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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 II

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Under the general editorship Prof. doctor of science Anatoliy Pavlenko

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ANALYSIS OF ACCURACY DESCRIPTION PROPERTIES OF SUBSTANCES

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There has been accumulated a sufficient quantity of the material on the topic of the thermophysical properties of pure refrigerants. The analysis of the existing methods to determine the thermodynamic properties (TP) of mixtures of substances shows that they have no predictive capabilities. Therefore, in practice, either one or another model approach of describing the thermodynamic behavior of mixtures is used, refined on the basis of experimental data.

These include the unified equations of state, which are single-structural forms that allow reproducing TP with a given small error, both liquid and gaseous mixtures. For a multicomponent system, the equations of state (ES) is a thermodynamic model of the equilibrium vapor and liquid phases separately.

It is known that using ES, one can reveal the dependence of thermodynamic functions on υ and P, integrate differential thermodynamic relations, calculate the volatility (fugacity) of system components, through which phase equilibrium conditions are usually written. In addition, it is possible to establish a connection between the equations of state and any of the thermodynamic potentials of the system, expressed as a function of its natural variables.

The use of these equations for describing the state of matter at high densities is associated with the complexity of determining higher-order virial coefficients. In this regard, there have recently been created the empirical equations of state in which pressure is presented as a polynomial in density with coefficients depending on temperature. These equations also contain an exponential term introduced to compensate for higher-order terms of the virial equation.

To conduct a comparative analysis of various forms of ES, in order to identify their capabilities in describing the thermodynamic surface of binary zeotropic mixtures of refrigerants, three widely used ES were selected and the results of TP calculation were compared according to the original version of the Peng-Robinson (PR) [1], modified by Lee-Kesler (LK) [2] and the Helmholtz free energy equation (HFE) [3] with optimal cross parameters.

The fundamental impossibility of a simultaneous accurate description of the critical point parameters of individual substances and mixtures based on them did not allow accurate reproduction of the experimental data by cubic ES PR. On the whole, the ES PR compared with multiconstant ES showed a fairly acceptable accuracy for engineering calculations.

A comparative analysis of various forms of ES was carried out using experimental data on the boiling pressure and density of binary zeotropic mixtures of refrigerants. At the same time, to find the cross-section coefficients of the ES LK and HFE, we took into account the entire array of experimental data obtained both in this work and the data of other authors, taking into account the errors of the measured values.

The comparison showed that the experimental values of the boiling pressure of binary zeotropic mixtures of refrigerants are quite adequately consistent with the data published by a number of authors. This allowed us to rely on these results with confidence.

A detailed comparison of the three ES forms in describing the boiling pressure of the ternary mixture, R401A refrigerant, showed that the cubic ES PR using limited information and without taking into account the interaction of the mixture components (θij = 1) is in satisfactory agreement with experimental data.

In some cases, the multiconstant state of the ES LK is superior in accuracy to the state of HFE for binary mixtures of refrigerants, but in general it is inferior to it when describing the thermodynamic surface of a multicomponent mixture.

The model for the description of TP of substances of multicomponent mixtures of refrigerants, based on the corrected parameters of the ES HFE, gives an opportunity for more realistic description of the available experimental data, compared with other methods based on the rules for combining ES constants.

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EXPERIMENTAL RESEARCH OF THE DRYING GRAIN MATERIALS AT VARIOUS HEAT SUPPLY

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The work was carried out with the aim of establishing a rational method of supplying heat including a combination of microwave heating.

The experiments were conducted with a dense layer of oats at a fixed initial moisture content on the experimental setup, which provides research with microwave, microwave-convective and convective drying.

Research of the drying kinetics were conducted on the following modes: pulsed and continuous microwave energy supply, microwave-convective supply, cyclic and continuous, and convection.

In pulsed mode the microwave supply periods alternating with pauses.

We research the effect of the power-on time of the magnetron τ_{MW} and pauses τ_p on the regularities of changes in temperature and moisture content of the material, drying speed and specific energy consumption.

In the experiments to measure the power of the magnetron, the initial and final masses (m_0, m_f) and temperature (t_0, t_f), the duration and number of inclusions magnetron (τ_{MW}, n_{MW}) and pauses (τ_p, n_p).

Comparison of microwave drying and microwave-convective cart shows that the increase in the speed of the blown air temperature increases the drying rate.

This result is reflected by the dependence, which generalizes the corresponding experimental data:

$$\frac{N_{\text{MW-C}}}{N_{MW}} = 1 + 0{,}0003937\, Re^{0{,}799} \left(\frac{t_a}{t_{\text{e}}}\right)^{1{,}037}$$

Where: $N_{\text{MW-C}}$ – the speed of drying under microwave-convective supply of energy, N_{MW} – under microwave cart, t_a – the temperature of the air blown through the layer of material, t_{e} – the temperature of the environment.

The formula is valid with an error of 5.7 % at Reynolds numbers up to $Re = 4500$ and the temperatures of the ventilating air within $t_a = 19 \div 70$ °C.

The table shows data on drying in the modes, providing the most favorable characteristics of the process.

The specific energy consumption was determined as the heat of the drying process, related to kg of evaporated moisture.

Characteristics of drying at different ways of energy supply

Mode	The type and pattern of energy supply	The speed of drying, kg/(kg·s)	The specific energy consumption, MJ/kg
1	MW continuous	$4{,}5 \cdot 10^{-4}$	15,79
2	MW-pulsating	$4{,}4 \cdot 10^{-4}$	8,13
3	MW-convection, cyclic	$4{,}3 \cdot 10^{-4}$	9,07
4	MW-convection, simultaneous	$12{,}7 \cdot 10^{-4}$	5,65
5	Convective	$4{,}1 \cdot 10^{-4}$	34,82

Obtained that the optimum simultaneous MW-convection method of energy supply that achieves maximum drying speed, the minimum specific energy consumption and material temperature does not exceed acceptable.

INVESTIGATION OF GAS FLOW IN THE ENERGY EFFICIENT CENTRIFUGAL COMPRESSOR CHANNEL DIFFUSERS

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1. Introduction. Centrifugal compressors are widely used in many industries, in particular in power plants for many processes that use compressed gases. Reducing the energy consumed by centrifugal compressor drives is an actual scientific and technical problem.

One way to accomplish this is to increase the efficiency of the compressors. This requires the creation of methods for calculating and designing the elements of the compressor stage based on the physical and mathematical models of the swirling viscous compressed gas flow.

Much of the energy (40-60%) transmitted by the gas in the impeller of the centrifugal compressor is kinetic. Diffusers are used to convert the kinetic energy of a gas stream into a potential one, that is, to reduce the velocity and increase the pressure. The most common types of diffusers are vaneless, vane and cannel. Each type of diffuser has its own design features and characteristics.

A mathematical model was developed for the channel diffuser, which was used to design gas-dynamically advanced diffusers.

2. Design method. According to the presented method the diffuser design is based on the preseparation condition of the boundary layer along one of the vane surfaces. Stratford (1959) obtained experimentally the close to zero skin friction flow along one of the surfaces of the two-dimensional diffuser. In that case the maximum pressure rises, which is possible for given diffuser dimensions should be achieved. Mathematical model for solving the inverse problem of gas dynamics is developed for the steady adiabatic gas flow without separations.

Система рівнянь, розв'язання якої дозволяє отримати форму профілю сегментів КД має вигляд:

$$\begin{cases} r_{in}\cdot\lambda_{in}\cdot\cos\alpha_{in} - r\cdot\lambda\cdot\cos\alpha = \dfrac{b\cdot z_v\cdot p_{in}^{*}\cdot\sigma}{\overline{m}\cdot a_{cr}}\cdot\displaystyle\int_{r_{ex}}^{r}\left[\pi(\lambda_{ps})-\pi(\lambda_{ss})\right]\cdot r\cdot dr, \\ \overline{m} = \lambda\cdot\varepsilon(\lambda)\cdot a_{cr}\cdot\rho^{*}\cdot 2\pi\cdot r\cdot b\cdot\tau\cdot\sin\alpha, \end{cases}$$

where $\lambda, \lambda_{ps}, \lambda_{ss}$ are the mean flow velocity within the diffuser channel, velocity along the pressure surface and velocity along the suction surface of the vane respectively; α is the

mean flow angle within the diffuser channel; stagnation parameters are designated *; $a_{cr} = \sqrt{\frac{2\gamma}{\gamma+1} \cdot R \cdot T^*}$ is the critical velocity, γ is the ratio of specific heats.

3. Numerical simulation. Numerical simulation was performed by use of commercial CFD-software ANSYS CFX v.14 for two different compressor stages. The first one is the model compressor stage with CD of traditional geometries. The second stage has the same impeller as the first. The only difference is the diffuser, which was designed using presented method.

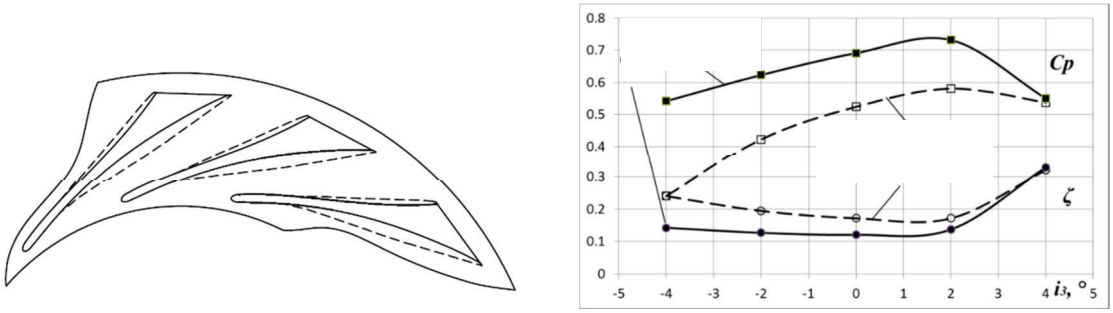

Fig.1. Profiles and characteristics of the CD of traditional geometries (dashed lines) and those designed using presented method (social lines)

The results of numerical investigations show a significant improvement in the gas-dynamic characteristics of channel diffusers (Fig.1), which was designed using presented method, compared to traditional geometry diffusers.

Experiment results. Experimental investigations of the diffuser model, which was designed using presented method, made at the aerodynamic stand (Fig.2).

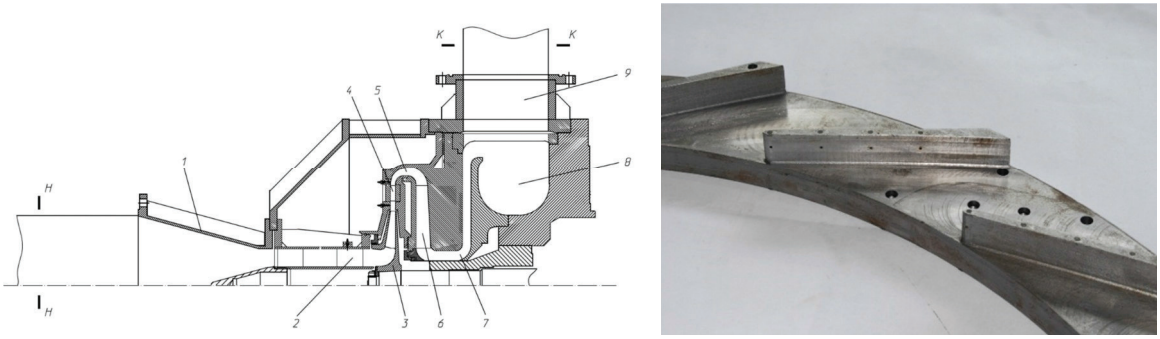

Fig.2. Scheme of experimental model and channel diffusers

The results of the investigations confirm that the proposed method of profiling of channel diffusers of centrifugal compressors allows profiling of efficient channel diffusers for a wide range of flow angles at the inlet of the diffuser (12 ÷ 30 °).

