon organic fuel is not an end in itself. The main thing is to reduce harmful emissions into the atmosphere now, without waiting for 2050.

One of the major sources of atmospheric pollution in cities are heating boiler houses and CHP plants. In European countries, rather harsh regulations have been adopted regarding the possible content of such harmful substances as nitrogen oxide and carbon in the products of combustion of organic fuels. In particular, for natural gas, this limit is 100 mg/ ^{m3} NOx and SO. In Ukraine and, accordingly, in Kyiv, only some boilers recently imported from the European Union meet such requirements. But they are no more than 2-3% among all boilers operated in Ukraine.

To correct the situation, two ways are possible: a complete replacement of the heat-generating equipment with a new one or their gradual modernization in order to meet the requirements of European standards for emissions into the atmosphere. The last option applies more to more or less powerful boilers - from 2 MW and above. The cost of upgrading less powerful boilers can be equal to the cost of a new modern boiler that meets existing standards.

In turn, modernization can also be designed in two variants. It can have the goal of only improving the ecological characteristics of the boiler, or have a complex nature - in addition to improving the ecological indicators, it can also increase the efficiency of the boiler. However, an increase in efficiency leads to a decrease in specific fuel consumption and, as a result, to an increase in environmental indicators due to a general decrease in the volume of combustion products.

In both modernization options, it is necessary to replace the existing automation systems of the existing boilers, which are hopelessly outdated, with modern ones. Modern systems make it possible to use adaptive control algorithms, perform high-precision regulation of boiler power in accordance with changes in the heat needs of consumers, as well as flexibly regulate combustion processes in boilers taking into account changes in the fuel composition, in particular, maintaining the optimal ratio of the supply air flow to fuel consumption.

However, the realization of all the possibilities of modern automation systems can be hindered by the outdated equipment of the gas supply system of heat generating units and the boilers themselves. First, almost all water-heating boilers in heating boiler houses were regulated manually. Automation will ensure only safe operation of boilers. Secondly, for district boiler houses and heat supply stations in Kyiv, gas supply systems were designed in the 60s and 70s of the last century, at the same time when the heat sources themselves were designed and built. Today, the equipment of gas regulating points and installations do not meet the requirements of the latest low-emission burners with their precise and fast-acting regulation systems. In addition, during the years of their operation, the equipment and the load on them were sometimes changed in the boiler houses, but no changes were made to the gas supply system.

Because of the above, when developing projects for the modernization of water heating boilers of heating boiler houses , especially of large capacity - district and heat supply stations, it is necessary to provide for the reconstruction of the gas supply system.

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INDIVIDUAL HEAT STATION WITH HEAT PUMPS FOR HEAT SUPPLY SYSTEMS

Today the system centralized heat supply Ukrainian bridge are in a difficult condition. Amount provided services from provision of heat for heating and hot water for the population constantly is reduced to improve situations are needed two decisive measures basic directions.

The first direction is this strict compliance with the rules of operation, timely carrying out emergency, capital and preventive repairs that will ensure stability work existing infrastructure.

Second direction - replacement equipment that has run out your passport term operation However like that replacement has consider modern trends in the field heat supply. Choice new, more energy efficient technologies has been based on a comprehensive modernization system heat supply, taking into account the last one's scientific development and practical experience, in particular countries Northern of Europe. In these countries systems centralized heat supply is actively developing, demonstrating innovative approach to use various sources thermal energy

Modern systems heat supply are characterized disposal secondary heat from thinking objects and trade centers, large computing complexes and others objects and involvement renewable sources energy, such as geothermal systems and solar installations with air- water, water-water and soil -water heat pumps.

Since similar heat sources are mainly low-potential, that is, with a low temperature of the coolant, it follows from this that it is necessary to use a reduced temperature schedule in the system. The second feature of Western heat supply systems is the integration of heat supply systems with electricity supply into a single one the energy network of the city. It allows maximum efficiency use excesses electricity from renewable sources such as wind and solar power plants. Electricity can be directed to heat pumps, heating devices or heat accumulators.

In Ukraine also set out downward trend of the temperature graph compared to the normative schedule of 150/70 °C in DBN. For example, in Kyiv is applied graph 115/70 °C. It due to desire reduce risks breakthroughs worn out pipelines at elevated coolant temperatures.

It is desirable to further reduce the temperature schedule, for example to 80-60 °C or even 50-30 °C. Such a schedule, in addition to realizing the possibility of connecting to the heat network distributed sources of renewable heat or utilization of renewable heat from some objects, provides a significant reduction in heat losses in pipelines and makes heat networks cheaper due to the reduction of requirements for pipe materials and fittings.

The use of a reduced temperature schedule has its advantages, but it faces the problem of insufficient capacity of existing heating systems in residential buildings that are already in use. Heating systems in such buildings were designed to maintain the indoor air temperature at +18 °C when using a temperature schedule of 95/70 °C. In modern regulatory documents, the requirement to ensure a temperature of +20 °C is

fixed, which creates additional challenges. In order to avoid a complete reconstruction of heating systems in order to increase their capacity, two possible ways are proposed.

The first one is the thermal sanitation of the building. This involves reducing heat loss through a set of insulation measures (replacement of windows, insulation of facades, roof, etc.). However, the complete thermal modernization of the building is a difficult and expensive task, which in the conditions of Ukraine is implemented slowly and often chaotically, which may not provide the expected effect.

The second way is more realistic and can be achieved by two methods. You can use direct electric heating, which is simple to implement, but is characterized by high energy consumption, which makes it economically unprofitable in the long run. Or use heat pumps. This option is more energy efficient, which allows you to significantly reduce electricity costs. In this case, three options are possible. Waste water from the sewage system can be used as a heat source. But there are two drawbacks to this method – firstly, high water pollution requires the use of additional equipment for cleaning, and secondly, the uneven supply of water during the day requires the installation of buffer tanks. The second option is the use of air heat pumps. In this option, there is a problem of dealing with the noise generated by the heat pump fan. In addition, as the temperature of the outside air decreases, the conversion factor of the air heat pump decreases.

Therefore, the integration of a water-to-water heat pump directly into the subscriber input system is seen as the most effective solution, which allows you to effectively reheat the coolant at the entrance to the building by cooling the return water with minimal losses.

In the proposed scheme of the heat point, the evaporator of the heat pump is located on the return pipeline after the subscriber input, and the condenser is located on the supply pipeline before the subscriber input. For example, with a reduced schedule of 80/60 °C on the coldest days (five days), in order to reach the required temperature of 95 °C in the heating devices, it is necessary to compensate for a deficit of 15 °C. To ensure this difference, the heat pump must take heat from the return pipe, reducing the temperature of the return water. A decrease in the temperature of the return coolant by 15 °C leads to the achievement of a temperature difference between the evaporator and the condenser of 50 °C. With such a significant temperature difference, the efficiency of the heat pump can significantly decrease. This is due to the fact that to ensure such a difference, more energy is needed to drive the compressor, which affects the conversion factor. With a significant temperature difference between the evaporator and the condenser, efficient operation of a pump with a high COP becomes unlikely. Therefore, to implement such a scheme, it is necessary to carefully analyze the technical and economic feasibility and look for ways to reduce the temperature difference or optimize the pump design.

To ensure a high coefficient of heat conversion at significant temperature differences, it is advisable to use double heat pumps. In the dual circuit, the first stage of the heat pump condenses the coolant, transferring heat to the intermediate heat exchanger. In this heat exchanger, the heat of condensation is used to vaporize freon in the second stage, ensuring efficient transfer of thermal energy even under conditions of large temperature differences. Double heat pumps allow you to optimize the operation

of the system in different temperature regimes, ensuring stable efficiency while reducing climatic loads. This approach is technically feasible for modern and promising heat supply systems with low temperature schedules.

Water supply and wastewater. Engineering. Technologies

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BUILDING CODES FOR THE DESIGN OF EXTERNAL WATER SUPPLY AND SEWERAGE NETWORKS IN UKRAINE: RELEVANCE, PROBLEMS AND PROSPECTS

To date, the State Building Codes (DBN) of Ukraine for the design of external water supply and sewerage networks do not take into account modern technologies, materials and world experience. This leads to inefficient use of resources, an increase in the cost of construction and operation of networks, as well as a negative impact on the environment. There is a need to analyze the existing DBN, identify their main shortcomings and justify the need for them updating, as well as consideration of key technical aspects that need to be taken into account when developing new DBNs, and proposals for the stages of their implementation.

The existing DBN for the design of external water supply and sewerage networks were developed many years ago and do not meet modern requirements. The main disadvantages of these standards are their technical obsolescence, lack of flexibility, lack of an integrated approach, insufficient attention to environmental aspects and complexity of application

This can lead to the impossibility of using innovative solutions that could ensure a more efficient and economical implementation of the project, as well as to design errors and a decrease in the quality of construction.

The lack of consideration of modern technologies and materials leads to an increase in the cost of construction and operation of networks, as well as to the irrational use of resources. The lack of flexibility of standards makes it difficult to adapt them to the specific conditions of each project, which can lead to suboptimal solutions. In addition, the lack of an integrated approach and insufficient attention to environmental aspects can lead to negative impacts on the environment and public health.

In this regard, updating the DBN is an urgent need. New standards should be developed taking into account current trends in the field of water supply and sanitation, as well as comply with international standards.

When developing new DBN, it is necessary to pay special attention to such technical aspects of the design of external networks as the choice of pipe materials, hydraulic calculation, corrosion protection, seismicity consideration, the use of geographic information systems (GIS) to optimize design, energy efficiency, environmental safety, an integrated approach and accessibility and clarity.

The impact of networks on the environment should be taken into account and measures to minimize it should be provided. It is necessary to take into account the relationship between different engineering systems and ensure their coordinated operation. This will avoid conflicts and ensure the efficient operation of the entire infrastructure.

New DBN should be accessible and understandable to a wide range of specialists, which will help improve the quality of design and reduce the number of errors. To do this, it is necessary to use clear and understandable terminology, avoid complex formulations, and ensure the availability of illustrative materials and examples.

The implementation of new DBN involves an integrated approach and includes the following stages: conducting a detailed analysis of existing DBN and world best practices; development of the concept of new State Building Codes, which will determine the basic principles and approaches; development of a draft of new State Building Codes, which will contain specific technical requirements and standards; publication of the draft of new DBN for public discussion; finalization of the project taking into account the results of public discussion and its approval as new DBN and the introduction of new DBN into the practice of design and construction.

At the implementation stage, it is necessary to train specialists, develop methodological recommendations and ensure control over compliance with new standards.

The development of new State Building Codes for the design of external water supply and sewerage networks is an important step towards modernizing and improving the efficiency of Ukraine's infrastructure.

New DBN should take into account modern technologies, materials and world experience, as well as be more flexible and adapted to the specifics of specific projects.

This will reduce the cost of construction and operation of networks, increase their reliability and durability, reduce the negative impact on the environment, ensure sustainable development of water supply and sewerage infrastructure in Ukraine, promote the introduction of innovative technologies and materials in the industry, improve the quality of design and construction of networks and ensure compliance of Ukrainian norms with international standards.

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ELECTRO-DEWATERING OF ACTIVATED SLUDGE OF SEWAGE TREATMENT PLANTS, TERNOPOL

The sewage sludge formed at wastewater treatment plants constitutes a small percentage of the volume of treated wastewater. However, the costs associated with sludge treatment and disposal account for the lion's share of the operational expenses of wastewater treatment plants. The sludge contains harmful and toxic substances. On

the other hand, sludge is a source of carbon, nutrients, and trace elements, meaning it can be effectively utilized. An important stage in sludge disposal is its dewatering, particularly with the use of electric current.

The study investigated the electro-dewatering of activated sludge with a moisture content of 98% from secondary clarifiers at the Ternopil wastewater treatment plant using direct electric current. Empirical research methods were used.

Experiments were conducted on a laboratory setup with a U-shaped glass tube and carbon rod anode and cathode. The inner diameter of the U-shaped glass tube is 20 mm. A portion of activated sludge with a volume of 100 cm^3 was poured into the tube. A voltage of 30 V was supplied to the electrodes from the rectifier, and therefore a direct current was supplied through the activated sludge. The duration of activated sludge treatment with direct electric current was 24 h and 48 h. Electrodehydration was carried out at room temperature. Under the action of an electric current, sediment settled with the release of a layer of clarified water.

The effect of the electric field was observed during the fading period, when, after a significant amount of water had been separated from the sludge, the electro-dewatering process slowed down. The obtained results were compared with those from the electro-dewatering of activated sludge with a moisture content of 98% from secondary clarifiers at the Ternopil wastewater treatment plant on a setup with a graphite rod anode and a flat cathode, as reported by other researchers. Electro-dewatering of activated sludge on both setups produced practically the same effect. In the process of electrodehydration on both stands, as a result of electrolysis, the release of gas bubbles on the electrodes was observed.

It was confirmed that sludge dewatering using direct electric current can be applied on sludge drying beds at wastewater treatment plants.

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EXPERIMENTAL STUDIES OF BEARING CAPACITY OF PIPE STEEL OF SEWAGE SYSTEMS

Among the main causes of destruction of pipelines of water drainage systems, corrosion damage to the pipe material occupies a significant place. Experimental studies have been conducted to study the kinetics of crack growth, the dependence of the crack resistance parameters and long-term strength of pipe steels of different service life and their structural and phase composition. It has been established that the critical stress value for all experimental steels increases with increasing service life of pipes. At the same time, the impact strength of the experimental samples decreases, which indicates structural embrittlement of steels associated with their sharp hydrogenation. It has been shown that the highest viscoplastic properties and resistance to brittle fracture are possessed by steel grade 06G2BA, which is economically modified with a carbide-forming element (vanadium). This material is distinguished by a fine-grained structure and has a low content of harmful impurities, in particular, sulfur and

phosphorus. X-ray structural methods were used to assess the microstress of the α-Fe crystal lattice, as well as the quantitative decomposition of cementite and the redistribution of carbon between ferrite and pearlite. Steel grade 06G2BA is recommended for use in the construction of pipelines and, for example, bridge structures that are constantly under cyclic loads while simultaneously in contact with a corrosive and aggressive environment. The effect of the service life of pipelines on the hydrogen content and microcracking in pipe steels was determined. A diagram of the relationship between long-term and static strength depending on the hydrogen content in steels was recommended, which can be used by designers for a rational selection of the type of steels with high crack resistance in aggressive technological environments.

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DEVELOPMENT OF COMPLEX WASTEWATER TREATMENT OF GALVANIZING LINES

The prospective of increasing of environmental safety level for industrial enterprises as a result of the implementation of new complex wastewater treatment technology are considered. An analysis of literary sources was carried out regarding the effectiveness of the existing methods of wastewater treatment that contain compounds of heavy metals. The efficiency of iron ion extraction was investigated by processing of steel pickling solutions using the ferritization with various activation methods of the reaction mixture. X-ray phase analysis of the obtained ferritization sediments confirmed the presence of highly dispersed ferromagnetic phases of iron oxides and oxyhydroxides. The sorption capacity of magnetite sediment obtained by ferritization on the efficiency of zinc ion extraction from the wastewater of the galvanic line was studied. The influence of pH value and ultrasound on sorption treatment of washing wastewater by magnetite sediment was determined. When using ultrasound for sorbent treatment and raising the pH to 10, the residual concentration of zinc ions in the washing wastewater decreases to 0.31 mg/dm3, the degree of purification is 98.9%. Such water meets the standards for its use in the operations of washing parts at electroplating facilities or discharge into the city's central sewage system. The prospects for the utilization of spent sorbents in powder paint and varnish materials as a result of the inclusion in their composition of ferritization products obtained from electroplating waste are considered. The use of ferromagnetic waste from sorption treatment improves the corrosion resistance of the resulting coatings compared to traditional ones. The implementation of research results at enterprises will prevent environmental pollution by toxic substances, change outdated production technologies and obtain from production waste materials for corrosion protection of metal construction.

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INTENSIFICATION OF SWIRL-VORTEX CHAMBER OPERATION FOR THE FORMATION OF FLAKES AND ITS TECHNOLOGICAL AND CONSTRUCTION PARAMETERS

In modern conditions, increasing the efficiency of water purification from surface sources is very important. This work aims to intensify the work of the swirl-vortex chamber for the formation of flakes during the preparation of water from surface sources.

The designed swirl-vortex chamber has a rectangular shape and two transverse partitions that divide the tank into three sections. The width of the chamber is equal to the width of the settling tank. Two pipes are placed at the bottom of the chamber to distribute the water along the length and width of the chamber. The nozzles are located at an angle of 45° to the bottom of the flake formation chamber and tangentially directed in opposite directions relative to each other. Perforated pipes are provided at the bottom of the chamber near the distribution system to discharge the flake formation chamber. The number of fittings with nozzles in each section is four (two fittings with nozzles on each pipe in one section). In the first and second sections of the flake formation chamber (counting from the beginning of the settling tank), shut-off and regulating devices are installed for the possibility of changing the conditions of the flake formation process (velocity gradient, upward flow velocity, maximum permissible velocity, water residence time in the chamber).

The principle of operation of the proposed swirl-vortex flake formation chamber is as follows: before supplying the source water to the flake formation chamber, a coagulant solution is entered into the distribution system. Next, the water with the coagulant solution moves through the distribution system and inlets the fittings, followed by the nozzles of each chamber section. Outlet from the nozzle, the flow acquires a circular motion and rises. Due to the tangentially directed nozzles in opposite directions relative to each other, the rotary motion gradually turns into a chaotic, progressive one. Having reached the top of the partitions, the flow of water and the formed flakes moves horizontally and enters the horizontal settling tank.

Based on the research results, the following parameters of the swirl-vortex chamber for the formation of flakes (flocculation) were adopted: the chamber is built-in or attached to a horizontal settling tank; water residence time is 200-300 seconds; speed gradient - 45 - 80 s^{-1}; the height is calculated depending on the depth of the sump; the distance between distribution pipes is 3 m; the distance from the distribution pipe to the chamber wall is 1.5 m; the angle of inclination of nozzles-nozzles - 45° to the bottom; nozzles-nozzles are arranged tangentially and directed in opposite directions relative to each other; complete emptying of the flake formation chamber is carried out by two perforated pipes, which are located next to the distribution pipes; the first and second

sections of the flake formation chamber have shut-off and regulating devices that are installed on distribution pipes (boxes).

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SIMULATION OF THE SEEPAGE PRESSURE UNDER THE DAM BY SEEP/W DURING ENGINEERING EDUCATION

The modern educational environment should ensure the formation of general and professional (special) competencies of the future specialist. The high education of STEM specialties is impossible without modern information technologies and special software in modern conditions. Developer companies and stakeholders are interested in training students using modern calculation software and provide various opportunities for training. Educational programs gradually reduce the amount of practice classes, the use of special calculation software allows to carry out more necessary calculations in short time, illustrate the results, correct the mistakes, choose the optimal constructive solution, therefore, it contributes to the development of critical thinking and independent learning skills of the student.

The practice of implementing information technologies into the education process from simple to complex software is widespread both in Ukraine and abroad. Using modern software activates practical learning, boosts professional identity, consciousness, motivation, and creation of the students.

