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IV International Scientific-Technical Conference

6–8 February 2020, Kielce
(Poland, Ukraine, Croatia, Slovakia, Sweden, USA)

ACTUAL PROBLEMS OF RENEWABLE POWER ENGINEERING, CONSTRUCTION AND ENVIRONMENTAL ENGINEERING

Book of abstracts

Part I

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Under the general editorship Prof. doctor of science Anatoliy Pavlenko

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STUDY OF THERMAL CONDUCTIVITY OF BURSHTYN TPP ASH-BASED POROUS THERMAL INSULATING MATERIALS

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Introduction. Thermophysical characteristics of porous thermal insulation materials (PTM) are generally determined by the structure, size, type and shape of pores, as well as by their mutual arrangement in the material [1, 2]. Thermal conductivity is one of the most important among these characteristics. Thermal conductivity in porous material is caused by different physical processes and can be reduced to three types: conduction, convection and radiation. Literature sources imply that thermal conductivity dependence is represented as an exponential function [3-5]. These dependencies fail to have a sufficiently clear and pronounced nature and do not allow developing an analytical expression to describe this function, especially at high values of material density.

In our experiments, the thermal conductivity coefficient was determined in the dry and sorption humidity states, not exceeding 20%.

The thermal conductivity of porous thermal insulation materials was studied using an IT - λ - 400 device. Cylindrical test specimens, 5 mm thick and 15 mm in diameter, were placed in the device and heated to 800°C. Within this temperature range, the material thermal conductivity was determined according to the standard procedure described in the device operating instructions.

The observed data were processed using the designed experiment approach. Thermal conductivity is considered as the target function (Y, W/(m·K)). The experiment was conducted according to the program of the central composite rotatable second-order design by Box-Hunter [5]. The design nucleus is represented by half-replicated experiment 2^{5-1} ($1 = X_1X_2X_3X_4X_5$). The factors, studied in the previous series of experiments, are considered as controllable ones. The selected factors comply with controllability requirements, mutual independence and unambiguity; variable factors shall meet these criteria during experiment design process. 16 experiments were conducted at basic levels and supplemented by another 10 experiments at star points (in our case, the axial distance value is 2) and six experiments at the plan centre. The basic levels, intervals of factor variation and research area boundaries were selected according to results of previous experiments and based on a priori information (Table 1).

The response function is approximated by a second-order polynomial:

$$Y = b_0 + \sum_{1<i<k} b_i X_i + \sum_{1<i<k} b_i X_i^2 + \sum_{1<i,l<k} b_{i,l} X_i X_l \qquad (1)$$

where k is the number of independent variables.

The observed data processing and analysis of regression model were performed using "Experiment design" module of Statgraphics 5.0 Plus statistical program. The significance of model coefficients was determined using P-level and shown on a standardized Pareto chart (Fig. 1). The vertical line in Figure 1 corresponds to 95% of the statistical significance of coefficients.

Table 1. *Basic levels and intervals of factor variation and research area boundaries*

Factor	Code	Value					Variability interval
		-2	-1	0	+1	+2	Δ
Content of Burshtyn TPP ash, weight fraction	X_1	0	30	60	90	120	30
Clay content, weight fraction	X_2	0	20	40	60	80	20
Water content, weight fraction	X_3	10	30	50	70	90	20
Processing temperature, °C	X_4	100	150	300	450	600	150
Content of Na_2SO_4, weight fraction	X_5	0	3	6	9	12	3

According to data in Figure 1, the coefficients for linear terms of the regression equation for ash, water and temperature contents are considered as statistically significant. In this case, the coefficients for pair-wise interactions are statistically insignificant and may be neglected for this model calculation.

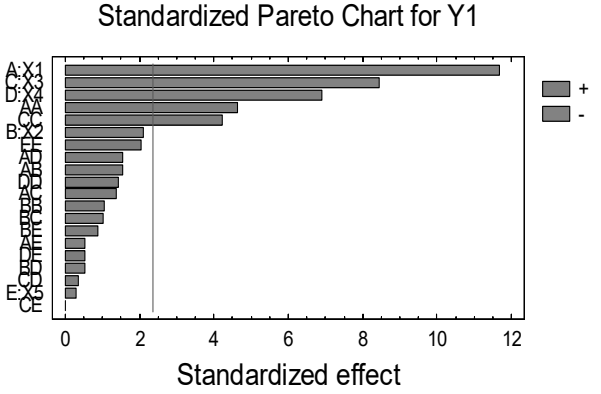

Fig. 1. *Significance of model coefficients (Pareto chart)*

Regression equations, considering significance of coefficients are as follows:

$$Y1 = 0.978724 - 0.00966389 \cdot X_1 - 0.00824062 \cdot X_3 - 0.000705556 \cdot X_4 + \\ + 0.0000322917 \cdot X_1^2 + 0.0000664062 \cdot X_3^2 \quad (2)$$

The model adequacy to the analysed process is confirmed by a high value (about 100%) of determination coefficient R_2 = 99.44%, and low value of standard error of estimate SE = 0.1598.

Figure 2 shows the comparison of observed and predicted data.

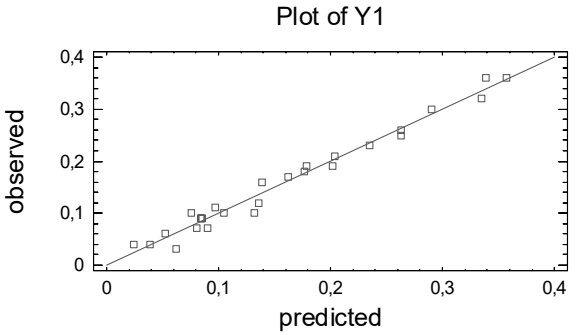

Fig. 2. *Comparison of observed and predicted model data*

As can be seen in many cases, the difference between these data is negligible. Most of the experimental points are located near the straight line.

In Figures 3, 4 the surfaces of pair-wise factors effect on thermal conductivity of Burshtyn TPP ash-based PTM.

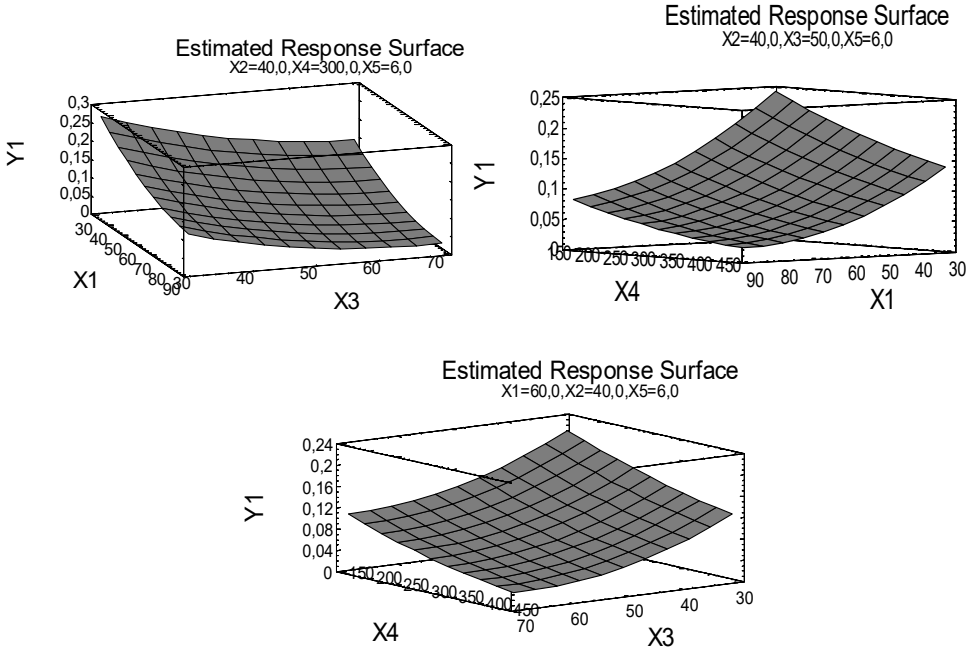

Fig. 3. *Surfaces of pair-wise factors effect on PTM thermal conductivity*

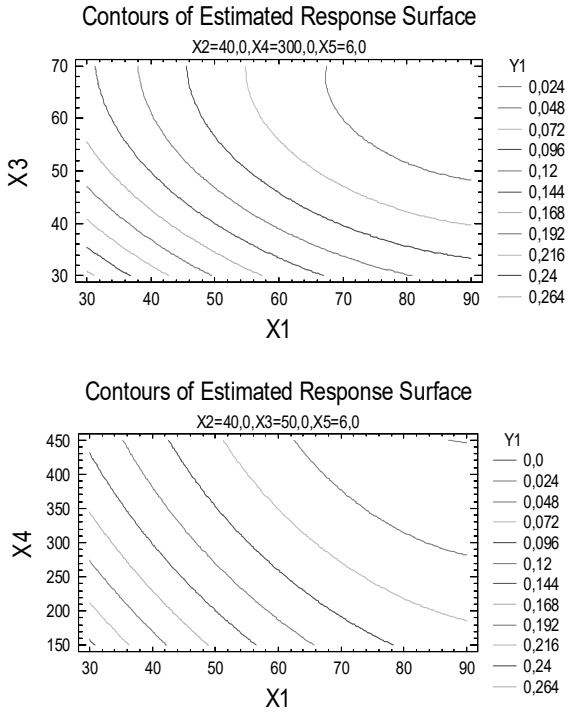

Fig. 4. *Surfaces of pair-wise factors effect on PTM thermal conductivity*

Conclusions. As it is obvious from three-dimensional cross sections of hypersurface Y_1 (X_i) and contour curves of these surfaces, thermal conductivity of porous thermal insulation materials increases as the weight fraction of Burshtyn TPP ash (X_1) and water content (X_3), as well as swelling temperature (X_4) decrease. It goes in line with our understanding of the effect of specified factors on thermal conductivity.

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HEAT TRANSFER DURING OPERATION OF AIR-GROUND HEAT EXCHANGERS OF GEOTHERMAL VENTILATION

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For a comfortable stay of people in buildings, one of the most important sanitary and hygienic conditions is the presence of fresh air in the premises, which is ensured by the operation of the ventilation system, which in itself is energy-intensive. Therefore, Institute of Engineering Thermophysics NAS of Ukraine is exploring ways to reduce energy use in these processes.

The purpose of the research work is the study of the main heat engineering parameters of the air – ground heat exchanger (AGHE) of the geothermal ventilation system of an energy efficient house.

At Institute of Engineering Thermophysics NAS of Ukraine a full-scale experimental stand was created to study thermophysical processes during the operation of a geothermal ventilation system [1-3]. The experimental stand consists of the main parts:

1. Outdoor air receiver (located in a sheltered place from direct exposure to solar radiation).
2. An air-to-soil heat exchanger of a P-shaped configuration (horizontal pipe Ø110 mm with polyvinyl chloride) 43 m long, immersed at 2.5 m.
3. Axial fan Vents TT 200 for pumping air through a heat exchanger.
4. Measuring system: Testo 405-V1 hot-wire anemometer, BME280 semiconductor sensors, which record the temperature, relative humidity and atmospheric air pressure at the inlet and outlet of the AGHE with a secondary device based on a microprocessor; integrated sensors DS18B20, which record the temperature of the soil mass in the zone of influence of AGHE to a depth of 3.5 m.

Thermophysical parameters of air and soil are recorded every 10 minutes. Experimental studies have been ongoing continuously since August 2018. It should be noted that the thermal characteristics of the system after a year of operation remain unchanged, which indicates a significant potential heat of the soil mass.

In the summer period, there are significant daily changes in the temperature of the outside air (up to 21°C) in the range from 14°C to 35°C, while there is a stable temperature of the air at the outlet of the AGHE – within 18°C±0.5°C year, the outdoor air warms up in the AGHE tract and henceforth enter the recuperator of the supply and exhaust unit for additional cooling with specified parameters.

The efficiency of heat transfer in air-ground heat exchangers can be influenced by such parameters as the depth of the heat exchanger, its geometric dimensions

and design, the temperature of the soil and air, the thermophysical properties of the soil and material of which the heat exchanger itself is made, the air flow through the system, as well as climatic terrain features and the like.

Experimental studies have shown that the geothermal ventilation system is an energy-saving technology. It is advisable to recommend such a system for energy-efficient construction and reconstruction of the existing fund of both residential and public buildings.

Conclusions

1. In the warm season, with significant daily fluctuations in the temperature of the outside air, the heat exchanger is considered operating in the regenerator mode.
2. Daily fluctuations in the temperature of atmospheric air affect the temperature state of the surface soil layer to a depth of 0.6 m.
3. The temperature effect of the soil-air heat exchanger on the soil mass extends to a distance of 0.4 m.
4. Significant weather fluctuations in the temperature of atmospheric air affect the temperature state of the soil mass to a depth of 2.2 m.
5. Creating a methodology for calculating and designing such technical devices is a necessary step towards improving the overall energy efficiency of buildings.

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THERMODYNAMIC EFFICIENCY OF HEAT PUMP SCHEMES OF ENERGY SUPPLY OF BUILDINGS USING THE AMBIENT HEAT

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Introduction. In heat power engineering, heat pump technologies are taking a more and more significant place. This is connected with the gradual depletion of traditional sources of energy – natural gas, coal and oil – and a consequent price growth and their scarcity. Alongside, the issue of environmental ecological safety is getting meaningfully important [1]. The mentioned problems may be solved by means of implementation of the modern technologies, namely heat pumps (HP), which allow to utilize unconventional renewable energy sources and secondary energy resources [2, 3]. However, mentioned in the literature systematic studies on the use of heat pump systems (HPS) of heat supply, which include systems of low-temperature water heating, ventilation, hot water supply, are insufficient, and they lack analytical dependencies or methods to determine the parameters of energy efficiency of HPS operation under different conditions of their practical application. Therefore, the issue of conditions for efficient usage of heat pump technology in heat supply systems is relevant and open.

Thermodynamic analysis of principal heat pump schemes of heating using such sources of energy as atmospheric and ventilating air, water, soil has been performed.

The analysis of the principle heat pump scheme of heating (Fig. 1) shows that at a given heating power of the HP and the temperature of the heat transfer agent in the heating system, which are determined by the object of heat supply, the temperature of the heat transfer agent at the output of the evaporator of the HP is ambiguous. This is due to the fact that the amount of heat extracted from the lower energy source (atmospheric or ventilation air, water, soil) depends on both the difference in temperatures at the input and the output of the HP evaporator and the flow rate of the heat transfer agent. Considering that the consumption of electricity for the HP compressor drive and the supercharger during the heat transfer agent temperature change at the output of the HP evaporator alter in opposite directions, there must be an optimal degree of cooling of the heat transfer agent of the lower energy source in the HP evaporator (the optimum depth of the lower source usage), which in turn will meet the minimum total energy consumption for the heat pump system as a whole.

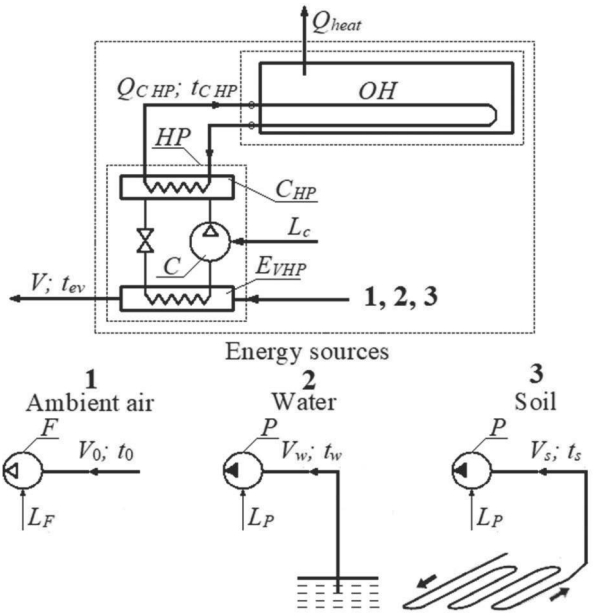

Fig. 1. *Principal heat pump scheme of heating: OH – object of heating; HP – heat pump; C_{HP} – heat pump condenser; C – heat pump compressor; Ev_{HP} – heat pump evaporator; F – fan; P – pump; Q_{heat} – heat flow conducted to the object of heating, kW; Q_{CHP} – heat flow in the heat pump condenser, kW; L_c – power of the compressor drive of the heat pump, kW; L_F – power of the fan, kW; L_P – power of the pump, kW; t_{CHP} – temperature at the condenser outlet, °C; t_{ev} – outlet evaporator temperature, °C; t_0 – temperature of the ambient air at the inlet of the evaporator of the HP, °C; t_w – temperature of the water at the inlet of the evaporator of the HP, °C; t_s – heat-transfer agent temperature at the inlet of the evaporator of the HP, °C; V – volumetric flow rate, m^3/s; V_0 – volumetric flow rate of the ambient air to evaporator of the heat pump, m^3/s; V_w – volumetric flow rate of the water to evaporator of the heat pump, m^3/s; V_s – volumetric flow rate of the heat-transfer agent to evaporator of the heat pump, m^3/s*

To solve the above-mentioned problem, theoretical and numerical research methods have been used. Based on the balance equations method there have been developed theoretical models of scheme solutions of HPS heat supply and the method of thermodynamic analysis of their work. The indicator of the thermodynamic efficiency is the value of the aggregate specific external energy consumption for HPS heating, which is determined by the ratio of external energy consumed per unit of heat received to meet the heating needs

$$l_{heat} = (L_c + L) / Q_{heat} \quad (1)$$

where: L_c, L – power of the compressor drive of the HP and the fan or the pump, kW; Q_h – the heat flow diverted from the heat pump condenser, kW.

Numerical analysis of the value of the heat has shown that when using unlimited energy sources in HPS heat supply, there is indeed an optimal depth of

heat usage of the lower energy sources in the HP evaporator, which are correspondent to the minimum aggregate energy consumption for HPS as a whole.

Conclusions. The scientific novelty of the work is to obtain a method for determining the optimal depth of usage of lower energy sources. The influence of changes of external and internal parameters on the efficiency of HPS heat supply has been determined. The results of the study are of practical importance in the form of the formulated recommendations to ensure the minimum specific external energy consumption for the HPS of the buildings heat supply. The contemplation for further scientific developments in this area is the thermodynamic analysis of combined HPS with the combination of different low-temperature energy sources and heat consumers in one system.

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NATURAL VENTILATION OF EDUCATIONAL INSTITUTIONS

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The effective use of energy resources occupies one of basic places of steady development. Having regard to the increase of standard of living, urbanization, part of buildings power mediums consumption grows. This range of problems touches public and housing building. Taking into account sourcing for coverage of building services, especially sharply the question of the effective use of power resources appeared in a budgetary sphere, that it is related to wearing out of building stock and shortage of financing [1]. Providing of the prudent use of energy without the loss of terms of comfort is basic directions nowadays.

At state level one of the most guided segments there are public building, among them the special attention is spared to establishments of education. Then over the intensive use brings to the substantial increase of CO_2 concentration indoors, which needs an additional study.

Lately large attention is spared to a vent constituent (to determination of air exchange rate) that can present 30-50% of general energy consumption. For providing of the proper terms of labour from the point of view of ventilation in a standard [2] regulated normative air exchange rate. In building the ventilation air exchange rate is provided in two ways: natural and mechanical. In most old building mechanical ventilation is not envisaged or not works. Thus through wearing out of main building stock the ventilation comes through air-channels, airing and leaks in windows, doors etc. Determination of natural ventilation exchange rate is difficult enough. One of approaches for determination of ventilation exchange rate on the basis of CO_2 concentration intentions needs research in great numbers of apartments, experimental data allow to define the value of ventilation exchange rate. An alternative variant is the use of empiric methods of determination of ventilation exchange rate on the basis of standards of ASHRAE and BLAST. Ventilation is created on the basis of three mechanisms: the stack effect, wind effect and mechanical ventilation, first two touch the natural constituent of ventilation. Among these mechanisms a wind effect has the most difficult nature [3] and depends on number of storeys, orientations of apartment speed and direction of wind et all.

A research aim is determination of ventilation exchange rate for higher and middle educational establishments on the basis of experimental methods and calculation. The 8-storeyed building of institution of higher education and typical 3-storeyed H-shaped school is select a research object in Kyiv.

The row of experimental researches of determination of CO_2 concentration in educational classes and environment is conducted with the use of TR-75Ui device. The conducted analysis showed on the basis of experimental data, that the concentration of carbon dioxide exceeded a legitimate value 2-3 times, natural ventilation exchange rate presents 0.2-0.3 $hour^{-1}$. Also on the basis of the improved empiric model [4] the calculation of natural ventilation exchange rate that corresponds to experimental data is conducted. The analogical results of research were got for the climatic conditions of China [5].

Conclusions. It is set on the basis of experimental and calculation methods of determination of ventilation exchange rate, that the actual natural ventilation exchange rate changes 0.2-0.3 $hour^{-1}$.

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THE METHOD OF NITROGEN OXIDE EMISSION REDUCTION DURING THE COMBUSTION OF GASEOUS FUEL IN MUNICIPAL THERMAL POWER BOILERS

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Introduction. Currently, the Polish heat management works mainly on solid fuel [1-3]. Such a policy causes more and more technical, economic and ecological problems due to the conditions set for us by the European Union countries [4, 5]. The combustion of organic fuel is accompanied by the formation and emission of toxic and carcinogenic substances into the atmosphere. In addition to nitric oxide, exhaust gases may contain carbon monoxide, aldehydes, organic acids and other carcinogenic compounds.

Experimental results. The method of water ballast injection, which has been used in this work, is considered one of the most promising scientific and technical solutions aimed at reducing atmospheric pollution by harmful products of organic fuel combustion [6-8].

Studies on reducing NO_x emissions are usually based on the structure of the flame in its entirety [9-11] with the separation of the flame nucleus and other parts thereof. However, the majority of the currently produced burners are characterized by turbulent-diffusion combustion organization. The flame in the burner tunnel and then in the furnace is not uniform. In a simplified form, not taking into account the turbulence of flame, Figure 1 shows the aforementioned flame division zones and SDW-s occurring in each monoflow [6].

Individual constructions of moisture injection heads (see Fig. 2) were developed for each boiler and burner. To ensure proper supply of water ballast to the SDW-I and SDW-II zones, the number of holes, their location and angle of inclination were subjected to each mono flame. During the tests, the pressure of injected steam was an additional factor.

The Figure 3 presents the example results obtained with the use of the directed metered flame ballast method. The characteristics presents that the specific mass emissions of nitrogen oxides are lower for boilers with maximum power with the system turned on than for boilers with the minimum power in normal operating modes (without the NO_x suppression system switched on). The application of an automatic suppression system of nitrogen oxides emission on each of the boilers allowed reducing this emission by average 30%. In the case of the DKVR 10-13 boiler, compared to the value obtained for actual operating conditions, the reduction in nitrogen oxide emissions reached 37%.