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TECHNICAL COMPONENTS OF ECOLOGICALLY SAFE INSTALLATION OF SMALL HYDRO POWER PLANTS IN THE UKRAINIAN CARPATHIANS

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The scenario of environmentally friendly development of small hydropower in the Carpathian region involves the construction of new derivative hydropower plants and the reconstruction of existing hydroelectric power plants [1]. Sometimes you may find objects such as micro-hydro (<0.1 MW) that do not have a dam. However, these objects are very small and are only expedient if the energy produced is consumed directly on site without being connected to a centralized grid. All hydropower facilities include energy-producing turbines. Existing types of hydroelectric turbines are divided into two main classes - impulse turbines and jet turbines, and in each class there are turbines of different design [2]. It should be noted that different types of turbines can have exactly the same characteristics, and then other factors (such as cost or variability of runoff), which are also important, should be based on the choice of turbine equipment. For the installation of 5 MW or less (micro-, mini-, and small-scale HPP (SHPP) recommended in terms of environmental safety for the Carpathian region), all models of turbines may be appropriate, depending on site conditions.

The environmental impact indicators are generally identical for turbines of any type. The same can be said about the water quality indicators in the upper and lower water. The operation of turbines and small hydropower plants can lead to changes in the dissolved oxygen content upstream due to the discharge of water through the spillway. Some differences in the design of the turbines may relate to the possibility of fishery leakage arrangements existing in the case of jet turbines but not in the case of impulse turbines. Small hydroelectric plants with a dam, a boom or a derivative pipeline are considered to be the most

expensive hydropower projects to be built or rebuilt in the Carpathian region. They may or may not include a water storage reservoir. Limiting water levels in reservoirs and levees are highly dependent on the size of the river, the relief, and the characteristics of the catchment area. Hydroelectric power plants with dams and reservoirs can affect the ecological status of watercourses. Careful management of the operation of these facilities is in accordance with the principles of good environmental practice, which allows to solve effectively the issues of water quality, flood control, fisheries needs, recreation and runoff in the boundary conditions [3]. Table 1 shows the characteristics of the key elements of the design of small hydroelectric power plants.

Table 1

Characteristics of key components of the HPP design

Elements	micro <100kW	mini 100kW – 1,0MW	small 1,0 MW - 5 MW
Dam height (m)	0-5	5-15	15-35
Reservoir (ha)	0	0- 10	0 -15
Turbine outlet length (m)	0 - 100	10 - 1000	25 - 1000
Diameter (m)	0,3 - 1.0	0,5 – 1,5	1,0 – 2,25
Hydroelectric power station (m^2)	None **	20 -120	100 - 180
Outlet channel length (m)	0 - 10	25 - 100	50 - 300
Notes: * All sizes vary widely depending on the location ** May not have HPP buildings - the facility may be located outdoors playground.			

In practice, the sizes can vary within a very wide range, depending on the characteristics of each site. Electricity production using water is considered to be a well-proven and proven technology. Any major breakthroughs in terms of technical improvement can hardly be expected since the technology is already characterized by a high level of efficiency and reliability. Turbine efficiency and cost indicators remain relatively stable, but construction methods and associated costs continue to change. Capacity utilization ratio (CF = actual annual electricity production in kilowatt hours divided by ideal annual energy production in kilowatt hours) is highly dependent on water availability. CF values can vary from 25 percent to more than 80 percent, although they are typically in the range of 40 to 80 percent for channel hydropower and 50 to 80 percent for rowing hydroelectric power plants. The levels of capital expenditure also vary widely, depending on the conditions of the particular riverbed. The following Table 2 provides data on the estimated cost of construction of new and major refurbishment of existing facilities, including operating costs, fixed costs, etc., which allow us to estimate the costs of implementing new construction projects and retrofitting existing hydropower facilities.

Table 2

Characteristics of small hydropower technologies

Type	New SHPP	Re-equipment of the existing SHPP
Performance Indicates	Changes from object	Changes from object
Typical Work Cycle	to the object	to the object
Net production capacity (MW)	0.1 - 10	0.1 -10
Power factor	50-80%	50-80%
Economic indicators ($)	2300 - 4100	1500 - 4500
Total project cost ($ / kW)		
Fixed operating costs	5 - 26 $ / kWh	5 - 25 $ / kWh
Variable operating costs	5 - 6 $ / MWh	5 -8 $ / MWh

Based on the analysis of hydro-ecological potential, ecologically safe component of potential hydropower resources was substantiated at the level of 15% [4]. This value for the Carpathian region is 4.5 billion kWh per year, that is, today the total capacity of environmentally friendly SHPP, for which we have solved the problem of selecting promising sites is more than 500,000 kW. The SHPP limit of 500,000 kW leaves enough space in the region for the introduction of other non-traditional energy sources. Additionally, longitudinal profiles of the major year were analyzed, and the choice fell into areas of abrupt change in the longitudinal profile with a steady increase in the partial slope (within the middle and lower reaches of the year). Consideration was given to the proximity of settlements that would become potential energy consumers, with higher capacity of SHPP corresponding to places with a higher concentration of consumers. In addition, the connection of the SHPP to the grid is cost-effective 2-5 km [5]. Thus, the complex influence of the above factors made it possible to identify promising sites for the placement of small, mini, micro hydroelectric power plants within the Carpathian region. Taking into account all of the above, the areas of prospective location of SHPP in terms of engineering-geological, hydrological, hydropower, and economic conditions at the level of pre-project recommendations were divided into three types: favorable, promising and problematic [4]. There are different types of sites: micro HPP (up to 100 kW), mini HPP (100-1000 kW), small HPP (1-5 MW).

The scenario of the ecologically safe development of small hydropower in the Carpathian region involves the construction of new derivative hydroelectric plants and the reconstruction of existing rowing hydroelectric power plants up to 5 MW. The complex impact of environmental safety factors allowed to identify prospective areas for the placement of small, mini, micro hydroelectric power stations to produce 4,5 billion kWh of electricity.

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SOLAR PHOTOELECTRIC STANCE IN THE ELECTRICAL SYSTEM OF THE SCHOOL

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Introduction. Energy consumption in today's world is growing rapidly and the amount of traditional fuel is steadily decreasing. The widespread use of fossil fuels leads to environmental problems. The main possible solution to the problem is alternative energy sources.

The main source of the world's alternative energy is the sun. Today, solar photovoltaic technologies are the most competitive and capable of dynamic development among all known methods of electricity production. Photovoltaic power stations (PPS) have several advantages: the long service life of the main components, minimal maintenance costs. Solar power plants are constantly being improved and can be used as additional sources of power supply, working together with others, or be fully autonomous.

The aim of the work is to choose the optimal composition of the photovoltaic station for the power supply of the school.

The object of the study was an elementary school located in Kyiv, which consumes 69,614 kWh of electricity per year. To reduce dependence on the external power grid, it is proposed to install PPS to generate electricity for their own needs and sell its surplus to the grid. According to preliminary calculations [1] to provide the school with electric energy during the year we choose solar power stations with a total capacity of about 65 kW.

To select the optimal variant of PPS, several types of solar panels [2-5] have been considered, the characteristics of which are given in the table 1. According to the technical characteristics and temperature coefficients, calculations of changes in output power of the modules depending on the ambient temperature have been made. The capacity of the modules may decrease by 1.7% in summer and increase by 18% in winter.

In PV*SOL software product [6], according to geometrical characteristics of the building and parameters of solar modules, a model of the solar photovoltaic station was built, mounted on the roof of the building, and 3D-visualization and shading analysis of solar modules surfaces was carried out.

The design was developed and the equipment for connecting the PPS to the network and to the consumer was selected.

For comparison and selection of the most optimal photovoltaic module, calculations in [6] of monthly electric energy generation of the PPS and electric energy consumption of the school were carried out.

During the year of the power plant's operation, 23187 kWh was consumed by the school and 52214 kWh was sold to the grid, 46439 kWh of electricity was consumed by the consumer from the grid during the year. In summer, higher solar radiation increases the production of electricity, and the consumption of electricity by the school is reduced, resulting in increased energy sales.

Table 1

Several types of solar panels and technical characteristics

Solar cell type	Capacity, kW	Area, m^2	Price, $USD	Generation, kWh	Specific generation, kWh/m^2	Cost of electricity $USA/kWh	Payback period, years
Yingli Solar YL 280C-30b	64,4	376,4	35818	73021	194,6	0,0754	9
JA Solar JAM 60S02-280 / PR	64,4	376, 08	34594	73528	195,5	0,0732	8,9
Longi Solar LR - 60 HPH 350H	64,75	345,65	42626	75262	217,8	0,0712	8,8
SunPower SPR-MAX2 - 350	64,75	327	457588	72425	221,5	0,0767	9,1

The table shows that it is optimal to install PPS with Longi Solar LR panels - 60 HPH 350H.

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NUMERICAL STUDY OF AIR-FILLED ANTENNA ARRAY GRID PARAMETERS

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The paper deals with air-filled antenna, the power system and emitters are fixed by means of attachment of two pins to each emitter. Because of the proposed antenna array is made on the airframe, it is necessary to take into account the impact of the locking pins for each element. Therefore, the task is to clarify the size of the radiators and optimize the antenna array using numerical calculation methods.

The rectangular shape of the micro-male emitter was selected for analytical calculation because it is simpler to analyze. The microstrip line method and the parallel power supply system were used to power the emitters, as this allows the number of elements to be matched at the same time, with less loss, since the percentage from the point of supply to each element of the grid is the same.

To calculate the geometric dimensions of the microstrip antenna, the transmission line model was used as the most suitable micro-strip power line [1]. This model represents a radiator in the form of two slits that are separated by low power line resistance.

The obtained geometric dimensions are refined by mathematical modeling by means of software package Ansoft/Ansys HFSS (High Frequency Structure Simulator). It also allows to optimize and to take into account the impact of the locking pins.

In the process of modeling at first it was created a single inter-male radiator on an air substrate, and its geometric dimensions were determined with the analytical method of calculation.

As a result of the optimization, a microstrip air-filled antenna array grid with a low reflection coefficient of -19.16 dB at a working frequency of 2.4 GHz with a low value of the standing wave factor of 1.255 dB was calculated (Fig. 1). This antenna has a high gain of -18.53 dB and can be used in wireless computer networks in the range of 2.4 ... 2.483 GHz (IEEE 802.11).

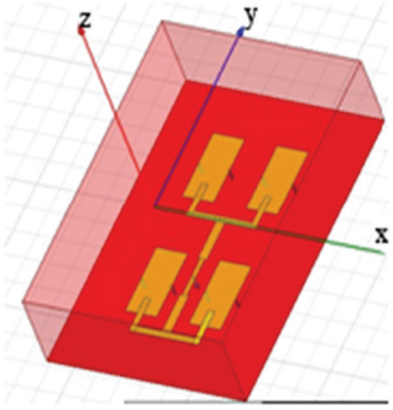

Fig.1 According to the obtained data, an experimental antenna was made with 24 radiating elements.