The aim of the work: to study the pressure seepage force on the base of the spillway using the software Seep/W for using during the educational process in calculations of the structure stability. The article provides the calculation of the seepage pressure under the dam by the ordinary handmade method and by Seep/W software. The fourth-year bachelor's degree students carry out this calculation during the concrete dam design. The comparison of the calculation results by hand and by Seep/W PC was made.

The use of engineering software for calculations is one of the components of the educational process, which allows students to work out a larger number of calculation options in practice and visually familiarize themselves with the consequences of changing the input data of the model. Modern engineering software are quite complex, require additional knowledge and practice skills, encourage students to survey additional information, which contributes to the development of the student’s individual trajectory. Most of the modern software are in English, which also stimulates the study of professional English vocabulary.

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USING THE EXPONENTIAL DISTRIBUTION AS A SYNTHETIC CURVE VOLUME OF RUNOFF TO DETERMINE THE VOLUME OF SURFACE RUNOFF

The problem of the accuracy of determining the volume of surface wastewater, which was formed as a result of precipitation and snowmelt on the territory of the drainage area and enters the surface wastewater disposal systems, is known and depends on the methods usually used to characterize the transformation of precipitation into runoff, which implicitly or clearly take into account the degree of waterproofing within the catchment area.

When determining the amount of surface wastewater formed on the territory of the drainage area as a result of precipitation and snowmelt, and entering the surface wastewater disposal system, the general (annual) flow coefficient is used, which differs depending on the type of surface and is determined on the basis of the data given in paragraphs 7.3 7.4 DSTU 3013-95"Rules of control over the removal of rain and snow wastewater from the territories of cities and industrial enterprises."

Regression models used to estimate area-averaged runoff coefficients are usually untransformed models based on the percentage or proportion of total impervious area in the basin. Although the runoff coefficient is the ratio of the volume of runoff to the amount of precipitation, the main factor that determines the total runoff coefficient is related to the type of surface that is characterized by waterproofing, the type of soil and the previous conditions of its moisture.

Modeling the parameter F/P, which characterizes the volume of losses from the total amount of precipitation depending on the properties of the surface, namely waterproofness and the filtration coefficient, allows generating the value of the total runoff coefficient for the conditions of the city of Kyiv, respectively, for waterproofness with a fraction of 0.2, 0.4 , 0.6, 0.8 and a filtration coefficient of 0.5, 1, 2, 4, 7, 12, 20 mm/h. For the samples from the generated values of the total runoff coefficient with the corresponding percentage of waterproofness, statistical indicators were calculated and box diagrams were constructed.

Descriptive statistics of samples of the general runoff coefficient for waterproofing with a share of 0.2, 0.4, 0.6, 0.8 in the form of functions of statistical characteristics made it possible to establish that the functions of the runoff coefficient from statistical indicators are approximated by a linear regression form. For the conditions of the city of Kyiv, the regression equation of the total runoff coefficient from the share of the total waterproof area with the corresponding soil filtration coefficient was obtained, which more fully take into account the infiltration potential of the soil and the moisture level of the water catchment before the start of rain, which makes it possible to more accurately determine the amount of surface wastewater, which were formed on the territory of the drainage area as a result of precipitation and snowmelt, and enter the surface sewage disposal systems.

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DETERMINATION OF THE FORCE OF HYDROSTATIC PRESSURE ON THE PLANE SURFACE OF AN ARBITRARY NON-SYMMETRICAL FORM BY THE THREE-COMMAND METHOD K123

Competitive struggle in the conditions of wide access to unlimited amounts of information and computerization of all branches of production and services imposes strict requirements on specialized knowledge, practical skills and general mathematical culture of future engineers.

The online program of the modern multivariate engineering calculation of the problem of determining the force of hydrostatic pressure on an element of a flat asymmetric surface with a curvilinear face is presented - - https://www.k123.org.ua/jeh5.html. Algorithms are implemented according to the author's method of three commands K123 © Kopanitsy Yu.D (hereinafter the K123 method). A client-server solution based on CGI technology with a web form for inputting source data has been implemented.

The results of the online calculation were performed according to new analytical dependencies, which were obtained on the basis of the method K123. In parallel, the numerical algorithms of the author's method of three K123 commands and the conclusions of the corresponding calculations in tabular form were implemented.

The server program generates graphics based on the coordinates of the points obtained by iterative calculations using algorithms for the numerical implementation of the K123 method. The relative error of iterative calculations and the estimation of the accuracy of the result are automatically determined based on the proposed exact analytical dependencies.

The work presents:

− research of options for programming a static web page with a problem statement for mobile and stationary platforms;

− formats of audio, video and text submission of reference information have been developed, which includes three options for solving the given problem: functional dependencies for accurate analytical calculation, presentation of a graphic solution to the problem, and algorithm and formulas for numerical implementation of the calculation of the problem according to the author's method K123;

− dynamic formatting and output of calculation results in an interactive online mode using client-server technology, taking into account the requirements for modern mobile platforms;

− the output of the results of a separate iterative calculation according to the K123 method is provided for debugging, testing and debugging the software code in the case of using programming elements in the computer mathematics system in the educational process (using CAS MAXIMA as an example);

− output in tabular format of all intermediate iterative calculations (without limiting the number of iterations) is implemented;

- the server part of the flight program scales and generates a graphic display of the results of iterative calculations corresponding to the given number of iterations;

− the analysis and generation of recommendations for assessing the accuracy of calculations in relative units for an analytical exact solution and a numerical result with a given number of iterations has been implemented;

- software-implemented automatic increased accuracy of calculations by doubling and quadrupling the number of iterations. In parallel, a comparative analysis of the calculation accuracy assessment based on the numerical implementation of the K123 method with the above-mentioned number of iterations and corresponding results based on the proposed analytical dependencies was carried out.

The results of the research were published in the collection "Problems of water supply, drainage and hydraulics", issue 47, 2024 - DOI: 10.32347/2524-0021.2024.47.12-22 The address of the client-server implementation of the software complex is via the link - https://www.k123.org.ua/jeh5.html

The considered online resource allows you to introduce elements of applied engineering calculations into the educational process, to master the methods of multivariate technologies of modern calculations, and to introduce new technologies, new theoretical provisions and applied calculations.

The implementation of an open online service and instant calculation with the display of results allows introducing modern information technologies into the educational process.

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OPERATIONAL FEATURES OF COLLECTING PIPELINES IN THE PRESENCE OF TRANSIT AND GROUNDWATER LEVEL SLOPE

The conditions of operation for pressure collecting drainage pipelines in melioration systems that function in the presence of transit flow and groundwater surface levels have been considered. The system of differential equations describing the fluid motion with variable flow rate in the drainage pipe has been analyzed, taking into account the inflow of liquid from the surrounding soil through the side walls in a filtration mode. This system of equations consists of the hydraulic equation of variable mass and a modified filtration equation. The pipeline under study is laid horizontally and operates with a groundwater level slope. A significant complication in the operation of such pipes is the presence of transit flow that enters their initial cross-section and is transported along the entire length of the drainage pipeline. By introducing new variables, the original system is transformed into a dimensionless form. The solution to this system of equations is presented. It is shown that, in this case, the solution to the original system of equations depends on the magnitude of four main factors: the

resistance coefficient of the collection drainage pipeline «ζ_l»; the generalized parameter «A» which comprehensively considers the structural and filtration characteristics of the flow under consideration; the slope of the groundwater level «I»; and the magnitude of the transit flow «Q_{tr}» The analysis employs the concept of an infinitely long horizontal drainage pipeline that operates with a groundwater level slope and transit flow, or, equivalently, a pipeline with infinite filtration capacity of the side wall surfaces. Based on the conducted analysis, relatively simple and convenient analytical expressions have been obtained for calculating the variation of flow rate and head loss along the length of the drainage pipeline operating with transit flow. To simplify the calculations, corresponding auxiliary graphical dependencies have been proposed.

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PROSPECTS FOR IMPROVING TECHNOLOGIES OF GROUNDWATER DEIRONING FOR LOCAL DRINKING WATER SUPPLY SYSTEMS

Considering today's challenges related to the need to operate drinking water supply systems in the conditions of military operations and significant anthropogenic burden on the environment, the decentralization of water pipes, the provision of backup sources of their power supply in the projects, and the use of local water supply systems for consumers are gaining relevance. And for drinking needs, underground water, which is better protected from the ingress of various types of pollution from the surface of the earth, is the most acceptable source.

However, a large part of the underground sources of water supply is characterized by a high content of iron, and the water from them needs to be de-ironed before being supplied to consumers. In the absence of dissolved oxygen, iron in groundwater is most often found in ionic form and complex divalent compounds. In the absence of dissolved oxygen, iron in groundwater is most often found in ionic form and complex divalent compounds. Most underground aquifers of Ukraine are characterized by high iron content (mainly with concentrations up to 5 mg/dm^3). To date, many technologies for iron removal of groundwater have been developed with various constructive solutions for their implementation in practice. Removal of excessive iron content from groundwater can be carried out by reagent or reagent-free methods, using water-de-iron installations of various design schemes and resorting to measures that increase the efficiency of their work. Under favorable conditions, deironing of water is attempted using reagent-free methods, which simplifies water treatment technology, reduces capital and operating costs of water treatment plants while ensuring high efficiency of their work.

Reagent-free methods of deironing water are implemented in practice, involving various processes and facilities in the technology, for which the following can be used:

- simplified aeration and filtering;
- vacuum-ejection aeration and filtering;
- "dry" filtration.

These methods do not require the introduction of additional, usually expensive reagents, which can cause secondary water pollution and deteriorate its quality.

However, reagent-free methods allow you to effectively remove iron in cases where:

- source water has a pH of 6.7 or higher and an alkalinity of at least 1.5 mg-eq/dm^3;
- permanganate oxidizability is no more than 9.5 mgO_2/dm^3;
- the content of trivalent iron Fe^{3+} is no more than 10% of the total content of Fe_{gen} iron;
- content of $CO_2 \leq 80$ mg/dm^3 and $H_2S \leq 2$ mg/dm^3.

In the case of insufficient efficiency of the application of reagent-free iron removal, reagent methods are used to purify underground water from iron. For this, they use processes and structures that can be provided in their technological schemes:

- simplified aeration, water treatment with strong oxidizers and filtering;
- pressure flotation with liming and subsequent filtering;
- liming, settling in a thin-layer settling tank and filtering;
- filtering through modified loading;
- electrocoagulation;
- cationization.

When applying the reagent method of iron removal, special reagents are introduced into the source water to transform dissolved iron into an insoluble form. The required effect is achieved either with the help of oxidizing agents (ozone, chlorine or its compounds), or by artificially increasing the pH of water above 8 by introducing milk of lime, soda or other pH correctors.

Based on the analysis of existing technologies for removing iron from underground water and modern trends in the field of water treatment, it is proposed for local water supply systems to use a filter with an automatic control valve and technology, which involves reagent-free de-ironing of groundwater as a result of oxidation of dissolved iron by air cushion oxygen and subsequent retention of the formed sediment in the layer of a multi-component filter load. This technology is characterized by low cost and wear resistance of natural filter materials, ease of operation, environmental friendliness, which excludes secondary contamination of purified water with reagents, compactness and automation of control processes, which is especially relevant for small settlements.

The analysis of technologies for removing iron from underground water and the experience of their application in practice in combination with the research of modern trends in the field of water treatment made it possible to determine the prospects for improving the technological schemes of water de-ironing. For local water supply systems, it is proposed to use a filter with an automatic control valve and the technology of reagent-free de-ironing of groundwater, which is carried out by oxidizing dissolved iron with oxygen in a compressed air cushion and retaining the formed sediment in the column of a multi-component filter load.

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ANALYSIS OF DOMESTIC WASTEWATER DISINFECTION METHODS USING CHLORINE DIOXIDE AND SODIUM HYPOCHLORITE

The most serious problem today, in the conditions of war, remains the protection of sources of centralized economic and drinking water supply from pollution, in particular, it concerns surface water bodies and underground sources, since the population's need for a sufficient amount of high-quality and suitable for consumption water always remains vital. After improper wastewater treatment at municipal enterprises, mineral and organic pollutants gradually accumulate in water bodies, which in turn worsens the ecological situation and leads to outbreaks of infectious diseases. The reason for periodic violations of the operation of treatment plants is the imperfection of the technological regime. The technologies and equipment used for the treatment of wastewater from the population centers of Ukraine were built in the middle of the last century, and because of this, the necessary degree of its purification and disinfection is not always ensured. More than 2.6 billion m^3 of polluted wastewater, which contains about 8 billion tons of various pollutants, is discharged into the surface water bodies of Ukraine annually. As a result, we have eutrophication of water bodies and the unsuitability of their use to meet water supply needs. Screening and monitoring of water in the Dnipro River basin has shown extremely high concentrations of herbicides, insecticides, fungicides and various pharmaceutical substances such as carbomazepine, lopinavir, diclofenac and efavirenz. Therefore, there is an urgent need to improve the efficiency of existing biological treatment facilities by means of measures that ensure compliance with environmental requirements for urban wastewater treatment.

The methods used for wastewater disinfection are conventionally divided into the following groups:

chemical (application of various compounds of chlorine, ozone, hydrogen peroxide, etc.);

- physical (thermal, electrical, electromagnetic);
- physical and chemical (flotation, coagulation, electrofiltration, sorption);
- disinfection in the conditions of artificial and natural biocenoses.

Chlorine or its compounds are used as disinfectants: chlorine dioxide, sodium hypochlorite, calcium hypochlorite and others.

The advantages of chlorine dioxide as a disinfectant compared to chlorine include:

- the oxidizing power of chlorine dioxide, which is higher than that of chlorine;
- the biocidal effect of chlorine dioxide, which is higher than that of chlorine at the same doses of reagents and disinfection exposure;
- properties of chlorine dioxide that do not depend on the pH of the water;

- chlorine dioxide when interacting with ammonia and amines does not form chloramines and toxic side products of chlorination (trihalomethanes);

Most often, chlorine dioxide is used to disinfect domestic wastewater from small settlements, local facilities, including transport facilities and wastewater that carries an epidemiological risk (for example, in infectious hospitals). In some cases, it is more appropriate to use hypochlorite salts (sodium or calcium hypochlorite) for disinfection.

The use of hypochlorites for disinfection, including sodium hypochlorite, has a number of advantages over liquid chlorine:

- significantly greater environmental safety during transportation and storage of hypochlorite compared to liquid chlorine;
- supply and storage in containers that are not under excessive (anti-atmospheric) pressure;
- insignificant release of chlorine from the product during storage and use, lack of gassing of the working area, which poses a danger to people;
- the positive effect of the alkali contained in the product on the processes of coagulation and removal of suspended substances from water;
- 15-20% less formation of trihalomethanes and other organochlorine compounds compared to liquid chlorine;
- high ability to oxidize iron and manganese compounds contained in water;

So, we can conclude that today more attention is paid to ecologically clean methods of disinfection of household wastewater, alternative to chlorination. Chlorine dioxide and sodium hypochlorite have a number of advantages compared to the use of chlorine and are increasingly used in wastewater treatment plants.

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THE POTENTIAL OF ALTERNATIVE WATER SOURCES FOR POTABLE WATER SAVINGS IN UKRAINE'S RESIDENTIAL AREAS

According to Water Framework Directive (2000/60/EC) achieving sustainable development, environmental protection must be an integral part of the development process and cannot be considered. Water reuse and rainwater harvesting systems provide essential technical alternatives for water supply management.

There are several alternative water sources (AWS) available for reuse after some needed treatment. The most common is rainwater, that collected from roof surfaces or other aboveground surfaces. Very close to the previous is stormwater. In this type of AWS precipitation from roads, sidewalks, paths in parks, and other surfaces is collected to the drainage system. Another type of AWS is greywater, that refers to wastewater that has not been contaminated by toilet discharge, infectious or hazardous bodily waste, or unhealthy substances from industrial processes. Greywater typically includes treated wastewater from bathtubs, showers, bathroom sinks, washing machines, and laundry tubs, but excludes wastewater from kitchen sinks and dishwashers. In the some

way people should use drainage water as AWS. Foundation drainage refers to nuisance groundwater that is removed to protect the structural integrity of a building or facility. This groundwater would otherwise seep into the foundation, potentially causing damage, and is typically diverted away from the structure. In many cases, this drainage is prevented from entering the sewer system to avoid overloading it. Foundation drainage differs from non-potable groundwater extracted for a beneficial use, such as irrigation or industrial processes.

Deeply studied by authors, two types of AWS greywater and harvesting rainwater.

Today, rainwater harvesting remains a crucial water management technique, adapted for modern infrastructure to support sustainable water use and resilience against water scarcity. Countries around the world have successfully integrated rainwater harvesting into their water management strategies, adapting techniques to meet local needs.

Another type of AWS is greywater. It is reported that about 25–30% of potable water consumption can be reduced by reuse of greywater. The amount of greywater produced in a household can vary significantly, depending on various factors such as: geographical location and climate, lifestyle, culture and habits, type of infrastructure etc.

The comparative analysis of rainwater harvesting and greywater reuse reveals distinct constructive features tailored to their respective functions. Understanding these differences is crucial for selecting the most suitable alterna-tive water source, depending on local conditions, regulations, and specific water needs.

When planning new residential developments, it is essential to incorporate rainwater harvesting for non-potable uses in the initial design phase. Research focused on estimating the amount of water that can be sourced from alternative, non-potable supplies based on territory size and building density.The authors indicate that harvesting systems can reduce water usage for toilet flushing by 48% to 267%, depending on specific design parameters.

In Ukraine, the total runoff volume of rain and meltwater discharged into stormwater systems can be determined according to Usage Rules or DSTU 3013-95 for warm and cold periods.

The results for the calculated annual water volumes from low-rise developments, resulting from rainfall with varying precipitation depths ranging from 350 to 750 mm, and population density for low-rise development, depending on building density, is 0.4 – 130 persons/ha and 0.54 – 180 persons/ha as well as greywater volumes, are presented.

The volume of greywater that can be collected from low-rise residential areas exceeds the volume of rainwater that can be harvested from roofs, even at Ukraine's maximum precipitation depth of 750 mm. At a building density of 0.4, the volume of greywater is 3.11 times greater for 350 mm of rainfall and 1.45 times greater for 750 mm. Similarly, at a building density of 0.54, the volume of greywater is 3.19 times and 1.49 times greater, respectively. With comprehensive water recycling systems, it is possible to reduce freshwater demand by approximately 30% through greywater reuse and by around 10% with rainwater harvesting. These savings offer both economic and environmental benefits, making water recycling especially advantageous for water-scarce regions seeking to mitigate the impacts of climate change.

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INFLUENCE OF GEOMETRIC PARAMETERS OF PIPE NARROWING ON PRESSURE LOSSES IN A PRESSURE SHORT PIPELINE

Pipelines with narrowings are used in water supply, sewage, ventilation, energy, and other fields.

A literature review has shown that, with a pressure drop H=const at the ends of a pressure pipeline with a section of varying cross-sectional area for a liquid of constant properties, a significant change in flow rate can be achieved.