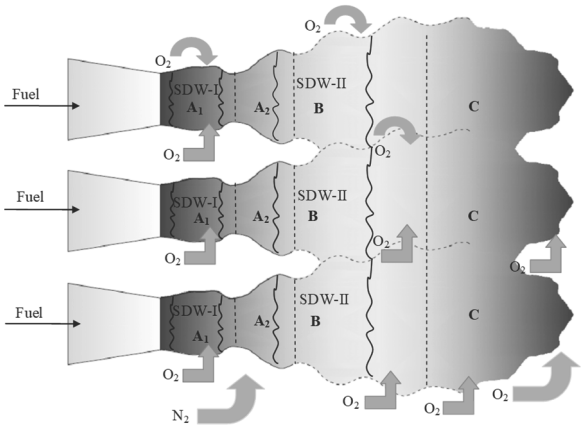

Fig. 1. *Schematic diagram of the structure of a turbulent multi-stream flame*

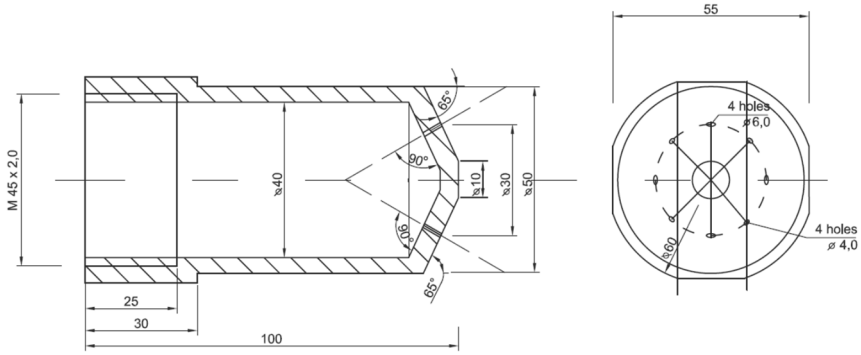

Fig. 2. *Technical drawing of the exemplary design of the head for injecting moisture into the zones of decisive influence for the DE 25-14 boiler with the GMP-16 burner*

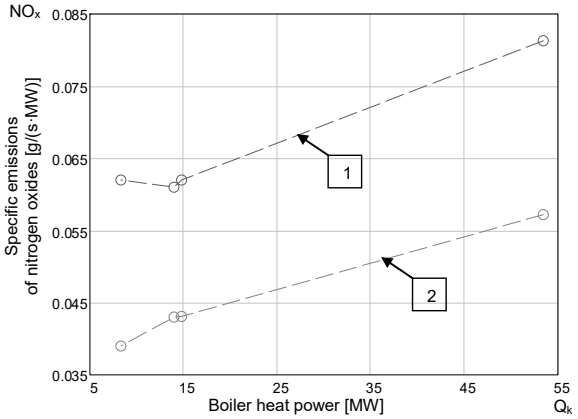

Fig. 3. *Dependences of specific emissions of nitrogen oxides as a function of boiler heat power (1 – boiler without additional systems activated; 2 – boiler with activated system of suppressing nitrogen oxides emission)*

Conclusions

1. A method for reducing nitrogen oxide emissions in city heat boilers has been developed and proposed. The method relies in directing the dosed moisture injection into the flame zone.
2. The method has been experimentally verified on steam and water thermal power boilers with capacities from 8.37 to 53.79 MW. The number of the burners in these boilers was form 1 to 12.
3. It has been proved that the proposed method allows a reduction of nitrogen oxides by 30-40% with moisture injection not exceeding 0.9% of the boiler efficiency. Due the work of a boiler with moisture injection is accompanied by an increase in its efficiency to 1%, the use of the proposed method does not reduce the efficiency of fuel consumption in the heat source.

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THERMOPHYSICAL-BASED EFFECT OF SELF-PRESERVATION GAS HYDRATES

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Introduction. Many works are devoted to experimental studies of the gas hydrates self-preservation effect [1, 2]. There are studies devoted to the application of this effect for gas hydrates long-term storage or transportation under nonequilibrium conditions [3]. Many works have been devoted to the gas hydrates forced conservation technological process [4]. However, as a review of literary sources reveals, the thermophysical mechanisms of this phenomenon are not researched. The work is devoted to the study of thermal processes occurring during the gas hydrates dissociation that improves their storage and transportation under nonequilibrium conditions production technology. For research, a test installation (Fig. 1), that enables to simulate the dissociation conditions of a large gas hydrate mass, has been installed.

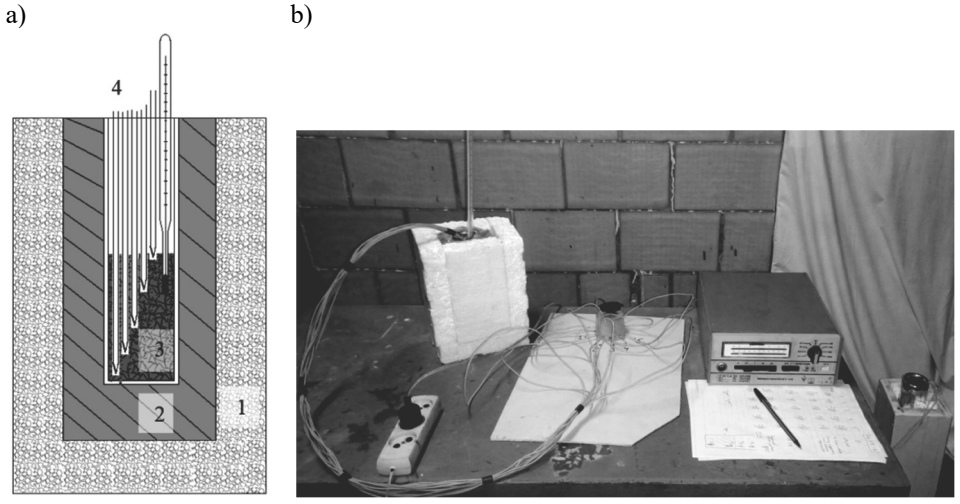

Fig. 1. *The scheme of the test installation (a) and its general view (b): 1 – a layer of expanded polystyrene; 2 – layer of mineral wool; 3 – gas hydrate inside the Dewar vessel; 4 – thermocouples*

It has been experimentally established that the temperature inside an unlimited hydrate array changes according to an exponential law, which parameters are determined by the composition of the hydrate and the heat input rate from the array surface. The temperature on the surface of the GH is a consequence of the heat balance between the heat input from the environment and the heat sink due to

dissociation processes in the near-surface and deep hydrate layers. Improving the quality of the hydrate leads to increase in the heat sinks attenuation in the hydrate depth.

By mathematical modeling, dependencies have been obtained for determining the temperature distribution, the power of the volumetric heat sinks and the gas emission inside the dissociating one and two-dimensional hydrate array. A computer program for calculating the dissociation processes of an arbitrary gas hydrate array has been developed. It has been shown that the calculation results coincide with the results of field experiments.

Conclusions. The scientific novelty of the work is to obtain quantitative dependences of heat and mass transfer intensity on the interphase surface under conditions of GH dissociation. Based on the results of experimental studies, the comparison of the hydrate temperature regime with theoretical calculations has been performed. The thermophysical mechanism of gas hydrates self-preservation has been installed.

The practical significance of the research results is to determine the quantitative relationships for determining the rate of mass transfer processes under conditions of propane hydrate dissociation. Prospects for further research studies in this area are storage facilities and containers for transporting gas hydrates design optimization.

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TECHNOLOGIES OF ACCUMULATION AND EXTRACTION OF THE HEAT

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Technology of heat storage is based on developed in ITTF NAS Ukraine method of organization of ground vertical accumulator. In base of method analysis of joint work of group of ground heat exchangers of pipe type is placed. Technology is realized in experimental system, built on territories of Institute and reserved for heat supply of premises with help heat pump. Ground heat storage is source of energy for heat pump. Ground heat storage occurs at help different pipes systems, by which intermediate heat carrier circulates, warming ground with summer (heat storage) or ground cools with help heat pump in heating season (extraction of heat). Accumulator consists of "bush" of ground heat exchangers of U-shaped type different configuration that are lowered in the wells with depth 20-25 m heat capacity 11 kW. Part of heat exchangers is executed of pipes of "sewed" polyethylene (PEX), and part from simple polyethylene (PE). They are connected with one another and with giving and removing pipelines with help brass fittings [1].

Vertical single-type double-loop heat exchangers are installed in wells with a diameter of 280 mm, a depth of 20.5 m and form a regular hexagon. It limits the main area of accumulation. A three-loop U-shaped heat exchanger is located in the center of the hexagon in a 25 m deep well. Temperature sensors (RegMik TSM-205 primary temperature converters) are fixed on the outer walls of the tubes of the heat exchangers evenly along the length. A total of 68 sensors are installed. The sensor outputs via a cable are connected to eight channel digital temperature measuring and control devices UKT38-Shch4.

Processing of values received from various sensors is performed sequentially by the central microprocessor. Information through the adapter goes to the computer, where the data is recorded and processed using the software “ORM”. A multilayer insulating shield of the upper surface of the accumulator with a thickness of 1.5 m was created to reduce external effects on thermal processes in the accumulator and prevent heat loss. The temperature regime of the ground, depending on the daily and seasonal fluctuations in air temperature, was investigated.

A large array of experimental data has been obtained on changes in ground temperature up to 25 m in depth under variable climatic conditions for 7 years. The analysis of these experimental data makes it possible to organize the efficient operation of the ground heat accumulator and optimally balance the soil accumulator – heat pump system [2].

A comprehensive experimental installation for conducting field studies on the use of low-grade ground heat for space heating was created. The installation

includes a horizontal ground heat exchanger of shallow laying in the ground, a heat pump from the Swedish company IVT, heat pumps "Greenline HT Plus C" with a power of 6 kW and a low-temperature heating system "warm floor". Ground heat exchanger take heat, accumulated in surface soil (depth – 1-3 m) in result solar radiation (direct heating, deposits, heat of air). Horizontal ground collector combined area 240 m^2 and heat capacity 6 kW is executed of polyethylene tubes with diameter 32 mm, calculated on pressure of 6 bar. Pipes are put in trenches in type loops with step 1 m beneath the surface 1.5 m. After leakage test and installations of measuring gauges of trench were fallen asleep. In quality heat-carrier in contours they use 30% solution of propylene glycol, which circulates in pipe selecting heat of the soil. Connections are found inspection pit to distributing heat exchanger – giving and inverse.

The experimental installation has been operating since 2009. Continuous monitoring is carried out in an automated real-time control and measurement system. As a result of long-term studies, an array of experimental data was obtained on the temperature regime of the surface ground layer during the extraction of natural ground heat (heating season) and during its natural recovery (summer period), depending on daily and seasonal fluctuations in air temperature and solar insolation. During the heating season, the ground, which is located in the zone of influence of the coil of the horizontal heat exchanger (depth 1.65 m), undergoes repeated temperature changes that are periodic in nature, associated with the periodicity of the heat pump (with the periodic extraction of heat from the ground). Above and below this depth (0.55 m and 2.65 m), the vertical temperature distribution during the day varies slightly. The lowest ground temperature at depth was recorded in March, and the lowest air temperature was in January-February, which indicates the inertia of the change in soil temperature in depth due to its large thermal resistance and thermophysics properties. It was also found that during the summer the ground has time to regain its temperature potential.

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DEVELOPMENT OF UNIVERSAL ABSORPTION REFRIGERATORS FOR OPERATION IN A WIDE RANGE OF ATMOSPHERIC AIR TEMPERATURES

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In the recent years, greater weight in the structure of agricultural production in Ukraine belongs to individual farms and farmers. In these farms arise the problems of forming a regular economical budget, including a major problem in the preservation of the grown crops for three to six months in commercial quantities and at minimal energy costs. However, the acknowledged fact in world practice is the loss of most of the harvest of agricultural products in the absence of adequate refrigeration storage. Currently, the bulk of Ukrainian harvested fruits and vegetables is traditionally stored in the basements, where during the warm seasons (August–November, April–May) the required temperatures (5-12°C) often cannot be maintained. To ensure the required regimes of storage, the market of household and commercial refrigeration equipment for small wholesale manufacturers offers national and imported demountable (panel) cold storages of volumes 3-9 m^3, equipped with compression refrigeration machines. In modern conditions in rural Ukraine, operation of such cells is hampered by lengthy power outages and by poor quality electricity incoming (range of fluctuation of voltage is 160-250 V). The current situation makes appeal to heat-powered pumpless absorption refrigeration units (ARU). Refrigeration units of ARU have a number of unique features such as: the possibility of use in a single ARU a number of different sources of heat – both electric and alternative (heat of combustion of fossil fuels and biogas, solar radiation, exhaust emissions of internal combustion engines); the ability to work with low-quality sources of energy, including electricity network in the voltage range of 160-250 V; noiselessness, high reliability and long service life.

The advantages of ARU should include the minimal price among existing types of small capacity refrigeration equipment, which in many cases determines their popularity among customers. Important in modern conditions is also the fact that the working fluid of ARU – water-ammonia solution with the addition of inert gas (hydrogen, helium or mixtures thereof) belongs to natural refrigerants and is therefore completely environmentally safe (has zero ozone-depleting potential and the potential of the "greenhouse" effect). One of the most effective developments is the universal low-temperature chamber (LTC) of the "chest" type series, including the vehicle type (installed on car trailers), with a useful volume: 100; 180; 220; 240; 280 dm^3. LTC's original design of the "chest" type is protected by Ukrainian patent No. 50941 and has two refrigeration units (on the sides or on the rear wall in

a row), designed to provide storage regimes in a wide temperature range – from minus 18°C (long term storage) to plus 10-12°C (short-term storage of fruits and vegetables). All the developments are made on the basis of modern serial industry technologies of Vasylkivsk refrigerators plant (VRP). Design features of “chest” help to preserve cooled air inside the chamber, so that when you open the lid from the room, the air with a high moisture content does not get on the heat-receiving panels. This can significantly reduce the rate of formation of snow coats and thereby improve the performance and power characteristics of LTC.

The implementation took place at the VRP. Achieved reducing energy consumption – up to 50%, enhanced functionality. To create a batch sample of absorption refrigerator with alternative energy sources, it is necessary to develop and produce the burner that works on, for example, liquefied gas, kerosene, diesel fuel, or gasoline. It is expedient to consider the use of biogas and gas generators.

CFD-SIMULATION OF HEAT TRANSFER AND HYDRODYNAMICS PROCESSES IN THE HEAT ACCUMULATOR TANK

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Continuous growth in the price of fossil fuels requires that modern heating and hot water systems maximize the use of alternative heat sources. Due to the fact that the heat generation and consumption peaks in such systems do not usually coincide in time it is impossible to ensure efficient use of alternative sources without integration into the acumulation tank heat supply system. A heat accumulator is usually a heat insulated tank designed to store heat and heat hot water. Today, heat storage tanks have become an integral part of heating systems. They are used as heating systems in conjunction with solar collectors, heat pumps, solid fuel boilers and night-rate electric heaters [1-3].

The principle of operation of the tank of the heat accumulator is the use of high heat capacity of water. Reservoirs are used in heating systems usually in conjunction with solid fuel boilers, electric boilers, heat pumps and other sources of heat. The acumulation tank allows to relieve system tension from temperature changes, protect against boiling, and also capable to maintain the temperature of the coolant, for a certain time when the heat source is switched off. Similarly, the buffer tank allows you to extend the range of temperature control of the coolant. The storage tanks can be equipped with a coil to heat the hot water or to maintain the set operating temperature of the coolant. This is their fundamental difference from the boilers of indirect heating. However, the water tanks of the batteries are characterized by the phenomenon of thermocline and high thermal inertia.

The difference between the presented structure and the known is the presence of the so-called “thermal core” in the center of the insulated tank filled with water. As a heat-accumulating material “thermal core” is used paraffin, the heat-accumulating properties of which are not worse than that of water. The need to use a “thermal core” is aimed at intensifying the heat exchange and preventing stratification in the tank height of the heat accumulator.

The purpose of the presented study is to determine the thermophysical properties of paraffin to be used in the formation of a “thermal core”. To achieve this, the assumption was made that the acumulation tank was heated for 1 hour with water at a temperature of 115°C that moved along the surface of the heat exchange, which is structurally made in the form of a coil with a flow rate of 2.2 m^3/h. During the studies, the cooling time of the tank to a temperature of 50°C was also determined.

The problem is solved as follows: by means of the software complex Fluent determined the temperature distribution of the coolant in the coil. The following data is transferred to the calculation module "Transient Thermal" software complex ANSYS, where further calculations of the non-stationary temperature distribution in the tank. The CFD model of the heat storage tank is shown in Figure 1. The model contains a "thermal core" in the form of a paraffin container (1), surrounded by a volume of water (2). Heating or cooling of this system is by means of a coil (3), which is located on the periphery of the acumulation tank. The model also contains the design elements of the acumulation tank, as shown in Figure 1 and which also consumes heat. The presented model allows studying the processes of heat exchange and hydrodynamics that are observed, both in the thickness of water that washes the "thermal core" and in the water moving along the coil. The flow in the coil is directed from top to bottom as indicated by the arrows (Fig. 1).

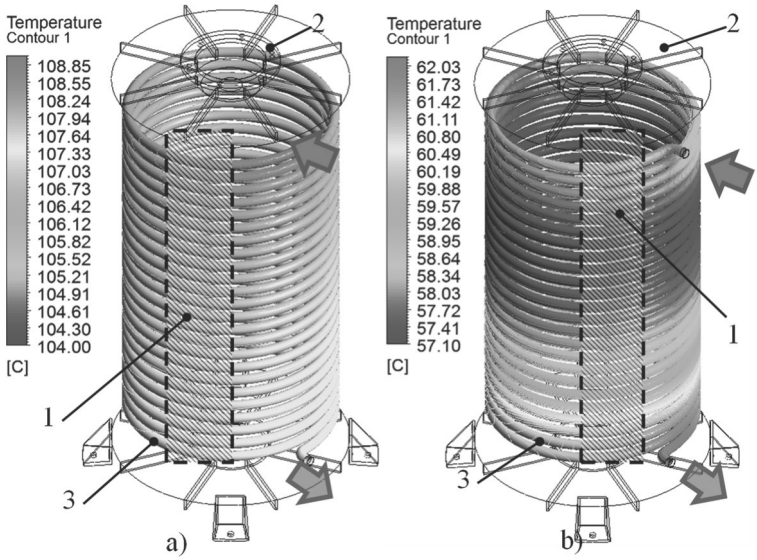

Fig. 1. *Three-dimensional temperature field of the coil wall when heated (a) of the heat storage tank and when cooled (b)*

The temperature of the coil wall, along which the water flowed at 2.2 m^3/h and at 115°C, was determined by CFD simulation. The problem was solved in a stationary setting, while the water in the tank was heated under conditions of free convection. The stationary formulation of the problem is chosen from the assumption that the water moving in the coil has a limited specific heat, so the temperature field in the coil wall will be uneven, but constant.

At the same time, the temperature field of the coil wall was determined, along which water flowing at 2.2 m^3/h but with a temperature of 50°C was also moving. The problem was solved in a stationary setting, while the water in the tank was cooled in conditions of free convection.

The calculated temperature field of the coil wall was used in non-stationary heating problems, and thus also the cooling of the battery tank to determine the non-uniform field of water volume and heat core temperatures.

The result of the calculation of the inhomogeneous temperature field of all elements of the storage tank was used to determine the time of complete cooling of the storage tank heat. The conducted research allows to automate the process of calculation of the tanks of the batteries and to carry out their modernization to increase the efficiency of use.

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ANALYSIS OF THE PROBLEM OF NATURAL GAS WATERLOGGING

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The historical orientation of the fuel balance of Poland towards solid fuel causes huge technical, economic and ecological problems for the country, also on an international scale. The Polish government has announced a broad programme of ensuring of energy security of the country by diversification of the natural gas supply from various sources and directions thanks to the effective use of the LNG terminal on the Polish coast and creation of new cross-border connections (Project 2019). It anticipates development of the gas supply industry in the coming years and at an unprecedented pace. In the conditions of the anticipated development of the domestic gas industry, the key issue is to increase the capacity of the Polish natural gas transmission network and to ensure reliability of the gas supply process as well as its appropriate quality (Polish Standard 2011-2). One of the acute problems from this point of view is the moisture content of the gas fuel (Szkarowski et al. 2013). This problem is further intensified by the increasing scale of the use of the liquefied natural gas being technologically associated with the cryogenic processes. It is not widely known that water may appear in the gas pipelines that distribute the natural gas directly to the consumers. On the other hand, the specialists in the field of operation of the gas networks deal with this phenomenon on a daily basis. Where does this water come from? Certainly not through the leakage places arising on the network due to mechanical damage or corrosion, as the gas pipeline is always under positive pressure.

The natural gas extracted from the ground is usually contaminated with solid fractions and loaded with moisture as well as has caustic properties. The previously dried gas taken from the underground gas storage facilities is also saturated with water. The presence of water in the natural gas is undesirable because it intensifies corrosion of pipes and equipment, especially in the presence of H_2S and CO_2, while in winter it forms ice plugs. It may also contribute to formation of the hydrates that block the flow of the gas, especially in case of liquid hydrocarbon recovery processes, such as freezing or cryogenic processes.

The gas suppliers are aware of the contradiction described above. To ensure adequate gas properties, the transmission network operators provide declarations regarding the properties of the transmitted fuel on their official sites. They include *inter alia* the permissible moisture content in the form of the maximum dew point temperature t_r, separately for summer and winter. The safety of the gas in transport

and further use depends on it directly and its efficiency is important from the point of view of fulfilment of the contractual tax obligations.

However, the hazards arising during the operation of the gas networks in case of presence of the condensed water in the gas pipelines are much more important. That is why it is so important to analyse each failure and the resulting conclusions thoroughly – in terms of the causes of the abnormal states and disturbance of the stability of the supervised systems as well as of the ways to prevent such events in the future. The authors have attempted to conduct such analysis on the basis of the gathered data on gas network failures and their own measurements. The most well-known failures include the one of the Russian gas transit system (supplier – Russian State Concern Gazprom), when the Polish customer (Operator Gazociągów Przesyłowych GAZ-SYSTEM S.A.) announced suspension of all gas supplies from the Yamal gas pipeline on 22 June 2017. This was done due to the failure of the Russian gas drying instance in fear of the safety of the Polish gas pipelines. In this information, it was stated that Poland did not have its own installation for drying of such gas flows and that the closest one was in Germany. The most commonly used solutions are glycol installations and the supply system is stabilised in such a way that it provides the opportunity to choose the optimal time of contact of the gas with the glycols. Even the effective trade agreements ensure such stabilisation of supplies, as in case of lower consumption, the generated surplus of the transit gas is injected into the underground warehouses all over Europe.

The gas drying cycles operate in a much worse way in the regional gas distribution systems based mainly on the local wells with the nitrogen-rich gas mines. These systems are characterised by large fluctuations of the flows during the transitional periods (spring and autumn), in case of sudden changes of the weather and even during the day. Then, the drying processes encounter a big problem due to lack of the possibility to stabilise the gas-glycol contact time. This situation occurs in all distribution networks in Poland supplying the *Lw* and *Ls* subgroup natural gas to the customers. Many typical failures are currently very well analysed and described in the field of the actions to be taken. Even the failures that are very well known to the public are often typical and the extent of their consequences determines their publicity. Another type of the events includes the ones which surprise the specialists, since they do not have well-developed and proven methods of action. One of such unexplained failures on the low-pressure gas network was the sudden suspension of the natural gas supply to the Spa District in Kołobrzeg in February 2016.

Pressure measurements at the sampling points showed unacceptable values in the range of 0.65-0.82 kPa. At that time, the reduction stations supplied the gas at the right pressure with a large capacity reserve. This indicated that the main gas pipeline was no longer permeable. After cutting of the pipe, water escaped from it instead of the gas and a pump was installed instead of the bag-positioning device. In total, about 500 litres of water were pumped out, which meant geometrically that a section of the gas pipeline of the length of almost 7.50 m was completely flooded with water. The sections flooded with water were also found in other areas of the network system.

Fig. 1. *Cutting of the DN300 gas pipeline at Myśliwska Street in Kołobrzeg*

The analysis of the causes of the incident from the side of the gas plant was conducted only in one direction – the search for a potential place of leakage which would allow for penetration of such quantity of water into the gas pipeline from the outside. Such a place was not found until these gas pipelines were replaced with new polyethylene ones. Therefore, the thesis that water got into the gas pipeline through the places of leakage has never been proved unambiguously.