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USE OF n-CdTe SINGLE-CRYSTAL SUBSTRATES IN SOLAR POWER ENGINEERING

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Introduction. The urgency of the energy problem necessitates the development and production of renewable energy sources, among which a special place is occupied by semiconductor solar cells (SC), providing direct conversion of solar energy into electrical energy. These include, in particular, amorphous silicon (α-Si: H), copper-indium dyslenides (CIS) and copper-indium-gallium (CIGS), as well as cadmium telluride (CdTe). Another advantage of these semiconductors is their more efficient absorption of optical radiation, which allows the manufacture of cheaper thin-film solar cells. This paper discusses a number of technological methods for changing the physicochemical properties of the surface of single-crystal n-CdTe substrates, leading to an improvement in the basic electrical and photoelectric parameters of metal-semiconductor contacts.

The study of integral light characteristics showed that for all diodes (CdTe, CdTe:Li, CdTe:O_2), qualitatively similar dependences are observed. They were measured using a solar radiation simulator based on a xenon lamp and a calibrated set of neutral filters.

In this case, the short circuit current I_{sc} is a linear function of the lighting level L when it changes within more than four orders of magnitude. Open circuit voltage V_{oc} is proportional $\lg L$ to low voltage and tends to saturate at high light levels. The absolute values I_{sc} and V_{oc} are determined by the type of diodes and magnitude L, and their average values were measured for five samples of each group at 300 K under conditions of sunlight AM2.

The short circuit current density

$$J_{sc} = I_{sc} / \mathrm{S}$$

was calculated taking into account the effective photosensitive area, which for the studied samples was ~$2 \cdot 10^{-1}$ cm^{-2}. An analysis of these data shows that the modification of substrates leads to an increase in the efficiency η of SC, with the highest η observed for diodes with a quantum-sized surface.

Note that the change in the photoconversion efficiency is due to a change in other parameters of solar cells associated with it by a known expression

$$\eta = \frac{J_{sc} \cdot V_{oc}}{P} \cdot ff \ .$$

Here ff is the filling factor of the load characteristic of the SC, and P is the solar radiation power, which at AM2 is 69 mW/cm^2.

Conclusions. Obviously, to obtain the maximum photoconversion efficiency, all three factors in the numerator of the right side of the expression should be maximized. The solution to this problem requires experimental studies to establish the influence on the mentioned parameters of both the technology of manufacturing diodes and their operating conditions - temperature, light level, etc.

INCREASING THE EFFICINCY OF AIR CONDITIONING SYSTEMS THROUGH RATIONAL DISTRIBUTION OF THERMAL LOAD

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The efficency of air conditioning systems and the performance of their refrigeration machines depends on the current thermal load and duration of operation during the year. The higher the load and the longer the air conditioning system operates during the year in changing climatic conditions, the greater the annual cooling production that is needed to meet current cooling needs. It is reasonable to consider annual cooling production as the criterion for selecting the total design load on an air conditioning system.

The rational value of project cooling capacity of the air conditioning system must satisfy the hourly and seasonal changes in the thermal load on the air conditioning system and should not significantly exceed the set values. Thus, a methodological approach to improve the efficiency of the air conditioning system must ensure a rational distribution of cooling capacity in the ambient air cooling processes to meet the actual changing climatic conditions and at the same time maximum (close to them) annual values of cooling production. For this purpose, the overall thermal load on the air conditioning system, designed to ensure maximum annual cooling production, should be divided into a relatively stable basic thermal range of the ambient air, which can be provided by the operation of the conventional refrigeration compressor in a nominal or close to it mode, and the second, variable thermal load range, in accordance with cooling capacity needs for precooling ambient air under variable thermal loads with operation of refrigeration compressor in partial modes. The variable thermal load range can be covered by applying the variable speed compressors (variable refrigerant flow technology) or other energy saving technologies to cover peak loads by using the excessive cooling capacity accumulated under reduced current thermal loads.

The proposed method is quite useful for rational designing of traditional central air conditioning systems and for modern systems with variable refrigerant flow (VRF), which typically operates within the range of 40% to 80% of the design cooling capacity. It may also be adopted for the design of systems without variable refrigerant ducts provided by ventilation through an external air procession system and their advanced (combined) version with a common outdoor air handling unit for preventing the lack of cooling capacity in the indoor units.

DEVELOPMENT OF SUN AIR HEATERS FOR MODERNIZATION OF GRAIN DRYERS

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The current state of organization of grain drying requires the transition to new energy-saving, environmentally friendly and accelerated technologies that allow to obtain high quality products. Innovative ways of drying and upgrading chamber dryers are used to reduce energy consumption, reducing fuel consumption by 25-50%.

The purpose of the work is to develop solar air heaters for the modernization of grain dryers. Currently, there are existing developments of solar collectors for heating the air. Their samples are shown in fig. 1.

a) b)

Fig. 1. Flat air solar collector (SC). a – scheme, b – photo (from internet)
A - absorber (heat sink); TI - transparent insulation; ThI - thermal insulation; AF - air flow; AG - air gap.

The paper proposes a number of solutions for solar air heater. They differ in materials and design of the absorber and insulating transparent coating. A fundamentally new element of the solar air heater is the two-sided washing of the absorber by the flow of air. This increases the efficiency of heat removal from the absorber and lowers the temperature on the silo wall. The method of calculation of heat exchange processes in the solar air of the heater is developed. Design calculations were performed and the surface area of the solar collector was determined.

For the incident solar radiation density E = 630 W / m^2, ambient temperature t = 20 ºC, collector tilt angle φ = 90%, for collector width δ = 0.25 m, wind speed w = 5 m/s, obtained: heat loss from 1 m^2 of collector surface Q_{loss}= 143.9 W, useful heat flow value Q_u = 454.7 W, heat flux absorbed by the plate Q_{abs} = 598.6 W.

The modernized grain dryer is capable of saving gas costs and ensuring the quality of the finished product. A solar air heater for grain drying is created. Directing the heated air directly into the furnace creates the possibility of additional savings (up to 50% or more) of natural gas. When choosing methods and modes of grain drying, it is necessary to take into

account its thermo - and moisture resistance, structural and mechanical properties, on which the quality of the obtained products depends.

THERMAL CONDUCTIVITY OF THE WET POLLUTION LAYER ON CONDENSING HEATING SURFACES OF EXHAUST GAS BOILERS

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Additional energy saving by utilizing the exhaust heat in internal combustion engines (ICE) of the thermal power plants (TPP) allows to save fuel. Using of condensing low-temperature heating surfaces (LTHS) in exhaust gas boilers (EGB) allows to increase the economic efficiency and environmental performance of boilers and TPP in the whole. When fuel oils are burnt the intensity of low-temperature corrosion (LTC) increases to 1.2 mm/year at wall temperatures above 130 °C. In the case of water-fuel emulsions (WFE) combusted with water content of $W^{r} = 30$ % there is a significant decrease of LTC intensity to the level 0.25 mm/year. That makes it possible to apply condensing LTHS at a wall temperature t_{w} below the dew point temperature of sulfuric acid vapors $t_{H_2SO_4}$ within high working reliability of these condensing LTHS. With this a pollution intensity of LTHS increases, but the condensing heating surface is covered with a layer of wet pollution which is easier to remove.

Experimental researches of pollution intensity at wall temperature values below dew point temperature of sulpfuric acid vapors were carried out at the experimental setup with combustion of fuel oil and WFE (Fig.1).

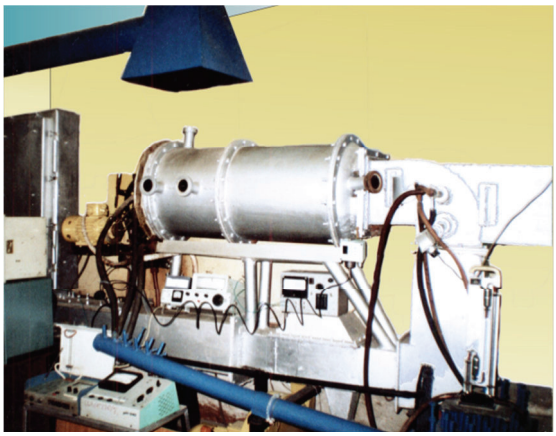
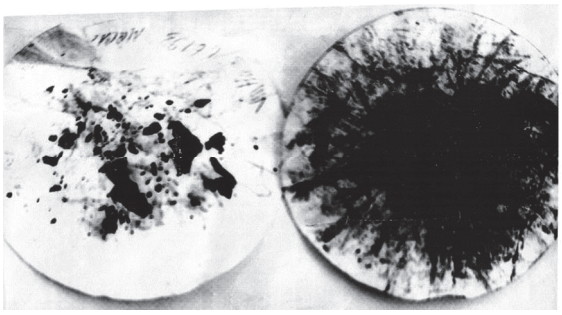


Fig. 1. General view of experimental setup

Fig. 2 shows flushing pollutions during combustion of fuel oil and WFE. When WFE is burnt with $W^{r} = 30$ % the pollution consists mainly of membrane of sulfates with soot and ash. When fuel oil is burnt with $W^{r} = 2$ % the pollution consists of soot and ash deposits. Determination of specific mass on pollution external surface of sample tubes was carried out by gravitation method.



a b

Fig.2. Microstructure of pollution: (a) – on a sample filter using WFE; (b) – fuel oil

The thickness of pollution layer and its thermal conductivity λ_{eq} in the presence of experimental data on the mass of pollution per 1 m^2 of pipe surface depends on the porosity value. According to the adopted methodology it is assumed that the layer porosity is $P = 0.3$ when fuel oil ($W^r = 2$ %) is used and the average porosity value is $P = 0.48$ when WFE ($W^r = 30$ %) is used.

Maxwell equations give results that are generally in good agreement with experimental data for porous materials, which can be attributed to the deposition when using fuel oil and WFE, taking into account the conditions corresponding to the influence of the modes of combustion and deposition of particles. Therefore, it was decided to use a formula to determine the value of λ_{eq}, which takes into account the porosity of the liquid-filled sulfates

$$\lambda_{eq} = \frac{2\lambda_d + \lambda_c - 2\Pi(\lambda_d - \lambda_c)}{2\lambda_d + \lambda_c + \Pi(\lambda_d - \lambda_c)}\lambda_d \qquad (1)$$

where λ_d – the thermal conductivity of the dispersed phase; λ_c – thermal conductivity of continuous phase; P – porosity.

Taking into account the different state of pollution (dry at $t_w > 140$ °C, vapor-liquid at $t_w = 140…120$ °C and wet at $t_w < 120$ °C), it is necessary to determine the coefficients of equivalent thermal conductivity λ_{eq} for each zone of wall temperatures.

Calculations of thermal conductivity were carried out under different variants of pollution states on the heating surface, taking into account the accepted structure of pollutions: 1) the dry layer of deposits on the sulfate layer (the space between the particles is filled with flue gases) at t_w above 180 °C; 2) a layer of deposits with superheated acid vapors at 140 °C $\le t_w \le$ 180 °C; 3) a layer of deposits with a vapor-acid mixture (condensate and vapors of sulfuric acid); 4) a layer of deposits filled with sulfuric acid condensate of different concentrations at t_w below 110 °C; 5) a layer of deposits with sulfuric acid condensate of lower concentration due to the absorption and condensation of H_2O vapor at $t_w < 70$ °C.