In general, for an open-type pressure hydraulic system with a working liquid flow rate Q=const, the pressure regulation characteristic, with and without measures necessary to change energy losses in the pipeline of the pressure hydraulic system, depends on the hydraulic resistance of the liquid in the regulated and unregulated sections of the pipeline.

There was considered a short pipeline in which water flows without changes in properties, without affecting its unregulated section. The regulated section represented a segment of the pipe narrowing. In this case, the reduction in cross-sectional area could be in the form of a gradual narrowing (converging nozzle) or a sudden narrowing.

The regulation function includes the relationship of pressure loss coefficients for these local hydraulic resistances. Moreover, the first was considered using measures necessary to change energy losses in the pipeline of the pressure hydraulic system, while the second was considered without them. The formula for calculating the pressure loss coefficient structurally reflects only the change in the geometry of the pipe. For the first case, the correction factor is variable and depends on the cone angle of the converging nozzle and the length of the converging section. This requires certain dimensional parameters for the placement of the first local hydraulic resistance compared to the second. However, the pressure coefficient for the first case is always less than that for the second.

Negative values of the regulation function indicate a reduction in pressure losses at the pipeline narrowing when using the aforementioned measures, while positive values indicate an increase in pressure losses.

It has been shown that changes in the geometric parameters of the narrowing section of the pressure pipeline in a pressure hydraulic system affect pressure losses both in the pipeline and, overall, throughout the entire system.

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INFLUENCE OF TECHNOLOGICAL PARAMETERS OF BIOLOGICAL WASTEWATER TREATMENT USING LEMNACEAE ON THE DEGREE OF ANTIBIOTIC REMOVAL

Wastewater from pharmaceutical enterprises often contains substances, in particular, antibiotics, which have a negative effect on activated sludge microorganisms and hydrobionts of natural reservoirs. These substances include chloramphenicol, an antibiotic used to treat bacterial infections in humans and animals. Getting antibiotics into natural reservoirs can contribute to the development of antibiotic resistance in pathogenic microorganisms, which poses a threat to human health and environmental problems, therefore the problem of cleaning wastewater from antibiotics is extremely important and urgent. One of the promising areas of wastewater treatment is biological treatment using aquatic plants, in particular *Lemna minor*. This plant has the ability to absorb, transform and accumulate toxins due to photosynthesis, rapid growth and active metabolism, which allows reducing the concentration of pollutants in water.

The aim of the work is to determine the efficiency of chloramphenicol removal from wastewater using *Lemna minor* depending on the following parameters: the initial concentration of the antibiotic, the time of the purification and the specific biomass of duckweed, and establishing their rational values to ensure the highest efficiency and the lowest economic costs.

The research was carried out in laboratory conditions using imitations of wastewater prepared on settled tap water with an initial concentration of chloramphenicol of 2, 5, 10 and 20 mg/L. The effectiveness of antibiotic treatment of wastewater was determined by the specific biomass of *Lemna minor* 36 and 50 g/L. The time of the process was taken as 1-72 hours, samples of purified water were taken and the antibiotic content was determined using liquid chromatography.

The conducted studies showed that the degree of removal of chloramphenicol depends on the specific biomass of plants and the time of the process. The greatest decrease in the content of the antibiotic was observed during 24-48 hours of the cleaning process, then the efficiency of its removal decreased and after 72 hours it practically did not change.

For concentrations of 2 and 5 mg/L with a specific biomass of *L. minor* of 36 g/L, the efficiency of cleaning in 72 hours reached 23.2% and 26.8%, respectively. When the biomass increased to 50 g/L, the efficiency was 17% and 19%, respectively.

The efficiency of chloramphenicol removal at a concentration of 10 mg/L reached 33%, when the specific biomass of *L. minor* was 36 g/L, and at a concentration of 20 mg/L – 29.5%. For a specific biomass of 50 g/L, this indicator was 23.6% for an antibiotic content of 10 mg/L and 21% for a content of 20 mg/L.

It was established that the optimal parameters for the removal of chloramphenicol are the cleaning time of 48 hours and the specific biomass of *L. minor* 36 g/L, providing a cleaning efficiency of 29.4% at an initial chloramphenicol concentration of 10 mg/L. A

further increase in time does not significantly affect the improvement of cleaning efficiency. An increase in duckweed biomass leads to a decrease in the effectiveness of antibiotic adsorption due to probably insufficient contact of the roots of the upper layers with the solution and inhibition of photosynthesis in the lower layers of the plant.

Purification using *Lemna minor* can be implemented to further treat wastewater after aeration tanks to increase antibiotic removal efficiency.

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ASSESSMENT OF THE MICROORGANISM COMPOSITION IMMOBILIZED ON CARRIERS OF DIFFERENT TYPES

Biological wastewater treatment is an essential part of modern water supply and wastewater disposal systems. A key task in the operation of treatment facilities is the rapid assessment of the status of activated sludge or biofilm. Thus, complex and time-consuming methods are not applicable. Morphological methods for evaluating the state of activated sludge include hydrobiological analysis, commonly used in technological monitoring of treatment facilities, where indicator protozoa are used as test objects to evaluate sludge condition.

The study aims to determine the composition of biofilm microorganisms immobilized on different types of carriers using hydrobiological analysis.

The research was conducted at the Department of Bioenergetics, Bioinformatics, and Ecobiotechnology at Igor Sikorsky Kyiv Polytechnic Institute.

Hydrobiological analysis of biomass by indicator microorganisms and activated sludge analysis was conducted using a research-grade biological microscope ULAB XSP-139TR with photo and video outputs. Biomass accumulation on various carriers was achieved using activated sludge microorganisms, aeration, and biogenic substances (model solution). Studies were conducted on biofilm characteristics on plastic elements – carriers for biofilm attachment – in four different shapes and sizes: spherical with a diameter of 47.09 mm; disk-shaped – 125.93 mm; and wheel-shaped with diameters of 9.95 mm and 9.34 mm under the same conditions. All investigated carriers belong to the dispersive type, distributed throughout the aeration tank and differing in size, structure, surface area, and material.

In addition to experimental research, identification of indicator microorganisms in the biological film was performed using optical microscopy, allowing for the study of the composition and structure of microbial communities. A series of results was obtained that characterize the uniqueness of the biofilm biocenosis immobilized on various types of carriers.

The assessment of microorganism composition in immobilized biomass on different carriers was carried out using a four-point scale based on the abundance of hydrobiota.

Hydrobiological analysis of biofilm enables fast determination of wastewater purification levels. For instance, as the level of wastewater pollution increases, the species composition typically decreases. Thus, changes in species composition serve as indicators of variations in water quality.

The presence of sarcodines indicates the oxidation of most organic substances, meaning a reduction in BOD. A sufficient presence of rotifers and oligochaetes in bioreactors suggests high biomass mineralization and the formation of a higher trophic chain, which enhances the water purification process. These organisms consume detritus and bacteria, which may otherwise exit the treatment facility with the purified water, thereby reducing microbial biomass growth and cutting treatment and sludge disposal costs; they also mineralize biomass, which improves sedimentation properties of sludge.

Water quality assessment based on the species composition of biofilm organisms on all four carriers shows that the biofilm on the wheel-shaped carrier with a diameter of 9.95 mm is the most suitable for effective wastewater treatment among the carriers studied.

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ANALYSIS OF EXISTENT CATALYTIC FILTER MATERIALS FOR REMOVAL OF IRON AND MANGANESE

The main task of water treatment in decentralized water supply is the purification of water from iron and manganese. Water purification from iron and manganese on pressure filters using catalytic loading is a modern trend in local water treatment. Catalytic loadings have been used for a long time, but most manufacturers do not provide clear and practical recommendations for their use. The use of such materials usually depends to a large extent on many factors and is based on the experience and qualifications of the specialist. The main components of the successful selection and setting of the correct technological scheme of water purification are the analysis of the technical parameters of the filter materials and parameters of the quality of the source water, the selected dose of reagents. Analysis of the technical and physicochemical parameters of the catalytic materials Birm®, Greensand Plus®, Filter Ox®, Katalox Light®, DMI-65® provided by the material manufacturers showed that these are natural materials that contain on their surface or in the porous structure of the granule's oxidation catalyst, mostly manganese dioxide. The intensity of work of catalytic materials depends on numerous factors, such as pH of the environment, redox potential, concentration of iron and manganese ions, level of dissolved oxygen and the presence of other impurities. Among the most interesting materials, it is worth noting Greensand Plus®, Filter Ox®, Katalox Light®, the advantages of which are understandable capacities of filter materials for different types of pollutants, a wide pH range, the possibility of using oxidizers, and a long service life. Monitoring five locations where filters with catalytic materials were installed during commissioning showed that iron was

removed with an efficiency of 85-95%, and in some locations it did not meet regulatory requirements, and manganese reduction was less than 50%. Calculation of the Water Stability Index (LSI) using Wave software showed that it was negative at all sites. By adjusting the pH of the source water to the level of 7.7-7.8, it was possible to achieve a change in the LSI index to a positive one and to achieve stable results in the removal of iron and manganese at all locations.

Therefore, the catalytic materials proved to be quite effective even when it is necessary to extract manganese at a water stability index in the range of 0.2-0.4 and at a pH higher than 7.8.

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NUMERICAL ONLINE EXPERIMENT IN THE CALCULATION OF CHANNELS OF THE HYDRAULICLY MOST ADVANTAGEOUS PROFILE OF A TRAPEZEIDAL FORM

Determining the depth of uniform movement is an integral part of many hydraulic calculations of open channels and various hydraulic structures. It is necessary to know it when constructing the curves of the free surface, studying the forms of conjugation of biefs. When designing new channels, the following parameters can be taken into account: slope laying coefficient, flow rate, coefficient of roughness of the bottom and walls of the channel, slope of the channel bottom. Among a number of possible options, there is one for which the average speed will be maximum, and, accordingly, the cross-sectional area will be minimum. A cross-section satisfying these conditions is hydraulically the most advantageous. The task is to determine the appropriate width and depth of the channel, which can be solved both analytically and with the help of numerical modeling in computer algebra systems.

The online calculation program includes client and server parts, which are implemented using CGI technology in the PERL language. A static page includes:

- a block of general statement of the problem;
- the condition of the educational example;
- algorithm and formulas of iterative calculation;
- reference technical information;
- graphical visualization of the results of a typical calculation;
- a web form of output data with a starting standard set of values

Reference information is presented in the format of a reference card (hereafter QRC – quick reference card), which opens when you click on the icon. The paradigm is software implemented - all information in a compact format in one window. The so-called "blinds" technology is used - in this way, the limited capabilities of the screen of mobile devices are taken into account.

Reference Cards (QRC) provide access to:

- roughness coefficients of the selected channel with artificial fastening;
- the maximum permissible (non-eroding) average cross-sectional velocity depending on the type of soil, (without) fixing channels and depth of flow.

Graphic solution of the given task with an example of graphs generated by the software code of the server part of the program based on the source data of the online data entry form.The goal of developing an interactive server online technology for calculating an educational task is to introduce elements of computer calculation (numerical modeling) in computer algebra systems into the educational process. The work was performed on the example of using an open software product - CAS MAXIMA. The problem of mastering the elements of numerical calculation (modeling) of an engineering problem in modern systems of computer mathematics, which are distributed under the open license GPL and can be recommended and implemented in the educational process, is solved.

The server program generates the results of individual step-by-step iterative calculations in tabular format. We have the ability to simulate an unlimited number of responses for an arbitrary set of input data. The corresponding calculation formulas are presented in the side information block in parallel with the results of iterative calculations. This is how we have all the necessary information and the ability to debug the software code in the CAS MAXIMA environment. Compare the online test answer and your own calculations in the CAS MAXIMA program.

The system of computer mathematics allows to expand the methods of engineering calculations of the problem with the help of the graphic system of the program. The server part of the program generates a visualization of the graphical solution to the problem based on iterative calculations. Corresponding coordinates – the results of iterative calculations, which are presented in tabular format, complement the graphics. The program for online calculation of channels of the most hydraulically advantageous trapezoidal profile, which is implemented using client-server technology, makes it possible to generate an unlimited number of various problems.

The interactive part of the web form for entering data and an unlimited number of instant calculations introduces elements of modeling and calculation experiments with various parameters of a trapezoidal channel: slope, roughness, channel reinforcement material, etc.

One problem can be solved: analytically, graphically or by iterative numerical methods. Verification of the obtained solution, separate iterative calculation, graphical display of dependencies is carried out by using the web form of the client-server program and generating a dynamic page with multivariate output formats of numerical experiment results.

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MODERNIZATION OF DESNIANSKA WATER TREATMENT PLANT: JUSTIFICATION OF THE NEED AND SELECTION OF TECHNOLOGICAL SOLUTIONS BASED ON PILOT STUDIES

Providing the population with high-quality drinking water is one of the fundamental aspects of social well-being and sustainable development. In Ukraine, which is facing wartime challenges and the need to modernize critical infrastructure, this task is of particular relevance. The Desnianska Water Supply Station (DVS), which supplies drinking water to a large part of Kyiv, needs a comprehensive renovation. This is due to the deterioration of the quality of water in the water supply source, outdated cleaning technologies and the use of potentially hazardous reagents.

Over the past decades, there has been a steady trend towards deterioration of water quality in the Desna River, which is the main source of water supply for internal combustion engines. Anthropogenic load caused by the development of industry and intensification of agriculture leads to an increase in the concentration of organic substances, heavy metal compounds and microbiological pollutants in river water.

The situation is aggravated by seasonal fluctuations in water quality associated with the processes of "blooming" and dying off of phytoplankton, as well as winter freeze-up, which contributes to the desorption of pollution from bottom sediments.

Existing water treatment technologies for internal combustion engines, which were introduced in the middle of the last century, are not able to provide an appropriate level of water purification in modern conditions. The use of chlorine and ammonia for disinfection, although it is an effective means of combating pathogenic microflora, leads to the formation of dangerous by-products, in particular trihalomethanes (THM), which have carcinogenic and mutagenic effects on the human body. In addition, the storage of significant amounts of chlorine and ammonia on the territory of the plant creates serious man-made risks.

The modernization of the internal combustion engine will allow the introduction of modern water purification technologies that will remove a wide range of contaminants, increase the efficiency of water and energy use, which will help reduce operating costs and reduce the negative impact on the environment, as well as increase the capacity of the station to provide quality drinking water to the growing population of the city.

Pilot studies are an important tool for optimizing and selecting effective technological solutions before their large-scale implementation. They make it possible to simulate and compare the efficiency of various technological schemes directly on real water from a water supply source, which ensures the adequacy of the results obtained. During the pilot studies, the optimal parameters of the treatment facilities for each technological scheme are determined, which will allow to achieve maximum efficiency of water purification and disinfection with minimal consumption of reagents and energy.

Based on the analysis of water quality in the Desna River and existing water treatment technologies at the internal combustion engine, four alternative technological schemes were proposed.

To model and compare the efficiency of the proposed technological schemes, a pilot installation was developed, which takes into account the specifics of the internal combustion engine and the requirements for research.

The main technical solutions of the pilot plant include the possibility of parallel operation of pressure and non-pressure cleaning lines, the use of a patch panel for flexible connection of elements, the use of standard and non-standard designs, as well as the introduction of an automatic control and monitoring system.

The terms of reference for the research include the development of technological schemes during all seasons of the year, laboratory control of water quality at all stages of purification and disinfection.

Based on the results of the work, specific modernization measures will be recommended, such as the introduction of new technological processes, infrastructure upgrades and increased automation, which will improve water quality, reduce energy costs and ensure the stability of water supply

Modernization of the Desnianska water treatment plant is a complex and multifaceted task that requires an integrated approach and consideration of numerous factors.

Pilot studies at a specially designed facility will make it possible to choose the optimal technological scheme of water treatment, which will ensure high quality of drinking water, minimize man-made and environmental risks, and will also be economically feasible in the long term.

This will help improve the standard of living of the population, ensure sustainable development of the city and strengthen the national security of Ukraine.

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USE OF COMBINED WATER SUPPLY SYSTEMS TO INCREASE THE RELIABILITY OF WATER SUPPLY

Water supply is a key component for sustaining human life and the development of human settlements' infrastructure. Water security is a complex and multifaceted issue due to the constant growth of population, land use changes, migration to cities, floods, droughts and other hydrological impacts associated with climate change, which affect the availability, quality and quantity of water. In emergency situations, such as natural disasters, man-made disasters or military operations, water supply systems face serious challenges. A reliable water supply is critical for ensuring hygiene, nutrition and health care in crisis conditions.

Centralized water supply provides a reliable supply of water to urban residents, but such systems in large cities are vulnerable to external factors during military operations and emergencies. The main risks are the destruction or damage of key

infrastructure facilities: water intake facilities, pumping stations, treatment plants and pipelines.

Decentralized water infrastructure is an alternative to traditional centralized systems for implementing sustainable water infrastructure in urban settings. Such a water supply system is a group of water supply subsystems with a certain degree of autonomy from the entire system. A decentralized system allows for better management of pressure in the network, which contributes to the reduction of leaks, facilitates the detection, localization and control of supply anomalies, identifying areas where capital investments will be best used, protects the network from possible attacks through accidental or malicious contamination.

The transformation of centralized water supply systems into decentralized ones is one of the effective methods of increasing the reliability of water supply, especially in emergency situations, including military operations. The advantages of decentralized systems are reduced infrastructure costs for long-distance transportation and treatment of rainwater, drinking water and wastewater, as well as optional treatment to drinking standards of water used for purposes other than drinking and bathing; more efficient use of the resource; increased service safety; reduced risk of water supply system failure; strengthened local economies; restored and protected natural environments; enhanced community well-being.

The result of increasing investment in decentralized infrastructure solutions while maintaining centralized schemes is a process of hybridization, where centralized and decentralized systems coexist. Water infrastructure needs to be more flexible and adaptable to be sustainable. Hybrid systems combine features of centralized and decentralized water supply. They can provide centralized water supply in densely populated areas and use decentralized solutions for remote areas. Such systems reduce resource consumption due to lower transportation requirements and the need to treat all water to the same high standards. An integrated decentralized-centralized approach can offer flexible solutions wherever certain population density thresholds are exceeded. In addition, various combinations of centralized and decentralized systems can have positive results in terms of sustainable water supply.

While centralized systems are cost-effective and reliable, decentralized systems are based on the principle of environmental sustainability and can manage the water cycle, protecting the natural environment, and are more flexible. Combined water supply systems combine the advantages of both centralized and decentralized systems.

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ENSURING THE SAFETY OF DRINKING WATER FOR ALL IN UKRAINE

Drinking water supply and sewage are fundamental components of the social and economic development of the country. Ensuring access to drinking water for the population, sustainable water supply, and wastewater management contribute to the establishment of comfortable living conditions, public health, and the development of social sectors and the economy. Effective management in the field of drinking water

supply and sewage is a key factor for successful social reforms. In addition, some of the main Sustainable Development Goals for Ukraine up to 2030 are:

- ensuring the accessibility and sustainable management of water resources and sanitation;
- ensuring access to affordable, reliable, sustainable, and modern energy sources for all;
- creating resilient infrastructure;
- ensuring the openness, safety, resilience, and environmental sustainability of cities and other settlements;
- ensuring the transition to rational consumption and production models, etc.