All analyses and research in the field of natural gas humidity have always concerned the area of mines, high-pressure transit gas pipelines and – to lesser extent – medium-pressure gas networks. The current water protection system ends with dehydrators installed as a standard on the inlet systems of the medium-pressure gas stations. There is no data on the study of this phenomenon at the side of the low-pressure network, i.e. directly in front of the consumer.

The author's analysis of a number of failures has showed that the low-pressure systems may contain water, the presence of which cannot be explained by leakages or penetration of precipitation into the network. Therefore, it has been decided to carry out an analysis of the water content in the low-pressure natural gas that is supplied directly to the customers.

The measurements were carried out with the use of XENTAUR portable dew point analyser, HPDM type. It is a microprocessor-controlled, battery-powered moisture meter, equipped with a dry chamber for storage of the sensor.

The thermodynamic calculations allow for calculation of the experimentally obtained dew point temperature value based on the known conditions in the higher-pressure gas pipelines. The generally accepted principles of such recalculation are based on the Goff-Gratch formula or on a similar method of the World Meteorological Organization. In the work, the JSC “Ecological Sensors and Systems” humidity calculation software, which allows for comparison of the results according to both methods and for changing of the type of the analysed gas, has been used. Both the measured values and the ones obtained as a result of such calculations are presented in Table 1.

Table 1. *Natural gas humidity measurement and recalculation results*

Date of measurement	Dew point temp., ºC	Gas humidity, g/m^3	Recalculation into medium-pressure conditions			Recalculation into high-pressure conditions		
			Pressure, MPa	Dew point temp., ºC	Gas humidity, g/m^3	Pressure, MPa	Dew point temp., ºC	Gas humidity, g/m^3
25.06.2019	-29.4	0.322	0.298	-16.1	4.36	4.2	16.4	46.42
06.06.2019	-22.1	0.66	0.292	-7.7	13.84	2.5	19.1	88.83
20.06.2019	-25.5	0.461	0.297	-11.9	9.92	4.23	22	83.53
21.05.2019	-27.5	0.385	0.293	-14.4	9.75	4.22	18.7	104.33
22.05.2019	-27.7	0.366	0.293	-15.2	12.56	4.19	17.5	133.38
13.06.2019	-25.8	0.362	0.296	-14.8	6.9	4.2	17.9	72.94
21.06.2019	-27.9	0.362	0.298	-14.9	8.25	4.21	17.7	86.76
23.06.2019	-28.1	0.351	0.294	-15.7	10.62	4.15	16.8	112.05
21.06.2019	-28.2	0.35	0.298	-15.4	6.61	4.3	17.7	72.2
01.07.2019	-28.3	0.35	0.297	-15.4	6.98	4.1	16.9	72.91
01.09.2019	-28.3	0.344	0.296	-15.4	4.89	4.02	16.7	50.13
26.06.2019	-28.5	0.34	0.297	-15.5	4.59	4.13	16.9	48.19
24.06.2019	-28.7	0.331	0.299	-16	6.84	4.31	16.8	74.61
24.05.2019	-28.8	0.329	0.294	-16.3	7.12	4.22	16.3	76.95
06.08.2019	-28.9	0.327	0.297	-16.2	6.17	4.02	15.6	63.07
27.06.2019	-28.9	0.325	0.298	-16.3	7.31	4.02	15.3	74.56
02.07.2019	-29.2	0.316	0.298	-16.8	8.24	4.29	15.8	89.68
21.08.2019	-29.4	0.305	0.3	-17	6.51	4.25	15.3	69.78
22.06.2019	-29.9	0.293	0.299	-17.6	6.61	4.09	14	68.39
16.06.2019	-30	0.289	0.298	-17.8	6.9	4.21	14.2	73.63

Measurement conditions: t = 22ºC, p = 1.13 kPa ($p_{abs.}$ = 0.102625 MPa).

The Table 1 data shows that the gas with a very low dew point temperature is formally transported through the low-pressure network. On the other hand, the recalculations into the medium- and high-pressure conditions show that the same water vapour content before pressure reduction does not exclude the possibility of water condensation in the domestic climate conditions.

PROSPECTS FOR APPLICATION OF REGENERATOR WITH GRANULATED MATERIAL FOR DISPOSAL OF LOW-POTENTIAL HEAT

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During any technological process, there is an incomplete use of primary energy. Prospects for the utilization of secondary energy resources (SRE) provide the opportunity to obtain significant fuel savings and substantially reduce capital costs for the creation of appropriate energy-saving plants. Thermal SRE can be used both directly in the form of heat and for separate or combined production of heat, cold, and electricity in recycling facilities. According to the degree of concentration of energy distinguish sources of ESR: high-potential: first of all thermal high-temperature (400-1000°C), medium-potential: thermal flows with a temperature above 150°C; low-potential: temperature up to 150°C.

Currently, heat exchangers for the utilization of high-temperature and medium-temperature thermal emissions are well developed. The utilization of low-potential thermal emissions was considered irrational due to the low temperature head. This problem can be solved by using granular materials in the form of a dense layer. In this case, the heat transfer surface is much more developed, even in comparison with the finned surfaces.

As shown by their own research conducted in the Academy's laboratory, it is rational to design heat exchangers for the recovery of heat of regenerative type with granular nozzle. The granular nozzle falls asleep into the channel in the form of a dense layer through which the flow of exhaust gases passes. The schematically studied layer is presented in Figure 1.

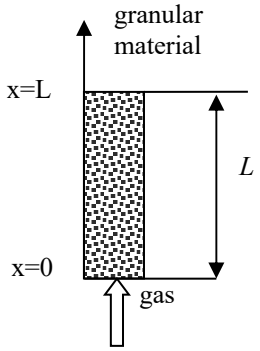

Fig. 1. *Scheme of the section of heat exchange between the flow of gas and granular material*

Figure 2 shows typical curves of temperature dependence on the duration of heating of a layer.

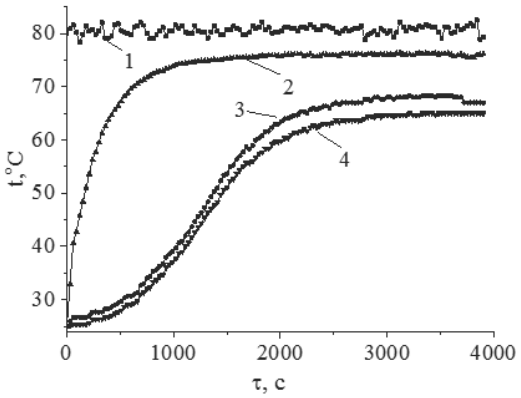

Fig. 2. *Change in temperature of air and expanded clay with time*

In Figure 2 the designation of the curves corresponds to the following parameters: 1 – air temperature at the entrance to the apparatus; 2 – material temperature at x = 0 m; 3 – air temperature at the outlet of the apparatus; 4 – material temperature at x = 0.52 m; filtration rate = 1.0-2.0 m/s: inlet air temperature t = 80°C; L = 0.52 m; mass of material in the apparatus m = 5.25 kg. Experiments have shown that it is advisable to limit the value of the final particle temperature to 80% of the gas inlet temperature.

It is obtained that the heat transfer coefficient for the non-stationary mode of heat exchange between the air flow and the material layer depends not only on the flow rate and the temperature head, but also substantially depends on the duration of heating.

Dense-layer regenerative heat exchangers can be used to heat living spaces and auxiliary areas.

ADVANCED EXERGOECONOMIC ANALYSIS IN CASE OF NEGATIVE EXOGENOUS CAPITAL INVESTMENTS

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The exergy-based methods provide information concerning location, magnitude, causes and costs of thermodynamic inefficiencies in an energy-conversion system [1-3]. As a result unlike to the energy-based analysis the exergy-based one is a more powerful and convenient tool for investigation and improvement of energy-conversion systems without the need of additional estimation and iterations.

In an exergoeconomic analysis exergy destruction represents costs of the irreversibilities and investment expenditures associated with the components of the system [1].

Advanced exergy-based analyses are novel methods that can identify interactions among components of the systems and reveal the real potential for improvement of individual components and overall energy-conversion system. According to the methodology of advanced exergy-based analysis the total exergy destruction and the total investments costs in each system component can be split into endogenous/exogenous parts ($\dot{E}_{D,k} = \dot{E}_{D,k}^{EN} + \dot{E}_{D,k}^{EX}$ and $\dot{Z}_k = \dot{Z}_k^{EN} + \dot{Z}_k^{EX}$), unavoidable/avoidable parts ($\dot{E}_{D,k} = \dot{E}_{D,k}^{AV} + \dot{E}_{D,k}^{UN}$ and $\dot{Z}_{D,k} = \dot{Z}_k^{AV} + \dot{Z}_k^{UN}$), and combined according to the two approaches of splitting ($\dot{E}_{D,k} = \dot{E}_{D,k}^{UN,EN} + \dot{E}_{D,k}^{UN,EX} + \dot{E}_{D,k}^{AV,EN} + \dot{E}_{D,k}^{AV,EX}$ and $\dot{Z}_{D,k} = \dot{Z}_{D,k}^{UN,EN} + \dot{Z}_{D,k}^{UN,EX} + \dot{Z}_{D,k}^{AV,EN} + \dot{Z}_{D,k}^{AV,EX}$).

The sum of the avoidable capital investments caused by the irreversibilities within the *k*-th can be defined as [1]

$$\dot{Z}_k^{AV,\Sigma} = \dot{Z}_k^{AV,EN} + \sum_{\substack{r=1 \\ r \neq k}}^{n-1} \dot{Z}_r^{AV,EX,k} \tag{1}$$

where $\dot{Z}_r^{AV,EX,k}$ represents the part of the exogenous investments within the *r*-th component but caused by the irreversibilities occurring within the *k*-th component.

The works [2, 3] present results of advanced exergoeconomic evaluation where for several components of the systems exogenous values of investment cost rates are negative. In these cases the investigator should do additional analysis concerning possibilities of decreasing such costs. The authors [3] shows that investment cost of a component with negative $\dot{Z}_k^{EX} = \dot{Z}_k - \dot{Z}_k^{EN}$ increases when

other components operate under theoretical conditions (without exergy destruction). Thus, in order to decrease the cost of a component with negative exogenous investment cost, the exergy destruction within the other components must be increased (opposite effects). In [2] the authors state that negative values of exogenous investment cost rates $\dot{Z}_k^{EX}$, $\dot{Z}_{D,k}^{AV,EN}$, $\dot{Z}_{D,k}^{AV,EX}$ of a component revealed that the investment costs within this component can be decreased by increasing the investment costs within the other components.

The work is devoted to advanced exergoeconomic estimation of heat pump systems "air-water" and "water-water" with emphasizing the necessity of additional analysis in case of negative exogenous parts of investment cost.

The analysis is performed for a typical space heating system in Ukrainian conditions.

The results of advanced exergoeconomic analysis have shown that for the air-source heat pump system exogenous investment cost of the compressor as the most expensive component is positive. A more detailed study has shown that avoidable exogenous investment part of the compressor is negative and consists of negative values of investments due to irreversibilities occurring within the evaporator and condenser. The conclusion is to increase thermodynamic efficiency of the evaporator and the condenser which provides some decrease of investment expenditures for the compressor. This has been confirmed after calculation of the total investment cost of the compressor – it is reduced.

In case of the "water-water" heat pump system avoidable exogenous investment part of the compressor is also negative and consists of negative values of investments due to irreversibilities occurring within the evaporator and condenser. But according to the obtained results exogenous expenditures for the compressor due to irreversibilities occurring within the evaporator are negative and due to irreversibilities within the condenser – positive. So, in order to decrease investment expenditures for the compressor thermodynamic efficiency of the condenser has been increased. Decreasing irreversibilities within the evaporator has increased investment costs of the compressor.

So, in case of application of advanced exergoeconomic analysis with negative exogenous investment parts additional study should be applied for finding possibilities of decreasing capital expenditures of one component at the expense of other ones

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INCREASING THE ENERGY EFFICIENCY OF BUILDING VENTILATION SYSTEMS BY USING EUROPEAN ECODESIGN REQUIREMENTS FOR FANS

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Introduction. The European Union has defined the 20-20-20 target, with the aim to reduce energy consumption by 20%, reduce carbon emissions by 20% and increase the share of renewable energies by 20%, by 2020 [1].

Ukraine belongs to the countries partially supplied with traditional types of primary energy, which necessitates significant volumes of their imports. Although Ukraine's energy dependency is Central European (the share of imports in the total primary energy supply to Ukraine has been around 38% in recent years), this dependence is facilitated not only by the lack of sufficient energy resources, but also by their inefficient use. The energy intensity of Ukraine's GDP is much higher not only in comparison with the leading economies of the world, but also with the neighboring countries of Central and Eastern Europe [2].

Currently, much attention is paid to the energy efficiency of various processes, equipment, etc., including building ventilation systems. The ventilation systems themselves can be designed both for moving air (gases) and for moving treated air (heating, cooling, heat recovery, etc.). In the first case, electric (or other) energy is consumed, in the second case, electric and thermal energy [3].

When designing a ventilation system in accordance with state standards, the required supply air flow is determined from the conditions for ensuring sanitary and hygienic standards, fire safety standards, conditions that exclude the formation of condensate, etc. The ventilation system can be constructed in various ways: various ducting and the number of parallel branches are possible, respectively, all possible variants of ventilation systems will have different aerodynamic losses and, therefore, efficiency. Therefore, these losses can be considered conditionally constant, because we cannot change the configuration of the ducts. On the other hand, the energy efficiency of the ventilation system is also affected by the fan itself and its drive (engine).

That is way, in this work, it is proposed to pay attention exclusively to the issues of improving the energy efficiency of fans.

Main part. Within the framework of the Energy Community Treaty, Ukraine is obliged to implement a number of EU directives and regulations at the level of national energy efficiency policy. So far, Ukraine has made significant progress in transposing EU energy labeling legislation and is now making the first steps towards ecodesign.

What is Ecodesign?

- Mandatory legal basis under which manufacturers have a duty to reduce consumption energy during the life of their products and reduce the negative effects on the environment.
- Applies at the design stage, before how to produce products and bring them to market.
- Applies to manufacturers and importers.
- Establishes general and specific requirements ecodesign.

Directive 2009/125/EC on the ecodesign of Energy Related Products [4] is a major EU framework directive for the improvement of the energy and environmental performance of products, with the aim of gradually displacing the products with the greatest negative impact on the environment. The ErP directive (Energy Related Products – 2009/125/EC) has replaced the EuP directive 2005/32/EC.

October 3, 2018 in Ukraine Directive 2009/125/EC is implemented in the legislation of Ukraine by adopting a resolution of the Cabinet of Ministers of Ukraine approving the Technical Regulation on the establishment of a system for determining the requirements for ecodesign of Energy Related Products [5].

An EU directive is either transposed by the member states into national law for its implementation or it becomes effective via an EU regulation which then becomes directly valid in all member states. This procedure was chosen for the requirements of the Ecodesign Directive for electric motors, fans, as well as HVAC systems and their energy-relevant components.

So in 2011 came into force Regulation EU 2011/327 [6] for fans that prescribes minimum target efficiency requirements (corresponding to system efficiency). This regulation applies to fans with motors with an electrical input power between 125 W and 500 kW. The system efficiency of a fan unit represents the product of the efficiencies of the fan, motor, drive (V-belt, flat belt or direct) and speed control and is specified by the manufacturer. The system efficiency must be at least equal to or greater than the target efficiency. In Annex I 2, Table 2, equations for the target efficiencies η_{trgt} are given for each fan type, which can then be calculated depending on the electrical input power and specified efficiency levels.

In HVAC units, mainly radial fans with backward-curved blades without housing are used at present. For this type of fan, Table 1 shows the data used to determine its minimum efficiency ratings.

This EU Regulation is implemented in the legislation of Ukraine by Technical regulation approved by the resolution of the Cabinet of Ministers of Ukraine of February 27, 2019 No. 151 [7]. The regulation covers:

- Minimum energy performance requirements.
- Product information requirements.
- Technical documentation (conformity assessment).
- Measurement and calculation methods.
- Verification procedure.
- Test one unit per model.
- Indicative benchmarks for Best Available Technology.

Table 1. *The minimum energy efficiency requirements for fans according to Regulation EU 2011/327*

Fan types	Measurement category (A-D)	Efficiency category (static or total)	Power range P (kW)	Target energy efficiency	Efficiency grade (N)
Centrifugal backward curved fan without housing	A, C	static	$0.125 \leq P \leq 10$	$\eta_{target} = 4.56 \cdot \ln(P) - 10.5 + N$	62
			$10 < P \leq 500$	$\eta_{target} = 1.1 \cdot \ln(P) - 2.6 + N$	

For evaluation of benefits for Ukraine from implementation of this technical regulation in Ukraine Cost benefit Analysis (CBA) was conducted. CBA is the core component of an impact assessment, a key policy making tool used by the European Commission per the EC's Better Regulation Guidelines. CBA assesses the impact of various policy options in order to help policy makers achieve policy objectives at the lowest cost and ensure policy interventions are beneficial.

Scope of the modelling focuses on:

- Products with largest saving potential,
- Products with highest sales,
- Depends on data availability.

Data requirements:

- Stock (installed motors) or sales data,
- Price data,
- Improvement cost data,
- Technical data including lifespan, average efficiencies, per unit electricity demand,
- Average operating hours and load factors.

Selection criteria:

1. No data were found that would provide a reliable *stock* estimate of number, type and size of fans that are installed in Ukraine.
2. Ukraine national statistics data is available on sales of fans.
3. The scope of the analysis was therefore based on the categories of fans used for Ukraine national statistics.
4. Future sales to 2030 based on industrial growth levels during the first 5 months of 2016 (3.5%) according to Ukraine's State Statistics Service.

The results of Cost benefit Analysis (CBA) of implementation of this technical regulation in Ukraine are shown:

- Data were obtained from Ukrainian manufacturer tech sheets for actual fans.
- Ukraine 2016 average efficiencies are compared to EU 2011 (pre-regulation) average efficiencies. EU manufacturers had similar challenges.
- The fan efficiency calculation is presented below.

Table 2. *The results of Cost benefit Analysis (CBA) of implementation of the technical regulation in Ukraine*

Fan size	Avg. Electrical input Ukraine (kW)	Avg. Static Efficiency Ukraine, 2016 (%)	Tier 2 Static Efficiency Requirements (%)	Avg. Electrical input EU (kW)	Avg. Static Efficiency EU, 2011 (%)
Axial	1.1	32.3%	33.9%	1.17	35.9%
Centrifugal forward curved – with casing	0.55	31.9%	36%	0.44	30%
Centrifugal backward blades – with casing	4	51.6%	56.8%	3.76	50%
Mixed flow (or Roof fans)	1.1	35.3%	50.9%	1.2	40%
Cross flow	0.49	n/a	n/a	0.42	

Results

- Projected annual electricity savings: 3.680 GWh/yr by 2030.
- Equivalent to ~3.5% of 2014 Ukrainian industrial electricity consumption.
- Energy saving estimates are likely to be conservative because new sales will replace older fans with efficiencies less than 2016 reference ones.

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ASSESSMENT OF VOLUME OF AGRO-PELLETS IN THE HEAT POWER INDUSTRY OF UKRAINE

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One of the prerequisites for the successful development of bioenergy in any country is the availability of sufficient biomass resources.

Ukraine has a great potential for biomass, in 2018 the share of bioenergy in the total energy supply in Ukraine is 3.4%, and the production of biofuels is 3 mtoe/year. The main constituents are waste and by-products of agriculture and energy crops, and the contribution of wood biomass is relatively small from the total biomass energy potential.

Agricultural biomass remains today the main real component of biomass energy potential in Ukraine. This is due to factors such as high development of agriculture in the country, continuous improvement of agricultural production systems, limited resources available to the energy needs of wood biomass and the relatively slow development of the direction of cultivation and use of energy crops. As for the last factor, it should be noted that the potential of energy crops in Ukraine is also significant (the presence of large areas of unoccupied agricultural land), but it currently has a potential volume unlike the actual crop residues and other types of agrobiomass.

Ukraine annually produces 50 to 60 million tons of cereals and legumes. Straw is produced in the same volumes. It is mainly used as a soil fertilizer, as well as in animal husbandry as bedding and animal feed. From 20% to 30% of straw can be used annually for alternative use: direct combustion and use as raw material for biofuel production (briquettes, pellets). If we use the potential of all bioenergy in Ukraine, the volume of gas replacement will reach the equivalent of 20 billion m^3 per year, which is 2/3 of the country's gas supply needs.

Studies conducted in EU countries indicate that for energy purposes it is possible to use 25-50% of the crop of straw and crop residues of corn on grain, 30-50% of waste of sunflower production without negative impact on soil fertility. For the conditions of Ukraine, it is possible to use the average value of the volumes of field use of up to 30% of theoretical potential of straw of grain crops up to 40% of theoretical potential of industrial crop production wastes (rapeseed, corn for grain and sunflower). There are other alternatives to the energy use of bland agrarian biomass, in particular by the agro-producers themselves: burning bale straw in periodic boilers, with pre-grinding in continuous-action boilers, and heat dryers (on elevators) for grain drying.

When burning pellets of agricultural origin in boilers, it is possible to provide hot water and heat for heating buildings. These processes are provided by

autonomous independent heating systems. Such systems can be of different heat output and can be used for households as well as for large areas or businesses.

It is advisable to transport biofuel agro-pellets (pellets) and briquettes in the economic conditions of Ukraine to a distance of 100-150 km. They do not accumulate moisture, rot or lose their fuel properties during storage. Agro-pellets are most suitable for mechanized (automated) loading into the power plant. The whole process of moving the pellets from the manufacturer to the consumer is done without manual labor.

The use of pellets of agricultural origin for heat supply to household consumers is a strategically important area for achieving Ukraine's energy independence and building an energy-efficient economy,

This reflects the objective processes taking place in the energy sector of Ukraine and in the world, based on environmental, economic and political factors.

CALCULATING BOUNDARY CONDITIONS USING CFD-CODES FOR ANALYSIS OF MODIFICATIONS HAVING IMPACT ON CRITICAL ELEMENTS OF THE NPP TURBINE

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Introduction. Ukrainian NPPs with 1000 MW installed capacity operate two types of turbines running on dry saturated steam: a high speed K-1000-60/3000 turbine and a low speed K-1000-60-1500 turbine designed in three modifications which would require carrying out a comprehensive research to ensure safe operation of power units while maintaining the required safety level. One of research areas is impact assessment of the modification on turbine's critical elements. This paper examines a standard high speed K-1000-60/3000 turbine, that is installed and operated at Rivne NPP Units No. 3,4, Khmelnitsky NPP Units No. 1,2, South Ukraine NPP Unit No. 3.

When assessing impact of the modification on the service life of critical elements of the examined turbine it is suggested to use the pattern as follows:

1. Assessment of a current service life: building a 3-D model; calculation of initial and boundary conditions (using CFD-codes or criterial equations as specified in [1]); determining a nonstationary temperature field in the solid critical element for further calculation of thermal load; strengh calculations (low-cycle fatigue, static loading, etc.) to determine a strengh deformed state; assessment of remaining service life.
2. Service life assessment with account of the modification: adjustment of a 3-D model (if needed); recalculation of boundary conditions; determining the strengh deformed state; impact assessment on remaining service life.

This paper provides for a developed 3-D model of the high-pressure cylinder, as well as CFD modelling to identify boundary conditions for subsequent determining of low-cycle loads for with and without modification cases.

Conclusions. In accordance with suggested approaches a 3-D model was built for the high-pressure cylinder of the high speed K-1000-60/300 turbine. Based on the 3-D model a computer model was developed for the HPC 1st stage in the Ansys-CFX code.

The received results for stationary position illustrated acceptable consistency with the results received in [1] which upon summarizing can be used to receive nonstationary boundary conditions for a subsequent calculation of low-cycle loads.