When determining λ_{eq} for zone of the layer with a vapor-acid mixture, it is necessary to take into account the degree of dryness x of this mixture in the layer, as well as the dependence of H_2SO_4 concentration on the wall temperature. At wall temperature $t_w = 140$ °C, the degree of dryness x was taken to be 1, at $t_w = 110$ °C was equal to 0, and at $t_w = 130$ °C (end of the adsorption zone) was 0.9. The value of λ_{eq} for this temperature range was determined by the formula:

$$\lambda_{eq} = \lambda_a + (\lambda_{a.v.} - \lambda_a) \cdot x \qquad (2)$$

where λ_a – the thermal conductivity of the acid, which depends on t_w, W/(m · K); $\lambda_{a.v.}$ – thermal conductivity of sulfuric acid vapor, which depends on t_w, W/(m · K); x – degree of dryness.

As a result of the conducted research, the values of the coefficient of equivalent thermal conductivity depending on t_w were obtained for variants of the state of deposit layer when

liquid fuels at $W^{\text{r}} = 2\%$ and WFE based on them with $W^{\text{r}} = 17$ and 30 % are used (Fig. 3).

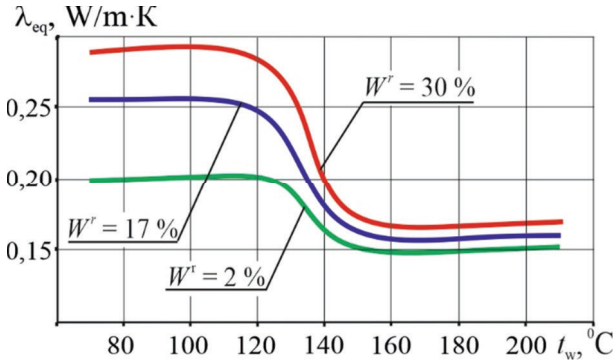


Fig.3. Dependences of the equivalent thermal conductivity λ_{eq} of pollution layer on the wall temperature t_w when liquid fuel and WFE are used

In the wet capillary-porous body, together with energy transfer in the form of heat, energy is transferred due to mass transfer. It is necessary to take into account the presence of internal sources of heat, because in the layer there is an additional amount of heat due to the passage of absorption processes and the passage of chemical reactions. According to the accepted mechanism of processes when WFE are used with $W^{\text{r}} = 30$ % at wall temperatures below the dew point temperature of sulfuric acid vapor except the process of condensation of H_2SO_4 vapor (by contact mechanism) in the presence of SO_2 and SO_3 sulfur oxides in the gas flow and an equimolar mixture of nitrogen oxides (NO and NO_2) there are a number of chemical reactions of nitrosyl sulfuric acid formation. This conclusion is based on the fact that the temperature level of gases, the metal surface and the H_2SO_4 condensate layer, the concentration of H_2SO_4 in the field of LTHS boilers at t_w below $t_{H_2SO_4}$ in the exhaust gas flow fully meet the technological conditions of sulfuric acid obtaining by nitrous mechanism in sulfuric acid production. Therefore, these processes will lead to the appearance of an additional amount of H_2SO_4 by this mechanism.

Therefore, it is accepted that chemical reactions of nitrosyl sulfuric acid formation occur in pollution layer with H_2SO_4 condensate, as well as simultaneously the processes of condensation, absorption and dilution of condensate of acid vapor by H_2O vapor, which are accompanied by the release of additional heat in pollution layer. When sulfur fuels oils are burnt, the actual adsorption temperature of H_2SO_4 vapor at a pollution layer temperature is about 180 °C (acid concentration is maximum 92 %). In the area of acid peak (wall temperature is 100...110 ºC) there is a decrease of acid concentration to 72...67 %. When WFE are used with $W^{\text{r}} = 30$ % in the region of acid peak at $t_w = 100\ldots110$ ºC, the H_2SO_4 concentration is at the level of 57 %, at which the maximum absorption intensity of SO_2, N_2O_3 is observed with the formation of nitrosyl sulfuric acid with subsequent release of sulfuric acid. The thermodynamic dew point of water vapor is $t_{pH_2O} = 53$ °C. At wall temperature t_w up to 60...70 °C, due to the passage of adsorption processes of H_2O vapor, a porous pollution layer occurs an increase of actual temperature of water vapor dew point.

Conclusions. Thus, as a result of the passage of these processes, an additional amount of heat is released. As calculations showed, the passage of these processes in pollution layer creates a constant source of heat in pollution layer, which leads to a change in the mechanism of thermal conductivity of this layer and increases the specific heat flow by an amount $q_{\Xi} = q_{\text{к}}(1 + \sum_{i=1}^{n} q_i)$, where $\sum_{i=1}^{10} q_i$ - the amount of additional thermal effects, which is about 10 %.

STUDYING THE OPERATION OF TWO-STAGE SODIUM-CATION INSTALLATION SF-10A

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Water treatment is the most significant task in industry while water is an integral part for many manufactural processes. Initial water contains a lot of different impurities. The application of raw water leads not only to corrosion and limestone deposition in pipes but to premature wear and rising pf power inputs in a thermal network. Therefore, the creation of effective and inexpensive technology for water treatment is a topical problem.

This work the object for investigation is the boiler house of Hofron Ltd, situated in Zhovkva district, Malehiv, 70 Lesi Ukrainki str., intended for the steam supply of the enterprise and for heating the industrial premises.

The treatment of a feed water for Ferroli boilers of Vapoprex HVP 800 type is accomplished by a water treatment equipment (WTE) SF-10A. The mentioned installation includes two sodium-cation filters with a common control block and a tank for the preparation of a saline solution. Cation-exchange resin having a high-water hardness capacity is used as a filter medium. In the article [1] are given reactions that describe the ion-exchange process by two-stage sodium cation and the advantages of the given method. The laboratory investigations are conducted for the purpose to study the influence of WTE SF-10A upon the quality of water. It is proved that the water hardness decreases to 0.01 mg-eqv/l. Several phases for regeneration of the sodium-cation installation are represented.

The estimation of the specific NaCl (A) consumption per a regeneration is given; it is determined that on the first stage filter A is 135 g/g-eqv and on the second – 350 g/g-eqv respectively. The data concerning the effectiveness of WTE SF-10A are analysed and the cost-performance characteristics of Hofron Ltd after WTE modernization are computed. It is determined that the WTE performance factor before and after modernization is equal to 82 and 91% respectively.

Therefore, the application of WTE SF-10A in the boiler house of Hofron Ltd allowed:

- to get a high level of softened water;
- to reuse spent regenerative solution (SRS), because this reduces the consumption of reagent for the regeneration of filters of the first stage by 30-50%, as well as reducing water consumption for own needs;
- to save technical salt by 31%. In addition, the saving of the salt and the reuse of SRS has led to a reduction in the release of chlorides to the environment;
- to increase the quality of the steam used in the turbine to generate electricity;
- to reduce the cost of the repair and maintenance of equipment by 10 times;
- to increase significantly the level of process automation and reduce the risk of human-related emergencies;
- to reduce the cost of producing 1 m^3 of water almost to 3 times.

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THE INFLUENCE OF THE POWER TRANSFORMER RADIAL CHANNEL WINDING PROFILE ON THE KIND OF THE COOLANT CIRCULATION

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Introduction. In the windings of the power transformers are distinguished vertical and horizontal (radial) oil channels. Vertical channels are formed by the surfaces of insulating cylinders. Horizontal are formed by the surfaces of the coils, which are separated from each other by remote insulating gaskets [1]. The following assumptions were taken into account during the process of creation the numerical model:

- insulating gaskets do not protrude into vertical channels and do not create additional resistance in them;
- linings and rails do not overlap the intersection of vertical and radial channels.

In real winding, this assumption is not true, but the influence of gaskets and rails does not create significant resistance to oil flow and can be neglected.

Radial channels of a power transformer windings have the form of a regular parallelepiped, but in real transformers horizontal channels can have the form of a trapezoid [2]. The horizontal channels of a real transformer have a variable section and narrow as the fluid flows to the winding axis and expand when flowing in the opposite direction. This is achieved through various crimping of insulating pads.

To analyze the influence of the radial channel profile on the nature of the coolant circulation, two numerical channel models were created. They were filled with transformer oil. The temperature of oil at the inlet of the channel is 335K. The temperature of the coils is 355 K. The trapezoidal channel differs from the rectangular one in that its left border is less than the right one by 0.1 mm (10% of the width of the channel intersection). The velocity field in the rectangular radial channel of the transformer is presented in Figure 1, and in the trapezoidal is presented in Figure 2.

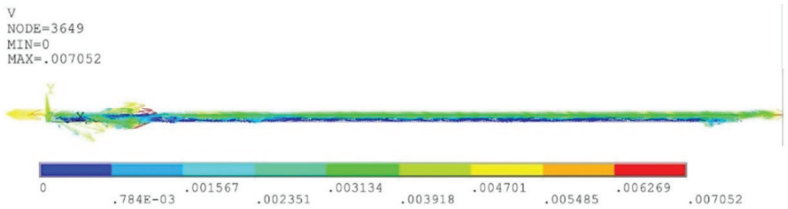

Fig. 1.The oil velocity field (m/s) in the rectangular radial channel of the transformer

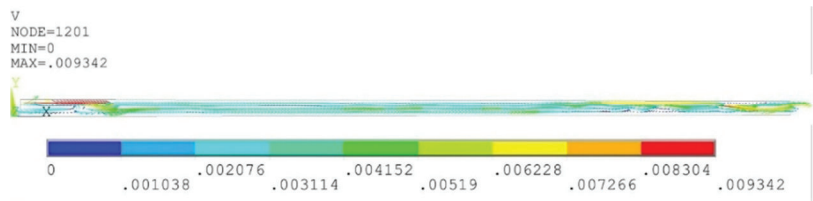

Fig. 2. The oil velocity field (m/s) in the trapezoidal radial channel of the transformer

Comparing the results, it becomes evident that the pattern of oil circulation in rectangular and trapezoidal radial channels is similar. Oil flows into the channel at the bottom and flows into the upper. The speed of movement of the medium in the central part of the channels is much lower than in its lateral areas. However, in the trapezoidal channel, no formation of zones of oil stagnation is observed, unlike rectangular. This is due to the fact that the oil viscosity is required to move the oil upstream of the channel along the inclined upper boundary. This is what will lead to the through circulation in the radial channel. However, the average velocity of the oil flow in the trapezoidal channel is almost no greater than the flow velocity in the rectangular.

Therefore, the effect of the through flow in the trapezoidal channel on the thermal and hydrodynamic processes in the transformer disc windings is identical to the effect of the oil flow in the rectangular channel. However, in the case of investigating the nature of the transformer oil motion in a separate horizontal channel, it is impossible to assume that the rectangular shape of the channel is due to the fact that this will greatly distort the results obtained.

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EFFECTIVITY OF USING SOLAR COLLECTORS IN SCHOOL HEATING SUPPLY SYSTEMS

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Due to the increase in energy tariffs and accordance with the Energy Strategy of Ukraine [1], the introduction of renewable energy sources in budget institutions becomes more important, which will significantly reduce the consumption of primary energy resources.