The most effective methods for ensuring the safety of drinking water supply, according to the World Health Organization (WHO), are the development and implementation of Safe Water Supply Plans (SWSP). The approach based on SWSP is WHO's response to the call contained in Sustainable Development Goal (SDG) 6, which aims to ensure the safety of drinking water for all.

In the countries of the European Union (EU), a Safe Water Supply approach is implemented in drinking water supply systems to provide consumers with safe drinking water, which is incorporated into national drinking water legislation. Additionally, the requirements of the Protocol on Water and Health recommend the use of the Safe Water Supply approach.

One of the main components of effective Safe Water Supply planning is the comprehensive assessment and risk management approaches that are carried out from water extraction to its delivery to the population. The Safe Water Supply plan serves as a management tool for the everyday operations of the system and ensures the reliability and safety of the drinking water supply system.

The principles underlying the Safe Water Supply plans can be adapted to all types and sizes of drinking water supply systems.

It should be noted that Ukraine, as a member of the Energy Community, is obligated to implement into national legislation the requirements of the core Directives of the European Parliament and Council 91/271/EEC of May 21, 1991, on the treatment of urban wastewater, and 2020/2184 of December 16, 2020, on the quality of water intended for human consumption. Ukraine must align its current legislation and ensure the achievement of indicators in accordance with the Protocol on Water and Health to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes of 1992, ratified by the Law of Ukraine on July 9, 2003, No. 1066-IV.

The aforementioned has necessitated the development at the state level of draft regulations for the development of schemes for optimizing centralized water supply and sewage systems.

The principles of Safe Water Supply are the foundation of these regulations, incorporating the core directives and taking into account the requirements of the Protocol on Water and Health.

Yes, the development of optimization schemes for centralized water supply and sewage systems, considering Safe Water Supply, includes the following stages:

1) Holding meetings on the development of the optimization scheme with the participation of representatives from all stakeholders;

2) Collecting baseline data to determine the main indicators for the optimization scheme;

3) Analyzing the current state of centralized water supply systems and identifying their key issues;

4) Defining strategic development goals for centralized water supply systems;

5) Conducting hydraulic calculations of the current state of centralized water supply systems;

6) Identifying ways to ensure the resilience of centralized water supply systems during emergencies and in wartime;

7) Performing calculations to determine the indicator values for the development of centralized water supply systems;

8) Developing and comparing scenarios for the development of centralized and decentralized water supply systems or their elements based on the values of indicator indicators, hydraulic and spatial analysis, and risk minimization of drinking water supply;

9) Developing and forming a list of measures for the development of centralized water supply systems with subsequent prioritization;

10) Conducting a cost assessment of the measures and forming an implementation plan;

11) Identifying sources of funding for the measures and developing a financial model for the optimization schemes;

12) Analyzing, assessing, and managing risks in drinking water supply;

13) Developing additional sections and documents to obtain funding from international donors;

14) Holding meetings to discuss the interim results of the optimization scheme development;

15) Preparing the textual and graphic components of the optimization scheme;

16) Preliminary discussion of the optimization scheme with the participation of representatives from all stakeholders;

17) Adjusting the optimization scheme based on the results of the preliminary discussions;

18) Preparing and presenting the final version of the optimization scheme;

19) Implementing and monitoring the optimization scheme.

In other words, it should be understood that the optimization scheme is a document that incorporates the Safe Water Supply principles and includes other components such as sewage, financial models, etc.

Funding for the development of optimization schemes is planned through the measures of the State Target Economic Program for the Energy Modernization of Water Supply and Sewage Enterprises that are state or municipal property, for the period up to 2030, which was approved by the Decree of the Cabinet of Ministers of Ukraine dated November 15, 2024, No. 1133-r.

The developed optimization schemes provide an opportunity to receive funding from international donors for the implementation of planned activities.

Heating, ventilation and air conditioning. Engineering. Technologies

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EVALUATION OF THE EFFECTIVENESS OF AIR EXCHANGE FOR THE FORMATION OF A BIO-SAFE AND COMFORTABLE ENVIRONMENT OF PREMISES WITH A MASSIVE PRESENCE OF PEOPLE

The problem of the biosafety and comfort of mass people gatherings remains relevant. The airborne infections and deterioration of immunity due to discomfort are harmful factors with temporary disability, which burdens the employer (overloading other employees, underperformance) and the country's economy (disability payments, hospital treatment). For people with cardiovascular and cancer diseases, these factors are dangerous due to cardiac dysfunction, acute cerebrovascular accident, etc.

Today, two methods compete in air conditioning – mixing ventilation, i.e. supplying air with a significant temperature difference and velocity to the upper zone by jets that mix used air and return it to the working zone (air exchange coefficient 1....1.5), as well as displacement ventilation – air supply to the working zone with low temperature difference and velocity forming a significant temperature stratification by height (air exchange coefficient 2...2,5 and up to 3,5 at a great height and heat gains) and minimal return of used air to the working zone. The latter helps to reduce the spread of aerosols in the room. Increasing the air exchange rate and temperature difference leads to a decrease in the air exchange rate and energy consumption for supply-air treatment. The change in these parameters is the opposite in both methods. The choice of method is controversial.

For simplicity, a simulator was created in the SciLab system, which built all possible straight processes within the range of moisture content from 0 to 20 g/kg and temperature from 0 to 50 °C on a grid of starting and ending points with a step of 0.2 g/kg and no more than 0.1 °C. The results showed that the air exchange coefficients for temperature and enthalpy or moisture content are interchangeable with a deviation of up to 3.7 %.

The obtained results made it possible to compare the consumption of cold and heat for the reheating in air conditioning systems of halls with mass people gatherings. For mixing ventilation, the air exchange coefficient was taken to be 1.05...1.15, and for displacement ventilation – 2...2.5. The simulator automatically selects an air conditioning system with and without first recirculation.

Tens of variants have been calculated, which have shown that in some cases it is possible to reduce the air exchange, "cold" and heat for secondary heating with mixed ventilation. Consequently, providing increased biosafety and comfort with displacement

ventilation can be more energy-intensive. It is necessary to look for other more efficient ways.

In some museums (in particular, the Louvre), temperature drop and velocity in displacement ventilation are increased. Such solutions cannot be recommended due to discomfort. It is proposed to combine mixing ventilation with natural sanitation with phytoncidal plants: *Citrus limon*, *Chlorophytum comosum*, *Ficus benjamina* Wiandi*, Sansevieria, Ficus benjamina, Dracaena fragrans, Azalea, Yucca elephantipes*, *Zamioculcas zamiifolia*, *Fuchsia*, *Hibiscus rosa-sinensis*, *Spathiphyllum*, *Dracaena marginata* Lam*.*, *Amaryllis*, *Monstera deliciosa, Philodendron hastatum, Philodendron*, etc.

Transit and transit-dead-end air exchange schemes are not recommended for rooms with a large number of people, in which air is supplied from one side of the room and removed from the other side or both sides, respectively. This creates directed airflow in the working zone. If the flow rate is standard (0.2...0.3 m/s), the aerosol will spread over 2...3 m in 10 s with the recommended distance between people of 1.5 m. Therefore, to increase biosafety, it is necessary to supply air evenly in the plan.

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ANALYSIS OF THE IMPACT OF KEY FACTORS ON THE DUST COLLECTION PROCESS IN SCRUBBERS WITH DISC ATOMIZERS

The influence of the main factors on the dust collection process in dust collectors with disk atomizers is analyzed. Aspects such as particle wettability, droplet size, and concentration of mechanical impurities are considered, which play an important role in increasing the efficiency of wet dust collectors.

During the interaction of dusty gases with a torch of sprayed liquid, the temperature of the gases decreases. This can be explained by the fact that during contact with a finely dispersed liquid torch with hot gases, the process of evaporation of droplets occurs. The source of energy for evaporation is the excess heat of dusty gases, which, being unsaturated, transfer the entire warm drop of liquid. As a result of this evaporation, the droplet diameter decreases, which is a factor for further condensation and purification of the gas stream.

As the temperature of only the steam-gas medium drops below 100 °C, steam condensation occurs. Steam condenses on condensation nuclei, which can be both small water droplets and solid dust particles present in the gas-air stream. the condensation process impairs the reduction of the number of contaminants in these systems, which significantly increases the efficiency of cleaning.

The degree of purification of the gas-air flow in wet dust collectors depends on the wettability of the particles. If the parts are well wetted (they are hydrophilic), they, having reached the surface of drops or a water film, are completely immersed in it. This prevents the possibility of the gas flow throwing these parts back into the air. Thus, the hydrophilic parts are successfully removed from the gas stream.

On the other hand, poorly wetted (hydrophobic) particles do not have the ability to sink into liquid drops. They remain on the surface of drops or a water film, forming a peculiar layer on it. As many new particles approach this layer, they are repelled and returned to the gas flow, carrying it into the atmosphere. This is the main problem in the purification of hydrogases from hydrophobic particles.

The constant influx of solid particles into circulating water until the accumulation of these particles in significant quantities. However, paradoxically, it helps to improve the process of capturing hydrophobic particles. At a concentration of mechanical impurities in water up to 2.5 kg/m³, the efficiency of capturing hydrophobic particles is significantly achieved. This is explained by the fact that as the concentration of impurities increases, the number of interactions between particles and water droplets increases, which is likely to result in the successful capture of these particles by liquid droplets.

In addition, droplet size, which deteriorates during water dispersion, also affects the efficiency of the process. Smaller droplets deposited by disc atomizers have lower kinetic energy and are therefore more difficult to mix uniformly with the gas stream. Due to these small droplets, it is not possible to achieve full interaction with gases, which reduces the cleaning efficiency. A decrease in the droplet diameter also complicates their separation from the gas flow due to increased droplet entrainment.

On the other hand, an increase in the concentration of mechanical impurities in the drivers leads to a decrease in the particle-free surface of the droplet, which can affect the ability of the droplet to interact with new parts.

To optimize the process, it was found that the dispersion of droplets can be effectively controlled by changing the speed of rotation of the disk atomizers, the concentration of mechanical impurities, the flow rate of the liquid and its physical properties, such as viscosity and surface tension.

Summing up, it can be noted that the use of dispersed water with mechanical impurities is an appropriate method for cleaning aspiration ages. approach improves dust capture efficiency and reduces emissions of solid particles into the atmosphere, which is a place to reduce environmental damage.

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ANALYSIS OF THE EFFECTIVENESS COEFFICIENT OF DECENTRALIZED VENTILATION SYSTEMS WITH HEAT RECOVERY

Increasing energy efficiency requirements have led to modern buildings becoming virtually airtight. This, in turn, has led to a deterioration in indoor air quality. To solve this problem, efficient ventilation systems, such as decentralized supply and exhaust systems with recuperators, are needed. Unlike centralized systems, decentralized systems are lower in cost, do not require bulky air ducts, and are easy to install without significant construction work.

Natural ventilation, while a simple and cost-effective solution, has significant limitations. Its effectiveness is highly dependent on external conditions, such as

temperature differences. The unreliability of natural ventilation in sealed spaces makes it difficult to maintain high-quality air exchange, which is important for a healthy microclimate. This is especially noticeable in modern buildings focused on energy efficiency, where natural ventilation fails to control air quality. In such conditions, decentralized mechanical systems become a more effective solution, as they consistently maintain comfort and optimal air exchange regardless of external factors. The study of existing decentralized ventilation devices and the development of an energy-efficient regenerative heat exchanger is a critical task. This will not only improve indoor air quality, but also contribute to the energy saving of buildings, especially given the current environmental challenges and climatic features of Ukraine and Europe.

The paper presents the results of studies of the efficiency of three decentralized ventilation systems with heat recovery. The main attention was paid to ensuring the same requirements for conducting research, as well as the same microclimate parameters of the “warm” and “cold” chambers. Although the test results showed that all systems worked quite efficiently, the data analysis revealed the potential for further improvement. Increasing the tightness of the systems could significantly improve their performance. The efficiency of the systems may vary depending on the specific conditions of their operation, including the actual air flow and air flow balance. The highest efficiency was shown by the Klimatronic 160 Basic system, however, there is a possibility that the system operated in a mode of imbalance between the exhaust and supply air flows. Thus, further research should determine the actual flow rate of each device to better understand the efficiency assessment.

The results obtained can be used to optimize the design of the decentralized supply and exhaust ventilation systems and develop recommendations for their integration with other ventilation systems to ensure an optimal indoor climate and reduce energy consumption.

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NATURAL VENTILATION AS AN ENERGY-EFFICIENT SOLUTION FOR THERMALLY MODERNIZED BUILDINGS

Insulation of the exterior walls of buildings remains a key measure to improve energy efficiency, especially for apartment buildings, which suffer from freezing walls and humidity in winter and overheating in summer. External thermal insulation can significantly improve the microclimate in apartments by protecting the walls from the negative effects of moisture, wind and ultraviolet radiation. Replacing outdated windows and balcony units with sealed profiles with double-glazed windows also helps to create a stable indoor climate, which in turn helps to significantly reduce energy consumption.

Thanks to the high level of airtightness and thermal insulation, thermally modernized buildings significantly reduce heat loss, but this creates the problem of limited air exchange, which reduces indoor air quality. Typically, mechanical ventilation systems are used to address this issue, ensuring proper air exchange and control of

indoor environmental parameters. However, since these systems consume a significant amount of energy, they often contradict the main goal of thermal modernization - minimizing the energy consumption of the building.

In the context of modern requirements for energy efficiency in buildings, it is important to find alternative ventilation methods that will reduce or even avoid dependence on mechanical systems. Ensuring effective ventilation in thermally modernized buildings should take into account not only proper air exchange but also minimal energy consumption. That is why it is promising to study natural ventilation solutions, including the use of wind catchers and window airer. These systems have the potential to provide efficient airflow without additional energy costs, which is especially important in light of government energy efficiency programs and policies.

The study analyzes the results of modeling the impact of natural ventilation on the microclimate of a thermally modernized building using the example of a single room, which is a key aspect for ensuring energy efficiency and comfortable living conditions.

The purpose of the study is to compare the efficiency of two types of supply air equipment: a wind catcher of the original design and a window airer with options for location above and below the window, and to assess the impact of different air flow rates on the nature of its distribution and circulation in the room under different supply options. The modeling was carried out for two climatic conditions: warm and cold seasons, which allowed us to comprehensively assess the impact of supply air on the indoor microclimate under different climatic conditions.

A thermally modernized one-story residential building located in Kryvyi Rih was selected for the study. The supply air temperature, taking into account the climatic conditions of Kryvyi Rih, is «-21°C» in the cold season and «+20°C» in the warm season. The internal air temperature is assumed to be «+20°C». The modeling of the impact of natural ventilation on the microclimate of the thermally modernized building was performed using the licensed software Solidworks Flow Simulation.

The analysis of the modeling results showed that the use of ventilators in the warm season, when the temperatures of the supply air and the room coincide, both variants of the ventilator location (above and below the window) are able to provide sufficient air exchange, evenly distributing the air. During the cold season, when air with a temperature of «-21°C» is supplied, significant temperature gradients are formed near the ventilators, especially when supplied through the lower ventilator. This creates cold zones in the lower layers of the room, which leads to a decrease in thermal comfort in the room and an increase in energy consumption required for additional heating of the room.

The use of a wind catcher with the ability to control the temperature, flow rate and direction of the supply air clearly demonstrates the flexibility in creating a stable microclimate in different conditions: ensuring uniform air distribution and promoting efficient air exchange during warm periods and maintaining a comfortable indoor temperature during cold periods.

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APPLICATIONS OF AUTOMATION CONTROL FOR COMMERCIAL GAS ACCOUNTING BASED ON THE CONCEPT OF VIRTUAL POINTS

In Ukraine, approximately 10 million household gas meters with mechanical mechanisms are in use, while most of them lack temperature compensation for natural gas. Without this feature, accurately measuring gas consumption in energy units, as required by regulations, becomes challenging and less cost-effective. To address these metering issues on the global level, a concept involving virtual gas metering points has been introduced, presenting a potential solution for more precise gas accounting. The scope of this research is focused on designing an automation system based on the concept of the virtual points of gas metering, with the primary objective on intelligent control aspects throughout the many elements of the system, but also concerning other areas of the system, such as server-side cloud-based software and infrastructure, and client-side user interfaces, as well as integration of them into a comprehensive automation system.

Gas metering should be performed in kWh. Calculations of the consumed gas energy consumption require the following parameters: volume of gas consumption, standard gas temperature, temperature at the metering environment, altitude of gas metering location, and gas calorific value for the gas line. While the volume of gas consumption is a direct output of the physical gas metering device and standard gas temperature is constant, the other parameters should be controlled, approximated, and predicted. For example, to provide accurate kWh values, the system should predict caloric values based on historical data, as the current month’s values would not yet be available. And, to define the temperature at the specific location without the installation of a physical thermometer, the approximation techniques should be developed and evaluated.

The server-side part of the gas accounting automation system is responsible for gas usage calculations, data aggregations, integrations, and other end-user-facing functionality. It should connect external systems to fetch the data required for gas metering calculation parameters approximation and prediction: gas lines database, temperature of air database, and caloric value of natural gas database. The client-side mobile application provides the end customers with the user interface to submit physical gas meter measurements as well as see the current month's gas consumption values and the history of gas usage in the energy units.

Overall, the automation system aims to solve the issue of inaccurate gas metering by leveraging the idea of virtual points of gas metering and defining software-level automation encompassing control system elements as well as information system elements in the scope of one system.

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PROSPECTS FOR USING GAS TO BALANCE THE ELECTRICITY SUPPLY SYSTEM

Electricity in Ukraine was produced in a volume that fully satisfied the needs of domestic consumers, the surplus energy was exported to other countries. As a result of Russia's large-scale military aggression against Ukraine and the destruction of electrical networks, there is a periodic shortage of electricity. In conditions where more than 50% of the Ukrainian electricity infrastructure has been damaged and part of the nuclear, renewable and hydropower capacities are still located in the occupied territories, the best option for balancing the energy system is to use the possibilities of gas generation.

Natural gas extraction from gas fields continues in Ukraine and, as a result of the decrease in consumption by industry (many metallurgical enterprises have been destroyed or are located in the occupied territories), there has been an opportunity to use this unused volume of gas for the generation of electrical energy.

The gas transmission system is less vulnerable to damage from destruction, as gas production is quite dispersed and the network is mainly underground. Vulnerable are compressor stations that provide the necessary gas pressure for its transportation. The availability of gas reserves in gas storages increases the reliability of system operation.

In addition, there is a potential opportunity to use biogas for electricity generation. Based on the available raw material base, Ukraine can produce 21.8 billion cubic meters of biogas and/or biomethane annually. The greatest potential for biogas production is in Kyiv, Vinnytsia, Poltava and Cherkasy regions. The introduction of “combined energy “natural gas plus hydrogen”” allows reducing the share of natural gas through the use of alternative gas.

An effective measure to maintain the balance of electrical energy is maneuverable mobile generation based on gas turbines. This technology can quickly ensure the supply of energy in a critical situation based on the existing gas infrastructure. This is a reserve that will insure the entire energy system if necessary. Therefore, it is necessary to maximally implement the installation of such equipment (gas turbines, internal combustion engines, etc.).