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SIMULATION OF HEAT-ENERGY AUTOMATED TECHNOLOGICAL COMPLEXES

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Introduction. Imitation modeling (or simply the simulation) of cyber-physical systems is very important component of the 4th industrial revolution. The simulation model of the cyber-energy system is the digital twin that allows you to develop, adjust and upgrade automation tools for heat-energy facility.

Goal of the paper. The main purpose and task of the research is the development and practical implementation of the simulation site for heat-energy automated technological complex (ATC).

ATC consists of an automated technological facility (ATF) and a developed process control system (PCS). PCS software and hardware tools – programmable logic controllers (PLCs) and HMI/SCADA systems.

The urgent task is to test an ATC even before the installation of developed PCS at a real ATF. Traditionally, this is done in two ways: 1) mathematical modeling of ATC; 2) testing PCS with physical (full-scale) modeling of ATF. Modern software technologies of computerization and automation allow you to implement effective simulation modeling of ATC.

Simulation of physical systems – software (computer) modeling that simulates the structure and dynamics of real (physical) systems [1].

The tasks of simulation of ATC are:

1. Modeling of the ATF in Computer Mathematical System (CMS). The ATF simulation should be performed in real time, i.e. in pace with the technological process. Implementing real (not momentary) simulation time requires special mode of CMS operation.
2. Implementation of developed local automation algorithms in the PLC.
3. Implementation of developed supervisory automation algorithms in the HMI/SCADA system.
4. Data exchange between the CMS (i.e. real-time ATF model), the PLC and the HMI/SCADA system should be performed using standard OPC servers (for field buses used in real ATC).
5. Comprehensive ATC modeling: real-time ATF modeling; realization of tasks of controller automation; implementation of supervisory automation tasks; data exchange between ATF model, PLC and HMI/SCADA system; simulation of real perturbations and obtaining real transients; statistical processes analysis.

Thus, the ATC simulation site reproduces (that is, simulates) real ATC structure and dynamics. Real ATF (real-time ATF model in CMS) is simulated. Real PLCs and real HMI/SCADA system are used. Real perturbations and real transients are reproduced.

There are two simulation methods (Fig. 1) – hardware-in-the-loop (HIL) simulation and software-in-the-loop (SIL) simulation. HIL-simulation site and SIL-simulation site differ in the way of implementation of controller automation tasks. HIL-simulation site uses real PLC (hard PLC). SIL-simulation site uses software PLC – soft PLC (real soft PLC or hard PLC software simulator). HIL-simulation site is closer to real physical ATC. SIL-simulation site is mobile and can be used to simulate ATC at computers without using hard PLCs.

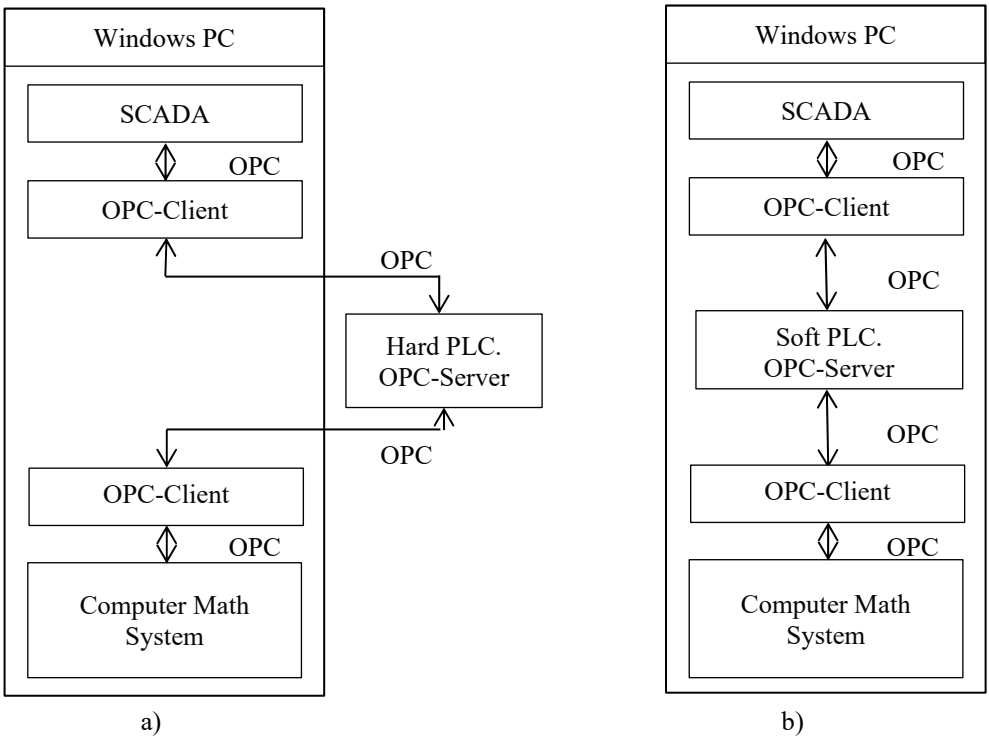

Fig. 1. *Two simulation methods: a) the structure of HIL-simulation site; b) the structure of SIL-simulation site*

SIL-simulation site is usually used for testing the ATC at the stage of technical design. HIL-simulation site is usually used for testing the real ATC at the stage of the modernization of legacy PCS and the replication of actual PCS.

The Department of Automation of Heat and Power Engineering Processes of Kyiv Polytechnic Institute has developed the SIL-simulation site for simulating ATCs. During the development of the site, the following tasks were solved: 1) technical problems – selection of element base and organization of data

exchange; 2) research problems – robustness studies of the simulation model of the ATC; 3) approbation problems – testing the site for typical heat-energy ATF using typical automation regulation systems [2].

Simulink, CoDeSys, InTouch software products, which are recognized as global brands and leaders of relevant industrial automation markets, are selected as the element base of the SIL-simulation site. CMS Matlab Simulink is used to perform real-time ATF simulation. Soft PLC CoDeSys is used to perform control automation tasks. HMI/SCADA system InTouch is used to perform supervisory automation tasks. Native OPC-servers and OPC-clients of selected software products are used to perform data exchange between the software components of the site. Real-time operation of simulating ATF in Simulink is provided with using OPC-client functional blocks READ and WRITE.

Studies have shown that developed SIL-simulation site is robust (from the standpoint of automatic regulation theory), so it can be used to simulate industrial ATC. The SIL-simulation site was tested at classical heat-energy facilities (simulated in CMS) – industrial furnaces, elements of power boilers, engineering systems of life support in buildings and houses. The SIL-simulation site itself was generally a simulation model of the corresponding ATC, including real-time imitation models of ATFs and real-time imitation models of corresponding PCSs.

Conclusions. The SIL-simulation is effective tool for simulation of ATC – testing real developed PCS at programmatically simulated ATF. SIL-modeling allows you to simulate industrial ATF and test the functionality of the developed two-level PCS at the simulated ATF. The effectiveness of the SIL-simulation is achieved with using modern software products – CMS (for example, Simulink), soft PLC (for example, CoDeSys), HMI/SCADA system (for example, InTouch). The technique of SIL-simulation as modern simulation methodology for dynamical systems [3] is recommended for use both in educational process and for testing the ATC at the stage of technical design.

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PHYSICS OF GLOBAL WARMING: ANTHROPOGENIC AND NATURAL CONCEPTS

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Global warming (the so-called "greenhouse effect") is one of the most discussed environmental and geopolitical issues, which has caused protesting environmental movements in the world and discussions among experts about the causes and consequences of climate change.

Widely discussed are both anthropogenic and natural concepts of global warming with the dramatic effects of climate change on the planet and individual regions. At the same time, the anthropogenic concept of climate change is closely linked with the energy sector, mainly with the burning of fossil fuels.

A review of authoritative literary sources is carried out, with an analysis of anthropogenic and natural factors of global warming, including an explanation of processes from atomic physics and atomic collisions that occur during solar-geomagnetic activity.

The state of the problem is assessed, the essence of the greenhouse effect, forecasts of increasing global surface temperatures, as well as scenarios of warming in Ukraine over a number of periods up to 2100 are presented. The results of studies and measures to reduce the greenhouse effect are presented. Ways and directions of increasing energy efficiency in the use of energy resources to reduce greenhouse gas emissions have been identified.

The greatest potential for improving energy efficiency in the use of energy resources, and thereby reducing greenhouse gas emissions, lies in the heat supply sector of the country's housing and communal services. Prospects for further research are related to the development and implementation of organizational, economic and technological innovations in this energy sector. If we talk about forecasts of the development of energy and, accordingly, the nature of the dynamics of greenhouse gas emissions, then according to the “experience of genetic forecasts of world energy” in the coming decades, trends will manifest themselves:

1. Stabilization of national specific energy consumption per capita at a level that is mainly determined by the climatic and geographical factors of countries.
2. A steady and almost linear decrease over time in the carbon intensity of world energy (the amount of carbon dioxide per unit of energy consumption) as a result of changes in the structure of the fuel and energy balance has been observed for more than a hundred years (the transition from coal to oil, gas and more recently – to increase the volume of renewable energy resources).

The latter trend leads to a decrease in the rate of anthropogenic impact on the climate system, and therefore, very moderate changes in the composition of the atmosphere and climate of the planet should be expected. Strong countries of this world (G7, G20) at climatic summits, in the presence of political will, can influence the anthropogenic factors of global warming. Climate change due to solar-terrestrial interaction is extremely difficult. But to the consequences of the combined action of both factors, it is necessary to develop adaptation measures to possible natural changes.

TECHNOLOGY FOR PRODUCING BIOPESTICIDES IN A MICROWAVE FIELD

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Introduction. Insufficient financing of the agricultural sector and increasing environmental standards necessitates the search for new methods of extracts for pest control. The use of modern, resource-saving and safe methods for producing extracts using the intensification of the process of the release of biologically active substances is a topical issue today. The development trend of the world market of biopesticides, where the United States takes the leading place (40% of the global volume), causes an urgent need to develop this issue in Ukraine, which in turn will reduce the purchase cost of products and improve the quality of the plant material grown. The treatment of plants with biopesticides affected by bacteriological or fungal diseases leads to increased land fertility and product quality, improved soil microbiota, and an increase in the yield of main crops. Today in Ukraine, 1,092 drugs are used as pesticides, most of which are banned in European countries. Despite the known dangerous impact on the environment and harm to humans, introducing a ban on the use of chemicals is quite difficult. Due to the development and implementation of a number of biopesticides in the agronomic sphere, the insecticidal and herbicidal spectrum of actions is expected to reduce the use of chemical pesticides and insecticides by 6 times, bringing the share of agricultural enterprises with organic farming to 20%. Thus, the creation and use of highly effective biological products for agriculture is the most important task, the solution of which will ensure the production of environmentally friendly products and the preservation of the ecosystem.

The technology for producing biopesticides is a complex and little studied process, requiring a large number of additional factors. Increasing the efficiency of the process of extracting the target component (TC) from plant material in order to reduce energy costs can be achieved by exposing the extractant to a microwave field [1]. During microwave (MW) extraction, the process of the release of substances is accelerated, which may be the result of the local nature of heating, and the synergistic combination of two transport phenomena: unidirectional gradients of heat and pressure. The intensification of the extraction process under given conditions occurs due to the grinding of the solid phase (plant matrix), destruction of the cell walls by microwave, the inclusion of the molecular

mechanism of internal mass transfer, turbulization of the extractant due to shock waves at the liquid-plant material interface [2].

The technological scheme of a pilot plant for extracts in a microwave field is shown in Figure 1. The installation is a closed variable-action system with the ability to adjust the material feed rate, temperature control and recirculation.

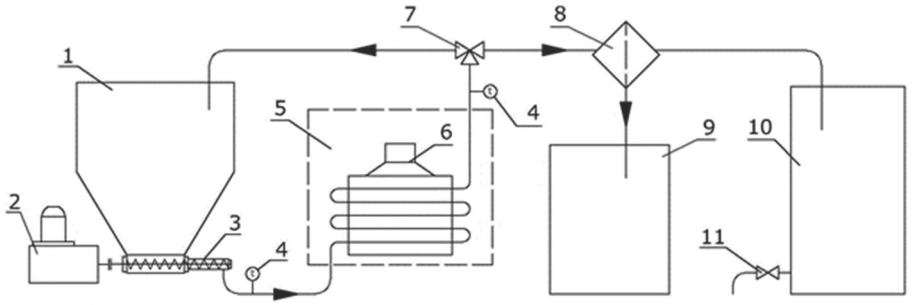

Fig. 1. *Technological scheme of extracts in the MW field: 1 – capacity for supplying material; 2 – electric motor with gear; 3 – auger; 4 – thermometer; 5 – microwave heating chamber; 6 – magnetron; 7 – three-way valve; 8 – filter separator; 9 – collection capacity; 10 – the capacity of the collection of extract; 11 – drain cock*

The feedstock is loaded with a container for feeding material 1, at the bottom of which a screw 3 is located. Using a dispenser, the solvent is fed into the working tank 1 and thanks to the screw mechanism designed for grinding and pushing the plant mass into the microwave heating chamber 5, where the plant mixture is heated to a predetermined level temperature, which is set for each target component based on the reference data. The speed of advancement of the material through the pipe channels is regulated by an electric motor with a reducer 2. At the exit from the chamber 5, the temperature is automatically measured by a thermometer 4, if the specified parameter values have not been reached, the plant material is returned to the material supply tank. To collect the finished extract, a container 10 is used, before it enters the primary filtering process (separation of the solid phase) on the filter separator 8. The installation provides for the use of reusable circulation of plant material, which is associated with the properties of the plant cell, namely, the complexity of the destruction of the plant shell. Another important point is the lack of pre-treatment of the material before loading, namely, mechanical grinding and wetting of the material.

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THREE DIMENTIONAL CELLULAR AUTOMATONS AS A TOOL FOR MAP OBJECTS DISPLAY

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Introduction. Cellular automata are discrete dynamic systems whose behavior is fully determined in terms of local interactions. It was first discovered in the 1940s by Stanislav Ulam and John von Neumann. Although some machines were studied during the 1950s and 1960s, they were not popular until the 1970s and Conway's "Life" games. Interest in the subject has expanded beyond the limits of academic science, due to the increase in computer computing power and availability. The scope of the models of such a system is boundless: from the simplest "naughty crosses" to artificial intelligence. The most studied are two-dimensional cellular automata, such as the game "Life" and the Ant Lang.

The analysis of the obtained results anylysis. However, by this time, three-dimensional cellular automata are still little investigated, although they have tremendous potential for use. The first reason is the complexity of the study of automata and the storage of a three-dimensional state of the machine. In addition, there are no software tools for conducting such research. The reflection of three-dimensional automata, their task and review of the process of their evolution need a special functional that is not provided with tools for working with two-dimensional cellular automata. Therefore, there is a need to create a software tool for working with three-dimensional cellular automata and study their properties with the help of the created program.

The advantages of using three-dimensional cellular automata are their versatility in the application field: from the generation of three-dimensional objects to the simulation of complex molecular processes, physical, chemical phenomena and quantum effects. This flexibility is achieved by the discreteness of the size of the machine and its evolutionary time, as well as the free ability to formulate its own rules of evolution, depending on the context of the study.

Three measurable cellular automata can be attributed to GIS mapping systems because they have implemented a systematic approach to cartographic representation and analysis, the system is almost fully automated and uses the mapping data, uses the techniques of map creation and building the new one, the result is an approximation to the real sites, multivariate and create new types of terrain.

Each stage of the reproduction process of the object is considered as a map image where each pixel corresponds to a corresponding cell of the machine. In the studies considered the generation of cave levels using two-dimensional cellular automaton. For this purpose we used a cellular automaton with two States: solid corresponds to a value of 1 and air corresponds to a value of 0. In accordance with this rule, a cell can

be and the environment that changes its state in accordance with the ratio of air and solids around it. Option connectivity will correspond to the ratio of the solid cells and the air around them, which ensures the further development of the cells.

For example, we present the results of generating a three-dimensional object that meets the following rules:

- the number of living cells corresponds to the number of neighboring cells with the same condition;
- using the ratio of the number of cells up to (2R+1)3, where R is the radius of build object define the state of the cell. If this ratio is less than the parameter of the accession of the cell, the cell changes from a solid to the air condition (Fig. 1).

The object inside is not empty and has the property of inversion that provides the ability to predict its development.

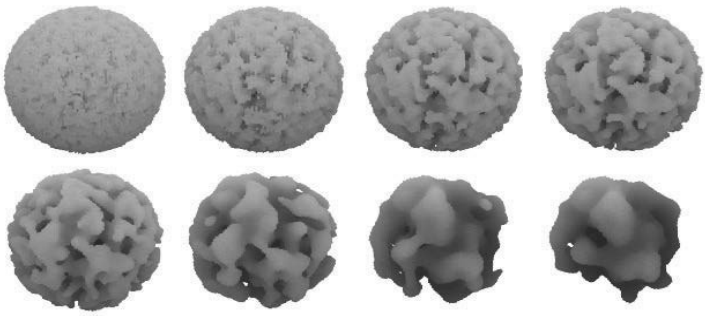

Fig. 1. *Selective iterations with the cave rule*

Density 0.5 degree of attachment 0.5 and radius 1. Left to right: 1, 2, 3, 4, 5, 13, 20, 37 iterations.

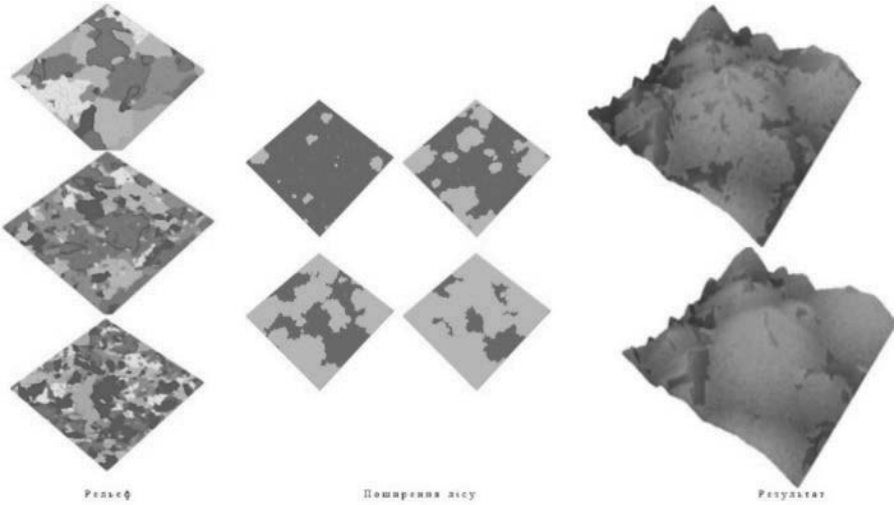

Fig. 2. *Example of landscape generation*

Input – relief image, forest spread image. Output is a three-dimensional landscape model.

To achieve the goal, we must accomplish the following tasks: analyze the existing classifications, rules of generation and visualization of two-dimensional and three-dimensional cellular automata, to define the necessary list of visualization functions for research of cellular automata, design architecture and develop software for the study of three-dimensional cellular automata.

Scientific contribution: methods of investigating the evolution of three-dimensional cellular automata under the influence of external factors have been improved, determination of the criteria for the presence of elements of regularity in a chaotic structure during dynamic development, proposed new ways of generating three-dimensional objects and structures.

The practical value of the results obtained: software was developed that implements the main functions for the implementation of the evolution of three-dimensional automata means of setting the function of influence during the development of a dynamic object; tools for reviewing the condition and structure of the object during evolution have been developed.

Conclusion. With 3D cellular vending machines, it is possible to visualize the evolution of dynamic processes and to generate three-dimensional objects based on their two-dimensional mapping. Using the cellular vending machine to reproduce the object provides the prediction of the global development of the cave, depending on the input local parameters, to track the state of its evolution, got a simplified system for determining the transition to a trivial state, as well as the ability to record and load the state of the cellular machine with the rules.

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IMPROVING ENERGY CHARACTERISTICS OF GENERATORS-THERMOSYPHONS OF ABSORPTION REFRIGERATION DEVICES

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Switching to natural refrigerants, carried out at the moment, attracts the attention of developers to the absorption refrigeration units (ARU) and the absorption refrigeration devices (ARD) based on them.

ARU's working body is a water-ammonia solution (WAS) with the addition of an inert gas – hydrogen or helium. So, ARU are completely environmentally safe and have zero values of the ozone-depleting potential and the potential of the "greenhouse" effect.

ARD with ARU also have a number of unique qualities, such as: noiselessness, high reliability, ability to use several different sources of thermal energy in one device and ability to work with low-quality energy sources. What's more, they provide the entire temperature range of refrigerated storage in domestic conditions (from minus 18°C to 12°C), both in stationary and in transport conditions.

At the same time, the production of ARD in different countries of the world makes up only 5-10% of the total output of household refrigeration devices. Such a structure of production has developed due to their increased (by 40-60%) energy consumption compared to compression analogs.

Theoretical studies of the operating modes of serial ARU produced by the Vasilkovsky refrigerator factory (Kyiv region) with a U-shaped horizontal bubbling rectifier, carried out at Odessa National Academy of Food Technologies, showed that: ARU energy efficiency with burner devices is 3 times higher than with electric energy sources (for the conditions of Ukraine); the main energy losses in ARU are due to the processes of steam generation and transportation of a liquid phase in a generator-thermosiphon (when working on electricity – 72%, with burner devices – 64%).

As results of the pumping thermosyphons' experimental studies, numerical values of the heat input power and the temperature at the output of the generator-thermosyphon, corresponding to the minimum energy consumption, were identified.

The presence of a minimum of energy consumption is explained by the fact that in the studied range of the thermosiphon regime parameters, an optimal ratio of the composition of liquid and vapor phases at the generator-thermosiphon's output is achieved.

Two types of ARD in the “medium temperature” and “low temperature” versions, differing in the composition of the working body (WAS), were taken as study objects.

Experimental studies of the ARU generator-thermosiphon showed a significant (up to 7°C) non-uniformity of the temperature field along the length of its lifting section, which is associated with heat loss to the environment. In such a situation, there is a partial condensation of the steam stream and additional energy consumption during steam generation.

To eliminate heat loss, an additional electric heater was installed on the lifting section of the generator-thermosyphon. In this case, heat was supplied to WAS in a sequential manner – first in the main heater zone, and then in the additional heater zone, i.e. solution passes through, sort of, the first cascade of heat exposure and then the second. The value of the thermal power of the additional electric heater in experimental studies did not exceed 20% of the thermal power of the main electric heater. The total power of the main and additional heaters did not exceed the rated power of heat supply to the ARU generator-thermosyphon. Due to the lack of generally accepted terminology, we have called the proposed method for supplying heat to the ARU generator-thermosiphon as “cascading”.

Reduction in energy consumption in cascade mode of heat supply was 10-12%.

STRUCTURE AND MECHANISM OF ELECTRICAL CONDUCTIVITY OF RESISTIVE COMPOSITIONS FOR THICK-FILM METAL-CERAMIC HEATING ELEMENTS

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The work is devoted to the solution of scientific and technical problems of creating granular resistive thick films used in the manufacture of metal-ceramic heating elements. Using the method of mechanosynthesis, particles of transition metal borides and aluminoborosilicate glass of complex chemical composition were obtained.

The electrical and thermal properties of thick-film metal-ceramic heating elements with a resistive layer based on modified particles of a conductive material are studied.

The heating elements of the new generation are made by the method of thick-film technology, which is widely used in microelectronics in the manufacture of hybrid electronic circuits. Structurally, the thick-film heater is a base (metal with a dielectric coating, ceramics, glass, glass), which is consistently applied through a mesh stencil resistive paste and a dielectric protective coating.