Today solar energy is beginning to be considered as an alternative option in the design of heat supply systems.

The main factor determining the expediency of solar installations is a significant number of sunny days per year.

On the territory of Ukraine, the solar energy for one average annual light day is 4 kWh/m^2 (in summer days - up to 6-6.5 kWh/m^2), which is about 1.5 thousand kWh per year per each square meter. This is about the same as in average Europe, where the use of solar energy is very widespread.

Thermal solar collectors are the most popular nowadays [1]. In the international market, this class of technical devices is widely represented by various manufacturers.

The purpose of the work was to determine the efficiency of using the heat supply system based on solar collectors for maintenance of school hot water supply.

The object of the study was a high school in Kyiv, which has 680 pupils and 70 employees, hot water consumption was 5840 l/day, and the annual amount of heat was

447 GJ. The solar heat supply system based on solar collectors would partially cover hot water supply requirements. It was planned to place the system on the roof of the building. There are no trees or tall houses around the school on the roof level, so there would be no shading of the collectors.

The solar system of hot water supply includes solar collectors with the area from 111 m^2 to 126 m^2 depending on type and manufacturers, a tank-accumulator for 2000 liters, pump group, expansion tank, duplicating source in the form of electric heating elements located in a tank-accumulator, pipelines, and an automation system. The cost of installing the system, depending on the firms of equipment manufacturers was from $ USA 88,000 to $ USA 110,000.

The average performance of collectors by months of the year was calculated. The amount of thermal energy produced during the year by a flat collector was 60,000 kWh, and by a vacuum collector - 70,000 kWh.

In this work, comparative modeling using T*SOL [2] and RETScreen [3] software of two types of solar collectors from different manufacturers [4-7] were carried out:

flat: Vitosol 200-F and SunMax-DH2;

vacuum: Vitosol 200-T and SunMax-30.

According to the results of simulations [2] with a southern orientation of collectors, the optimum corner of installation of a vacuum collector was an angle of 45 degrees to the horizon, and for a flat was 50 degrees.

The average cost of the received thermal energy from solar collectors was 0,1 UAH for 1 kWh of energy from 1 m^2 of a surface of a vacuum collector and 0,05 UAH for the flat.

According to calculations [2], the installation of solar collectors would reduce fuel consumption by 36-40%, and by [3] - up to 44%. During the summer period, the replacement ratio of fuel by solar collectors was almost 100% due to increased solar power supply and reduced hot water consumption.

The payback period of the system is 16-19 years.

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ELECTRICAL PROPERTIES OF THIN LAYERS OF CdTe OBTAINED BY CHEMICAL OBTAINED ALLOYING WITH CALCIUM IONS

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Introduction. Promising for solar power is the second generation of photovoltaics, which usually uses such thin film materials cadmium telluride (CdTe), a mixture of copper, indium, gallium, selenium. Despite the fact that cadmium telluride has bipolar conductivity, obtaining low-ohmic crystals or p-type layers continues to be an urgent task. This is due to the need for p-n junctions with low sequential resistance, as well as the problem of making low-ohm contacts to high-ohm p-CdTe. In addition, p-CdTe thin films are promising for photovoltaics based on CdS / CdTe, ITO / CdTe heterostructures and the like.

To obtain the doped films, the base substrates were 5 × 5 × 2 mm^3 plates, which were cut from a CdTe bulk crystal. The doping was carried out by boiling the substrates in aqueous suspensions of Ca $(NO_3)_2$, the duration of which varied from 15 to 60 minutes. The surface layers of the samples change the electronic conductivity to the hole, which is confirmed by a change in the sign of thermo-emf. At the end of the diffusion process, the samples were washed several times in boiling distilled water to remove residual salts.

Measurement of electrical parameters of semiconductor films was carried out on the developed automated installation according to the classical method, when a sufficiently high voltage is applied to the sample and the current flowing through the sample is measured. The type of conductivity was determined by the sign of thermo-emf.

Since doping only affects the conductivity of the surface layer, a rectangular sample can be represented as a parallelepiped with height h and base l x l having alloy walls of effective thickness d.

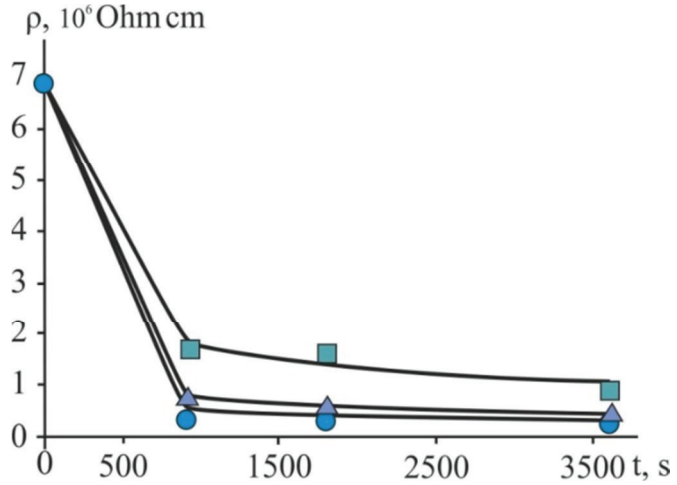

Fig. 1. Dependence of the resistivity on the doping time
(solution concentration ■ - 25%, ▲ –50%, ● –75%).

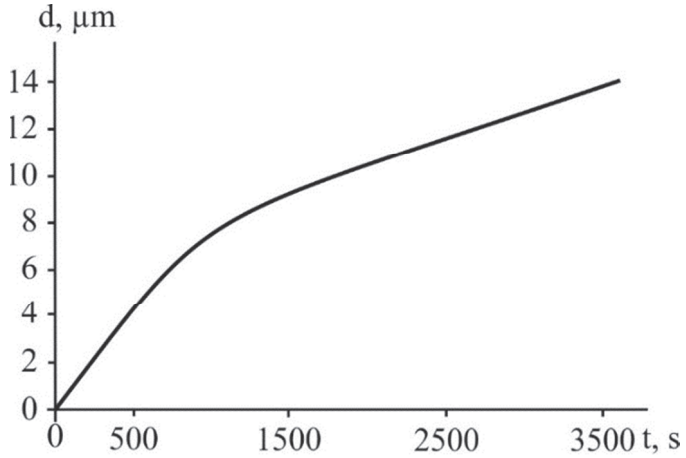

Fig. 2. Dependence of the penetration thickness of the dopant on the time of doping

Conclusions. By approximating the data (Fig. 1, Fig. 2) with the electrical model described in [1], the parameters and thickness of the surface layer for different doping times and concentrations of the dopant are determined.

The dependence of the electrical properties of the obtained films on the technological factors of their production is also investigated. The conductivity of the doped layer, velocity and depth of diffusion are determined.

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EXPERIMENTAL DETERMINATION OF PRESSURE LOSS IN A LOW-FLOW AEROTHERMOPRESSOR WITH INCOMPLETE EVAPORATION

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Complex schemes with cyclic air cooling are usually used to approximate the process of compressing the working fluid in gas turbine compressors to isothermal. It leads to increase the fuel and energy efficiency [1, 2]. One of the promising areas is contact cooling of cyclic air by using a two-phase jet apparatus – an aerothermopressor [3]. This device provides efficient evaporative cooling of gas turbine without loss of total pressure. Due to evaporative cooling in the aerothermopressor, an effect of thermogasdynamic compression is taken place – gas pressure is increased in the process of instantaneous evaporation of water injected into the gas (air) flow accelerated to a speed close to sound [4, 5]. An effective water dispersed atomization in the air flow occurs in the aerothermopressor. This ensures efficient evaporation of the water dispersed flow in the flow part of the gas turbine compressor bringing the compression process closer to isothermal.

It is important to determine the organization rational parameters of work processes with the corresponding development of the design of the aerothermopressor flow part at designing

jet devices. The aerothermopressor allows to compensate for pressure loss and reduce the work on compression in the compressor and to increase the working fluid flow and, accordingly, to increase the gas turbine capacity. In addition, the aerothermopressor is compact and structurally and technologically simple to manufacture in comparison with surface air coolers [4, 6].

A significant influence on the working processes in the aerothermopressor is carried out by design factors. The total pressure of the gas flow in the aerothermopressor is significantly affected by pressure losses due to hydraulic and local resistance in the aerothermopressor flow part (confuser, evaporation chamber and diffuser) [5, 7].

The installation of the aerothermopressor in the gas turbine cyclic air cooling system is proposed in accordance with the scheme (Fig. 1). This arrangement between the compressors will reduce the operation of the gas turbine high-pressure compressor due to lower initial temperature of the compression process. This will ensure isothermal compression during the evaporation of the finely dispersed mixture in the high-pressure compressor flow part.

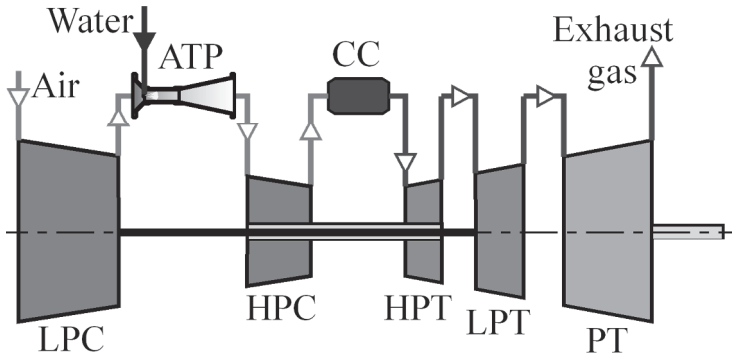

Fig. 1. Scheme of the gas turbine with cyclic air cooling by the aerothermopressor: ATP – aerothermopressor; LPC, HPC – low and high pressure compressors; CC – combustion chamber; HPT, LPT – low and high pressure turbines; PT – power turbine.

To conduct an experimental study of determining pressure losses in the aerothermopressor flow part, an experimental setup was developed. The experimental setup is designed to simulate the aerothermopressor operation in the cooling cycle air of the gas turbine.

The simulation of the aerothermopressor operation to cooling cyclic air of the gas turbine WR-21 from Rolls Royce (N_e = 25.250 kW, g_e = 0.190 kg/(kW·h), η_e = 41.2%) were considered.

To determine the local resistance coefficients for the diffuser and confuser, classical dependences of fluid dynamics were used.

Based on the obtained experimental data, for different values of the initial pressure at the aerothermopressor inlet P1 and the relative amount of water injected gw, an empirical dependence was established by approximation to determine the pressure losses coefficient in the aerothermopressor with the flow rate to 0.52 kg/s.

The reliability of the work results is ensured by: the tasks correct formulation of the theoretical and experimental research; confirmation of the adequacy of the mathematical model with satisfactory agreement between the calculated and experimental data; using modern methods of experimental research and analytical modeling.

Determination of the hydraulic resistance coefficient $\zeta_{ATP.E}$ for the aerothermopressor based on the data (Fig. 2): at P_1 = 300 kPa – $\zeta_{ATP.E}$ = 1.15-1.30, at P_1 = 250 kPa – $\zeta_{ATP.E}$ = 0.90-1.00 and at P_1 = 200 kPa – $\zeta_{ATP.E}$ = 0.70-0.75. The tendency of the hydraulic resistance

coefficient behavior is the same as for absolute pressure losses ΔP_r, that is, with a water flow rate increase, the hydraulic resistance coefficient $\zeta_{ATP.E}$ increases by 0.05-0.15. At P_1 = 150 kPa – the value of $\zeta_{ATP.E}$ practically does not change and it is – 0.35-0.40.