Gas turbines have the following advantages compared to traditional electricity generation: longer service life, quick start-up and reaching the required power, lower harmful emissions. Arguments for using gas generation include the possibility of quickly creating additional generation facilities; regulation of generated power in a wide range; maneuverability and independence from weather conditions; availability of gas resources.

The relevance of using gas generation will not decrease in the post-war period in the conditions of rebuilding the energy system. Other generation options (nuclear, solar, hydro, etc.) are more complex, less maneuverable in terms of power and long-term in construction. In addition, gas generation can be switched to alternative gas, such as biomethane or synthetic gas, in the future.

To balance the electricity supply system in the face of potential shelling of territories, the following short- and long-term measures are proposed.

Short-term measures:

1. Increasing energy production, including electricity production in mobile power plants using natural and liquefied gas, biogas, hydrogen or a mixture of these gases as fuel.

2. Emergency energy supplies from other countries.

3. Repair and restoration of damaged infrastructure.

2. Optimization of energy consumption.

Long-term measures:

1. Expansion of the range of electric power generation sources;

2. Development and modernization of energy infrastructure;

3. Integration with European energy markets;

4. Attracting international partners and investors.

These measures, both in the short and long term, will help strengthen Ukraine's energy independence and ensure a stable energy supply for all sectors of the economy.

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ANALYSIS OF WAYS TO SAVE ENERGY AND INCREASE THE ENERGY EFFICIENCY OF RESIDENTIAL BUILDINGS

In modern buildings, heat loss through walls, ceilings of the upper floor and above basements is approximately 34%, or 34 kWh/m² per year. These losses occur due to insufficient thermal insulation of building structures, which is a typical problem even for new buildings. However, ventilation emissions account for a significant share of heat loss in new buildings, about 50%. This is because ventilation provides an influx of fresh air, but it also causes a significant outflow of warm air from the premises, which leads to an increase in heat loss.

Changes in the level of air exchange compared to the standard values have the greatest impact on the overall level of heat loss. Excessive air exchange leads to higher heating costs because more heat is lost through ventilation systems. On the contrary, insufficient air exchange can reduce heat loss, but at the same time causes a deterioration in indoor air quality, which can affect the health and comfort of the occupants.

For buildings in the new housing stock, which are characterized by a heat loss rate of about 100 kWh/m² per year, the distribution of heat loss by different types is as follows: a significant portion of heat loss is due to ventilation and insufficient thermal insulation of external structures. Heat loss is also affected by windows, doors, foundations, and roofs, which, if not properly insulated, become “weak points” in the building's heat balance.

When adjusting the regulatory requirements for thermal protection of windows, it is necessary to take into account not only the total heat loss of the room, but also the peculiarities of heat exchange between humans and the environment, depending on the

geometric parameters of the designed room. For example, if a room has large window areas or high ceiling heights, this can affect the perception of thermal comfort by residents.

In old buildings, it is necessary to increase the level of thermal protection of the building envelope. It is worth noting that increasing the thermal insulation of windows and blank walls has almost the same thermal efficiency.

The most effective way to improve the thermal protection of reconstructed buildings is to insulate the exterior walls using efficient thermal insulation materials. In addition, this contributes to a significant improvement in the temperature and humidity conditions of the external envelope, which has a positive impact on the building's durability and comfort of living. It is advisable to use lightweight and efficient thermal insulation materials to insulate roofs, attic and basement floors.

Glazing balconies and loggias is an important measure to improve the energy efficiency of buildings during the reconstruction of the housing stock. This allows not only to reduce heat loss through external structures but also to improve the overall thermal comfort in the premises. In addition, the installation of automatic devices for closing entrance doors and attic doors helps to keep the heat inside the building, preventing unnecessary heat loss through constantly open or poorly closed doors.

Another effective solution is to equip vestibules in buildings that do not have them. This allows you to create an additional buffer zone between the outside environment and the room, which significantly reduces heat loss when doors are frequently opened.

A set of measures aimed at achieving energy efficiency in buildings may include the following key aspects:

- Increasing the thermal efficiency of the building envelope, which involves improving the thermal insulation characteristics of walls, roofs and windows. This can significantly reduce heat loss through the building's external structures, which in turn increases its energy efficiency and comfort.

- Improving the regulability of heating and heat supply systems. This means the introduction of modern technologies that allow for automatic or manual adjustment of the indoor temperature regime according to the needs of users. Such systems help to avoid overheating or insufficient heating of premises, while reducing energy consumption.

- Increase the efficiency of the heat supply systems in operation. This includes the transition to the use of alternative decentralized heat supply systems, such as heat pumps, solar collectors and other modern solutions. Alternative heat sources not only reduce the load on central networks, but also help reduce emissions of harmful substances into the environment.

- Implementation of forced ventilation systems using exhaust air heat recovery technologies. This approach provides not only efficient ventilation but also a significant reduction in energy costs for maintaining a comfortable microclimate.

A modern building should be characterized by an efficient energy saving system, which includes a number of measures aimed at reducing energy costs to maintain comfortable conditions and lighting. At the same time, it is important to ensure a high quality indoor climate.

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PROBLEMS OF WIDE-SCALE INTRODUCTION OF HEAT PUMPS IN UKRAINE

The need to introduce energy-efficient technologies caused by the rising cost of fossil fuels and the problem of environmental pollution. Governments in developed countries have been aware of these challenges for some time and have been actively integrating heat pumps for heating both residential and industrial facilities. As you know, a heat pump is a system designed to convert low-potential energy from natural or secondary sources into usable heat. These installations are not only efficient and environmentally friendly, but also allow for significant savings on the use of conventional fuel. The decisive indicator of their efficiency is the ratio of electricity consumed to heat produced, which can be 3-4 times higher than the energy consumed.

The global application of heat pumps is being explored through various successful implementations in different countries. In Sweden, for example, since the 1970s, a concerted effort has been made to reduce dependence on fossil fuels, which has led to a significant integration of heat pumps into heating systems. In addition, there are examples from Europe, the United States, and Japan where these technologies have become a widespread and reliable way to deliver heat.

The large-scale deployment of heat pumps in Ukraine faces several challenges. Key challenges include the lack of legislative and economic incentives to encourage investment in energy efficient technologies, the high costs associated with initial investments, and the lack of domestic production of these systems. In addition, it was noted that there is insufficient funding for pilot projects that could demonstrate the benefits of heat pumps.

For the successful introduction of heat pumps in Ukraine, it is necessary to:

- Develop and implement programs of subsidies, tax breaks and grants for heat pump installation, as is done in many EU countries.
- Develop new and modernize existing energy saving standards, building codes, and regulations that include requirements for heat pumps in new and modernized buildings.
- Conducting information campaigns for households and businesses about the benefits of heat pumps. Explain the economic benefits and return on investment to raise awareness.
- Introduce preferential conditions for heat pump manufacturers in Ukraine to develop local production, which will reduce the cost of equipment.

Heat pumps are not only environmentally friendly, but also allow you to refuse gas for heating and water heating. The savings on these needs alone are up to 80%. While a conventional electric boiler produces the same amount of heat as it consumes electricity, heat pumps produce 3-5 kW of heat from each kilowatt of energy consumed. In fact, the only drawback of heat pumps is their high cost, which is why most European countries subsidize their installation, contributing to their own energy independence. Heat pumps can also be used in old apartment buildings.

The introduction of heat pumps in Ukraine is inevitable, but most of the equipment will be imported in the coming years. Despite this, there are many reasons to be optimistic that this technology will eventually become widespread in our country, helping to reduce energy dependence on gas imports.

The price of gas has not changed for more than two years, but it is much lower than the market price paid by businesses. In a time of war, there is no guarantee that the state will continue to subsidize the cost of natural gas from the budget for a long time.

In Ukraine, heat pumps have significant prospects for energy savings; however, their widespread adoption requires government support and proactive efforts to educate both the public and businesses about the benefits of these systems. The analysis of the available data emphasizes the importance of revising energy efficiency strategies and advocates for the introduction of globally recognized technologies to address the country's pressing energy and environmental challenges.

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GROUND SOURCE HEAT PUMPS: REGULATORY FRAMEWORK AND ENVIRONMENTAL IMPACT ON SUBSOIL

The process of implementing energy-efficient solutions for establishing heat energy sources for residential, public, or industrial facilities must occur within the framework of the state's existing program to enhance energy independence from fossil fuels and in compliance with building standards. The subsoil is a part of the earth's crust located beneath the land surface and the bottoms of water bodies, extending to depths accessible for geological study and development. Subsoil is the exclusive property of the people of Ukraine and is provided only for use. All water resources (objects) within Ukraine's territory, including groundwater and springs, constitute its water fund.

The construction of ground-coupled heat pumps is directly subject to national legislation on subsoil and water resources, due to its design. The construction of primary circuit geothermal heat exchangers generally involves the installation of wells that intersect various geological layers, including those containing strategic aquifers.

Almost any land plot in the country considered for constructing a social or industrial facility requires water supply, and thus, full compliance with all regulatory requirements regarding the ecological safety of water usage is essential.

The most significant administrative barrier to the widespread use of geothermal energy is the legal regulation of this resource, particularly relevant for deep geothermal installations. Investors need a clear roadmap of their actions and the right to explore and subsequently utilize geothermal resources.

According to the current practice of applying geothermal heat pumps, the procedure for developing and approving project documentation includes obtaining technical specifications from the Kyiv Hydrogeological Expedition of the State Enterprise "Ukrainian Geological Company." The technical specifications provide detailed information about the geological-hydrogeological structure of the area where the heat exchange probes are planned to be installed.

The analysis of geological-hydrogeological materials allows the conclusion that the installation of heat exchange probes outside all sanitary protection zones will not significantly impact the main aquifers used for artesian water supply. The thermal impact of heat exchange probes on aquifers is calculated during the preparation of project documentation in the "Environmental Impact Assessment" section.

Given the sharp trend of rising energy costs, the economic feasibility of using geothermal energy is no longer in question. However, Ukraine still lacks national standards or generally accepted methodologies that fully disclose the principles and procedures for designing, constructing, and operating high-capacity (>30 kW) heat pump installations based on ground-coupled heat pumps in terms of regulatory framework.

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NATURAL AIR POLLUTION TECHNOLOGIES IN THE PREMISES OF HEALTH CARE INSTITUTIONS

The paradigm of sustainable development contains requirements for environmental protection, social justice, absence of racial and national discrimination and is aimed at raising the standard of living of the population, etc.

Among others, attention is drawn to Goal 3 "Strong health", which aims to ensure a healthy lifestyle and promote well-being for everyone at any age and which contains 9 tasks, including are as follows:

- ensure ... access to quality basic health services and to safe, effective, high-quality and low-cost essential medicines and vaccines for all (task 3.8);
- until 2030 significantly reduce the number of cases of death and disease as a result of exposure to hazardous chemicals, pollution and poisoning of air, water and soil (task 3.9).

As a result of the implementation of the tasks by 2030 the number of deaths and illnesses as a result of exposure to hazardous chemicals, pollution and environmental poisoning should be significantly reduced. Engineering support systems create and maintain standardized values of air environment parameters in the premises of buildings and structures of various purposes. With the signing of the association agreement with the European Union in Ukraine, the adaptation of state standards to European requirements for indoor microclimate and technological solutions for its organization and maintenance began.

Medical institutions, hospitals, and especially operating rooms are premises whose microclimate has always had particularly strict requirements. Not only the well-being of the surgeon and his assistants, but also the patient's health depends on the level of humidity and air temperature in the operating room.

In many cases, non-compliance with the norms regarding the humidity and temperature regime, etc., can cause unwanted complications in the patient's well-being. Requirements for the conditions and organization of the provision of medical services to the population (medical services) are established by the State Sanitary Norms and Rules.

Currently, the most effective way of bacterial disinfection of indoor air is the use of ultraviolet light. The main disadvantage of this method of air purification from pathogenic microorganisms and viruses is the harmful effect on human health of possible excess radiation, excessive concentrations of ozone and mercury vapor - ingredients of the first class of danger, which are released during the processing. In addition, disinfection occurs exclusively in those places and areas where direct ultraviolet rays enter, and exclusively in the absence of people. To eliminate these shortcomings, an innovative technology for cleaning air in closed rooms is proposed, which is based on natural processes of disinfection of pathogenic microflora. The method is harmless to humans and pets. Design solutions of haloaerators - devices for air disinfection in closed rooms and the technology itself - have been developed and successfully tested. According to the results of the tests, their effectiveness was confirmed - the level of bacterial air pollution in a closed room decreased from the initial value of 1500 in 40 minutes of operation of the device to 10 CFU/m^3.

The proposed method contributes to the saturation of the air in closed rooms with useful microelements with an increased disinfecting effect. When using it in a closed room, a positive effect was achieved, which consists in reducing bacteriological indicators.

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IMPROVING THE EFFICIENCY AND RELIABILITY OF SPRAY DRYING EQUIPMENT FOR DAIRY PRODUCTS

The development of Ukraine’s dairy canning industry is associated with increasing the technological and energy efficiency of one of its main processes—drying dairy products to improve their quality and extend product shelf life. Modernizing the production process requires advanced, efficient equipment, particularly energy-efficient spray drying units. In recent years, demand has increased for equipment to dry whey, a by-product of cheese production. The equipment at Ukrainian dairy plants previously consisted mainly of outdated A1-ORC units with single-stage drying processes, which are unsuitable for whey drying. Imported VRA-4 units have limited air heating temperatures in steam heaters and produce unacceptable atmospheric emissions. Existing recommendations for the calculation and design of equipment for drying milk and dairy products require improvement or clarification.

This study presents the results of theoretical and experimental work conducted during the development and enhancement of spray drying units at PJSC "Kalynivka Machine-Building Plant" (Kalynivka, Vinnytsia region). Based on these results, a practical methodology has been developed for calculating improved designs of spray drying units with modern technological and energy parameters. Data from experimental studies on the drying processes of pilot models and full-scale industrial drying units

during their creation, improvement, and the development of drying processes for new dairy products were used to formulate theoretical solutions and recommendations on the aerodynamics of the drying chamber and the fluidization of fine dry dairy products. It was established that the improved methodology for calculating heat and mass transfer in the drying chamber should additionally include determining the active evaporation volume under the achieved parameters of moist air. Based on scientific and design work in mastering the production of spray drying units with moisture evaporation capacity from 500 kg/h to 2500 kg/h, a transition was made from outdated single-stage spray drying with product cooling in pneumatic transport to a unified three-stage process, which includes spray drying, drying in a fluidized state, and vibro-cooling. Positive results were obtained through the step-by-step modernization of the drying chamber, forming the necessary aerodynamics for a stable drying process. Under a single-stage scheme, during the first stage of modernization by replacing the chamber's flat bottom with a cone, unloading the product through a rotary airlock, and side removal of exhaust air, complete drying was not achieved, nor was the stability condition met for spray drying with the product particles remaining airborne until fully dried. In practice, the average air passage time through the drying chamber (≈ 20 s) significantly exceeded the droplet’s suspension time before settling (≈ 1 s), causing intense sticking of undried product to the cone walls in the exhaust air removal zone. The reliability of the spray units, preventing sticking, was achieved by increasing the drying time of particles in the chamber with the use of an "air bottom"—a cylindrical chamber with a flat perforated bottom at the lower edge of the cone, providing appropriate jet flow aerodynamics. The application of a fluidized (boiling) layer of milk powders as the second stage of spray drying was studied on four types of laboratory models, and the results were implemented in the fluidized bed chamber designs for all types of drying units. It was found that the presence of the fluidization chamber increases the drying unit's moisture evaporation capacity by 10-15%.

The effectiveness of the implemented patented technical solutions was confirmed by commissioning tests of the modernized drying units and their subsequent operation. The scientific and technical experience gained by PJSC "Kalynivka Machine-Building Plant" in the modernization and commissioning of spray drying units, combined with experience in producing equipment for dairy product processing—such as high-temperature gas air heaters and vacuum evaporation units—serves as a foundation for organizing their serial production.

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CURRENT CHALLENGES AND ENERGY-EFFICIENT TECHNOLOGIES IN UKRAINE'S DISTRICT HEATING AND GAS SUPPLY SYSTEMS

Heating and gas supply systems are essential components of Ukraine's housing and utilities sector, responsible for providing heat and gas to both residential and industrial facilities. Key areas for the development of these systems include centralized district heating and gas supply, automated management, and the use of renewable and secondary energy sources. One important objective is to reduce harmful emissions into

the atmosphere, which will help minimize ecological impact and enhance energy efficiency.

The heating system comprises devices for the production, transportation, and distribution of thermal energy in the form of hot water, steam, or heated air to the end user.

Main Elements:

1. Heat sources – responsible for the production of thermal energy.
2. Heat networks – transport heat to consumers.
3. Heat substations – ensure efficient distribution of thermal energy.
4. Local heating systems – manage the final consumption of heat.

The gas supply system is aimed at safely and continuously delivering gas to consumers. A key feature is the ability to disconnect individual sections for maintenance and repair, enhancing the reliability of the system. Approximately 80% of heating systems in Ukraine are centralized. These systems help reduce air pollution and enable optimal resource use through combined heat and power production at CHPs (combined heat and power plants).

Significant heat losses, which reach 30-40%, are a major issue, often due to insufficient insulation of pipelines, particularly in non-passable channels with mineral wool, which loses insulation properties upon contact with water.

The use of heat pumps, solar collectors, and thermal storage systems helps reduce dependency on fossil fuels. The application of cogeneration technologies (simultaneous production of heat and electricity) enhances the overall efficiency of the system. Energy-Efficient Buildings: Modern energy-efficient buildings with advanced insulation materials and airtight structures allow for a 20-30% reduction in energy consumption.

Regulation Models: Modern heating systems utilize quantitative, qualitative, and combined regulation, which provides optimal conditions and allows for up to 15-20% energy savings through automatic temperature control based on weather conditions. Accounting and Monitoring: Implementing heat metering systems enables monitoring of energy consumption efficiency, reducing costs by introducing economic measures.

The use of pre-insulated pipes in non-channel installations helps reduce heat losses, extend system life, and lower repair costs. In Ukraine, this technology is actively developing but requires further implementation to meet European standards.

The use of advanced heat exchangers and regulators reduces energy consumption, and regulated heat carrier supply schemes help avoid unnecessary heat loss during periods of low demand.

Enhancing energy efficiency and integrating renewable energy sources are strategic objectives for Ukraine's district heating and gas supply systems. The adoption of new technologies, such as pre-insulated pipes, automatic temperature regulation, and energy metering, will optimize costs, reduce heat losses, and help lower emissions. These measures will allow Ukraine to reach European standards of energy efficiency, ensuring the sustainable development of the heating and gas supply sector.

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PASSIVE TECHNOLOGIES FOR MAINTAINING MICROCLIMATE IN MODULAR BUILDINGS

The aim of the study was to explore the possibilities and advantages of applying integrated passive systems for ensuring microclimate parameters in modular buildings of various purposes using alternative energy sources.

The research object included integrated passive systems for maintaining microclimate in modular buildings of different types.

The research subject involved the study of the technical, economic, and environmental aspects of applying integrated microclimate systems in modular buildings, focusing on the use of alternative energy sources. The research aimed to identify optimal solutions for achieving energy independence and enhancing energy efficiency in modular buildings.