Direct heat transfer from the heating film to the substrate of the heat remover, due to the very low thermal inertia of the design, provides a quick exit of the heating element to the operating temperature. This feature of heaters opens new opportunities for their special use.

The resistive layer is a complex heterogeneous disordered system containing regions with a metallic conductivity and dielectric portions. The electrical conductivity in such systems is a superposition of the metallic type – in the conducting phase and the activation phase – through the interlayer between the particles. The layer plays the role of a potential barrier for current carriers and largely determines the predominance of one of the electromigration mechanisms. Its composition and properties are formed during the interaction of molten glass with oxide films of particles of the conductive phase and doping of the compositions.

One of the main physical parameters that determines the shape of the potential barrier affecting the electrical transfer and its properties is the output of the conductor (conductive phase), the dielectric (interlayer) and the magnitude of the electron affinity in the glass.

In the considered low-ohmic compositions, on the basis of which the heating elements are made, electrical transmission through the layer is carried out by

means of carriers injected from the current-conducting phase. To estimate the level of injection of electrons under the influence of the contact potential difference at the phase-layer interface, a model problem was considered – a spherical particle of a conductive phase surrounded by glass, and the contact potential difference and the dielectric constant of glass ε_r are considered known.

The spatial distribution of electrons injected into the dielectric $n(r)$ can be determined by solving the Poisson equation

$$\Delta^2\varphi = -\frac{\rho}{\varepsilon_r} \tag{1}$$

where: φ – electrostatic potential; $\rho = -e \cdot n$ – charge density; n – is the concentration of injected electrons.

For the selected compositions, the value of n, taking into account the diffusion additive in the contact potential difference was 10^{17}-10^{18} cm^{-3}.

The resulting Poisson equation distribution of the concentration of electrons injected into the interlayer was used to estimate their average mobility (μ_{er}). The structure of the resistor for calculation was represented by a set of structural fragments "particle-layer-particle".

Obtaining composite particles of the conductive phase in the process of preparation and heat treatment of materials allows you to purposefully change the properties of the nanoscale interlayer between these particles, which leads to the possibility of creating a group of materials and heating elements based on them with a complex of new properties.

A technology has been developed for the manufacture of heating elements for voltage supply from 1.5 V to 750 V, from a power of up to several wats to 10 kW, from the specific power of the dissipated power to 50 W/cm^2 and from thermal elements of a square millimeter to sizes that correspond to technological equipment.

The design capabilities of the heating elements and low heat loss during the transfer of thermal energy and the work surface have reduced energy consumption in products up to 30%.

ARC BRAZING OF GALVANIZED PIPES

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One of the ways to protect metals from corrosion is to cover the metal surface with other metal that has much lower chemical activity to oxygen. Zinc is most commonly used as a protective material for steels because it has high corrosion resistance and is inexpensive.

In recent years, there has been a growing tendency of using in construction pipes and light structures with zinc protective coatings. Galvanized pipes are most often used for the arrangement of water supply and fire networks, chimneys, etc.

However, the use of galvanized pipes requires the use of highly efficient means of joining them, which would ensure the reliability of the base metal joining and the integrity of the zinc coating.

Most often, galvanized pipes are joined by threaded connections or arc welding. The use of threaded connections is costly and time consuming, and arc welding leads to the formation of pores in the weld and the destruction of the zinc coating in the welded area, as well as requires additional measures of corrosion protection of the weld and welded area. Therefore, it is advisable to use technology that would provide sufficient strength and quality of joints, as well as maintain a protective zinc coating.

In recent years, leading automobile companies have been using arc brazing to join materials with protective coatings. This technology allows to provide the high strength of joints and does not lead to the destruction of the coating, since the basis of this process is the low investment of heat into the base metal, which leads to the melting of only the additive material [1].

The rapid development of digital technologies in recent years has influenced the creation of a new generation of welding equipment. In particular, the well-known European company FRONIUS has developed a multifunctional welding platform Trans Process Solution (TPS), which allows to realize the process of arc brazing.

Literary analysis of arc brazing technology has shown that most studies of work capability of brazed joints have been performed for put on thin sheet structures, and have been limited to stretching strength determination [2].

In this paper, for comparison purposes, we investigated the stress-strain state of butt joints of galvanized pipes made by arc welding and brazing, which were loaded with an internal pressure of 9 MPa.

The studies were performed on samples of galvanized pipes (with the diameter of 150 mm, wall thickness of 3.2 mm made of 16GS steel) that were connected to the joint. Arc Welding (MIG/MAG) was performed using a CB-08G2C welding wire in a gas mixture (82% Ar + 18% CO_2), and arc brazing using $CuSi_3$ and $CuAl_8$ copper based filler materials in argon medium.

Previous studies by means of the imitational method of modeling showed that when using standard V-shaped edge preparation, the greatest stresses in the pipe samples occur in the welded area of the annular weld [3]. Accordingly, the destruction of samples during stretching tests also occurred in this area. These studies have shown that such geometry of welds does not provide the adequate joint strength. In order to reduce the maximum magnitude of the annular tensions and to eliminate their localization near the weld, it is necessary to change the geometry of the weld and, accordingly, the shape of the pipes' edges. By parametric optimization in SolidWorks has been determined the optimal shape of the edges for brazed pipe joints with the sizes shown in Figure 1.

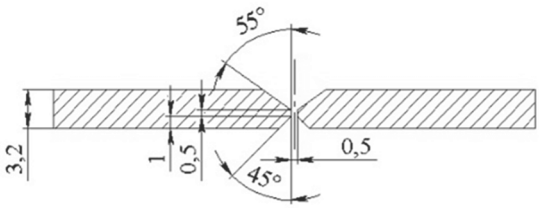

Fig. 1. *Optimal shape and sizes of edge preparation*

Therefore, further studies were performed on samples with standard and optimized shape of edges.

The determination of the efficiency of arc welding for galvanized pipes operating under internal pressure was carried out by the study of the stress-strain state of the weld and the welded area.

Stress measurements were carried out by means of strain gauge method. For this purpose, at 8 points near the annular welded and brazed joints were pasted strain gauges, which were connected to the registration complex "SPIDER-8".

Having processed the obtained numerical data from the registration complex, a graph of the distribution of annular stresses in the surrounding area of the welded and brazed joints of the pipes was constructed at the internal pressure of 9 MPa (Fig. 2).

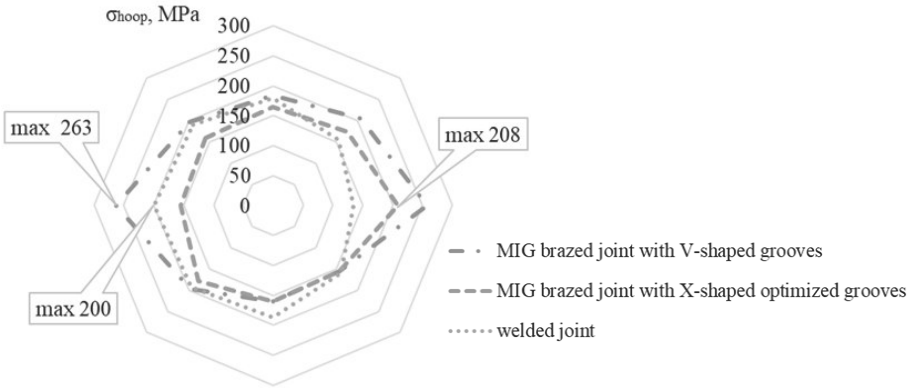

Fig. 2. *Distribution of hoop stresses along the outer pipe wall with the internal pressure load of 9 MPa*

From the diagram of stress distribution we can see that at the pressure of 9 MPa, the maximum value of the hoop stresses is the greatest in the brazed joint with V-shaped edge preparation and is 263 MPa, in the welded joint it is 200 MPa and in the welded joint with the proposed form of edges preparation it is 208 MPa. Conducted researches have shown that the strength of the joints of galvanized pipes made by the method of arc brazing is high enough, almost at the level with welded ones.

Therefore, the use of arc brazing for the connection of galvanized pipes allows providing the sufficient joint strength and high corrosion resistance.

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FEATURES OF A SMALL ELECTRICITY DISTRIBUTION SYSTEM WITH RENEWABLE ENERGY SOURCES

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The development of the Ukrainian energy sector and reforms implementation consist in energy infrastructure elements combination, in particular those related to electricity consumers supply using the potential of renewable energy sources, in certain units of the energy system ensuring the exchange of power between previously separated systems.

According to the Law of Ukraine "About Electricity Market" it is envisaged to create small (closed) distribution systems (SDSs), which are connected to the networks of the main distribution system operator (DSO) or transmission, and which distribute electricity to a certain number of users. In addition, the Code of Distribution System defines the criteria and classification of SDS, in particular as number of consumers for whom DSO may be distributor.

A feature of modern SDS in Ukraine is the simultaneous combination of the Distribution system Code requirements, in particular, regarding the possibility of electricity distribution for 10,000 household consumers.

Each of these household consumers, under the terms of the Law "About Electricity Market", can act as an active market participant, carrying out both consumption and production of electricity. On the other hand, the development of non-traditional and renewable energy sources is considered in Ukraine (especially in the private sector) as an important factor in improving energy security.

Thus, in the context of the DSO, the situation within the SDS can be considered as a problem with a number of constraints with many unknown factors, with the final result (the mode of SDS electric energy consumption) to be at the SDS and DSO distribution networks edge. In fact, these can be integrated energy hubs [1, 2], which can be considered as a generalization or extension of a network node in electrical grid for increasing number of energy sources, given the possibility of their mutual transformation. The development and implementation of approaches to optimize the functioning of such energy hubs is a promising project in the context of sustainable development of Ukraine's energy sector.

It can be concluded that the use of renewable energy sources in SDS users imposes certain limitations on relations with territorial DSO in part of SDS electricity consumption modes formation and can be implemented using probabilistic prediction methods and networks.

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RELASERS WITH ELECTRO-HYDRAULIC RETARDERS AS AN EFFECTIVE ALTERNATIVE FOR SHORT CIRCUIT AND OVERCURRENT PROTECTION

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Introduction. It is known that circuit breakers (CBs) installed in distribution cabinets (DCs), better known as "enclosed circuit breakers", depending on the execution, are designed for [1-3]:

- protection against emergency states of grids: overvoltage and short circuit (s/c) or voltage drop below the permissible level (circuit breakers installed on the grid do not always provide protection against voltage reduction);
- protection of AC motors, as well as for combined installation with other electric devices (CBs can service by grid sections as well as separate motors if CBs are used to operate the wound-rotor motor or starting devices, they must include voltage drop protection);
- to be used as disconnectors for supply and trunk networks.

Overcurrent protection is done by a bimetallic plate, while an electromagnetic releaser provides s/c protection.

The main features inherent in this technical solution of overcurrent protection include:

- relative dependence on ambient temperature;
- inability to quickly switch on again after the CB is triggered;
- unstable time-current characteristics of the CB.

National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" and "E.NEXT Ukraine" offers an alternative solution for the design of CB protection elements [4], which is an integrated overcurrent and short circuit protection at the same time in the form of a releaser with an electro-hydraulic retarder.

A releaser with an electro-hydraulic retarder triggers the CB actuator, which breaks the contact group of the CB when the current exceeding the set maximum permissible value (s/c or overcurrent) is passing through electrical equipment. The main part of this releaser is an electromagnet, whose coil is connected in series with working contacts in the circuit of the operating current. Schematic design of the releaser with electro-hydraulic retarder is shown in Figure 1.

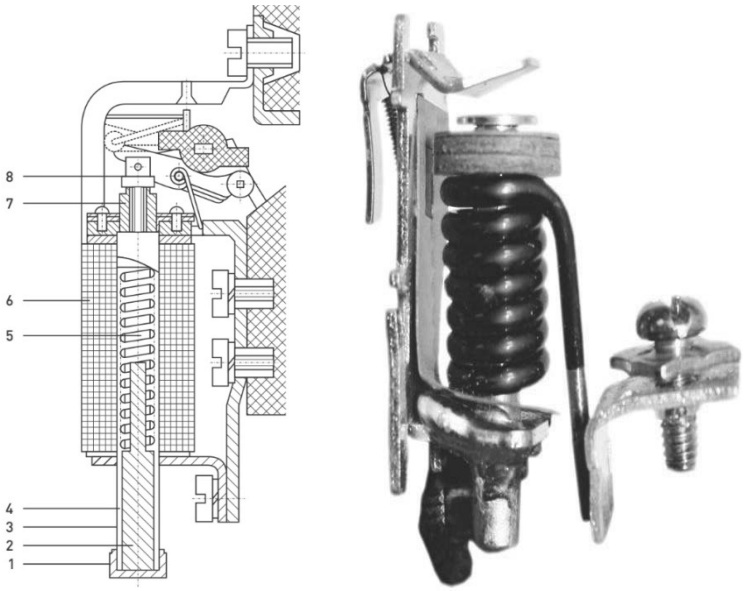

Fig. 1. *A sketch of the CB releaser with hydraulic retardation: 1 – non-magnetic cover; 2 – plunger; 3 – a cylindrical glass; 4 – cavity filled with organosilicon liquid; 5 – rotational spring; 6 – the coil; 7 – pole tip; 8 – armature*

Conclusions. The scientific novelty of the work is in the comparison of two technical solutions for the implementation of overcurrent and short circuit protection, one can conclude that the use of a releaser with an electro-hydraulic retarder gives CBs certain advantages over the use of a traditional releaser – a bimetal plate:

- a relative independence of the releaser on the ambient temperature;
- fast re-activation after being triggered in case of an emergency mode;
- shorter actuation time in the event of an overload (decrease in the performance of the AV, confirmed by repeated practical studies);
- stability of time-current characteristics of the CB;
- instead of two functional elements we have one multifunctional, which leads to a constructive reduction of the internal volume of the structure and weight of the CB;
- resistance to vibration.

Considering the advantages of using a releaser with electrohydraulic retardation in CBs, it should be noted that an alternative technical solution to protection against overcurrent and short – circuit currents shows promise of development in this area of electrical technical engineering.

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EVALUATION OF THE PROSPECTS FOR PRELIMINARY COOLING OF NATURAL GAS ON MAIN PIPELINES BEFORE COMPRESSION THROUGH THE DISCHARGE OF EXHAUST HEAT OF GAS-TURBINE UNITS

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For the transportation of natural gas through pipelines, gas pumping units (GPU) are installed at numerous compressor stations (CS), the energy carrier for which, in most cases, is transported natural gas. 0.5-1.5% of the volume of transported gas is consumed (burned) by the pumping unit drive.

The situation with the replacement of existing equipment with modern equipment is associated with significant investments, on the one hand, and the uncertainty with the transit of Russian natural gas through gas transmission systems of Ukraine in the near future. More promising is the way to increase the efficiency of the GPU cycle through the use of circuits with preliminary cooling of the compressed gas.

The aim of this research is studying the prospects for the application of technology for pre-cooling technological natural gas before compression in a gas pumping unit based on heat-using absorption refrigeration machines.

To analyze the effect of pre-cooling of technological natural gas on the compressor stations of main gas pipelines, gas pumping units – GTK-10I were selected.

The calculation of GPU power consumption and fuel gas consumption at various temperatures of the process gas at the inlet to the supercharger was performed.

The calculation of the operating parameters of the gas pumping unit is performed and the energy and financial prospects of the technology for cooling the process gas before compression in the GPU CS are shown. For the current economic situation (July 2019) in the Ukrainian gas market, the daily decrease in operating costs in standard gas pipelines with a decrease in gas temperature before compression in the gas pumping unit by 20 K ranges from 1800 USD to 3360 USD.

A scheme of a recycling plant based on absorption water-ammonia refrigeration machine (AWRM) is proposed, which in the range of initial data allows to reduce the temperature of technological natural gas before compression by 11-13°C.

The analysis of methods to reduce energy consumption during the transportation of natural gas through pipelines is done.

It is shown that lowering the gas temperature before compression also leads to a decrease in the work spent on gas compression, and cooling tasks can be solved most energetically efficiently using heat-consuming AWRM s with a wide range of cooling temperatures, which use the thermal energy of the exhaust gases for their work.

To assess the prospects of pre-cooling the process gas before compression, the working parameters of a typical gas pumping unit are calculated and, based on the analysis of the calculation results, the energy and financial prospects of such a solution are shown. So, for example, for the current economic situation (July 2019) in the Ukrainian gas market, the daily decrease in operating costs in standard gas pipelines with a decrease in gas temperature before compression in the gas pumping unit by 20 K ranges from 1800 USD to 3360 USD.

To implement the technology for pre-cooling the process gas, an original design of an AWRM-based heat recovery plant has been proposed, which in the range of typical operating characteristics allows to reduce the temperature of the process natural gas before compression by 11-13°C.

The technology for pre-cooling the process gas allows to reduce the temperature level of the compressed gas and to obtain an additional economic effect due to the ACA shutdown, which can be estimated for specific climatic conditions in the region where the compressor station is located.

ENERGETICS: TRADITIONAL AND "GREEN" TECHNOLOGISTS. ARGUMENTATION OF CHOICE

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In the 60-70 years of the twentieth century, the structure of global energy consumption began to change significantly.

The main energy resources were oil, coal, gas (Fig. 1 in [1]) and in the next one to two decades, they will remain in the range of 20-30% of global energy production with a steady increase in the contribution of natural gas and a reasonable differentiation of the energy balance structure across countries and regions [1-3]. At the same time, gas plays a special role, predicting a "golden age" in the coming decades [3].

Since 2000 year, rising oil, gas and coal prices have also increased public protests related to global warming. Emissions from burning fossil fuels, improving the technology of using non-traditional renewable energy sources (NRES); caused a steady tendency to increase the component in the global energy balance of NRES (to 10%) until 2035 year [2]. But in the last decade, the trends in the rate of change in the installed capacities of power plants based on a number of NRES will decreasing, this is especially true for solar and wind power plants. But for geothermal energy, accelerated development will continue.

Not everyone in the scientific community shares a view of the unbridled optimism of introducing "harmless technologies of the future" – the growing role of NRES in global energy consumption – and puts forward moral arguments in favor of fossil fuels. Below is a look at the "green energy" of Alex Epstein – a theoretician in the field of energy and president of the Center for industrial progress.

The future of development of a nuclear energy development program hinders the increased interest of the energy (political) public in the use of renewable energy sources (RES) in the country energy balance. Specialists in nuclear energy and renewable energy find and select arguments in support of precisely "their" industry. Proponents of ambitious actions to include RES in the energy balance recall the tragedy of Chernobyl and Fukushima (Japan, 2011) and list the problems of nuclear energy. At the same time, they rely on the ideology of the "Paris Agreement" (adopted in Paris on December 12, 2015 during the XXI Conference of the Parties to the UN Framework Convention on Climate Change). The implementation of the provisions contributes to the reduction of anthropogenic emissions and contributes to the low-carbon development of economic sectors that make up human life. Opponents, however, recall that RES is "dissipated" energy and build a number of barriers that prevent their widespread use: the selling prices of electricity received when using renewable energy sources significantly exceed

the price of electricity from nuclear power plants, there are technical limitations associated with introducing renewable energy into Integrated Power System (IPS) of Ukraine, etc.

The optimal choice of types of energy resources in the country's fuel balance does not consist in opposing one type of energy source to another, but in their reasonable, well-reasoned techno-economic and environmental combination. Nuclear power in the near future will retain its dominant role in the IPS of Ukraine. Also, RES can multiply their share primarily in the energy balance of autonomous energy supply (housing and communal services, the public sector). At the same time, modern technologies for using RES for energy supply make it possible to create buildings with low energy demand (passive construction) or even buildings with the “zero energy” [4].

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PRACTICAL RECOMMENDATIONS ON REDUCTION OF ANTHROPOGENIC LOAD ON THE ENVIRONMENT OF COAL THERMAL POWER PLANTS (BY THE EXAMPLE OF BURSHTYN TPP)

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Introduction. Soil, surface and groundwater pollution caused by operation of Burshtyn coal thermal power plant (Ukraine) remains one of the main problems as for protection and rational use of water and land resources in Halych district. TPP ash dumps were designed as auxiliary structures, with almost no waterproofing courses and anti-dusting means, therefore, they are considered as high-risk locations. Soil pollution around coal TPP occurs through wind erosion, as well as due to infiltration of its components through soil into groundwater. Ash is the cause of high dust content of air in the specified area due to its physico-chemical characteristics [1]. Every year, the amount of coal burning waste at Burshtyn TPP increases and accumulates. Nowadays, ash dumps are becoming overcrowded and new waste storage areas have not yet been prepared, as land around the thermal power plant is used mostly for agriculture and has priority over other categories. At present, the only solution for storage of new waste is to increase the dam height, which is already operated beyond its design level. However, this measure will not solve the waste accumulation problem either, as there is a threat of floods, typical for this area; they can ruin the dam and wash away all harmful substances from the sludge reservoir into the Dniester River and pollute it. Within the anthropogenic impact areas, unfavourable ecological conditions are formed, related to atmosphere air, soil, surface and groundwater pollution of Halych district.

Ash disposal and reduction of high-tonnage waste, generated due to production activity of this enterprise, is one of the important environmental problems to be solved in Halych region. Ash dumps are considered as a source of water and air basin pollution. The potential mass of dust, discharged into the atmosphere from the ash storage site surface, is 212.8 t/year, the volume of infiltration water through the landfill is 620 000 m^3/year. According to calculation results, obtained by the measures taken to eliminate the environmental pollution consequences, we came to the conclusion that closed ash dumps shall be conserved.

Results and discussion. Studies of the ash chemical composition from ash dump have shown that it contains insignificant residues of nitrogen, phosphorus, potassium and other components, insufficient for plant nutrition. Seeds are poorly rooted in such soils and the natural regeneration process is very slow. Another obstacle to the site overgrowth is the unstable water regime of the soil and its

deflation. Under strong winds, grass seeds can be carried off the soil; as well as sprouts can get covered ash, resulting in death of plants. In dry, rainless weather conditions, winds can take even two-year-old plants with roots from ash dumps. To eliminate these phenomena, it is possible to take measures to contribute to flora renewal on the lands, polluted with anthropogenic waste.

Addition of dehydrated activated sludge to ash will make it possible to obtain soil with the following properties: enriched with nutrients, resistant to wind erosion, capable to retain water. As a result, water filtration rate will decrease, the substrate fertility will improve, favourable conditions for active plant growth will be generated.

Considering our analytical studies and published materials [2], it is proposed to form a humus-accumulated horizon on the ash dump surface from ash and sludge components in the ratio 70:30 respectively. The humus layer of ash and sludge mixture is put on a layer up to 1 m high, made by pouring clay pulp or bentonite clay onto the ash dump surface. The top layer of the humus-accumulated horizon is sown with perennial herbaceous crops.

This technical solution makes it possible to retain of moisture in a gap between a layer of humus soil and a water-retaining layer of clay pulp or bentonite clay to humidify plant roots with in dry season and fix it.

Based on results of studies [3, 4], it can be concluded that the overwhelming weight of heavy metals is retained by the plant roots, the other part is spread onto the aboveground mass (stem, leaves). The absorption rate of heavy metals from soil by plants depends on their growth phase and development. The ability to accumulate heavy metals depends on the biological and ecological properties of plants:

- due to a long period of full growth and maturation of the species, heavy metals will accumulate in plant organs;
- the deeper the root penetrates into the soil, the less heavy metals is absorbed by the plant (but this does not apply to ash dumps);
- with increased water consumption, in plant phytomass, higher concentrations of metals (except Cu, Cd, Pb) are observed.

Based on research results, presented in Table 1, we can conclude, that: by the third year of plant growth, the content of heavy metals in the aboveground phytomass decreases.