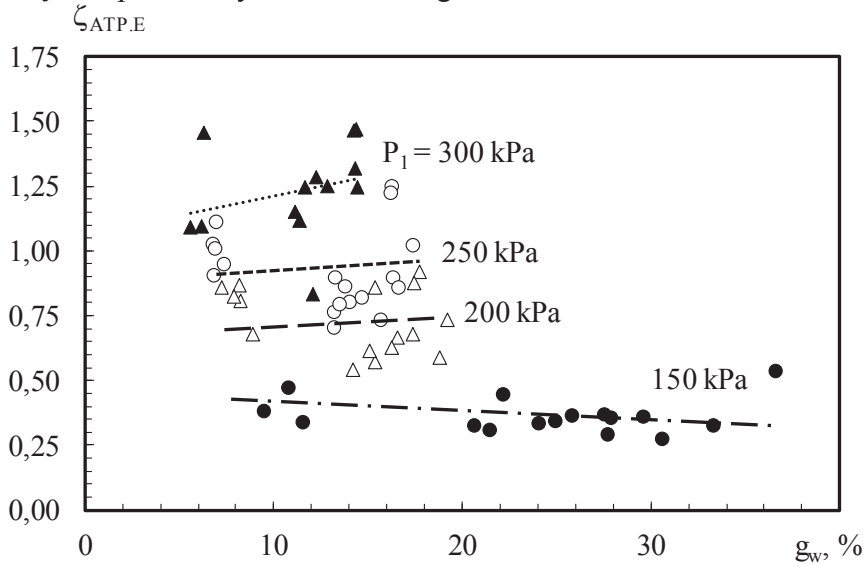

Fig. 2. Experimental dependences of the hydraulic resistance coefficient $\zeta_{ATP.E}$ on the relative flow rate of the injected water gw at various initial pressures: P_1 = 150; 200; 250; 300 kPa

The deviation of the calculated values of the hydraulic resistance coefficient $\zeta_{ATP.C}$ from those obtained during the experimental study $\zeta_{ATP.E}$ is $\delta_\zeta = \pm 25$ %.

Conclusions. During an experimental study of the low-flow aerothermopressor the hydraulic resistance coefficients of its flow part were determined. The experimental hydraulic resistance coefficient is $\zeta_{ATP.E}$ = 0.35–1.30, depending on the initial pressure P_1 and the injected water relative flow rate into the receiving chamber g_w. The absolute values of pressure losses are ΔP_r = 18-75 kPa (11-24%).

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INCREASING THE COOLING PRODUCTION OF INTEGRATED ENERGY SYSTEM BY TWO-STAGE HEAT CONVERSION

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Gas engines that operate on natural gas or alternative gaseous fuels (biogas, etc.) are widespread in integrated energy systems (IES) for combined cooling, heat and power (CCHP). Such gas engines are manufactured as cogeneration modules with heat exchangers to produce hot water or steam by using the heat of exhaust gas, charged air or gas-air mixture, engine jacket cooling water and lubricating oil. A hot water or steam is used as a heat source for absorption chiller.

The analysis of the energy efficiency of such trigeneration systems shows the presence of significant heat losses during conversion of engine exhaust heat into the cold by the absorption Li-Br chiller, using the hot water from cogeneration gas engine module as heat source, caused by a mismatch in the thermal conditions of the absorption Li-Br chiller effective operation and gas engine performance with using the return heat water as a coolant.

So, for reliable operation of gas engine by keeping its thermal state at the safe level the temperature of the heat water from absorption Li-Br chiller, which is returned to the gas engine inlet as a coolant, is limited by its specification value of 70 °C. When it exceeds this value the excessive heat of return heat water is discharged into the atmosphere by radiator.

As an example of the conventional transformation of gas engine exhaust heat into the cold the trigeneration plant for integrated electricity, heat and cooling supply of the "Sandora"–"PepsiCo Ukraine" in Nikolaev (Ukraine) is considered. The trigeneration plant includes 2 cogeneration gas engines JMS 420 GS-N.LC GE Jenbacher (electric power of each engine is 1400 kW, thermal power is 1500 kW). The heat of engine exhaust gas, charge air-gas mixture, engine jacket cooling water and lubricating oil is used for heating water. The heat of hot water is conversed by the AR-D500L2 Century absorption Li-Br chiller into a cold (2000 kW refrigeration capacity), which is spent for technological needs.

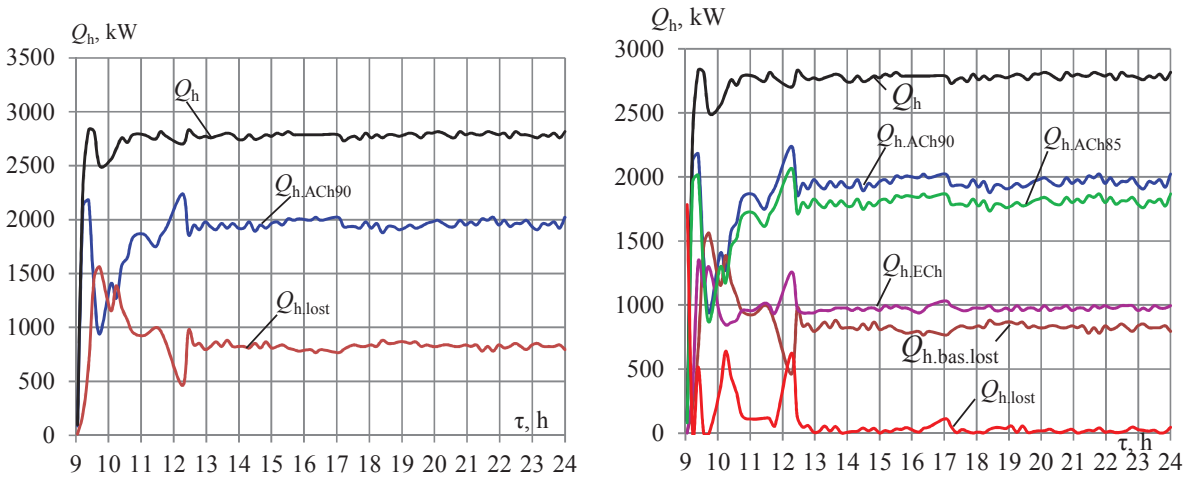
In accordance with the existing scheme, at a return water temperature at the outlet from absorption Li-Br chiller, for example 75...80 °C, i.e. above its specification value t = 70 °C for the inlet of the gas engine heat exchangers ensuring the optimum thermal state of the gas engine, some of the return water is cooled in the cooler of the return coolant CRC with the removal of excess heat into the atmosphere through the cooling tower 2 of dry type. It is not advisable to return the excess heat to absorption Li-Br chiller, because of its lower temperature level 75...80 °C in comparison with the specification temperature of the hot water at the inlet of absorption Li-Br chiller about 90 °C, since the decrease in the temperature of the hot water at the inlet of absorption Li-Br chiller causes falling the efficiency of heat transformation into the cold - reducing the coefficient of performance ζ, which is a ratio of the cooling capacity generated to the heat used.

A decrease in the temperature of heating water in absorption Li-Br chiller is usually not more than 15 °C. With this the temperature of return hot water after ACh is not lower than 75 °C (the temperature of hot water at the outlet of gas engine module of 90 °C) that is higher than its required temperature at the gas engine inlet 70 °C for maintaining the thermal state of gas engine at the safe level. The excessive heat is discharged into the atmosphere by the emergency radiator. Because of the heat losses into the atmosphere more then 30 %, the thermal coefficients (coefficients of performance) of the gas engine heat recovery system are significantly lower than the coefficient of performance of the absorption Li-Br chiller, which causes a substantial decrease in the cooling capacity.

In order to exclude these heat losses, the refrigerant ejector chiller (ECh) was proposed as a low-temperature stage for deep heat conversion after the existing absorption Li-Br chiller. The innovative scheme of two-stage absorption-ejector system for deep heat utilization was developed. In ECh the heat of hot water from gas engine is used in generator to produce a high pressure refrigerant vapor as forced working fluid for ejector to suck a low pressure refrigerant vapor from evaporator for cooling water for technological needs (and/or air for space conditioning or others).

The generator of ECh consists of economizer section for heating liquid refrigerant from condenser to the temperature of its boiling in evaporative section of generator. According to the scheme proposed, the heat of hot water from gas engine module is firstly fed to the evaporative section of ECh generator, after which it is delivered to ACh. The water of lowered temperature behind the ACh is used for economizer section of ECh generator and leaves it with temperature of about 70 °C just required for returning at the inlet of cogenerative gas engine module.

The values of the heat Q_h of hot water from cogenerative gas engine, conversed into cooling capacities Q_0 in traditional heat conversion system with absorption chiller and in proposed advanced heat conversion system with two-stage absorption-ejector chiller are presented in Fig. 1 and 2.



a) *b)*

Fig. 1. The values of the total heat of hot water from cogenerative gas engine Q_h, heat of hot water consumed by absorption chillers $Q_{0.ACh90}$ and $Q_{0.ACh85}$ at the temperature of hot water at their inlet 90 °C and 85 °C, heat of hot water consumed by ejector chiller $Q_{h.ECh}$, heat lost $Q_{0.lost}$ by discharging into the atmosphere through the radiator: a – traditional heat conversion system with absorption chiller; b – the proposed advanced heat conversion system with two-stage absorption-ejector chiller

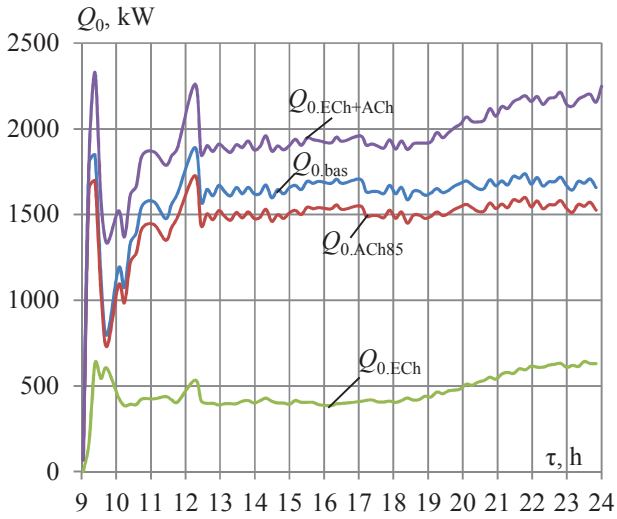


Fig. 2. The values of the total cooling capacity $Q_{0.ECh+ACh}$ of the proposed advanced gas engine heat conversion system with two-stage absorption-ejector chiller, cooling capacity of basic (traditional) heat conversion system with absorption chiller $Q_{0.bas}$ at the temperature of hot water at chiller inlet 90 °C, cooling capacity of ejector chiller $Q_{0.ECh}$ at the temperature at its inlet 90 °C and cooling capacity of absorption chiller $Q_{0.ACh85}$ (installed behind ECh) at the temperature at its inlet 85 °C of the proposed two-stage absorption-ejector chiller

As Fig. 1 and 2 shows, the proposed advanced gas engine heat conversion system with two-stage absorption-ejector chiller provides increasing cooling capacity by about 400-600 kW as compared with traditional heat conversion system with absorption chiller due to utilizing practically all available heat.