Scientific novelty of the obtained results:

– Based on analytical research and statistical data processing, graph-analytical dependencies for determining the potential of renewable energy sources for specific regions of Ukraine were refined.

– Designs of modular buildings for various population groups were proposed, taking into account functionality, energy efficiency, and cost-effectiveness.

– A system for selecting the optimal type and thickness of thermal insulation for modular buildings was developed using multicriteria analysis.

– For the first time, a thermosiphon collector design with adjustable air layer thickness inside the unit was developed.

– A system for passive solar energy utilization was improved, particularly by using a thermosiphon collector as a heat ventilation device integrated into the exterior of a modular building.

– The method of computer modeling was advanced, enabling the evaluation of temperature regimes of the thermosiphon collector under various operating conditions over a wide range.

– For the first time, the thermal ventilation characteristics of the proposed thermosiphon collector design were experimentally established for both gravity and mechanical operation modes, and regularities of efficiency variation with different heights of intake openings and air layer thicknesses were identified.

– Thermal process modeling was conducted for the proposed thermosiphon collector design in heating, ventilation, and cooling modes.

– Based on experimental studies of a geometrically similar modular building model in a wind tunnel, aerodynamic coefficients on the facades of the modular building were determined, and areas of excessive static pressure and suction were identified.

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EVALUATION OF ENERGY EFFICIENCY INDICATORS OF ELEMENTS OF CENTRAL AIR CONDITIONING SYSTEMS BY THE EXERGY EFFICIENCY INDEX

When designing, constructing and operating engineering systems and their structural elements in buildings and structures, Ukrainian government regulations generally set forth provisions for energy saving and energy efficiency. The regulations provide for basic requirements for the use of energy for heating and cooling of premises or a thermal zone, humidity control, hot water supply, ventilation and lighting, etc.

The main requirement for energy saving and energy efficiency should be met through a number of measures, including optimization of energy consumption by building engineering systems. Among the most energy-consuming building engineering systems, central air conditioning systems (CACS) occupy a special place, given that they consume all types of energy generated by municipal and industrial generating units. Regarding these systems, regulatory requirements provide for the determination of efficiency, namely, the *efficiency* of their operation mode and the control of the relevant climate parameters.

The authors have developed and are implementing a methodology for assessing the energy efficiency of various schematic solutions of the CSCS, their individual functional elements and air handling units. The methodology is based on the main provisions of the *exergy* analysis, which, in our opinion, is the most correct and perfect for these systems.

This report presents the results of analytical studies to assess *the exergy efficiency* of individual functional elements of the CSCS. The study covers devices for heating, cooling, humidification and dehumidification of air systems of domestic manufacturers and suppliers of the relevant equipment. The original methods were used to calculate air heaters and coolers, air washes for humidification and dehumidification, and exhaust air heat recuperators for different operating modes during warm and cold design periods.

For the first time, we obtained correct numerical results of research on the *exergy efficiency* indicator. For the studied elements of the CSCS, its values, depending on the period, were as follows:

- 7...25% for the air washes;
- 20...50% for air heaters and heat recovery units;
- 30...45% for air coolers.

We have shown that *exergy analysis* for CSCS proves the possibility of correct assessment of individual system elements in terms of energy saving. Unlike traditional methods, which compare individual types of energy with each other, such as heat or electricity, exergy analysis operates with a single thermodynamic potential - *exergy*, which has the property of additivity and allows us to evaluate energy flows characteristic of air conditioning systems and determine the corresponding energy efficiency indicators.

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FEATURES OF HEAT SUPPLY WHEN ESTABLISHING CIVIL PROTECTION STRUCTURES IN PUBLIC BUILDINGS

In the conditions of martial law and full-scale war in Ukraine, a separate direction of construction was actualized, namely the arrangement of civil defense facilities in public buildings, in particular educational institutions, health care institutions, sports and entertainment facilities, etc. The main problem when designing engineering networks in shelters is heat supply, as this is an additional heat load for the building, which entails either the reconstruction of the general heat supply system or the construction of heat generation facilities.

Connecting heat supply systems of shelters in parallel with systems that cover the load of the main building can serve as an effective solution for providing heat to engineering shelter systems. During an air alarm, the main heat supply system is switched to standby mode (set according to the purpose and characteristics of the building), and the released thermal energy is sent to the engineering networks of the shelter. Since, usually, during an emergency, all people in a public building must be sheltered, this way heat is supplied to the part of the building where people are. This approach makes it possible to significantly save on the reconstruction of the general heat supply system.

The problem of such a solution may be excessive hypothermia of the main building, because according to DBN V.2.2-5:2023 "Civil Protection Structures", the shelter must be able to shelter people for 48 hours. However, statistics show that most air alarm during a high-intensity war last about 1.5 hours. Such a time for switching systems to the next mode when the enclosing structures comply with modern standards should not significantly affect the comfort conditions in the building. Of course, for the comprehensive implementation of such a regime of heat supply to a public building with a built-in shelter, it is necessary to conduct research on the thermal stability of buildings.

In general, it can be argued that the parallel connection of the heat supply systems of the main building and the shelter to the heat source is a real way to reduce the capital costs for arranging shelters in public buildings, which allows for a more intensive increase in their number.

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ENSURING OPTIMAL MICROCLIMATE IN MUSEUM PREMISES USING MULTI-JET AIR DISTRIBUTORS IN SYSTEMS WITH ADJUSTABLE AIR FLOW

Providing optimal microclimatic conditions in museum premises is a key aspect for preserving valuable exhibits and creating comfortable conditions for visitors. The parameters of temperature (16-24 °C, optimally 18-22 °C) and relative humidity (55% ± 5%) must remain stable to prevent damage to cultural heritage objects. However, traditional ventilation systems with a constant air flow rate are not always able to provide such conditions due to high energy costs and limited adaptability to changes in climatic and operational factors. Therefore, the use of multi-jet air distributors in systems with adjustable flow rate is a modern approach that allows you to optimize energy consumption and ensure effective maintenance of air parameters.

Theoretical studies of the functioning of multi-jet air distributors capable of forming fan, axisymmetric and combined jets were conducted. Three main air supply schemes were modeled: axisymmetric jet supply, fan jet supply, as well as combined supply with both types of jets. The use of different jets allows you to control the direction and parameters of the air flow, which is especially important for avoiding overheating or overcooling of the areas where the exhibits are located.

Mathematical modeling has shown that the fan jet provides a uniform distribution of temperature and humidity in the working area at an air flow rate of 25% to 100% of the maximum. In particular, the cooled fan jet contributes to the creation of a stable microclimate that meets regulatory requirements for the preservation of exhibits. The heated fan jet, on the other hand, rises to the upper layers of the room without reaching the working area, which leads to a disruption of air circulation. The cooled axisymmetric jet is effective only with a significant reduction in air flow (up to 25% of the maximum), while the heated axisymmetric jet requires additional regulation of the air outlet area.

Using both types of jets simultaneously allows you to achieve the best results for maintaining a stable microclimate in conditions of high air exchange intensity. This scheme provides a uniform distribution of temperature and humidity throughout the entire volume of the exhibition hall, minimizing vertical temperature gradients, which is important for the preservation of exhibits.

Mathematical modeling and theoretical research results confirmed the effectiveness of a cooled fan jet for maintaining regulatory parameters in the working area of museum halls. A heated fan jet is unsuitable for these conditions, as it disrupts the circulation regime, requiring more careful regulation. The use of combined jets is the most promising, especially for large rooms or rooms with a high level of heat release. The proposed results and recommendations can be useful in the design and modernization of ventilation systems in museums, where maintaining a stable microclimate is important for the preservation of cultural values.

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ENERGY-EFFICIENT VENTILATION AND SMOKE EXTRACTION SOLUTIONS FOR MULTI-LEVEL PARKING LOTS OF LARGE AREAS

When arranging ventilation and smoke removal of multi-level parking lots or parking lots, as a rule, classic design solutions are used. However, now pulsed or otherwise jet ventilation and smoke removal systems are often found. Depending on the mode, these systems can be used as ventilation systems for airing the room, or as smoke removal systems during a fire. The main difference between such systems and the usual ones is the absence of air ducts laid under the ceiling of parking spaces. During a fire, ventilation air or combustion products are transported to the smoke intake openings of exhaust shafts due to directed jets of air or flue gases from impulse fans evenly located under the ceiling of parking spaces. However, a particularly important requirement for the arrangement of such systems is that the supply and exhaust shafts should be as far away from each other as possible.

During the heating period, heat consumption for heating ventilation air in buildings is at least 30-60% of the total heat loss. In order to reduce these energy costs, various types of heat exchangers are used, which became the basis for the creation of ventilation units equipped with such devices. Another method of energy saving was the use of recirculation in ventilation systems, which allows for the second use of already heated air from exhaust systems by mixing it with supply air.

Under the condition of installing impulse ventilation and smoke removal systems, the issue of air recovery and recirculation has received a number of limitations and features. The use of recirculation forces the laying of additional air ducts and ducts, since the supply and exhaust are at considerable distances, plate and rotary recuperators are also difficult to use in such systems. One of the possible rational energy-efficient solutions is the use of recuperators with an intermediate coolant. Under such conditions, water or a water-glycol solution circulates between two heat exchangers, one of which is located in the exhaust channel, and the other in the supply channel.

The use of an additional heat exchange device in addition to the recuperator will allow air heating and ventilation to be combined. Also, with certain calculations, such a solution allows the use of a coolant supply with lower temperatures from a heat pump. In the warm period of the year, it is possible to recover the cold and use the thermal energy of the soil or surface water sources.

Traditionally, it was believed that systems with intermediate heat carriers do not have high coefficients of recovery efficiency, but the use of highly efficient heat exchange devices and new technical solutions significantly increase these indicators.

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EXPERIMENTAL STUDIES OF THE THERMAL REGIME OF THE ROOM WHEN IT IS HEATED BY AN ELECTRIC HEATING DEVICE

Mobile (portable) heat pumps are universal solutions for efficient and convenient heating of premises, especially in cases of emergency situations, including related to military operations, which lead to the destruction of heat supply systems of the population. One of the defining features of mobile heat pumps, mainly air heat pumps, is their compact and lightweight design. Thanks to this, they are easy to move, which allows you to choose specific areas for heating, providing efficient and fast heating.

The purpose of the work is to study the thermal regime of the building room when heated by an electric heating device, namely a mobile air heat pump of low power. Experimental studies were conducted on the example of using a mobile heat pump with a capacity of 1.5 kW. In the room with dimensions: length – 6160 mm, width – 3220 mm, height – 2660 mm, a heat pump was installed near the window, and in the window a corrugated exhaust pipe with a diameter of 15 cm was installed to discharge the exhaust air into the environment. During the operation of the heat pump, using a thermal anemometer, which was placed directly above the heater, the temperature and air flow velocity were measured along the distance from the surface of the heat pump. The end of the thermal anemometer, in which sensitive elements for measuring temperature and speed are located, is set flush with the front surface of the heat pump, which is the zero reference point for this experiment. To measure the temperature along the height of the room, a vertical string was installed, equipped with 12 TRP-100 temperature sensors, the signals from which were sent to the measuring complex and archived in the computer memory. The velocity of the air flow from the exhaust pipe was also measured using a portable hand-held thermal anemometer. On the basis of the conducted experimental studies, the features of the thermal regime of the room when it is heated by a low-power mobile heat pump have been established. The use of heating devices of this type will reduce the risks that can negatively affect the heat supply of the population in wartime and postwar conditions.

Ecosystems and water resources. Engineering. Technologies

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USE OF MILITARY WASTE IN CONSTRUCTION

One of the steps that accelerated the reconstruction of Warsaw after World War II was using of military construction materials and waste in construction. For example, surviving bricks were reused, and construction waste was crushed into concrete. Whole items such as bathtubs, door handles, railings and much more were used for installation in reconstructed buildings.

In countries such as Denmark, the Netherlands, and Germany, there is a direct requirement to use a certain percentage of products from recycled waste in new construction. In Austria, about 8.7% of construction and demolition waste is recycled. The most radical measures to combat the disposal of construction waste have been taken in Flanders, where there are direct bans on landfills for the recycling of fractions of construction waste. In the Netherlands, a law has been in force for about 10 years prohibiting the disposal of recyclable construction waste in landfills.

According to Martin Bjerregaard, director of the Disaster Waste Recovery company for the cleanup of waste after disasters, this category of waste is the most complex and dangerous for work and the environment. It cannot simply be dumped in a pit. For example, after Hurricane Katrina in 2005, according to the BBC, government workers in Louisiana (USA) dumped more than 30 million cubic meters of garbage in local landfills. New landfills were built urgently, often in violation of sanitary standards, and the waste was not sorted. In addition, the authorities temporarily allowed the removal of waste, the disposal of which is prohibited in peacetime. As a result, petroleum products, pesticides, and asbestos that are dangerous to humans ended up in the soil.

During the war with the russian federation, the problem of recycling military waste was very acute. Today, work is underway to dismantle the rubble resulting from military operations and clear populated areas of debris from destroyed objects. Such construction waste can be reused not only during the restoration of damaged objects but also during the production of building materials.

Three main stages can be distinguished: 1. Sorting. 2. Reducing the volume of waste, for example, by crushing. 3. Returning the collected materials to civilian circulation using them as secondary raw materials. There may be the following options:

- "Chernets" (crushed metal), can be returned to circulation after remelting.

- Construction "stone" waste is suitable for the production of various types of construction products. For example, as a filler under the road surface, they can also be used to fill craters from shell explosions.

- Surviving fragments of houses are suitable as building materials.
- Fallen trees are used as chips.
- Crushed stone obtained from recycled concrete is used to fill swamps and pits, as well as to create temporary roads.
- Asphalt is reused in road construction, but first, it is thermally processed at a very high temperature.
- Reinforcement is also reused in construction and many other cases.

Also, such waste can be used in building structures to create low-grade concrete. There are factories in Ukraine for the production of such concrete.

Today, a very popular use of waste is artistic objects in houses and adjacent territories. The traditional use of waste is flower pots and vases. It can be not only tiyres but also projectile fragments of the appropriate shape and tubes. Such objects are simultaneously war monuments. The main condition is the cleaning of residues from toxic substances from fuel and explosives. Residues of wooden and ceramic structures after grinding can be used as substrates for lawns of adjacent areas, flower beds and green structures.

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OIL AND GAS PRODUCTION AND THE ENVIRONMENT

Ensuring a sufficient level of oil and gas production development is a prerequisite for the stable development of any country. The oil and gas complex is one of the most important components of Ukraine's fuel and energy base. The oil and gas industry is a sector of heavy industry whose companies explore, produce and process oil and gas, as well as transport and store them.

At the same time, any oil and gas production is characterized by the fact that almost all stages of its operation have a harmful impact on environmental components.

A particular danger is the hydrosphere risk pollution, i.e., the possibility of untreated wastewater (flushing water) and pollutants entering water bodies. In addition, the construction of production wells generates hazardous waste and poses the problem of ensuring its reliable storage. Drilling wastewater, drilled rock, and spent drilling mud are integral elements of the drilling process. Drilling wastewater has the ability to filter through the waterproofing coatings of sludge pits, contaminating soil, surface and groundwater. Accidental releases and gushing of oil, gas and mineralized formation water on land within the water area are also dangerous. Water environment may be contaminated with oil products as a result of wellbore integrity damage.

Soil contamination occurs: - when oil gushes out of wells under drilling; - when drilling waste forms on the surface; - when oil gushes out of wells in operation

During field development, subsoil contamination occurs, and a violation of the tightness of the columns during production can lead to interstitial flow or open oil flow.

Based on the research, the following conclusions can be drawn.

Improving the environmental safety of oil and gas production should be considered in two aspects - at the drilling stage and at the production stage.

1) At the drilling stage:

2) Improvement of technology in well construction and creation of pits;

3) Improvement of land reclamation methods;

4) Improvement of methods of water waste treatment and water saving required for the technology, namely:

a. reuse of drilling wastewater;

b. reduction of fresh water consumption;

c. reduction of drilling wastewater generation;

d. safe storage of spent drilling fluids and sludge in sludge pits after their preliminary disinfection;

5) Sludge processing to obtain useful materials;

6) Use of environmentally friendly chemicals and materials for drilling fluids and improvement of their utilization.

In the process of oil and gas field development, environmental pollution can be reduced by:

1) Application of the most efficient extraction methods;

2) Extraction of associated components of industrial importance (oil gas, helium, iodine, bromine);

3) Preventing excessive losses and selective extraction of rich and easily accessible areas of the field, which leads to unbalanced production of reserves;

4) Carrying out additional exploration of the fields;

5) Conducting refinement work and maintaining the necessary geological and technological documentation in accordance with the applicable development rules;

6) Monitoring of changes in the condition and loss of reserves;

7) Prohibit activities that may cause damage to the deposits being developed and other mineral deposits located nearby, as well as the preservation of minerals conserved in the subsoil;

8) Keeping records of minerals that are extracted alongside, but temporarily not used.

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DEVELOPMENT OF A DESIGN SOLUTION FOR THE AUTOMATION SYSTEM OF AN EXPERIMENTAL BALLAST WATER TREATMENT FACILITY

This research introduces innovative technology for ship's ballast water treatment and disinfection that meets the International Maritime Organization's D-2 water quality standard requirements. The innovative approach to ballast water processing has been developed and validated by the research team at the Danube Institute of the National University "Odesa Maritime Academy" as part of the state-funded research project No. 0124U004399, supported by the Ministry of Education and Science of Ukraine. The study emphasizes the critical role of ballast water in modern maritime navigation, particularly its significance for vessel stability and operational safety. However, the

presence of numerous marine organisms in ballast water poses significant multidimensional challenges, ranging from threats to ecological balance to economic losses and sanitary-epidemiological risks. The transfer of ballast water between different geographical locations facilitates the invasion of non-indigenous microorganisms into new ecosystems, potentially leading to the destruction of local biota and causing substantial economic losses in coastal regions. The developed experimental facility implements a comprehensive approach to ballast water treatment through the sequential application of chemical, ionization, and mechanical processing methods. A key objective is the creation of an automated control system for the experimental ballast water treatment equipment, designed to ensure precise monitoring of technological parameters and optimize laboratory testing efficiency.

The developed multifunctional ballast water management system is designed for large-tonnage vessels and fully complies with D-2 standard requirements. Experimental studies have confirmed the high efficiency of the proposed technology in eliminating pathogenic microorganisms and purifying ballast water, as documented by laboratory test results. Currently, the system is undergoing type approval and certification procedures in accordance with international standards.

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GOOGLE EARTH ENGINE TOOLS FORSTUDY OF THE STATE OF THE HYDROECOSYSTEM

Monitoring studies of water bodies are relevant for timely detection of changes in their environmental state and prevention of negative consequences for the environment and human health. They provide data to assess the impact of climatic and anthropogenic factors on water quality, allowing for a timely response to potential threats. The use of indices such as BLUE and GREEN through the Internet platform Google Earth Engine (GEE) is relevant for assessing water quality, as they provide up-to-date information on transparency, pollution and biological activity in water bodies. These indices make it possible to quickly identify changes in the state of water bodies caused by climatic or anthropogenic factors. They are also important tools for monitoring and decision-making on water conservation.