Table 1. *Coefficient of biological absorption [3]*

Material	Cu	Zn	Pb	Cr	Cd
Lawn grass (80% of ash + 20% of sludge)	0.155/1.88	0.36/3.61	0.08/1.33	0.18/4.44	0.57/1.26
Lawn grass (100% of ash)	0.09/0.47	4.1/4.6	0.08/0.08	0.22/1.325	0.014/0.008

Most of them are retained by plant roots. It can be assumed that: the formation of complex metal compounds with soil organic substances will promote removal of

excess metal masses by plants from the upper soil layers. In Figure 1 the material balance scheme of ash dump after the proposed environmental measures is presented.

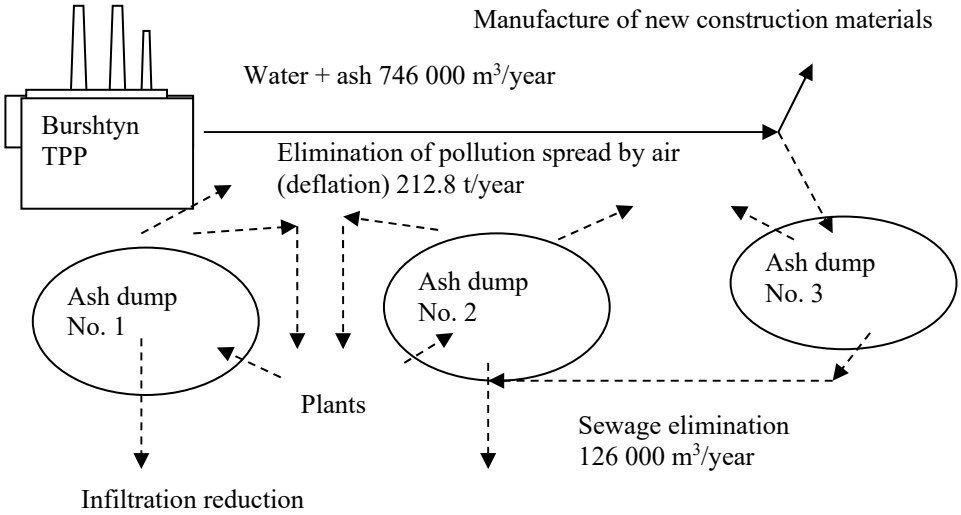

Fig. 1. *Material balance scheme of ash dump after proposal of environmental measures*

Conclusions. The results of the performed studies of the environmental conditions around the thermal power plant facility allowed to determine and evaluate the level of environmental pollution and develop the directions of changes in the ecosystem and predict their development.

Based on theoretical and experimental studies, the following proposals were made to reduce the anthropogenic load on the environment by a thermal power plant (Fig. 1).

The first step to reduce anthropogenic load is to use dry ash discharge in the production of new porous thermal insulation materials. Application of this solution will allow to abandon ash hydrotransport, reduce the amount of pollutant emissions into the atmosphere. With that, processes of polluted water infiltration through the ash dump into groundwater will be eliminated, sewage volume will decrease and, respectively, the condition of water-economic complex of Halych district will improve. The reclamation of ash dumps according to the proposed technology will stop soil deflation.

Therefore, implementation of this project will eliminate the pollution of anthropogenic waste, namely: dusting of ash dumps (212.8 t/year); water infiltration (620 000 m^3/year); sewage pollution (126 000 m^3/year), and elimination of water consumption (746 000 m^3/year).

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JUSTIFICATION OF INSTALLATION OF THE THIRD DERIVATIVE MINI-HPP ON THE BRUSTURIANKA RIVER

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One of the most effective directions of unconventional energy development is the use of energy of small streams employing small hydropower plants. This is explained, on the one hand, by the great potential of such watercourses with the comparative ease of their use, and on the other hand, by the practical exhaustion of the hydropower potential of large rivers.

Annually, total investments in small hydropower facilities are only increasing; in 2018, they amounted to about USD 8.5 bil. The average cost of construction of mini HPP ranges from 1.5 to 2.5 thousand USD per 1 kW of installed capacity [1].

The hydropower potential of Ukraine is used by 60% and this is mainly due to the large Dnieper cascade and other large hydropower plants. The rest of the hydropotential can be realized by installing new, less powerful ones, using small rivers of Ukraine and restoring old capacities of small HPPs.

The object of the study is a cascade system of pressure derivative mini HPPs [2] in Transcarpathian region "Brusturianka 1" with the capacity of 1 MW with a length of the derivation of 750 m and "Brusturianka 2" with the capacity of 1.2 MW with a length of the derivation of 820 m. Total electricity production is 10.4 mil. kW·h/year.

The purpose of the work is to substantiate the establishment of a third mini-hydroelectric power plant – Teresva – in the cascade system of power plants of the Brusturianka River.

For modeling in the RETScreen software environment, the hydro potential of the area and general physical and geographical characteristics of the Brusturianka River were considered. The average annual water consumption is 11.5 m^3/sec.

With the help of Google Earth Pro software [3], the vertical profile of Brusturianka and Teresva rivers was built and the place for installation of the third mini HPP was chosen – Ust-ChChorna settlement on the left bank of Teresva river in Tyachivskyi district of Zakarpattia region. The length of the derivation from "Brusurianka 2" to the planned Teresva station is 750 m. The route of the pressure pipeline runs in a closed type parallel to the right bank of the river and crosses it to the left bank. The location of the station building in relation to the derivation route is taken into account due to the terrain conditions.

According to the graph [4] at a water flow rate of 9.6 m^3/s and a drop height of 10.9 m the two types of jet hydraulic turbines can be used: Kaplan and Francis.

To select the most optimal variant of the turbine in RETScreen 4 [5] software environment, their comparative analysis has been carried out. The maximum water flow through the turbine is 7650 l/s. At use of the hydro turbine of Kaplan type, the capacity was 999 kW with an annual power generation of 6.5 mil. kW·h and Francis type turbine was 850 kW and 5.4 mil. kW·h, respectively. The sum of investments in the construction of the hydropower plant amounted to about 64 million UAH. Both projects proved to be economically feasible, though with a significant difference: the payback period of the mini-hydropower plant using the Kaplan-type hydro turbine was 3 years, and that of the Francis-type hydro turbine was 4 years.

As a result of the establishment of the third mini HPP in the complex of Brusurianka derivation stations, the total annual production of electricity is 16 million kWh/year. At the same time, 63 thousand kWh/year is spent on heating the buildings of the mini HPP and 5.6 mil. kWh/year on obtaining hot water for households, and the rest of 10 million kW/year – for power supply of other equipment in consumer buildings.

Guaranteed stable electricity supply provides an opportunity to improve the environmental situation in the region, as the annual reduction of greenhouse gas emissions is 2564 tons of CO_2.

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ENERGY CONSUMPTION DETERMINATION OF THE HEAT STORAGE DEVICE BASED ON THE PHASE CHANGE MATERIAL IN THE DIFFERENT TEMPERATURE RANGES

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The work is concerned with determining the energy performance of a heat storage device based on a phase change material. Experimental studies were performed with a heat storage, which is made of alloy of magnesium and zinc (Mg – 51% Zn) [1, 2] with a net weight of 143 g and a gross weight of 340 g.

The battery consists of two concentric steel cylinders with the bottom space filled with the alloy. The design of the heat storage device is determined by its purpose. It is used for the continuous operation of the solar dish Stirling UDS-1 [3, 4].

In the course of the experimental studies, the heat storage device was heated to a predetermined temperature (higher than 337°C corresponds to the melting temperature of the alloy) and cooled independently. During the cooling, the heat storage device temperature was measured at four points.

Based on the obtained data, the calculation of the heat storage device internal energy difference as the heat flux to the environment was performed. The heat flux diagram from the heat storage device to the environment was obtained.

The heat storage device cooling process was modeled in SolidWorks software. A model of the heat storage device was developed. A graph of the heat storage device borders temperature is set in the model, which was obtained from experimental studies.

As a result, the air temperature distribution in the area of its contact with heat storage device was obtained and the heat flow from heat storage device to air was determined (Fig. 1). Comparison of the obtained data during simulation with the data obtained as a result of processing the experimental data is performed.

On the basis of the obtained results, the heat capacity of the heat storage device in different temperature ranges (Fig. 2) of its use was calculated and conclusions were made about the peculiarities of the heat storage device operation in conjunction with the dish Stirling UDS-1 unit.

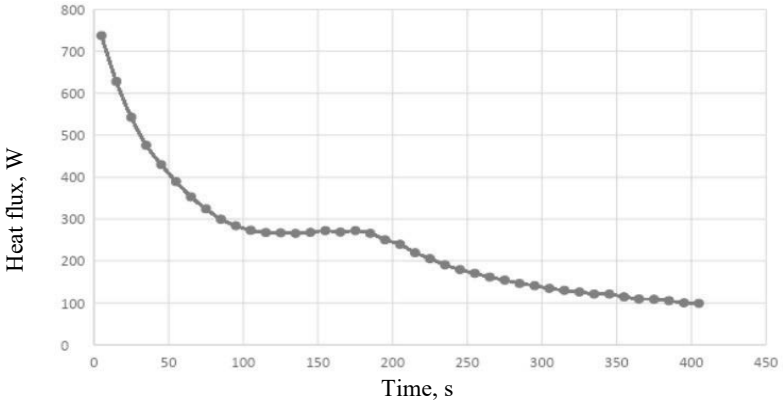

Fig. 1. *Dependence of battery heat loss with time*

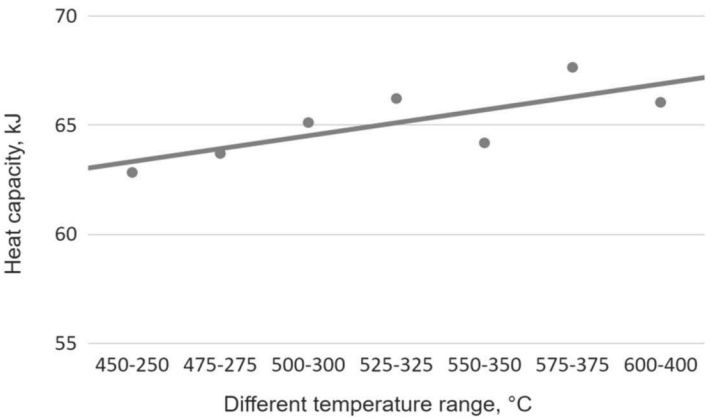

Fig. 2. *Dependence of battery heat capacity in temperature ranges*

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IMPACT OF WEATHER CONDITIONS ON THE OPERATION OF FLUE GAS DUCTS AND THE GRAVITATIONAL VENTILATION IN ROOMS WITH GAS APPLIANCES

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Introduction. Contemporary systems for removing flue gases and used air should be selected so that there is no risk of accumulation of hazardous and harmful substances in human health. The use of energy from the combustion of organic fuel always involves the emission of compounds hazardous to health, which should be removed from the atmosphere of the room as soon as possible. We spend a significant part of our lives in apartments, and even relatively low concentrations of harmful substances can pose a serious threat to health. Efficient ventilation and an exhaust system is a guarantee of the safe use of gas appliances.

In Poland, flats are ventilated mainly in a gravitational way, where the exhaust takes place through gravitational ventilation channels, and the supply through disordered infiltration and ventilation. In this case, air exchange at the recommended level is very difficult to achieve. The efficiency of air exchange, and thus the concentration of harmful substances in rooms, largely depends on changing conditions – i.e. outdoor air temperature, atmospheric pressure, wind strength and direction, as well as the way the rooms are used.

Purpose of work and research methods. The proper operation of ventilation and flue systems depends on many variables whose interaction generates a large number of variants.

The author of the article set themselves the task of examining the impact of weather conditions on the operation of flue gas exhaust systems and ventilation in rooms with gas appliances.

Subject of study. In order to determine the impact of weather conditions on the chimney draft, the work of the ventilation and flue gas system in a 4-story multifamily building located in Koszalin (II wind zone) (PN-EN 1991) was analyzed.

Two apartments located on the ground floor and on the last floor were analyzed. In each apartment there was a 4-burner gas cooker and a gas instantaneous water heater with a maximum power of 23.6 kW.

In the kitchen room, exhaust ventilation is carried out using a brick ventilation duct with a section of 140x140 mm, with a ventilation grille mounted under the ceiling. The air supply is carried out by means of an air grille installed in the door with a cross-section of 200x100 mm.

In the bathroom, the exhaust is carried out by means of a brick ventilation duct with a section of 140x140 mm, with a ventilation grille mounted under the ceiling.

The air is supplied by means of an air grille installed in the door with a cross section of 200x100 mm.

Flue gas discharge from a gas flow water heater via a flue pipe Ø140 mm.

Fig. 1. *Multifamily building with analyzed apartments*

Research methods and assumptions. Research methods. In order to determine the impact of weather conditions, meteorological data was analysed covering the period of 24 months, from January 2018 to December 2019.

In addition, in the last quarter of 2019, the results obtained were compared with the actual state during local visits. For this purpose, the multifunctional meter Testo400 type was used to measure ventilation air parameters.

Results of tests. Abnormal operation of the ventilation system has already been observed at temperatures less than 10°C, especially in rooms located on the top floor.

From the obtained results it can be concluded that with gravitational ventilation it is very difficult to achieve the normative required flow of ventilation air. On 10.10.2019, the ventilation air flow was only 8.52 m^3/h, for the kitchen located on the fourth floor, which with the required 70 m^3/h is only 12% of the required level.

In the channels, reverse air flow was observed even at low outside air temperatures, when the wind was blowing outside at an average speed of 20 km/h with gusts reaching up to 50 km /h (Fig. 2).

Calculations and measurements of harmful substances (combustion products) in rooms with installed gas devices with an open combustion chamber, show that in disturbed ventilation conditions the level of pollution increases rapidly, exceeding the permissible standards (Rozporządzenie 2018, Zarządzenie 1996).

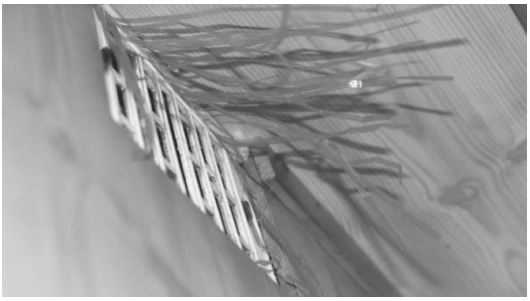

Fig. 2. *Backward flow of ventilation air from the ventilation sheet in the bathroom on the ground floor*

Conclusion. The efficiency of air exchange, and thus the concentration of harmful substances in rooms, largely depends on changing weather conditions – i.e. outdoor air temperature, atmospheric pressure, wind strength and direction,

It is very difficult to achieve the normative required ventilation air flow with gravitational ventilation. In adverse weather conditions it can be as low as a few percent of the required level or reach zero values,

Abnormal operation of the ventilation system has already been observed at temperatures less than 10°C, especially in rooms located on the top floor,

If during the combustion of natural gas the amount of air supplied is less than required, a negative pressure will be created in the room and the air flow in the ventilation ducts will be reversed, ventilation will not be able to discharge combustion products whose concentration in the room can significantly exceed the permissible standards,

In the literature, there is no data relating to changes in the temperature gradient in the exhaust gas flue. It is planned to expand the research related to this issue,

It is planned to supplement the experimental research with the analysis of data obtained with the help of programs for numerical modelling of CFD flow. Pre-construction tests could verify the relative location of buildings and help prevent unfortunate accidents due to poisoning.

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[3] Zarządzenie Ministra Zdrowia i Opieki Społecznej z dnia 12 marca 1996 r. w sprawie dopuszczalnych stężeń i natężeń czynników szkodliwych dla zdrowia, wydzielanych przez materiały budowlane, urządzenia i elementy wyposażenia w pomieszczeniach przeznaczonych na pobyt ludzi.

[4] Rozporządzenie Ministra Rodziny, Pracy i Polityki Społecznej z dnia 12 czerwca 2018 r. w sprawie najwyższych dopuszczalnych stężeń i natężeń czynników szkodliwych dla zdrowia w środowisku pracy.

ENSURING COMPLIANCE WITH QUALITY STANDARDS FOR THE CURRENT AT THE POINT OF CONNECTION TO THE NETWORK OF THE COMBINED PHOTOVOLTAIC ELECTRIC POWER SYSTEM OF THE LOCAL OBJECT

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Combined systems for local objects with photovoltaic batteries (PV) and connecting to a distributed AC grid (DG) of 0.4 kV are widely used. Improving the efficiency of such systems is achieved through the use of multifunction converter units (MCU). Therefore, at the point of connection of the load (including non-linear) of the local object and MCU to the DG, close to 1 coefficient power is maintained when using the equipment around the clock. THD_{i1} of DG current i_1 in accordance with IEC standards (IEEE Std 519-1992, 1547-2018) for objects with distributed generation sources should not exceed 5%.

On the other hand, for general purpose networks, a standard is applied (EN 50160: 2010), which allows non-sinusoidal voltage ($THDu_1 \leq 8\%$) and normed its harmonic composition (up to the 40th harmonic). And here there is a certain contradiction that needs to be solved, since this cannot but affect the quality of the current at the common connection point, even with a linear load.

Purpose of the work. Ensuring compliance with the IEC standards of quality indicators of current at the connection point of the CU of a local object with a photovoltaic battery to the DG in the entire range of the DG current by improving the structure of the MCU current control loop.

A single-phase MCU with a bridge grid inverter with a unipolar PWM in the mode of a current source is considered. Structure of single-phase CU (Fig. 1) containing: bridge AVI with output reactor L1 and PV with voltage converter VC (PV+VC), that supports a voltage setpoint U at the input of the AVI. AVI is connected to the DG with voltage $u_1 = U_{1m}\sin\omega t$ (U_{1m} – voltage amplitude DG, $\omega = 2\pi f$ – angular frequency, $f = 50$ Hz) and load. The load is active-inductive and non-linear (unmanaged rectifier). Capacitive filter is used to suppress higher harmonics at common point of connection to DG (C_F with a minor R_F). So, we have LC – filter, and given the inductance of the DG LG is actually an LCL – filter. Resistor R_F designed to reduce the quality factor of the filter (reduction of fluctuation). Appropriate sensors are provided for measuring currents and voltage (CS i VS).

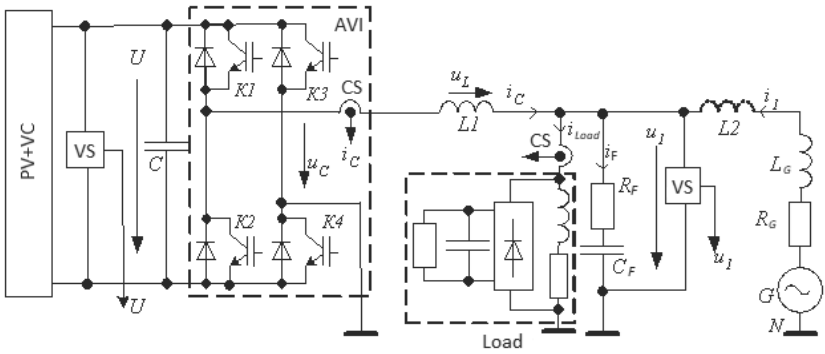

Fig. 1. *The structure of the power circuits of the single-phase CU of a combined electric power system*

It is proposed to use a compensating link for the capacitor current of the inverter output filter for the channel of forming of the reference of current value. Are justified the output filter parameters of a grid inverter. Taking into account permissible values of DG voltage harmonics, the voltage value in the DC link of the MCU is determined.

The Matlab model of the system "DG - MCU with PV – local object load (non-linear and active-inductive)" was developed. The simulation results confirm the efficiency of the obtained solutions. In the case of a non-sinusoidal voltage DG, the value THD$i_1 \leq 5\%$ is provided at DG current values (0.1-1.0) from the maximum.

RESEARCH AND DEVELOPMENT OF THE INSTITUTE OF ENGINEERING THERMOPHYSICS NATIONAL ACADEMY OF SCIENCES OF UKRAINE IN THE FIELD OF ENERGY EFFICIENCY IMPROVMENT IN BUILDINGS AND STRUCTURES

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Recently, in the IET NAS of Ukraine, a scientific and technical direction of the institute's activity has arisen and is actively developing, associated with theoretical, experimental and applied research in the field of increasing the energy efficiency of buildings. This is due to the fact that Ukrainian old buildings and their outdated engineering energy supply systems characterized by significant energy losses. In the building sector overall energy balance of Ukraine, a significant amount of energy resources is used inefficiently, comparable to the energy consumption of the entire industry.

The results obtained in important area of energy efficiency improvement.

In theoretical research: conducted research using commercial packages and developed original computer programs on temperature fields, wind flow fields and insolation fields are studied for single buildings and groups of urban buildings; the complex effect of insolation on the thermal regime of the building is investigated; comprehensively studied the temperature-humidity and mechanical stress state of thermal insulation on the facade walls of the building, depending on climate parameters; investigated the processes of heat transfer and infiltration through translucent structures; effects of heat transfer and hydro (aero) dynamics in porous media (for example, in building materials and/or in soil masses) are considered; investigated the coolant flows instability in the heat power equipment elements; research was conducted and methods developed for calculating the buildings heat supply systems, individual heating units control systems, warm water floors, soil heat exchangers, a buildings warm air curtain, and geothermal ventilation systems; modeling of agro-pellets in burners of domestic boilers combustion is carried out.

In experimental and applied research: a passive-type experimental house was designed and built as a full-scale stand for studying the thermal properties of heat-insulating building materials, building structures and innovative resource and energy supply systems on 4 floors (area 306 m^2) in the real climate of Kyiv; the specified building is brought to the level of “zero energy” type, constant energy monitoring of its operation is carried out; based on insolation and wind energy, an electrical supply system was created; on the basis of natural and specially accumulated energy of soil mass, a heat-pumping system for the building was

created, which is backed up by a solid fuel boiler with an innovative burner for the use of plant agro-pellets; a polygon of various (10 types) and socially accessible adhesive thermal insulation of wall facades was created and successfully operated in a real climate; a polygon of various (20 types) energy-efficient window structures was created and successfully operated in a real climate; energy-efficient windows were also developed; 4 original individual heat points were created to optimize the weather-dependent heat supply of the institute's buildings; created several innovative heat pump systems for heat supply of the premises of the institute; a landfill ground heat exchanger type has been created, such as vertical wells and horizontal horizontal multi-pass or multi-loop shallow-type structures for coolants soil-liquid, soil-water-water and soil-air; 2 pyranometers have been created and are successfully operating to measure the insolation of various orientations and the light beam incidence geometry; a whole series of various instruments for the thermal measurement of the characteristics of buildings, thermal insulation materials and fuels has been developed.

For structures: modeling was carried out and fire resistance of the main football stadiums of Ukraine was calculated; based on the simulation, the ventilation system of the Kyiv metro underground branches were optimized; modeling of heat transfer, air-humidity conditions and dust distribution fields for the safe operation of the confinement of the Chernobyl nuclear power plant machine room building was carried out.

HEAT AND MASS TRANSFER IN THE DIRECT CONTACT HEAT EXCHANGER OF GAS-DROPLET TYPE

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The problem of energy saving and efficient use of energy resources is one of the biggest challenges facing the energy sector today. One of the ways to solve this problem is to develop a complex of measures for utilizing secondary energy resources – heat of the flue gases exhausted from technological and power equipment.

Direct contact heat exchangers are widely used for heat recovery from exhaust gases of boilers and gas turbine power plants. This technology provides deep cooling of exhaust gases and, as a result, increasing efficiency of utilization of fuel heating value. There is a wide variety of designs of contact apparatus. The most common are baffle tray devices. Most of such apparatus have some disadvantages and need further heat transfer enhancement. Droplet contact devices with various sprayer designs, including centrifugal nozzles, are of great interest for such purpose. The intensification of heat transfer processes in such devices is achieved with the help of increasing the interfacial surface of thermal contact which leads to increase of the intensity of heat transfer per unit volume of the apparatus.