Conclusions. By utilizing the excessive heat of gas engine cogeneration module, remained after its conversion in absorption Li-Br chiller and normally discharged into the atmosphere, in advanced two-stage heat conversion system with absorption and ejector chillers an increment of about 15-20 % in the cooling capacity is obtained in integrated energy system for combined cooling, heat and power.

ANALYSIS OF EMULSION PRODUCTION METHODS

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Problem statement. Energy is a priority area for the sustainable development of any state. However, the energy sector of Ukraine is in a difficult position nowadays. It concerns thermal power stations, utility sector, which use mainly residual fuel oil as reserve. However, when burning it, there are problems of ensuring environmental requirements and overall

efficiency of its use. One of the promising ways of solving this problem is the use of water-emulsion fuels (WEF) [1]. However, the production of such high-quality fuel (stable finely dispersed emulsion) is impossible without improving the technology of emulsification.

Analysis of recent research. Emulsification processes are widely used in many industries such as petrochemical, food, heat and power, construction, etc. [2].

These issues are covered in the works by William Clayton [3], Philip Sherman [4],

V. M. Ivanov [5], I. A. Tuv [6], et al. The works by modern researchers such as A. M. Pavlenko, A. A. Dolinskyi, B. I. Basok [7] are also of scientific value. However, nowadays there is no single consistent classification of emulsification methods (EMs) and devices for their implementation. Therefore, it is difficult to choose an effective EM.

Purpose statement. The purpose of this paper is to critically analyse the existing EMs.

Main material. The authors [4, 7] classify EMs the following as condensation, dispersion (methods of intermittent shaking, mixing, colloid mill, homogenization), sonar (ultrasonic), electrical and physicochemical.

Ivanov V. M. [5] used the dispersing devices to obtain the emulsion which, according to the operating principle, were classified as: mechanical (colloid mills and mechanical agitators), pneumatic and steam (bubblers), ultrasonic, cavitation.

When studying finely dispersed emulsions, the author [2] used the devices which, according to the operating principle, were classified into mechanical, cavitation with moving elements, and cavitation and static.

The study [8] describes the process of obtaining emulsion by chemical, mechanical, electrical methods, self-emulsification and the vapour phase condensation method.

With such a variety of classifications, it is difficult to compare and select the optimal EM according to the following criteria:

- energy consumption for emulsification;
- emulsification performance;
- parameters of the resulting emulsion;
- economic costs (operation, maintenance and repair of emulsification equipment, staff qualification, etc.).

Conclusions. It is clear that it is difficult to create a single classification that takes into account all these criteria. Therefore, it is necessary to create an algorithm for selection of EM, including the classifications according to the above criteria. Such an algorithm will make it possible to perform the multivariate analysis. On the basis of this analysis it is possible to suggest EM to obtain emulsion according to the appropriate requirements.

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PROBLEMS OF ENERGY CERTIFICATION OF BUILDINGS IN UKRAINE

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Introduction. With the implementation of the new law for residential buildings in Ukraine, when receiving state aid for complex thermal modernization through the Energy Efficiency Fund, it is mandatory to develop an energy certificate. However, today in Ukraine there is an inconsistency in the normative documents regarding the definition of energy efficiency class according to the Energy Consumption under the State Standard “Thermal Insulation of Buildings” and energy consumption according to the “Methodology for Determining the Energy Efficiency of Buildings”. Two dwelling houses in Kyiv were selected as objects of research (house №1: 17 floors, 1992, walls made of silicate brick 0.51m thick; house №2: 24 floors, one-section, 2011, reinforced concrete frame filled with 250 mm ceramic brick, 100 mm polystyrene foam). According to the results of the energy survey, geometrical and thermal characteristics were determined and, according to the DSTU B A.2.2-12: 2015 [1] methodology, energy consumption (heating, cooling and hot water supply), energy consumption was calculated taking into account the efficiency of generation, distribution, heat transfer systems. The main difference is the method of determining the energy demand for DHW: according to DSTU B A.2.2-12: 2015, it is determined according to the recommendations in [kW·h/m^{2}year], and according to the "Methodology ..." - taking into account the regulatory volumetric consumption. Actual energy consumption is much lower than estimated, given: failure to observe the temperature schedule of the coolant supply; centralized hot water supply is absent for a long time (in summer); estimated consumption includes absent cooling. A recommended package of energy-efficient measures has been developed for each building, taking into account their economic feasibility. The following table shows the results of the energy efficiency class calculations for the two buildings.

Table 1

Comparison of calculation results by different approaches

Name		Actual energy consump-tion	DSTU [1]	Energy efficiency class	
				DBN "Thermal insulation of Buildings" [2]	"Metho-dology ..."
House №1	Energy consumption, [kW·h/(m^2·year)] -before energy-saving measures	110	220	E	G
	- after energy-saving measures	-	102	C	D
House №2	-before energy-saving measures	56	132	C	E
	- after energy-saving measures	-	95	B	D

Thus, the normative base of Ukraine regarding the classification of energy efficiency of buildings needs further improvement.

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PREDICTION OF SOIL SALINITY FROM GALVANIC SLUDGE

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Introduction. The problem of recycling waste from industrial production is urgent, which is caused by the constant increase in the amount of waste and insufficient rates of their processing. Of particular danger is toxic waste, which contains heavy metals. Such wastes include galvanic sludge. Annually in Ukraine, as a result of galvanic production, up to 12,000 tons of sludge is generated, which should be stored in the territories of enterprises [1]. Long-term storage of galvanic waste is allowed at special sites and in equipped storage facilities. However, as practice shows, artificial repositories have limited capacity and service life. During long-term storage under the influence of external atmospheric factors deformations and destruction of packing occur. Such phenomena lead to the leakage of reactive elements into the environment. As a result, not only the storage sites and also the soil of adjacent surfaces outside the area of the work site of the enterprise are contaminated with heavy metals. Contamination of the soil surface causes a number of problems related to soil salinization, soil water contamination, and increased levels of water mineralization in surface water bodies.

According to the degree of salinization soils are divided into weak, medium, strong, and extremely strong saline [2]. It is established that on poorly saline soils the crop yield

decreases on average up to 25%, on average saline up to 50%, on strongly saline up to 75% and on extremely strong saline up to 100%. Heavy metals which enter the water and are absorbed there by phytoplankton are of particular danger, which can in the future brings them to human consumption. The development of a method for predicting soil salinity levels and the possibility of contamination of reservoirs by galvanic waste is relevant.

Purpose and research goals. The article is devoted to the analysis of the ecological status of the territory of the enterprise with a galvanic shop, which produces printed circuit boards. The purpose of the article is to improve the method of predicting the impact of sludge on soil salinity and groundwater contamination.

Research matter and results. Copper is widely used in PCB manufacturing and electroplating because of its high electrical conductivity. The process of "copper etching" to ensure the drawing is carried out using a large amount of running water. Technological processes in PCB shops bring to the formation of liquid waste with metals in the process of etching and solid waste (sludge) - during utilization.

The authors carried out experimental studies of the process of accumulation of sludge at the enterprise during "etching" of printed circuit boards. The researches were carried out on the territory of the enterprise for the production of electronic equipment in Cherkasy region of Ukraine. The company has been operating for 48 years. The average output of PCBs is up to 2,500 m^2 per month. With an etching line productivity of 14 m^2/h, the amount of sludge in 8 hours reaches (100 ... 120) kg. For one month during the work in one shift the amount of sludge is up to 2500 kg and for two shifts - up to 5 000 kg. Based on the analysis of PCB waste, the percentage of a number of metals was determined (Table 1).

Table 1

Metal content of the sludge test specimens

Indicators	Metal content in sludge					
Type of metal bond	CuO copper	CaO calcium	Fe_2O_3 iron	Cr_2O_3 chrome	NiO nickel	ZnO zinc
Metal content, %	16	8	9	2	2	1
Harm class	3	4	3	3	3	3
Limit concentration in water, mg/dm^3	1,0	3,5	0,3[3]	0,05	0,1[3]	1,0

On the territory of the enterprise, the productivity of which varies from 2,000 to 4,000m^2 of boards, from 30 to 48 tons of waste accumulates annually. In previous years, sludge was stored on the territory of the enterprise in landfills in open areas. For the last 20 years, the sludge has been stored in polyvinylchloride packages. Soils in the area have the following structure: loam − up to 1.5 m; sand − up to 0.3 m; groundwater − up to 0,8m; clay − up to 1.2 m; further is interlayer water. Under the influence of atmospheric precipitation, metal ions are washed out and transferred to soils, surface and ground waters due to easy dissolution in acidic environment. Soil salinity is measured as a percentage of the dry soil density: in the presence of metal salts, less than 0.1% of the soil is considered unsalted; (0.1… 0.3) % − poorly salted; (0.3… 0.5) % − average salinity; (0.5… 0.75) % − strongly salted.

A method for predicting soil contamination in the sludge storage area is proposed. Simulation of the process of movement of salts from the surface of the earth to the underseam layers of the zone of aeration is by the laws of molecular diffusion. The research methodology is based on the use of the theory of physical-chemical hydrodynamics of porous media. The process of motion of metal salts can be described by the differential equation of motion and conservation of mass of matter for the vertical transfer of mass of matter [2]. The presence of sludge on the soil surface corresponds to the first-order boundary condition.

$$D\frac{d^2C}{dX^2} = \theta\frac{dC}{dT}, \quad (1)$$

where D is the molecular diffusion coefficient, m^2/s; C − salinity of rocks, %; Θ − volume humidity, %; X − the spatial coordinate, m; T − hour coordinate, p.

The analytical solution of equation (1) has the form:

$$C_h = (C_x - C_0)erfc[\frac{1}{2}\frac{h_x}{(D\cdot T/\theta)^{1/2}}], \quad (2)$$

where C_h is the predicted level of salinity at a depth of h_x, %; $C_x|h=0$ is the surface salinity of the aeration zone; $C_0|T=0_o$ − initial level of soil salinity before the beginning of storage; h_x − distance of the calculated points from the origin, i.e. from the surface of the earth, m; T − duration of the predictable calculation, year; *erfc* − tabulated function.

Predicted salinity is defined by the following target setting:

1. The level of salinity for 20 years during the sludge storage in the open area;
2. Salinity level for 20 years during sludge packing.

The following assumptions are made in the predictable process: the process of accumulation of metals is cumulative and does not take into account the annual seasons of changes in soil moisture. Long-term soil contamination prediction is obtained as a result of an iterative calculation for formula (2). Table 2 shows the penetration depth of metals with a level of salinity within (0.3… 0.344) %.

Table 2

Results of the depth of salinization calculation in the category of "poorly saline"

Calculated period, year	First target setting	Second target setting
	Salinization depth C_x =0,3-0,344, h_x, m	Salinization depth C_x =0,3-0,344, h_x, m
1	0,65	0,35
2	0,75	0,57
3	0,88	0,71
4	1,01	0,86
5	1,15	1,02
10	1,65	1, 35
12	1,81	1,55
15	2,02	1,84
20	2,43	2,43

As follows from table. 2, when the sludge is placed on the open surface for a year, 0.65 m thick soil enters the category of "poorly saline", in four years this level of salinity reaches a depth of 1 meter, in 12 years − h_x=2.02, which creates conditions for groundwater pollution. The contamination process is slower when the sludge is stored in the package. However, if the service life exceeds 15 years, the process of polymer destruction packaging takes place and further storage results in groundwater contamination. In order to avoid the accumulation of sludge on the territory of enterprises, it is proposed to use the technology of regeneration of waste etching solutions, in which the recovered metal is used as a secondary raw material for copper production, and the recovered solution is reused for PCBs etching [3].