Research data from the BLUE index (blue channel) from 1984 to 2024 of the Buh Estuary at the point of observation (46.975073, 31.949205) indicate the following patterns: high values may indicate the presence of clear water or atmospheric phenomena such as fog or smoke; Low values may indicate the presence of water contamination, algae, silt, or high levels of impurities in the water, which reduces transparency and blue light reflection; there is a general decrease in the BLUE index over time, this may indicate a gradual deterioration in water quality, the accumulation of contaminants or the growth of algae.

The GREEN index was obtained. High GREEN values (1992, 0.077) indicate active and healthy vegetation. Low values of GREEN (2015, 0.026) indicate poor vegetation condition or the presence of inanimate objects, such as contaminated areas.

In general, BLUE and GREEN indices are effective integrated indicators of the ecological state of a water body. General decline in the values of the BLUE and GREEN indices from 1984 to 2024. indicates a gradual deterioration in water quality due to increased pollution and erosion processes. These changes may be the result of anthropogenic impact, in particular industrial emissions, urbanization, coastal development, as well as the result of climate change.

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ACOUSTIC PROPERTIES OF MATERIALS USED IN THE CONSTRUCTION OF NOISE BARRIERS

The main purpose of using noise barriers is to reduce the level of sound pressure in regulated zones that are exposed to direct sound sources (engineering equipment, traffic noise, aircraft noise, etc.). Such zones can include: workplaces in industrial and production premises, workplaces and areas of public use in administrative premises, premises of residential buildings, premises of educational institutions, as well as territories directly adjacent to various types of buildings and structures.

The design, shape and dimensions of the noise barriers depend on the acoustic characteristics of the noise source, its location in relation to the normalized zones and on the results of the acoustic calculation.

The configuration of noise barriers (shape, dimensions) can be flat (line in plan) or complex (O, L-shaped in plan). The use of complex-shaped barriers is more efficient, from an acoustic point of view, and is usually used to protect against the noise of engineering equipment. Noise barriers of flat form are usually used to reduce the level of noise generated by vehicles. The effectiveness of reducing the noise level of each barrier configuration is determined by calculation methods.

From the point of view of acoustics, the materials in the noise barriers should have sound-absorbing and sound-insulating properties. Sound-absorbing material is various types of fibrous and porous materials with through porosity. The main task of sound-absorbing materials is to reduce the amplitude of the reflected (from this material) sound wave through the transformation of a mechanical phenomenon (sound wave) into a thermal one (transformation of sound energy into heat as a result of viscous friction). The quantity that characterizes the sound-absorbing properties of the material is the sound-absorbing coefficient (from 0 to 1). Effective sound-absorbing materials include: products made of mineral, glass staple fiber, basalt fiber without organic binders, products made of mineral wool, glass staple fiber, basalt fiber with a synthetic binder. The sound absorption coefficient of these materials varies from 0.2 to 0.95. The thickness of the sound-absorbing layer in the design of the noise shield must be at least 50 mm. The sound-insulating properties of a material are the ability to reduce the amplitude of a sound wave that has passed through this material. The sound insulation

value of air noise by the noise shield should be 15 dB higher than the required acoustic efficiency. The most common combination of materials with sound-absorbing and sound-insulating properties is the following construction of a noise-protective screen: a sound-absorbing layer (sound-absorbing mineral wool with a thickness of ≥ 50 mm) on the side of the noise source and a layer of sheet material on the side of the normalized zone.

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SYSTEM MODEL FOR ENSURING ECOLOGICAL SAFETY OF MUNICIPAL WATER SUPPLY AND WASTEWATER SYSTEMS DURING MARTIAL LAW

During wartime, ensuring the ecological safety of wastewater systems becomes critically important due to threats to infrastructure and ecosystems. To enhance safety, it is essential to implement monitoring and protection systems, develop alternative scenarios for wastewater disposal, control water quality, manage waste, and collaborate with international organizations to engage experts and resources. Furthermore, for effective management of water resources and reduction of ecological risks, it is necessary to integrate provisions for infrastructure protection with regulations for water quality monitoring in conflict conditions and to adapt legislation in the field of wastewater management during wartime. This may involve the implementation of temporary regulatory measures to ensure a rapid response to changes in system operations, as well as expanding the powers of local authorities for quick responses to ecological threats. Therefore, a comprehensive approach to managing wastewater systems and water resources is essential.

The concept of enhancing the efficiency of water supply and wastewater systems is defined by a comprehensive program-targeted approach to addressing interrelated national-level issues (organizational, economic, legal, and ecological) and specific technological and technical tasks related to design, construction, and operation. This approach is aimed at implementing modern energy- and water-saving, as well as environmentally protective technologies and equipment.

In developing a strategy to enhance the ecological safety of water supply and wastewater facilities, it is crucial to create a systematic model titled "Municipal Water Supply and Wastewater System." This model should take into account a wide range of factors that may initially appear unrelated but can directly or indirectly affect the operational lifespan of each system component, as well as their ability to fulfill relevant sanitary and ecological functions. Consequently, the coordinating vector of the proposed model is the use of integral indicators to assess the condition of the system elements. To assess ecological safety, a systematic model is proposed that implements a hierarchical logical-mathematical structure for classifying the safety status of the municipal water supply and wastewater system. This model consists of seven subsystems: "Source," "Water Treatment Facilities," "Water Supply Network," "Water Discharge Node," "Wastewater Reception Node," "Sewer Network," and "Wastewater Treatment Facilities." The condition of each subsystem is evaluated based on the worst-performing indicators of that subsystem, which informs the development of a series of

measures aimed at enhancing their operational reliability and ensuring ecological safety. A comprehensive ecological index is used for the overall assessment of the ecological safety of water supply and wastewater systems.

The proposed systematic model enables the prompt identification of risks associated with the functioning of various infrastructure elements, particularly during military operations. By analyzing integral indicators of the subsystems' conditions, the model facilitates the detection of potential threats that could adversely affect water quality and public safety. Based on the collected data, well-founded measures for risk management are developed, including preventive strategies, emergency plans, and the optimization of operational processes, all of which contribute to enhancing the reliability and ecological safety of the system in crisis situations.

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THE MAIN TRENDS OF PVC RECYCLING

Analysis of European and world experience. The main trends and innovations of PVC profile manufacturers to reduce CO2 emissions and introduce bio-technologies.

Polyvinyl chloride (PVC) is one of the most important materials in modern industry and construction. However, the issue of PVC disposal and recycling is becoming increasingly important in light of environmental challenges related to pollution and the depletion of natural resources. Studying and implementing effective recycling practices for this material is an important step towards creating a sustainable and environmentally friendly industry.

Europe is actively developing PVC recycling practices, increasing the amount of recycled PVC in production and following directives aimed at reducing waste and reusing materials. Some EU countries have successful recycling programs in place that serve as examples to follow. European initiatives have helped to raise awareness of the need for recycling and support companies seeking to reduce their environmental footprint.

In addition to Europe, innovative approaches to PVC recycling and reuse are being applied in the U.S. and Asia. Industry companies are working closely with governments to create the conditions for effective recycling. This interaction promotes the introduction of the latest technologies that help develop the PVC industry while reducing its environmental impact.

Modern PVC profile manufacturers are working to reduce CO_2 emissions by improving production technologies. The use of recycled materials and the development of new PVC formulas can reduce the environmental footprint. Some companies are also integrating bio-technology by using bioplastics, which makes production more environmentally friendly.

New methods of PVC processing are being developed to reduce energy costs, as well as modular systems that simplify dismantling and reuse of materials. Various companies are actively patenting new technologies and materials that reduce the ecological footprint and contribute to the sustainable development of the industry.

PVC recycling is an important step towards an environmentally sustainable future. Integration of modern innovations and cooperation between academia, manufacturers and governments can significantly accelerate this process, contributing to environmental protection and sustainable development of the industry.

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THE PROBLEM OF PLASTIC POLLUTION OF THE ENVIRONMENT

Humanity annually produces 57 million tons of plastic pollution, which is found everywhere: in the depths of the ocean, in the highest mountains, in the human body. Plastic pollution refers to plastic that ends up in the open environment and is not disposed of in landfills or incinerated. This volume of plastic can fill the entire Central Park of New York to the height of the Empire State Building skyscraper. The source of more than two-thirds of this pollution is developing countries.

This problem is particularly evident in Southeast Asia and sub-Saharan Africa, which produce the largest amount of plastic waste. India produces the most plastic pollution – 10.2 million tons, followed by Nigeria, Indonesia and China. Major polluters include Pakistan, Bangladesh, russia and Brazil. These eight countries account for more than half of the world's plastic pollution.

The list of cities generating the largest amount of plastic pollution is headed by Lagos (Niger). It is followed by Delhi (India), Luanda (Angola), Karachi (Pakistan) and Cairo (Egypt).

Every year more than 8 million tons plastic ends up in the ocean, threatening marine life and ecosystems. If current trends continue, it is expected that by 2040, annual plastic pollution of the ocean will reach 29 million tons.

Plastic pollution negatively affects wildlife, the habitat of wild animals and people. When plastic objects and products end up in the environment, they begin to decompose and release many toxic substances that poison the soil, water and air, and end up in the food of animals, birds and fish, killing them. On average, the decomposition period of plastic is from 20 to 500 years.

Plastic pollution has even entered our food chain. Humans consume about five grams of plastic per week, which is roughly equivalent to a bottle cap.

If plastic is burned outdoors, greenhouse gases are produced, as well as solid particles, dioxins and other pollutants that cause cancer, respiratory diseases, nervous disorders and birth defects in people. Such emissions can cause irreparable damage to health.

Plastic production makes a significant contribution to greenhouse gas emissions. It accounts for 232 million tons of greenhouse gases annually, and by 2030 this figure will surpass the emissions of coal-fired power plants.

As an example, plastic pollution occurs during the dismantling of decorations and advertising products fixed with plastic ties. The authors are aware of cases when in the

coastal resort area after the end of the season, electricians removed the lighting and threw plastic ties directly into the sea, which is especially dangerous for fish.

The way out of the situation is the reform of waste disposal, the transition to a circular economy, the ban on the use of plastic bags and containers, the production and use of biotechnologies that replace plastic.

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THE ROLE OF INTELLIGENT SYSTEMS IN RISK MANAGEMENT AND IMPROVING THE EFFICIENCY OF CONSTRUCTION PROCESSES

Intelligent risk management systems in modern construction are becoming indispensable tools that can significantly improve workplace safety and the efficiency of production processes. Their use is especially important in the construction industry, where high production dynamics and difficult working conditions pose increased risks to employees. The PDCA(Plan-Do-Check-Act) cycle combined with process automation in construction helps to reduce the number of occupational injuries and helps to reduce the cost of eliminating emergencies. The cycle is an effective tool for continuous process improvement and risk minimisation at each stage. At the Plan stage, specific goals are set and potential risks are identified; the Do stage involves the implementation of planned activities; the Check stage includes evaluation of results and monitoring of compliance with the plan; and the Act stage develops and implements the necessary improvements for the next construction project.

Let's look at examples of intelligent systems at each cycle stage. At the Plan stage, 3D design is used, which is called Building Information Modelling (BIM). BIM allows you to create detailed digital models that include all possible aspects of the construction process, helping architects and engineers identify and eliminate potential risks at the design stage. BIM is widely used in the European Union (Germany and the UK) as an effective tool for improving the quality of design and safety at construction sites.

In the Netherlands, Germany, and the UK, Digital Twins are used in the implementation of infrastructure and industrial projects (bridges, roads, industry), namely the creation of a digital copy of a physical object that reflects real data and allows monitoring, analysis, and forecasting of the physical object, as well as identifying possible risks and taking timely action.

In Germany, monitoring systems based on the Internet of Things (hereinafter referred to as IoT) are being actively implemented and used for construction sites at the Check stage, which, using sensors and software, allows monitoring the condition of equipment and environmental conditions in real-time, ensuring timely response to potential hazards and risks, increasing the level of employee safety, and the efficiency of construction management by obtaining a complete picture.

At the final stage of the Act, for example, the Netherlands, China, and the United States use a system of automated reports and recommendations. All of this allows collecting data on the technical condition of the equipment, information on the safety measures implemented during construction and analysing the equipment condition after its completion; assessing the effectiveness of the proposed measures, and offering recommendations for improving the system.

The integration of intelligent systems into the PDCA cycle helps to improve construction processes, minimise risks and improve working conditions at each stage of the work.

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ENVIRONMENTAL-SAFE HOUSEHOLD ALTERNATIVE

In everyday life, vegetables, fruits, meat and fish are cut on special cutting boards. It has always been believed that cutting boards made of wood are more environmental-friendly and safe for health compared to plastic or rubber ones. Nevertheless, according to results of scientific research, wooden boards have harmful bacteria in the cracks, which multiply due to the process of their daily use. Also, the wood is deformed due to the ingress of moisture, and sometimes due to excessive moisture, mould appears on them. Plastic boards wear out knife blades. When using these boards, microparticles of plastic with food enter the human body, as a result of which there is a gradual poisoning by pesticides and bisphenol contained in the plastic particles.

The way to solve the problem is to use new technologies that do not harm the human body. One of the options is the use of natural rubber with self-healing properties.

Self-healing natural rubber is a material that combines the properties of natural rubber with the possibility of automatic recovery after damage. The composition of this rubber includes harmful substances, which, when replaced with organic ones, will make it safe for use.

Technological advantages:

- Biodegradability (if there are organic substances in the composition, the decomposition of such a board will take up to 5 years)
- No latex, which causes allergic reactions (polyisoprene is used instead of latex)
- Ability to self-heal - restores cracks, which ensures the absence of bacterial reproduction.
- The self-healing surface of the board is antibacterial, which makes it hygienic.

Polyisoprene is a polymer consisting of repeating units of isoprene. This is the main component of natural rubber. It has a linear structure with repeating units of cis-isoprene, which gives it elasticity and strength. It has high wear resistance and satisfactory mechanical properties. Synthetic polyisoprene is hypoallergenic.

Sulfide and disulfide bonds (in rubber vulcanization processes) can be responsible for self-healing properties in such rubber. Sulfide and disulfide bonds are chemical structures found even in protein structures. In rubber, they are part of the polymer matrix, and therefore they do not harm a person (except for some sulfur compounds, which are not desirable to use when creating a board from self-healing natural rubber).

For safe use, it is desirable to: use bioplasticizers, biobased oils, natural antioxidants, biopolymers, synthetic hypoallergenic rubbers.

• Bioplasticizers: epoxidized soybean oils, citrate ethers, polyethylene glycol, sorbitol, triglycerides (requires research).

• Bio-based oils: castor oil, coconut oil (needs research).

• Natural antioxidants: vitamin C, vitamin E, beta-carotene, selenium, polyphenols.

• Biopolymers: cellulose, starch, polylactide, polyhydroxyalkanoates, chitosan.

• Synthetic hypoallergenic rubbers: polyisoprene, nitrile rubber.

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DIVERSIFICATION OF ENERGY SUPPLY RISKS OF MULTI-STORY RESIDENTIAL BUILDINGS IN WAR CONDITIONS

The war in Ukraine has significantly affected the country's energy infrastructure, causing widespread power outages and increasing the risk of power outages. The enemy is carrying out targeted and large-scale attacks on facilities that generate, transmit, and distribute electricity. The total damage to these facilities is estimated at close to $8 billion. High-rise residential buildings, which are home to a significant portion of the urban population, have become particularly vulnerable, where prolonged power outages can have catastrophic consequences, depriving civilians of electricity, heating, and water. Thus, diversifying energy sources to mitigate risks and save lives becomes particularly relevant in wartime. To ensure the reliability and sustainability of energy supply to high-rise residential buildings, several diversification strategies can be used, taking into account the diversity of external energy suppliers, on-site generation, energy storage, and demand management. The use of several external sources of electricity supply can ensure continuity of supply, resilience to failures, economic flexibility in choosing a supplier, but during the war this system has demonstrated its vulnerability.

The use of renewable sources and local sources of autonomous energy supply increases energy independence and environmental sustainability. At the same time, the installation of solar panels, heat pumps and wind turbines requires significant initial installation costs, specialized maintenance and is significantly limited by building density.

The introduction of storage systems to store excess energy and use it during peak loads reduces the need for constant external energy supply and provides a reserve in case of emergencies. However, there are certain limitations on the duration of energy storage and battery degradation over time.

The use of demand management technologies reduces energy consumption during peak hours, reduces electricity costs, optimizes energy use, and maintains environmental stability. However, this requires a developed "smart" network and the consent of all residents to possible temporary restrictions on energy consumption.

Optimal energy supply for a multi-storey residential building is achieved through various strategies and their combinations, taking into account the characteristics of the infrastructure, climatic conditions and the needs of residents. During a stable external energy supply, the use of on-site generation can be reduced, but in crisis situations, local generation can become the main source of energy. Local energy production with the possibility of storage in batteries allows for optimal use of own resources and minimize dependence on external suppliers. An energy storage system with intelligent control allows for avoiding peak loads and optimally using available energy, which is especially important for residential complexes with high demand. Such strategies increase energy independence, economic efficiency and reliability of energy supply.

Fundamental and applied scientific research. Efficiency. State-of-the-art design and operation

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EXPLOSION RESISTANCE OF TRANSPARENT STRUCTURES

In the conditions of martial law in Ukraine, the technical protection of critical and social infrastructure objects, as well as the housing stock from damage and destruction as a result of deliberate military strikes, acts of terrorism, criminal activity, etc., is important. During the reconstruction of the housing and communal economy in the post-war period, it is urgent to take into account the requirements for increasing safety standards for persons staying in premises of various purposes. Current normative acts on design in construction are usually limited to use in seismically active zones and do not take into account the relevant threats that are relevant for military operations and cases of terrorism. The introduction of justified changes in the regulatory documentation should support the resistance of buildings and infrastructure to explosive incidents.

To develop measures to protect housing and communal facilities and infrastructure from the destructive impact of shock waves from explosions, methods of quantitative assessment of the resistance of structural elements to shock loads and the level of danger arising from the destruction of structures are required. Modern approaches to research in this direction are numerical methods for calculating the

parameters of mechanical stresses in enclosing (including translucent) structures or field tests (experiments).

In order to develop criteria for determining structural characteristics, and subsequently test criteria for explosion-resistant glazing, it is necessary to determine the factors that should be taken into account under the influence of an explosion.

In addition to systematic studies of the destructive impact of explosions during military operations, the need to develop explosion-resistant glass for protection against accidental accidental gas or petrochemical explosions is also relevant. However, in this case, the blast waves will have a much lower pressure and a longer duration than the blast waves from high-explosive events. Explosive loads are most often considered as derivatives of exothermic reactions that occur as a result of detonation, however, shock waves in air can also occur as a result of the rupture of pressure vessels and the high speed of the flame front during combustion.