In droplet direct contact heat exchangers heat from the exhaust gases is transferred to the liquid through the surface of numerous droplets during direct contact of the fluids which significantly improves the conditions of heat and mass transfer and also reduces the nitrogen oxide pollution (NO_x) due to absorption. However, to the best the author's knowledge most of the works are devoted to experimental studies of processes of heat transfer between a single drop of water and steam-gas mixture. Investigations devoted to the drop ensemble may be regarded as practically absent. In engineering calculations of such devices the actual surface of the droplet of sprayed water is replace with a conditional one using the cross-sectional area of the contact device. In this case value and application of the obtained results are reduced. Taking into account the provided analysis it is relevant to investigate processes of heat and mass transfer in the system "steam-gas mixture – ensemble of droplets of sprayed water" of droplet direct contact heat exchangers referring to the actual contact surface of phases [1].

The main purpose of the work is to improve the methods of calculating coefficients of heat and mass transfer during the dynamics of interaction between droplets of liquid sprayed by means of a mechanical centrifugal nozzle and the steam-gas mixture in the droplet direct contact heat exchanger.

The object of the study is the mechanism of interaction of liquid droplets and steam-gas mixture in a gas-droplet system of direct contact heat exchanger with a centrifugal liquid sprayer.

The subject of the study is the influence of the mode parameters on the characteristics of the spray torch and heat and mass transfer under conditions of cooling steam-gas flow with steam condensation.

Coefficients of the transfer processes are determined on the base of experimental methods of investigations of condensation of water vapor from steam-gas mixture on the surface of liquid droplets [2].

Experimental studies of the transfer coefficients are carried out on a specially designed experimental facility. The intensity of the transfer processes is calculated on the basis of the following parameters: preliminary determination of the real contact surface of phases, measured values of the droplets temperature, dry and wet bulb temperature of steam-gas mixture after the cross section of the contact chamber, flow rate of the fluids.

The reliability of the obtained results is confirmed by comparing the obtained results with the results presented in the published works.

Conclusions:

1. Experimental data of the transfer coefficients from the steam-gas mixture to the water droplets sprayed with centrifugal nozzle have been obtained as a function of the operating modes of direct contact heat exchanger.
2. Generalizing dependences for the determining of average coefficients of heat and mass transfer have been obtained which are suitable for the development of engineering calculation method of droplet direct contact heat exchangers. Such dependencies take into account conditions of development of transfer processes in the real gas-droplet system of the heat exchanger as opposed to existed data for a single droplet.

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THERMODYNAMIC ANALYSIS OF PERIODIC OPERATION AMMONIA-WATER ABSORPTION REFRIGERATION UNITS IN ATMOSPHERIC WATER GENERATION SYSTEMS

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It is a common knowledge that one of the most valuable resources in the future of our planet is going to be fresh water, and the demand for water resources is already one of the main factors in global logistics of contemporary world, and this trend will only grow in the foreseeable future.

One of the developments in water production technology is mechanical air dehumidification – condensation of water vapor on the surfaces with a temperature below the dew point. In this case, there are great prospects for the methods associated with the work of independent generators of cold – chillers that are guaranteed to provide the temperature below the dew point temperature. A necessary condition for operation of compression refrigeration machine is the availability of electrical energy. At the same time, the majority of countries facing water scarcity are limited in energy resources, too. Often the readily available source of energy in there is the sun.

In this regard there have been developed original schemes of absorption water-ammonia refrigeration units of periodic operation (AWRU PO) based on solar collectors, which differ with autonomy and independence from the sources of electrical energy, and unlike heat-analogues (steam jet and lithium-bromide absorption) can be operated with air cooling of their heat-dissipating elements.

The method of thermodynamic calculations and analysis of AWRU PO cycles and of the design for atmospheric water generation system. The dependencies between the refrigerating capacity of periodic operation AWRU and operating parameters (composition of water-ammonia solution, the temperature of the heating source and the ambient temperature of the environment).

It is shown, that:

1. Increase in the temperature of the heating source from 65°C to 95°C leads to minimum temperature in the cooling zone decrease from 7°C to minus 17°C;
2. By increasing the outside temperature, the refrigerating capacity of AWRU PO is decreased.
3. Low-temperature ambient air enables attaining the maximum value of refrigerating capacity of AWRU PO by increasing the amount of ammonia in the generation zone initial composition. Thus, better value of refrigerating capacity can be obtained at 25°C temperature of atmospheric air by increasing the proportion of ammonia from 0.3 to 0.5, and this also enables lowering of the heating temperature from 95°C to 65°C.

Conclusions. By increasing the temperature of heating source, the proportion of ammonia in the G-A zone is reduced, allowing to obtain higher potential capacity of absorption process during the cooling phase, i.e. to increase the specific cooling capacity of AWRU PO and the performance by water extraction from the air. Since the temperature rise of the heating source from 65°C to 95°C, minimal temperature in the cooling area decreases from 7°C to minus 17°C.

When the ambient air temperature increases, the specific cooling capacity of AWRU PO decreases, and this tendency is especially noticeable at higher ammonia fraction in the generation area.

The performed estimation of specific cooling capacity of the AWRU PO has shown that it increases along with the temperature of heating source, and at lower ambient air temperatures, this trend is more obvious.

At low ambient air temperature, the maximal values of specific cooling capacity of the AWRU PO can be obtained, by increasing the amount of ammonia in the generation area.

BUILDING HEAT STORAGE SYSTEM BASED ON THE USE OF RENEWABLE ENERGY SOURCES AND NIGHT FAILURE OF POWER CONSUMPTION

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Introduction. According to "Ukrenergo", the gap between the daily peak and the night "failure" of electric load in winter reaches 7000 MW. This is equivalent to the operation of 7 nuclear power units with a capacity of 1000 MW each. It is known that in the field of energy supply of the population during the day there are two peaks in the growth of energy consumption: morning – from 6.00 to 9.00 – an increase in electricity and heat consumption due to an increase in hot water consumption, and evening is especially sensitive – from 16.00 to 21.00. The period of failure of night power consumption occurs from 23.00 to 6.00 hours of the day when there is a decline in electricity consumption due to inefficient operating modes of industry, transport and other sectors of the Ukrainian economy at night. The main way to rationalize the regimes is to make changes to optimize the daily load schedule through the use of energy management measures by the end user. By reducing the volume of night dips, it is possible to achieve significant harmonization and improve the existing situation with a lack of maneuvering capacity.

In recent years, among alternative options, primarily for large cities, electric heating with night heat storage and electric heating of the coolant at night in district heating systems have been considered. In both cases, the effect of equalizing the daily schedule of the electric load of the combined energy system of Ukraine will be achieved, which will favorably affect its work due to a more complete load of Ukrainian nuclear power plants that produce electricity at the lowest cost compared to other types of generation. Another positive aspect of the use of electric heating is the saving of natural gas. Thus, carrying out work on the creation and study of the accumulation system of electric heating, its effective automatic control is an actual task.

It is proposed to create an original electric heating system, which is designed in such a way that power consumption occurs only at time intervals with a minimum load and at a reduced rate, and the required temperature regime is maintained in each building's room (possibly changing during the day and week). The use of thermal monitoring sensors for each room individually significantly increases the energy efficiency of the system. The development of an energy-efficient electric heating system requires a highly efficient thermal accumulator (accumulation of heat at night and extraction during the day), automatic control systems, as well as the creation of a methodology for calculating the power of an electric boiler, a heat

accumulator depending on the characteristics of the room and the required temperature regime. Charging the heat accumulator is made when the electric boiler and a circulating pump charging circuit, only at night time the preferential tariffs. Weather regulation of the temperature of the coolant supplied to the heating devices, an energy-saving mode of operation and the necessary heating loads of the system depending on the outdoor temperature, emergency options for the functioning of the system are provided. When implementing the accumulation heat supply system of a building based on the use of renewable energy sources and a night power failure, the following results are achieved:

- reducing the nightly failure of electricity consumption in Ukraine, ensuring a more stable and safe operation of the country's nuclear power plants, as the main electricity generating capacities of Ukraine for today and in the near future;
- the creation of an alternative innovative heat storage system for electric heat supply of buildings and facilities (heating, hot water and air conditioning), its optimal functioning during the day, the possibility of rational operation in the event of an accident for 2-3 days due to heat accumulation;
- reduction of peaks (morning and evening) of hot water supply, peak of night-time conditioning;
- the economic attractiveness of this heat supply system, and therefore its demand for housing and communal services and the population.

When operating a system with a three-zone electricity tariff, the resulting heat cost is less than the cost of: heat from solid fuels (coal, biofuels), heat obtained by the use of heat pumps, significantly less than the cost of heat when used natural gas fuel. This leads to:

- improving the tariff policy in the field of heat energy;
- improving the ecology of the environment;
- an increase in the utilization factor of the installed capacity of nuclear power plants as the basis for electricity generation in Ukraine (according to the new energy strategy of Ukraine until 2035);
- easing of social tensions;
- strengthening the country's energy security.

CFD SIMULATION OF NITROGEN OXIDE GENERATION IN THE BOILER OF DKVR E-10-13 WITH JET-NICHE SYSTEM

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Today, there is an urgent need to save scarce energy, so burners are required to expand the power limits by reducing the starting pressure of the fuel, as well as increasing the unit power at the normative indicators of emission characteristics, as well as the efficiency of fuel burnout. Thus, for understanding the mechanisms of formation of harmful substances and the ability to predict their emission at a quantitative level when changing the ratio of fuel and oxidant in the mixture are one of the main issues of ensuring environmental standards. It is known that to achieve the required NO_x and CO emission levels, it is necessary to use those burners that have sufficient combustion zones, each optimized for a particular mode of operation and operating in a very narrow temperature range (1650-1900 K) [1-3].

The mentioned low levels of harmful substances can be achieved by using jet-niche technology of combustion (SNT), which is developed on the basis of research [2] conducted in the Laboratory of combustion of TEF of Igor Sikorsky KPI. This technology is a universal technology for combustion of gaseous fuels, the introduction of which in the industry and further study of its features is engaged in TOV «Production Association» Jet-niche technology» (Kiev) [3].

The results of CFD simulation of combustion processes of gaseous fuel in the furnace of steam boiler EKVR E-10-13 are presented in the paper of based on a mathematical model using the Ansys-Fluent application suite. The simulation used the standard technique for predicting NO_x formation by the means of this software. The subject of research is the volume of the boiler furnace type DKVR E-10-13. As a burner which is used by the SNA with the gas distribution of circular jets, fed into the stream of oxidizer perpendicular to the system of jets.

To analyze the effect on the combustion process and the formation of NO_x, the air mode factor a was chosen as the main mode parameter. Depending on *a*, a further visualization of the mean velocities and temperatures of the mixture as well as the distribution of nitrogen oxides was carried out. In the work, the studies were performed for 5 values of the coefficient of excess air: 1.12, 1.27, 1.62, 2.0 and 3.62.

The CFD model verification is performed by comparing the experimental measurements of the mixture temperature along the heat pipe, indicating that the deviations of the CFD simulation data from the experimental ones do not exceed 10%. As for the range of coefficients of excess air from 1.12 to 3.62, the temperature level measured experimentally varies from 1220°C to 860°C, whereas the calculated data change from 1320°C to 720°C.

In the conditions implemented in the work, namely for the specified range of coefficients of excess air a and methane velocities w_{gaz} = (61.5-20) m/s and air w_{air} = (13.9-12.2) m/s, that the developed CFD model accurately predicts the behavior of nitrogen oxides. The deviation of the CFD simulation data from the experimental data for a = 1.27-3.62 does not exceed 8%.

The studies determined the distribution of temperature and velocity of the gas in the furnace volume, as well as the concentration of combustion components. The simulation results indicate that the use of SNT provides a fairly uniform temperature field along the length of the furnace and reduces the concentration of nitrogen oxides to 125 mg/m^3 at the exit of the furnace.

The results obtained indicate the energy efficiency of the investigated flame stabilizer. As a general conclusion, it can be stated that computer simulation allows preliminary, fairly accurate estimation of the emission characteristics of burners when burning gaseous fuels. Numerous calculations can be used in the design of energy-efficient gas burner equipment.

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ROBUST INTERCONNECTING REGULATOR FOR INCREASING RELIABILITY OF GAS TURBINE GENERATOR IN BIOGAS POWER PLANT

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Changes of turbine torque and voltage variations from generator side cause that a shaft of a gas turbine generator in a biogas power plant is constantly affected by alternating torque forces. That, in turn, leads to the gradual wear of individual parts of the shaft due to the fatigue damage accumulation as a result of torsional oscillations and in some cases to accidents with shaft destruction [1]. It should also be noted that the currently used control systems of turbine speed and generator excitation are adjusted separately and do not provide proper damping of shaft torsional oscillations, sometimes even increasing them. In connection with this, the authors have proposed a method for the synthesis of a robust interconnecting regulator, which is able to coordinate the operation of these regulators, allows reducing dangerous torques in the cross sections of the shaft and therefore extending the life cycle of the gas turbine generator. The need to ensure the robust properties of such a regulator is based on the uncertainty conditions in which the gas turbine generator operates, as well as the presence of unmodeled dynamics in the mathematical model of the gas turbine generator, on the basis of which the regulator is synthesized.

The controlled plant includes a gas turbine, a generator, a turbine speed governor, and a generator excitation controller. The mathematical model of the plant is formed on the basis of physical principles in the form of a system of ordinary differential equations [2], and a linear transfer function is formed on the linearized system near an operating point. This transfer function in the regulator synthesis procedure is extended by an additive uncertainty with a weight function that can be determined by a special identification procedure.

The robust interconnecting regulator is synthesized by optimizing the H_∞-norm criteria of robust stability with the simultaneous placement of the closed-loop transfer function poles of the control system in a special area to ensure the proper level of damping of the shaft torsional oscillations [3]. The synthesis procedure uses an apparatus for solving systems of matrix linear inequalities. The result is a regulator matrix transfer function which has higher order than the controlled plant. The regulator model order can be reduced without significant loss of its properties by means of the special algorithm with the use of Hankel singular values.

Computer simulation of the control system with the synthesized regulator was performed using MATLAB & SIMULINK software in different operation modes of a gas turbine generator. The simulation showed the efficiency of the robust interconnecting regulator during transients.

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THE CONTACT COOLING EFFICIENCY INCREASE OF GAS TURBINE PLANT'S CYCLE AIR

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Introduction. The energy-saving technologies are used to improve the auxiliary systems work of gas turbine plants (GTP) [1, 2]. They ensure of the low-grade heat utilization of secondary energy resources and contribute to the improvement of the GTP fuel and energy efficiency. Such technologies include contact cooling of the gas turbine plant cycle air [3], which is based on the process of thermogasdynamic compression [4]. A feature of this process is an increase in pressure as a result of the instantaneous evaporation of injected liquid into the airflow accelerated to the speed of sound. The process of contact cooling cycle air GTP is taken place in a two-phase jet device. This device was named an aerothermopressor (Fig. 1). Besides deep air cooling in the aerothermopressor, there is also an effective spraying of liquid in the airflow and the pressure of this flow is increased.

To ensure the highly efficient operation of the aerothermopressor, it is necessary to determine rational parameters of the working process organization with an appropriate design of the flow part.

An analysis of a number of typical models was carried out using computer CFD modeling to determine the main characteristics of the aerothermopressor of the GTP cycle air cooling system. The simulation of the aerothermopressor operation to cooling cycle air of the gas turbine LM6000-PC SPRINT from General Electric Company (N_e = 46.800 kW, g_e = 0.171 kg/(kW·h), η_e = 41.8%) were considered. The SPRINT system has increased the turbine's output power in ISO conditions by more than 8%.

The following basic geometric characteristics of the aerothermopressor model flow part were adopted: aerothermopressor length (at (L/D) = 5) L_{atp} = 1782 mm; confuser inlet diameter D_{c1} = 260 mm; confuser convergent angle α = 30°; working chamber diameter D_{ch} = 100 mm; working chamber length L_{ch} = 500 mm; diffuser outlet diameter D_{d2} = 260 mm; diffuser divergent angle β = 5°; droplets diameter 5-40 μm.

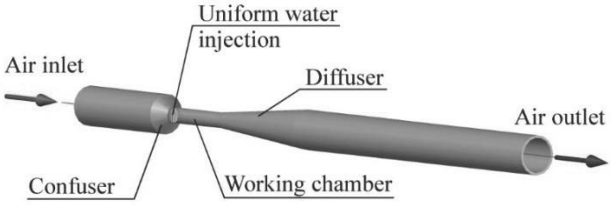
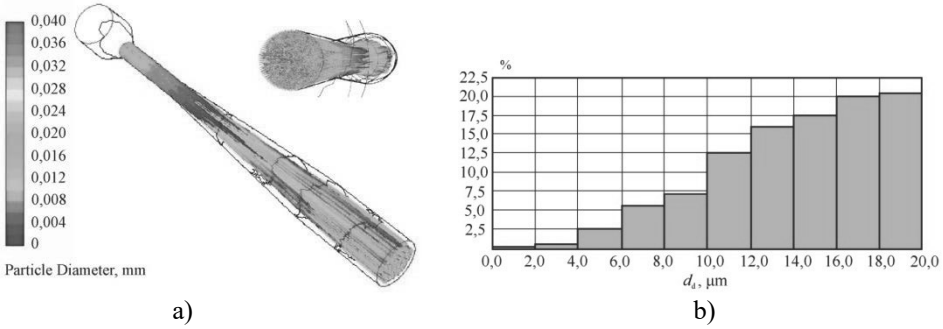


Fig. 1. *3D model of the aerothermopressor*

Water was injected in excess to ensure maximum pressure increase as a result of thermogasdynamic compression. To ensure minimal separation of droplets on the blades and the compressor housing the water flow dispersion at the diffuser outlet must be up to 10-20 microns. Such of flow dispersion creates the necessary conditions for the isothermal compression process in the high-pressure compressor of a gas turbine engine.

Results. At the first stage of the study, a "dry" aerothermopressor was modeled (without water injection into the working chamber). It was found that the decrease in airflow pressure due to friction losses was about 8%. At the second stage of the study, a simulation of the aerothermopressor with water injection into the flow part was carried out. As a result of thermogasdynamic compression, the increase in the relative air pressure at the outlet of the aerothermopressor has been 1.5-4.0%, and the temperature of the cooled air has been decreased by 130 degrees. In order to ensure effective air compression in the gas turbine compressor, incomplete evaporation of water in the aerothermopressor was considered. It made it possible to obtain finer water spraying at the diffuser outlet, while the average diameter of the water droplet decreased from 40 μm to 20 μm (Fig. 2).

Contact cooling of cycle air in the aerothermopressor reduces the work of the low-pressure compressor and at the same time increases the amount of working fluid in the cycle. This in turn will increase the efficiency of gas turbine plants.



a) b)

Fig. 2. *Dispersion distribution of water droplets in the aerothermopressor flow part (a), the ratio of the water droplets size at the aerothermopressor outlet*

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COMBINED HEAT PUMP SYSTEM OF HEAT SUPPLY BASED ON GROUND HEAT EXCHANGERS

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The analysis of known theoretical and practical studies of combined heat pump systems and their individual components allowed us to conclude that it is necessary to develop and study the operation of heat supply systems, which included various low-temperature heating devices and ground heat exchangers-low-potential heat sources for the heat pump. Taking into account the current state of the problem under consideration, the main tasks formulated in this work are formulated.

In order to study the optimal design and long-term operation of a horizontal ground heat exchanger, an analytical-engineering two-dimensional model was developed. This approach is based on the analysis of thermal processes in a soil massif equipped with a multi-loop pipe system with a pitch between the axes of adjacent pipes of 0.5-1.5 m.

The results of the research showed that the step between the axes of adjacent pipes ≈1 m is optimal when creating a horizontal ground-based accumulator of heat in conditions of the city of Kyiv. During the heating season, at such a step, the mutual influence of the neighboring loops of the ground collector is minimized.

It was also found that with the use of a horizontal shallow reservoir, the minimum surface temperature at the end of the heating season is from -2.5°C to -3.0°C. This caused the need to develop a method to restore the thermal state of the soil massif in the summer period of the year. The use of a passive conditioning system was proposed.

The next stage of the theoretical study was the development of the thermophysical model of hydrodynamics and heat transfer in the system of soil-horizontal soil heat exchanger – the heat carrier in full formulation for a more detailed analysis of unsteady heat transfer and fluid dynamics in horizontal multi-loop pipe systems.

With the help of the thermophysical model, it was established that the calculated heat removal capacity of the soil from 1 running meter of the pipeline of the ground heat exchanger is 28 W. Later these data were confirmed by the results of experimental studies.

The horizontal ground collector (accumulator) whose conditional area 10x25 m^2 of shallow deposition (at a depth of 1.65 m) created on the territory of the Institute of Technical Thermophysics of the NAS of Ukraine is analyzed and its work is analyzed as part of the heat pump system of heat supply of the laboratory room by using a heating device – a water "warm floor".

The horizontal ground collector is equipped with an automatic measuring complex of 64 sensors of TCM-205 resistance thermometers, 8 eight-channel temperature measuring and control devices УКТ-38-Щ4, an АС-2 output signal adapter and a PC with specialized software. The measurement integrity is from 1 minute to 1 hour (average value of 10 minutes), depending on the location of the sensor. Data archiving on PC occurs throughout the year.

A schematic diagram was developed and a heat pump system of heat supply of a laboratory room based on a ground-water heat pump with a thermal power of 5.9 kW was installed. The system operates in two modes – heating in the winter and passive conditioning – in the summer. Heating appliances – water "warm floor" laid in a bifilar spiral scheme and fan coil units (fan coils). The passive conditioning system is based on the use of fan coil units and a horizontal ground collector and has two purposes – air conditioning in the room and, at the same time, restoration of the thermal state of the soil massif.

In the horizontal collector, the area of the heat exchange surface (pipeline) of 19.77 m^2 during the heating period takes up to 3.6 kW of thermal generation power, while the average length of the heat transfer coefficient is 36.4 W/m^2K. Calculated average for the heating period, the conversion coefficient of the heat pump was COP = 3.34.

Presented are studies of the combined heat pump heat supply system based on ground heat exchangers, which was developed in 2015, and since 2016 provides the needs for heating, air conditioning and hot water supply of an energy efficient house on the territory of the Institute of Technical Thermophysics of the National Academy of Sciences of Ukraine. The heat supply system is developed on the basis of the approaches and results of the studies described above.

The main heat-generating equipment is a ground-water heat pump with a capacity of 6.0 kW and solar thermal collectors. Reserve – solid fuel boiler with a power of 12 kW. As a source of low-potential energy for the heat pump, a range of ground heat exchangers (4 heat exchangers of various designs) and a heat exchanger, which is located in the well of water supply, was designed.

The joint work of various low-temperature heating devices (including embedded in building structures) was studied experimentally. The average for the heating period, the energy conversion factor of the heat pump was COP = 3.62.

A system of heat (cold) protection of building enclosures with a passive air curtain and a pipe-type ground heat exchanger was developed and investigated. According to the results of the research, it was found that the reduction in the power of heat losses for heating needs amounts to 1.2 kW, which is a significant indicator of savings for energy-efficient houses.

METHOD OF CALCULATION OF MODES OF ABSORPTION WATER-AMMONIA REFRIGERATION MACHINES IN A WIDE RANGE OF WORKING TEMPERATURES

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Recent documents clearly regulate the specific refrigerants use for various types of refrigerators: for household and commercial refrigerators – propane; for medium-sized refrigerators – carbon dioxide; for large systems – ammonia.