Experimental methods are used in studies of the structural response of building elements. The effects of long-range detonation (explosive loading) can be analyzed by shock tube tests or by field detonation experiments. At the same time, different load scenarios are distinguished, because the structure can have destructive consequences and various damages can occur. Contact detonations are characterized by high pressure, which loads the structure for only microseconds. The impact on the structure is local. Shear and compression failure is activated, which, depending on the strength and plasticity of the loaded material, leads to fragmentation both on the side of the load and on the back side of the structure. Blast loading results in loading of the entire or significant area of the structure. This results in a global structural response such as buckling damage.

At the same time, the typical characteristics of the shock wave are represented. The explosive load is characterized by a shock front at the beginning of the load followed by an exponential decay in the positive phase, followed by the negative phase. The high-frequency oscillations shown in the pressure vs. time dynamics are a consequence of the high natural frequency oscillations of the pressure sensor used. In addition, an appropriate high value sampling frequency is selected to obtain highly accurate results.

For performance certification purposes of window structures, a load scenario is usually required that includes values for reflection pressure and momentum during the positive phase duration. In terms of testing, this means that the desired values for the failure-free strength of the translucent structure must be exceeded for the specimen in its location.

Numerical analysis can be used to predict the behavior of glass under the influence of a blast wave. These numerical simulations cannot replace experimental tests, but they can be used in test planning, to predict experimental results, and to perform parametric studies by changing, for example, boundary conditions, structure geometry, material properties, and explosive data.

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EVALUATION OF THE EFFECTIVENESS OF INFRARED RADIATION SHIELDING WITH GLASS FIBER

The relevance of the research and the implementation of materials for blocking infrared radiation is currently beyond doubt. In wartime conditions, there is an urgent need for materials that complicate the detection of objects by infrared radiation detectors. Moreover, in addition to acceptable properties, these materials should be easy to manufacture and have a low cost.

In this work, glass fiber is proposed as a material for shielding thermal radiation. This choice is based on its low thermal conductivity and significant absorption of infrared radiation in the spectral range of 8-14 μm, which is the working range of most thermal imaging devices. Indeed, the chemical composition of E-glass fiber, used to manufacture the glass fiber proposed as a shielding material, includes, in particular, 53-55% SiO2, 17-21% CaO, and 5-10% B_2O_3. The vibration frequencies of Si-O bonds overlap almost the entire range from 600 to 1100 cm^{-1}; Ca-O bonds are in the range of 700-1400 cm^{-1}; and B-O bonds are respectively 1300-1400 cm^{-1}. This results in the presence of intense absorption bands in the wavelengths of interest.

A theoretical assessment of the effectiveness of infrared radiation shielding by the material was conducted. It was considered that heat transfer through the material occurs predominantly by radiation, which is due to the low thermal conductivity of glass fiber ($\lambda \sim 10^{-2}$ W/mK). It was assumed that the shielding material represents a gray medium located between two gray and diffuse parallel flat surfaces. Such assumptions can be used to obtain approximate relationships since the infrared absorption spectrum of *E*-glass fiber is essentially continuous in the 8-14 μm range.

One-dimensional radiation transfer along a direction perpendicular to the material was considered. It was taken into account that, alongside the reduction in radiation intensity due to absorption, there is an increase caused by the material's own emission. It was assumed that the conditions of local thermodynamic equilibrium are met. As a first approximation for the temperature distribution in the material, a linear dependence of T^4 on the coordinate was used, which occurs in the case of an optically dense medium.

As a result, expressions were obtained that make it possible to estimate the temperature of the outer surface of the shielding material at a known temperature of the inner surface and the thermal resistance to heat transfer depending on the radiation absorption coefficient and the thickness of the material.

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CORROSION-RESISTANT FACING MATERIAL FROM SULFUR-GYPSUM COMPOSITE MANUFACTURED USING SULFUR-CONTAINING WASTE

Today, implementation in industrial construction is of particular importance

progressive and economic materials, which are made from industrial waste or local raw materials using energy-saving technologies.

A promising direction for solving these problems is the creation of high-strength and water-resistant construction materials based on gypsum binders modified with chemicals and industrial waste.

Gypsum binders are the most efficient in terms of technical and economic indicators, especially in terms of consumption of raw materials, fuel, electricity and labor per unit of production. Due to large reserves of gypsum raw materials in Ukraine and low cost, gypsum binders are widely used in construction. However, today the use of gypsum binders is limited by the low water resistance of their products.

An effective way to increase water resistance and improve other construction and technical properties of capillary-porous building materials, in particular those based on gypsum, is their impregnation with substances capable of hardening in the pore space of these materials, which contributes to the compaction of the structure and prevents the penetration of moisture into them.

Sulfur is the optimal impregnating substance for modification of gypsum concrete, as its melt has effective impregnating properties, strong adhesion to various mineral fillers, and high chemical resistance in various aggressive environments. In addition, there are large deposits of natural sulfur in Ukraine, as well as a large amount of sulfur, which is formed during the purification of natural gas and flue gases of industrial enterprises and CHP plants.

Fly ash from the Ladyzhynskaya CHP was used as a filler. Ash is known to be an effective additive to gypsum binders. At the same time, sulfur has strong adhesion to ash and gypsum particles. To reduce the viscosity of the sulfur melt and increase its fire resistance, it is possible to add various additives of complex action (styrene, dicyclopentadiene, etc.).

As a result of the conducted research, it was established that the strength of impregnated samples increases with an increase in the degree of filling of the pore space with sulfur. Thus, when the relative sulfur content (v = Us/Usmax) increases from 0.30 to 0.90, the compressive strength increases from 10.1 to 42 MPa.

In order to determine the area of rational use of products made of composite material based on gypsum, ash and sulfur in construction, studies of their water resistance and chemical resistance were conducted.

The data analysis shows that the water resistance of impregnated samples depends significantly on the degree of impregnation and the amount of fly ash. Thus, with partial impregnation of gypsum samples, the coefficient of water resistance is 0.50,

while with full impregnation - 0.72. When the fly ash content increases to 75%, the water resistance coefficient increases to 0.88.

It was established that gypsum and gypsum ash samples impregnated with molten sulfur have a chemical resistance coefficient of at least 0.7. This makes it possible to classify them as chemically stable in these environments.

The analysis of the main construction and technical characteristics of sulfur-gypsum composite shows that facing products made of this material have high operational characteristics and it is advisable to use them for facing fertilizer storages, drainage systems, floors and walls of livestock complexes, chemical and food industry enterprises.

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IDENTIFICATION OF CRITICAL SOURCES OF ELECTROMAGNETIC FIELDS IN PUBLIC BUILDINGS AND WAYS TO REDUCE THEIR IMPACT ON PEOPLE

Given the wide variety of electrical and electronic equipment used in industrial and educational premises, it is virtually impossible to determine the electromagnetic environment without conducting field measurements. Even with the same electrical loads in buildings, the overall values of electric, magnetic and electromagnetic fields can differ significantly. It was found that this is primarily due to the generation of higher harmonics of industrial frequency. The presence of a large number of consumers with nonlinear volt-ampere characteristics, more than 20 %, automatically leads to the appearance of harmonics in the neutral working conductor in multiples of three in a three-phase network. To a certain extent, this may be a consequence of the deviation from the sinusoidality of the voltage entering the building. In addition, capacitor units for compensating for reactive (inductive) power may not work properly in old buildings. It has been established that a sharp increase in the background values of the magnetic field of industrial frequency and its harmonics occurs when using backup power sources – electric generators. In most of them, the amplitude-frequency characteristics do not meet the current standards for the quality of electricity. The complexity of solving the problem of increased electrical and magnetic background is explained by the lack of sanitary standards for industrial frequency harmonics. Only 50 Hz and frequencies above 1000 Hz are subject to control. To some extent, this is due to the lack of certified instruments for determining the spectral composition of ultra-low frequency electric and magnetic fields. This problem can be partially solved by completely switching buildings to the TN-S grounding system.

To date, many devices have been developed to compensate for reactive power in the presence of harmonics and interharmonics of industrial frequency. Their common disadvantage, at least for systems with feedback, is their high cost. Therefore, it is advisable to develop and test in real operating conditions the simplest and most efficient system of reactive power compensation in the presence of harmonics of industrial frequency in the power grid. Reducing the levels of electromagnetic fields of ultra-high and higher frequencies is possible by using internal and external cladding with low

reflection coefficients of electromagnetic waves. The need for such a measure is due to the increase in reflection coefficients with the growth of operating frequencies of all types of wireless communication.

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MEANS OF INCREASING THE EFFICIENCY OF SHIELDING ELECTROMAGNETIC FIELDS BY HETEROGENEOUS BUILDING MATERIALS

The main problem of ensuring the electromagnetic safety of workers and the public is the cost of safety measures. The most effective method of reducing the levels of electromagnetic fields and radiation is shielding. However, the most effective protective materials – composites of various compositions – are expensive and require application to the external or internal surfaces of buildings. A rational way to improve electromagnetic safety is to impart protective properties to the building and facing materials themselves. The dependence of the shielding coefficients of electromagnetic radiation by reinforced concrete structures on the amplitude-frequency characteristics of radiation is investigated. The generalised relations make it possible to estimate the efficiency of a structure with different spacing and number of reinforcement layers. The possibility of shielding electromagnetic radiation by cement concrete with basalt reinforcement is investigated. It has been found that reducing the levels of electromagnetic radiation only by refraction of waves on inhomogeneities does not provide a significant shielding effect. Basalt fibre is a promising reinforcing material, but its use is limited due to fibre degradation in the alkaline environment of cement concrete. Therefore, it makes sense to cover the basalt with an electrically conductive material. This will provide the fibres with protective properties to shield electromagnetic radiation and protect them from the effects of the alkaline environment. Such a substance can be standard paints containing graphite or carbon black. In such coatings, basalt fibres can be considered as the conductive regular structure and a mathematical apparatus can be used to predict the protective properties of metal inhomogeneities. Previous studies have shown a high level of adhesion of polymer paints with graphite impurities to basalt. Carbonyl iron is used to produce heterogeneous solid flat materials with electromagnetic radiation shielding functions. Experiments have shown that by adding carbonyl iron with a dispersion of 6–8 μ to standard paint, it is possible to obtain materials with a reflection coefficient of electromagnetic waves of ultra-high frequencies of the order of 0,20–0,25, which is better than known analogues. The overall shielding coefficient is 0,8–0,9. The disadvantage of this material is its large thickness of 5 mm. To reduce the thickness, it is advisable to increase the dispersion of carbonyl iron or create a concentration gradient in the thickness of the material. This will make it possible to use the composition as an electromagnetic camouflage.

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INVESTIGATION OF THE SPECTRAL COMPOSITION OF CONSTRUCTION MACHINERY NOISE AND DEVELOPMENT OF A METHODOLOGY FOR IMPROVING THE EFFECTIVENESS OF PROTECTIVE EQUIPMENT

The noise levels of the most common equipment used in construction were measured. It was determined that the highest sound pressure levels in octave frequency bands occur at low frequencies up to 300 Hz. At the same time, the presence of infrasound is high. The difference between the sound level meter readings on the linear scale and the «A» correction scale is 20 dB and above. It is known that protection against low-frequency sound and infrasound is a difficult task due to the high permeability and low spatial attenuation of low-frequency waves. Reducing the levels of low-frequency sound and infrasound is mainly possible with resonant panels. The panels are tuned to the frequency(s) of oscillation of the highest amplitude, or two panels are tuned to the two predominant frequencies. The disadvantage of the existing mathematical apparatus for determining the highest sound absorption of a panel is the use of such indicators as «total material tension» and «bending stiffness», which are not reference values and must be determined experimentally. The calculation apparatus was improved. The calculations included data on Young's modulus, Poisson's ratio, and density, which are reference values for all materials. This simplified the process of designing protective panels. Similarly, a calculation tool was developed for panels with perforations. This reduces the quality factor of the oscillating system and increases sound absorption at frequencies above and below the resonance. It has been shown that the most effective way to reduce sound levels at medium and high frequencies is to use porous sound-absorbing materials. The corresponding equations are one-factor. To predict the protective properties of the material, it is necessary to determine the blowing resistance of the porous material using a standard method. To improve the noise protection properties of materials and structures, it is advisable to consider the possibility of manufacturing a resonant panel from a porous thin material. This will make it possible to reduce noise levels in the entire sound range and infrasound levels.

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INVESTIGATION OF MAGNETIC FIELD LEVELS OF ELECTRIC GENERATORS AND DETERMINATION OF MEANS OF THEIR REDUCTION

Electricity generation companies are critical infrastructure facilities, and therefore, proper, at least standard, working conditions must be created at the workplace. This applies to all enterprises that operate turbine generators. In addition to maintenance personnel, control room staff are constantly at work. Currently, there is no data on the magnetic fields of turbine generators. The available data relate to turbine generators TRV-100 and TGV-150, which are outdated. However, the data show that the magnetic field strengths around such machines are not proportional to their instantaneous power. The magnetic field strengths around the TGV-320 turbine generator were measured. At the time of the measurements, the generator was operating at 280 MW, which is its nominal capacity. It was found that on the one side of the electric machine, the magnetic field strength varies from 3,2 kA/m to 1,8 kA/m when the distance changes from 1 m to 5 m. On the other side of the machine, the magnetic field strength changes from 3,2 kA/m to 1,5 kA/m. At the same time, at a distance of approximately 3 m from the machine body, the magnetic field strength was 1,2–1,3 kA/m. This can be explained by different patterns of decrease in magnetic field levels of spatial field harmonics. In fact, this is the zone of the minimum field and it is the most acceptable for people to move around. It has been established that the fact of a decrease and then an increase in the magnetic field level is inherent in all synchronous four-pole electric machines. However, at the distance where the control panel of the machine room is located, approximately 5–6 m from the machine, the magnetic field strengths exceed the standard 1,4 kA/m. Therefore, it is advisable to protect the workplace with a ferromagnetic shield on the side of the electric machine. For this purpose, it is enough to use steel plate grade 121.

The magnetic fields near the busbars were measured. The operating voltage is 20 kV, the electric current is 2,8 kA. It was found that at a distance of 2 m from the outermost phase wire, the magnetic field strength was 1,6–1,7 kA/m. Thus, at least the bridge for people to move over the busbars should be shielded. Since the magnetic field of industrial frequency is quasi-stationary, the width of the shielding should be at least three times the area where people are present and moving.

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EXPERIMENTAL EQUIPMENT FOR RESEARCHING THERMOPHYSICAL PROPERTIES OF BUILDING MATERIALS

Recently, the development of energy-saving measures and technologies, aimed at implementing thermal processes with minimal heat loss, has gained particular relevance, along with the modernization of buildings and structures that are currently in use, to enhance their energy efficiency.

A key aspect of addressing these challenges involves determining and studying the thermophysical properties (TPP) of building, insulating, and cladding materials, whether they are currently in use or in development. The primary properties include thermal conductivity, thermal diffusivity, heat capacity, and thermal activity.

Thus, developing and implementing measurement devices that employ non-destructive methods to experimentally determine material TPPs is both reasonable and necessary. These methods are based on temperature measurement without compromising the integrity and performance characteristics of the material elements.

The most comprehensive information about a material's TPP can be obtained from its temperature field, derived as a solution to the boundary heat conduction problems under specified conditions of a given thermophysical experiment. It is worth noting that developing mathematical models of thermal processes in materials also requires determining the temperature field for different types of thermal exposure on their surfaces.

A measurement setup was developed for studying temperature fields in samples of building materials. It consists of ESP-32 microcontroller, digital temperature sensors DS18B20 and PC. The DS18B20 sensors are connected in a 1-Wire network, allowing for up to 16 sensors. The used digital thermometers allow measurements in the temperature range from -55 to +125 °C, with the resolution being adjustable via software. The smallest possible resolution for a measurement time of 750 ms is 0.0625 °C.

The ESP-32 microcontroller operates by cyclically polling the sensors, forming a data packet from the results, and transmitting it via RS 232 interface to a computer for further processing and storage.

The high-level application software was developed in the MatLab environment. The control program reads data from the COM port registers, parses the packets, visualises and saves the measurement results separately for each measurement channel. These files can then be imported into MS Excel for further processing.

It should be noted that using multiple sensors requires a preliminary assessment of their consistency. Calibration of temperature sensors generally requires specialized equipment. However, it is possible to assess the accuracy of available thermometers by placing them in an environment with a stable, known temperature and analysing the

results. Two sensors, placed in an isothermal zone, were analysed during the experiment. The results showed that their readings differed by 0.04 °C, with a standard deviation of ±0.03 °C.

Researching the TPP of building materials often requires prolonged measurements, which imposes limitations on sensor drift. Temperature drift was assessed by measuring the temperature in an isothermal zone over a certain period of time. Several measurement series were conducted, each lasting about 50 minutes. Processing and analysing of the obtained data allowed for determining the limits of drift deviations relative to the average value at ±0.15 °C.

The results, obtained during the conducted research, demonstrate the feasibility of using the developed measuring setup to determine the temperature distributions in samples of building materials and their thermophysical properties with sufficiently high accuracy. Additionally, the available capabilities for automated result collection significantly reduce the time required for necessary calculations and analysis.

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APPLICATION OF WASTE GLASS POWDER AS A PARTIAL REPLACEMENT FOR CEMENT IN CONCRETE

The unique properties of natural glass, such as its silicate nature, non-hygroscopic quality, high hardness, resistance to corrosion and heat, have motivated many researchers to explore the incorporation of glass into concrete mixtures and study its impact on concrete properties.

Previous studies have demonstrated the effectiveness of glass powder when used to partially replace cement at various levels—5%, 10%, and 15% of the cement mass. Concrete cube samples were prepared to test compressive strength and were compared with concrete samples without additives. Compressive strength was found to be higher with a 5% replacement of cement with glass powder, exceeding the strength of the control sample. However, with further increases in glass powder content, compressive strength began to decrease, attributed to the high magnesium content in the glass used for this research.

The compressive strength tests for B30 concrete were conducted at the laboratory of "Grand Beton" LLC according to DSTU B V.2.7-214:2009 on 100x100x100 mm cube samples at intervals of 3, 7, and 28 days. Mixtures contained glass powder at 0%, 5%, 10%, and 15% with proportional replacement of Portland cement types II/A-S-500 and II/A-S-400.

The test results demonstrated an experimental increase in the strength characteristics of hardened concrete. For example, on the 3rd day, samples with Portland cement II/A-S-500 showed an average increase in compressive strength of 6.5% compared to the control sample. A slowdown in strength gain was observed on the 7th day. However, on the 28th day, there was a significant increase in strength by

an average of 8.2%. The best results were shown by the sample with 10% glass powder content, reaching a compressive strength of 49.25 MPa on the 28th day.

Similarly, for Portland cement II/A-S-400, the 3rd-day samples showed an average compressive strength increase of 11.7% compared to the control sample. By the 7th day, the strength values approximately matched those of the control. On the 28th day, a sharp increase in strength was noted, averaging 12%, with the best results shown by the sample containing 10% glass powder, achieving a compressive strength of 46.25 MPa.

Based on the research findings, the feasibility of using glass powder as a replacement for Portland cement types II/A-S-500 and II/A-S-400 has been demonstrated, not only maintaining but even improving the strength characteristics. The most effective samples included a 10% replacement of cement with glass powder.

This provides a foundation for further research and demonstrates the feasibility of using glass powder as a partial replacement for cement in slag-based concrete.