Heat-using absorption water-ammonia refrigeration machines (AWARM) completely fit the modern trends in the transition to natural refrigerants. The refrigerant of AWARM is ammonia. Moreover, AWARM, unlike analogues – bromide lithium absorption refrigeration machines and steam ejector refrigeration machines in which refrigerant is water, have a wider range of applications, in particular in the conditions of negative temperatures up to minus 30°C.

Of particular interest are AWARM operating on renewable energy sources, in particular, solar energy. This interest is associated with the possibility of year-round use of solar collectors, which are currently widely used in heating and hot water systems. It is assumed that with an excess of solar energy in the warm season, part of it can be sent to the AWARM generator for the artificial cold production.

Widely known approaches to calculating AWARM for operation in solar-heated systems do not take into account the presence of three temperature levels in the absorption refrigeration cycle: maximum temperature in the generator (heating source) – average temperature in the absorber (environment) – minimum temperature (boiling point) in the evaporator. Then it is generally known that from these three temperatures only two can be selected relatively arbitrarily, and the third temperature is determined uniquely.

Relevance in conducting this kind of research is also associated with the active promotion in the market of heating equipment based on solar collectors with water as a heat transfer agent.

The problem of the scheme "solar collector on the water as heat transfer agent – AWARM" is associated with a limited temperature level of the heating source (not higher than 100°C).

Although, in the solar collectors market, there are also models of solar collectors on organic heat transfer agents with an operating temperature level of up to 250°C. However, they are of great cost.

To analyze the dependences of real AWARM, a calculation algorithm was compiled. The traditional simplest AWARM scheme is considered, including two regenerative heat exchangers – solutions and a refrigerant.

The algorithm for searching the operating modes of the AWARM was as follows. At the first stage, the temperatures of the cooling object were set from minus 30°C to minus 5°C.

For each numerical value of the temperature of the cooling object, a thermodynamic calculation of the AWARM cycle was carried out with a fixed value of the ambient temperature in the range 25-43°C in increments of 1°C. For the given values of the temperature of the cooling object and the ambient temperature, the circulation rate of the water-ammonia solution (WAS) was calculated with the temperature of the heat source being varied with a step of 1°C.

If the multiplicity of the WAS circulation is positive, it was concluded that the operation mode of the AWARM can be implemented, and in the opposite case, the operation mode is not implemented.

Analysis of the results shows that AWARM in a system with a solar collector on water as a heat transfer agent can be used only in air conditioning systems at cooling temperatures not exceeding 36-37°C. To work in cooling systems with temperatures up to minus 30°C, the temperature of the heating medium 140-150°C is needed.

HYDRODYNAMICS AND HEAT TRANSFER IN INTERGLASS SPACE OF MODERN DOUBLE-GLAZED WINDOWS

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Residential and public buildings remain the top priority of national energy efficiency policies. This area is one of the most energy intensive in the country. At the same time, housing and communal services have the greatest potential for improving energy efficiency. The main reserve for saving energy in housing and communal services is the reduction of heat consumption in residential and public buildings.

It should be noted that the technical condition of most existing buildings and structures does not allow to provide the required level of efficient energy performance. One solution to the problem of energy conservation is to improve the energy efficiency of buildings and structures, namely, the application of a set of measures to improve the thermal insulation properties of building facades. Among the façade elements of buildings, the most problematic in terms of energy losses are window structures, which account for up to 40% of heat losses through facades. It is known that the replacement of old window structures with modern windows increases the energy efficiency of the building by 20-30%. That is why the Institute of Technical Thermophysics of the NAS of Ukraine has been conducting thermophysical researches of modern double-glazed windows for several years in order to establish the basic laws of heat transfer through translucent structures.

In order to determine the peculiarities of the dynamics of air movement in the glass window space and the process of radiative – convective heat transfer through modern double glazing, a numerical simulation of these processes was carried out on the basis of the solution of a system of equations, which included Navier-Stokes equations, energy equations and state equations for gas environment in the interglass space, as well as the thermal conductivity equation for the glass. On the inner surfaces of the glass in the interglass space of the double-glazed window were set boundary conditions of the fourth kind, taking into account the radiation heat transfer. On the outer surfaces of the glass in the double-glazed window conditions of the first kind were set. In total, about 50 geometric models of one, two, and three-chamber double-glazed windows with ordinary glass were created during numerical modeling. The models varied between the thickness of the interglass space b from 0.006 to 0.05 m, the height of the double glazing H from 0.375 to 2 m, the angle of inclination of the double-glazed window to the horizon from 0 deg. up to 90 deg., at different values of internal T_{in} and external T_{out} temperatures.

As a result of modeling, the dependence of the change in the mode of motion of air from cyclic to vortex with increasing interglass space b is determined. Changing the mode of air movement was abruptly. With the increase of parameter b there was a significant increase in the value of thermal resistance of the double-glazed window:

$$R_{ter} = \frac{T_{out} - T_{in}}{q_{tot}} \quad (1)$$

until the moment of change in regime of air flow. After changing the mode, a further increase in b caused a barely noticeable increase in thermal resistance. At the same time, starting from $b > 0.025$ m, the problem became significantly non-stationary.

With the horizontal orientation of the double glazing and with a sufficient temperature difference $T_{out} - T_{in}$ in all models were observed well known cells of Rayleigh-Benard. In cases where parameter b corresponded to the cyclic nature of the air movement with the vertical orientation of the double-glazed window, increasing the angle of inclination of the double-glazed window from 0 degrees. up to 90 deg. led to a change in the regime of air flow in the interglass space: from Rayleigh Benard vortices to cyclic air movement. In this case, at the moment of change of air flow, the thermal resistance of the double-glazed window jumped more than 30%.

As a result of numerical studies of heat transfer through the double-glazed window, it was possible to establish the critical values of the Rayleigh number (Ra) at which there is a change of regime of airflow in the glass window space. In this case, in our opinion, we should talk about a certain range of values of the Rayleigh number, which is $6.0 \cdot 10^3 < \mathrm{Ra} < 6.7 \cdot 10^3$ and causes a change in the flow regime.

As a result of the simulation, the fraction of radiation heat flux in the total amount of heat transfer through the double-glazed window is established. This share is more than 53%.

DEVELOPMENT OF ENERGY-SAVING METHODS OF ABSORPTION REFRIGERATION UNITS' CONTROL

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Modern requirements for refrigerants in terms of ozone safety and minimization of the contribution to the greenhouse effect have opened up great opportunities for absorption-type refrigeration units or devices with absorption-diffusion refrigeration units (ARU) working with ammonia-water solution as a working medium. The main disadvantage of ARU, which holds their wide distribution back, is low energy efficiency. This factor not only determines increased costs compared to compression analogues, but also the corresponding contribution to the greenhouse effect.

Studies results of experimental and serial models of refrigeration devices with ARU showed that their increased level of energy consumption is predetermined by the existing calculation methodology and by the method of control during operation.

As shown by the exergy analysis of the ARU cycle, the greatest success in energy saving can be achieved by optimizing the thermosiphon (TS), in which the exergy loss reaches 60% of the total.

Analysis of the main areas of energy saving showed that the greatest success with a minimum of costs can be achieved through the use of optimal control systems for devices with ARU. In particular, due to a change in the amount of heat supply to TS depending on the temperature conditions at the characteristic points of the refrigeration chamber and ARU.

Energy saving problems in TS are connected with partial condensation of vapors in the lifting part of the dephlegmator. It can be solved by distributing the heat input to TS depending on the ambient temperature and the temperature in the refrigeration chamber. The energy-saving effect in this case is 15-16%.

The development of this direction was associated with the installation of an additional heat-insulating cover on the ARU dephlegmator. The energy-saving effect in this case amounted to: 21% (Kiev-410); 12% ("Crystal-408"); 17% ("Stugna-101"). To implement such energy-saving modes, it is necessary to control the steam temperature at the exit of the dephlegmator – it should not exceed the saturation temperature of ammonia at a working pressure in ARU (about 50°C).

When developing energy-saving methods of control, it was supposed that in the non-working period the temperature of the ARU drive circuit elements (thermosiphon, rectifier, dephlegmator), due to heat losses to the environment, decreases.

This is accompanied not only by cooling strong and weak WAS, but also by partial condensation of the vapor in the dephlegmator and the ARU condenser. In the case of vapor condensation, inert gas, which is previously located in the natural circulation circuit (NCC), takes its place. Obviously, the longer the non-working period, the lower the temperature will drop and the greater the volume of inert gas in the ARU deflegmator.

When a thermal load is supplied, inert gas is pushed into the NCC by the dynamic pressure of the vapor stream, the value of which will depend on the amount of the vapor phase. When it is ARU starting moments, a certain amount of steam generated in TS will be spent on heating the structural elements of the rectifier, deflegmator and condenser. Other conditions being equal, the transit time of the steam flow to the condenser will be determined by the degree of cooling of the drive circuit elements in the non-working period, i.e. by the non-working period. This suggests that the well-known position – "the longer the non-working period, the greater the economy", is not always applicable for household and commercial absorption refrigeration units.

To increase efficiency, it is necessary to prevent significant overcooling of structural elements of the ARU drive circuit.

It is possible to reduce the degree of overcooling of transport elements of the ARU drive circuit both by increasing the thermal resistance of the thermal insulation of the generator unit and by partially heating them during the non-working period.

EXPERIMENTAL VALIDATION OF NUMERICAL SIMULATION OF AIR-EARTH HEAT EXCHANGER WITH ROUND CROSS SECTION

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Several investigations have been dedicated to the study of technologies for the use of the earth's thermal potential for heating and cooling purposes. One of the solutions in this area is air-earth heat exchangers (AEHE). Validation of the obtained data of the conducted thermophysical simulation of heat exchange and aerodynamics of AEHE with an experiment is a necessary step for further study of such heat exchangers.

In this work, to study the flow of air in a U-shaped tube with a circular cross-section, located in the soil array used a commercial package Ansys Fluent. The thermophysical model is based on the assumption that: the properties of the soil used in the calculations are isotropic and homogeneous; soil temperature depends on depth, in accordance with climatic data. The calculations were performed on the basis of the system of equations of conservation of momentum, energy, kinetic energy and velocity of dissipation, which characterizes the process of heat exchange and aerodynamics in the AEHE.

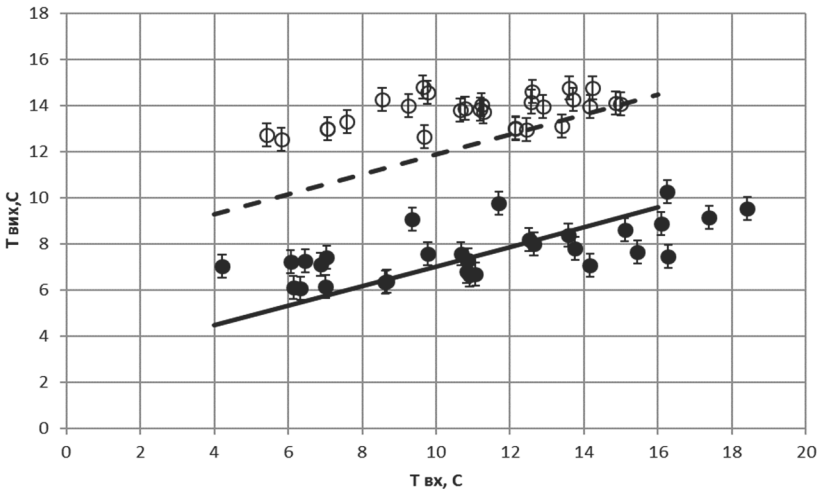

Fig. 1. *Validation of thermophysical modeling using experimental data: ——— - computation data (April); ● - experimental data (April); – — — – - computation data (October); ○ - experimental data (October)*

The calculations were validated at a full-scale experimental stand for the investigation of thermophysical processes during the operation of the geothermal ventilation system, which was created at the Institute of Engineering Thermophysics of the NAS of Ukraine.

A comparison of the results of the simulation of the stationary problem with the experimental data obtained in October and April is presented in Figure 1. The figure shows the average daily experimental values of inlet and outlet temperatures AEHE. The simulation results coincide with the experimental data within the measurement error. The slightly overestimated values of the experimental data for October can be explained by the fact that the stationary formulation of the problem cannot take into account the heat accumulation with a sharp change of temperature regime.

Conclusions. Theoretical calculations and experimental studies have shown that:

1. The geothermal ventilation system does not allow to reach the temperature of thermal comfort, but reduces the need for energy for heating or cooling the air to ventilate the room both in winter and in summer.
2. The average daily fluctuations in ambient temperature have little effect on the outgoing air temperature AEHE.

DEVELOPMENT OF HOUSEHOLD COMBINED DEVICES – ABSORPTION REFRIGERATORS WITH HEAT CHAMBERS

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A promising energy-saving direction for modern household appliances is the creation of devices that combine the functions of refrigerated storage and heat treatment of food products, semi-finished products and agricultural raw materials.

During most household technological processes, the temperature does not exceed 70°C. Only a dephlegmator and a rectifier – elements of the absorption refrigeration unit (ARU) – have such a temperature potential, of all types of modern household refrigeration equipment.

Various schemes of household refrigeration devices with heat chambers have been developed. They differ in: a method of heat transfer; a location of the heat chamber; a constructive design of the heat chamber (single-chamber, two-chambers); a source of waste heat.

The simplest in design is the scheme with an intermediate heat transfer device, which involves minimum design changes in the household combined device and ARU.

Two types of such household combined devices have been developed and researched – with air and liquid heat chambers (HC).

Calculation of the design parameters of HC was carried out at a thermal load of 19-22 W. The thermal insulation thicknesses of the side walls, bottom and top cover were determined as a result of mathematical modeling of unsteady temperature fields. At the same time the following was taken into account: orientation of the camera surfaces and its thermal connection with the refrigeration chamber; design features of HC; the working time coefficient of the serial model of the single-chamber absorption refrigerator "Crystal-408" (refrigerated volume 150 dm^3).

The experimental designs were produced at the Vasil'kovsky Refrigerator Plant (VRP) in Kyiv region.

Geometric parameters of the internal volume of HC were as follows: height – 0.420 m; depth – 0.540 m; width – 0.570 m; volume – 35 dm^3. Thermal insulation thicknesses were as follows: of side walls – 0.080 m; of a bottom – 0.075 m; of a cover, back and front walls – 0.10 m.

To ensure the thermal connection of the lifting section of the ARU dephlegmator with HC, a two-phase thermosiphon (TPTS) was used, 1.2 m long and 0.010×0.001 m in diameter. TPTS body material is stainless steel. The heat carrier is ethanol.

The study of HC thermal conditions was carried out both in stationary and in transient modes of ARU operation. As a result of the research, the optimal length of the TPTS evaporation section was determined – 0.15 m. At the exit of this section, the dephlegmator temperature is 73-76°C. The most favorable conditions for HC were the regimes with increased ambient temperatures – when the heat losses are reduced, and the ARU working time coefficient, as well as the period of heat load supply, increase.

Experimental researches of household combined absorption-type devices created on the basis of the serial model "Crystal-408" of VRP showed that adding the additional heat chamber, which is connected thermally with the lifting section of the ARU dephlegmator, does not lead to growth energy consumption and does not impair the performance of cooling chambers to the design of household absorption refrigerators, which is connected thermally with the lifting section of the ARU reflux condenser, does not lead to increased energy consumption and does not impair the performance of refrigeration chambers.

THERMAL CONDUCTIVITY CALCULATION METHOD: POROUS STRUCTURES

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In the article the mathematical description of heat transfer through the body with a closed porous structure was given. Effective thermal conductivity for closed porous structure was retrieved by analytical method. For the first time the coefficient of thermal permeability for porous structures was mathematically found [1]. The authors have proved, that in the porous material thermal conductivity reduction, by the pores, depends on the thermal permeability coefficient and porous structure geometric characteristics. It is also proved in the article that knowing the geometrical characteristic of the porous structure of heat insulating materials, one can calculate the thermal conductivity of this material.

A calculation model for the transfer of thermal energy through porous and fibrous-porous structures was developed, which made it possible to reduce the complexity of work in determining the effective coefficient of thermal conductivity of porous structures. The error of the method is less than 8% [2].

Numerous empirical characteristics and corrections have previously been used to calculate the transfer of energy through a porous-fibrous body. The new dependencies are based on the theory of thermal energy transfer by fluids and allow to calculate the amount of energy passing through a porous structure, taking into account the operating conditions, only by defining two semi-empirical coefficients previously. Thus, the product of the constants of the integration of the energy transfer equationby fluids and the geometric characteristics of the porous structure and the thermal permeability of fourteen porous materials used as thermal protection elements were found.

Thermal permeability of porous material

$$\phi_i = \frac{\Pi_b}{n_b}$$

where: Π_b – the total porosity of the material; n_b – the average number of pores in the thickness of the material b along the heat flux.

The dimensionless value ϕ_i is a thermal permeability of thermal channel.

Equals to the ratio of pore cross section line length to material surface area in the context of the pore

$$\Gamma = \frac{\pi d_2}{S - n\frac{\pi \overline{d_2^2}}{4}},$$

where: S – the intersection area of the heat pipe; d_2 – the average pore diameter.

So $$\lambda_{ef} = \lambda \cdot \phi \cdot \Gamma$$

The significant coefficients of progressive systems and the effective coefficients of thermal efficiency of porous products are very quickly used for thermal power equipment, and thermal opportunities for the use of thermal energy have been found.

After some simplification, based on the previously performed experiments, we obtain an equation describing the transfer of thermal energy by fluids in open structures

$$Q = \lambda \cdot \phi \cdot \Gamma \Delta T + \Gamma_O \left(C_7 T^2 + C_8 T \right)$$

The equation describes not only the transfer of thermal energy in duct pores but also takes into account the existing closed pores in the material.

Table 1. *Characteristics of porous work and thermal permeability of porous materials*

Porous materials	$\phi \cdot \Gamma \cdot \delta$	$\Gamma_O C_7$, W/(m²·K²)	$\Gamma_O C_8$, W/(m²·K²)
Metal sponge 12X17 П = 50%	0.529	0.16148	70.19
Metal sponge 12X17 П = 30%	0.529	0.0583	25.34
Foam concrete П = 58%	0.434	0	0
Foam-pumice concrete	0.388	0.011	17.35
Aerated concrete	0.681	0	0
Hollow refractory 22%	0.824	0.18962	81.24
Hollow refractory 40%	0.824	0.2734	116.18
Chamotte brick	0.871	0	0
Mineral glassy	0.473	0.188	72.39
Backing of expanded clay	0.878	0.037	54.36

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LNG EXERGY UTILIZATION. WATER PRODUCTION AS A BY-PRODUCT OF LOW PRODUCTIVITY LNG REGASIFICATION IN ARID REGIONS OF THE WORLD

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Over the past few decades the market for liquefied natural gas (LNG) has been expanding. This is due to a number of advantages characteristic of LNG transportation relative to compressed gas or pipeline transportation of natural gas. The main objective of introducing the technology for the production and supply of liquefied natural gas is to ensure the stable development of the energy sector.

To reduce the degree of thermal pollution, the regasification of liquefied natural gas is rational at the expense of heat taken from the environment or a "waste" source of low-potential thermal energy. Low capacity plants are usually equipped with atmospheric evaporators and do not use cold regasification.

Population growth and environmental problems have led to difficulties in supplying the population with clean water. The volume of fresh water suitable for use is only 0.5% of the total volume of water on Earth.

In the process of operation of evaporators of cryogenic liquids, moisture is frozen on its outer side. Since the disposal of frozen water does not require significant capital expenditures, this direction is quite promising for water supply to the population of countries located in areas with arid climate

This work presents the results of calculating an atmospheric evaporator designed for gasification of 250 m^3 per hour of LNG with a different number of external ribs (6, 8 and 12). During its operation for 10 hours, a layer of frost with an average thickness of up to 20 mm is formed on the surface of the atmospheric evaporator. The specific volume of water that can be obtained during regeneration of the evaporator is from 1 to 2.7 l/(m^3/h) depending on the duration of the evaporator and air humidity.

Using a fan to intensify heat transfer processes from the air side reduces the value of the heat transfer surface; while the volume of frozen water is reduced by 15-20%.

Assessment of the volume of fresh water that can be obtained in the process of recycling hoarfrost has shown that this volume is quite significant and can provide the daily intake of several people. Water utilization with regasification of only 1%

of the supplied LNG, provided that atmospheric evaporators are used for this, can provide water needs for several million residents. Therefore, this source can be considered as a promising alternative source of water supply in the case of placing regasification plants in the arid regions of our planet.

HEAT TRANSFER AND AERODYNAMICS OF FLAT-OVAL TUBE BANKS IN CROSS FLOW

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Search for rational ways of heat transfer intensity is one of the main direction of improvement of heat exchangers.

The problem decision becomes a challenging one in the context of the urgent need to modernize the natural gas transmission system for the purpose of increasing its efficiency and substantial decreasing "technological" gas losses in gas compressor units (GCU) equipped with gas turbine power plants.

Most of such gas turbine power stations use regenerative cycle with efficiency of heat regeneration which does not exceed the values 0.70-0.75. Therefore, the most realistic and relatively low-cost direction of modernization of these units is increasing the degree of regeneration to 0.80-0.85. As a result consumption of "technological" gas of one GCU-10 can be reduced by 1.5 million cubic meters per year. However, increasing the regenerator effectiveness is accompanied by an extensive increase of the size, mass and cost of the regenerative heat exchanger surface. In case of using heat exchangers with ordinary pipes of circular cross-section pressure losses of the gas and air flows within the gas turbine power station are also increased [1].

Application of tubes with well-streamlined shape, namely flat-oval tubes as the most technological ones, is proposed as alternative decision for solving such problem.

Preliminary design studies and estimation show that the use of flat- oval tubes compared to circular ones can significantly reduce the total pressure losses of gas and air flows. It also provides simultaneous increase of the regenerator thermal capacity and acceptable mass and size characteristics.

However, the application of flat- oval tubes in heat exchanger designs is hampered by the lack of reliable engineering methods for calculating heat transfer and aerodynamic drag of cross flow bundles of such tubes with wide variation in their geometric and layout characteristics. Moreover there are no fundamental data concerning the mechanisms and phenomena that influence the improvement of heat transfer in such surfaces [2].

The main purpose and task of the study is to increase the thermal and aerodynamic efficiency of recuperative heat exchangers by investigation and implementation of new types of heat exchange surfaces with bundles of flat-oval tubes.

The object of the studies is heat and momentum transfer in bundles of flat-oval tubes with forced cross flow of gas.

The subject of the studies – mechanisms of heat transfer and aerodynamic drag of bundles of flat-oval tubes within a wide range of changes of design and mode parameters.

Experimental methods for investigations of heat transfer and aerodynamics in the bundles of tubes were applied. The intensity of the convective heat transfer was estimated on the basis of the method of full thermal simulation by measuring the temperature field of the tube wall. During investigations of the characteristics of the flow the following techniques were used: the method of surface visualization of the flow with the help of soot-gas mixture and the method of numerical CFD modeling (software product "Fluent") [2].

On the basis of the performed studies engineering methods for calculation of heat transfer and aerodynamic drag of heat exchangers in the form of banks of flat-oval tubes have been developed which can be used in the design of a wide range of heat exchangers for energy and industry sectors.

Application of air heaters equipped with flat-oval tubes has shown the possibility of increasing of heat transfer coefficient by 1.3-1.8 times compared with heat exchangers with circular tubes. It provides significant decrease of the total length of tubes and the weight of the unit, decrease in number of pipes bends and collector openings and reduction of the total pressure losses of the gas and air flows.

Conclusions

The proposed new methods of thermal and aerodynamic calculations of the heat transfer surfaces with flat-oval tubes are a methodological basis for the creation of competitive types of heat exchangers with 30-40% reduction of size and weight, increased reliability and improved performance. All this will provide significant savings of material and energy resources. The implementation of the regenerative air heater for the GCU-10 will allow to save up to 48 million cubic meters of natural gas per year.

References

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