Conclusion.

1. On the basis of experimental researches of production of printed circuit boards the volumes and composition of sludge, conditions of their storage are determined.

2. Heavy metal oxides (copper, iron, zinc, nickel, chromium) have been found, contained in production sludge constitute a risk to the environment, humans and animals.

3. The method of long-term prediction of penetration depth and soil salinity levels based on the theory of physical and chemical hydrodynamics of porous media is proposed.

4. The results of experimental studies and calculations have shown the possibility of particularly dangerous contamination of soils and groundwater with heavy metal salts, which in Ukraine may lead to a reduction of agricultural land.

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PROSPECTS FOR IMPLEMENTATION OF THE GREEN CHEMISTRY CONCEPT IN THE CONTEXT OF COUNTERACTING THE NEGATIVE IMPACT ON THE ENVIRONMENT

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In order to achieve the UN goals for sustainable development, it is necessary to implement innovative technological smart-solutions in all areas of the national economy. And the creation of environmental protection technologies, in particular, the implementation of the green chemistry concept in science and production is especially important in this context.

Green chemistry technologies reduce pollution at its source, minimizing or even eliminating the dangers of chemical reagents or reaction products. However, not all environmentally-friendly technologies related to chemical processes are relevant to green chemistry. In particular, green chemistry innovation can be exemplified by technology aimed at replacing hazardous sorbent for air purification with still effective, but safer sorbent. In this case, the use of a new sorbent will lead to the fact that the primary hazardous sorbent will not be used and produced. Therefore, the new technology (or method) for removing the pollutant from the air will correspond to the sustainable development and green chemistry concepts.

Thus, according to the «Environmental Protection Agency» (USA), the main idea behind the green chemistry concept is to develop new chemical products and processes that reduce or even eliminate the need for hazardous substances. It is important to notice that the principles of green chemistry are applied throughout the life cycle of a chemical product, starting from its development, manufacture, use and finishing by its disposal. So, the purpose of the green chemistry concept is to improve technologies and chemical processes in order to make a positive impact on the environment.

According to the «American Chemical Society», one of the great examples of green chemistry implementation is the production of computer chips. Traditionally, this process requires a large amount of chemical reagents, water and energy – the production of a single chip requires the consumption of raw materials, which is almost 630 times higher than the weight of the chip itself. To make this process more environmentally friendly, scientists at the

Los Alamos National Laboratory have developed an alternative method that uses supercritical carbon dioxide at one stage of the production.

A similar example is the production of biodegradable plastic; the pharmaceutical industry is also constantly looking for ways to improve the production of medicines by eliminating their harmful side effects and using processes that create less toxic waste. Today one of the most respected international summits in the green chemistry sphere is the «Ark International Summit on Green Chemistry and Technology», which is also an interdisciplinary platform for the collaboration of researchers and practitioners to discuss the latest advances, trends and challenges in green chemistry. For example, according to the organizers of this summit, in 2020 the major focus will be on innovations and modern green chemistry approaches for sustainable societal and biosphere development aimed at minimization of waste production.

Thus, the active use of the green chemistry concept will enable our generation to mitigate the pressure on the environment, both by reducing pollution levels and by conserving valuable natural resources, as well as by reducing risks to human health.

INVESTIGATION OF LITHIUM BROMIDE ABSORPTION CHILLER MODEL WITHOUT SOLUTION CIRCULATION PUMP

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Market potential for space heating and cooling in industrial and commercial buildings accounts for more than 50 per cent of global energy use [1]. The area of buildings is of great potential due to thermal demand can be differentiated between heating and cooling for thermal comfort and hot water. Energy efficiency is an increasingly important contributor to climate change mitigation while at the same time presenting an opportunity for technological innovation.

District heating and cooling networks enable such technologies as combined cooling, heat and power (CCHP), or trigeneneration, to realize their potential by using waste heat. Incorporating this energy efficient technology yields fuel savings and leads to a significant reduction in greenhouse gas emissions.

Absorption technology is the most widespread thermal chiller technology for CCHP. Lithium bromide absorption chiller (ACh) capacities start from several kW, ranging up to multi-MW chillers.

The use of solar energy expands the scope of ACh. Systems that use solar energy are most widely used for air conditioning of residential and public buildings [2]. For stand-alone air conditioners with a cooling capacity of up to 70 kW, pumpless absorption chillers are of practical interest. In such chillers there is no pump for pumping the solution, which simplifies the design and increases the reliability of the installation.

This work is devoted to an experimental study of the model of pumpless lithium bromide absorption chiller (cooling capacity 10 kW) in which the circulation of working fluids (refrigerant-water, absorbent-bromide lithium) is carried out due to the difference in

their densities – the density difference of the vapor-liquid mixture in the generator and the cold strong solution in the absorber)

The main advantages of a stand-alone air conditioner with a pumpless ACh compared to an air conditioner that uses a vapor compressor chiller are its low power consumption, the use of an environmentally friendly working fluid, increased reliability, low noise and vibration levels, low maintenance, long service life. The disadvantages of using a pump free ACh are revealed in the need to ensure a vacuum in the system and the use of corrosion inhibitors.

The feasibility of the implementation of ACh in a pump-free design is explained by the following. The temperature range of condensation of the refrigerant in these units is 40-45 °C, and boiling is 5-10 °C. Accordingly, the maximum pressure difference between the condenser and the evaporator (generator and absorber) does not exceed 6-7 kPa. In installations up to 70 kW, this pressure difference is sufficient to circulate solution due to the density difference between the vapor-liquid mixture in the generator and the cold strong solution in the absorber.

Taking into consideration of the specific features of the experimental setup (the real absorber and evaporator are replaced by their simulators), the value of Q_0 was determined by calculation. The dependence of the calculated cooling capacity Q_0 of the installation on the temperature of hot water t_{g1} (at a temperature of cooling water at the inlet to the condenser equal to 30 °C) is shown in Fig. 1.

Fig. 1 shows that with an increase in the temperature of hot water at the inlet of the generator from 70 to 90 °C the cooling capacity of the installation increases, that can be explained by following: with increasing temperature of hot water the amount of heat supplied to the generator increases and the amount of evaporating refrigerant increases; - in the temperature range of hot water 70 ÷ 88 °C, the amount of solution, raised by the convection, significantly increases, the amount of absorbed refrigerant increases and, accordingly, the cooling capacity increases.

At a temperature of hot water at the inlet of the generator above 90 °C, in accordance with the above processes, the amount of solution supplied by the convective method decreases, and the cooling capacity of the installation decreases. In the tests performed, the cooling capacity of the installation varied in the range of Q_0 = 7.5-19.5 kW, which corresponded to the range of changes in the temperature of hot water at the generator inlet t_{g1} = 70-90 °C.

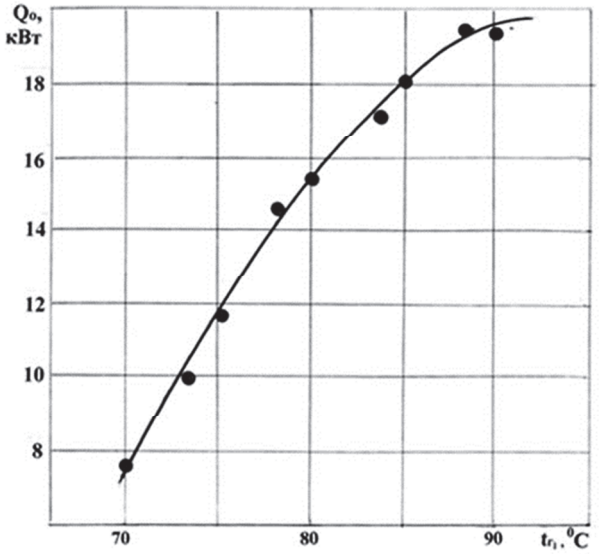

Fig. 1. The dependence of the calculated cooling capacity of the installation Q_0 on the temperature of hot water t_{g1}

Conclusion. Theoretical studies and experimental verification of the pumpless ACh model performance showed that ACh operates stably and reliably in the temperature range of hot water at the generator inlet 70-90 °C and the cooling water temperature at the inlet to the condenser 10-30 °C. Thus a stand-alone air conditioners with pumpless ACh, consuming low potential heat, can be used for year-round air conditioning of residential and public buildings.

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INFLUENCE OF WIND POWER PLANTS ON THE POWER SYSTEM

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Alternative and renewable energy (RES) generating installations are increasingly becoming a major trend in the development of modern electricity, with increasing investment and new generation capacity being built every year.

The use of RES for electricity production significantly reduces CO2 emissions, which has a positive impact on both the economic and environmental situation of the country.

However, there are also a number of problems associated with RES. In particular, it is the complexity of forecasting electricity generation, protection from the impact of RES on the grid, large areas of fertile land that cannot be used effectively, the utilization of storage cells, and the like.

There are many contradictions and problems that need to be investigated and resolved.

Wind power generation depends on wind speed, which in turn depends on weather conditions, natural obstacles and terrain. It also varies with height, so it is random and cannot provide stable power generation for the grid. Thus, as the share of wind energy in the total distribution network increases, there is a significant uncontrolled effect on the energy system. Among the problems that this leads to are the complications of the planning of the work of traditional power plants, the task of estimating the cost of electricity produced depending on the type of end user, planning of maintenance of components of large power plants, wind turbines or transmission lines, complications of the functioning of wind power stations in the market of electricity stations energy.

Therefore, to integrate wind power into the grid it is necessary to have tools for predicting their current capacity. Correct modeling of work of wind power plant, power system as a whole or its individual parts to predict the amount of electricity produced. And to do this, you need to be able to accurately forecast the weather conditions, including wind speeds in both the short and long term.

Therefore, there are some basic issues that need to be addressed when deciding on the construction of a wind farm that need to be investigated on a case-by-case basis and related to the random nature of wind. The possible level of loss of electricity generation, depending on

both the features of the terrain and the location of the wind farms themselves, is also of a random nature in the instability of wind flow.

The forecasting process requires the construction of a mathematical model for the dependence of the predicted value on certain factors, and in order to obtain forecasts based on the developed model. Short-term forecasting is usually understood to mean the hourly (sometimes half-hourly) values of the electrical power of a particular grid with a bias horizon of 24-48 hours.

To solve the prediction problem, there are many methods that can be divided into two categories. The first is physical methods that use many physical concepts to achieve high prediction accuracy. The second is statistical methods, such as auto-regression models integrated with the moving average ARIMA, which aim to find the relationship of measured and predicted power.

Conclusion. With the development of renewable energy, a considerable number of problems have arisen due to the complexity of forecasting electricity generation as well as the management of the electricity supply system as a whole. One way to partially solve the problem is to use electricity storage. However, this method is not a definitive and complete solution to the problem, since it is not perfect due to the lack of development of energy storage technologies. Therefore, in this case, this method can only be considered to improve the situation, not to fully resolve it.

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ECONOMIC ASPECT OF THE EFFICIENCY OF BIO-SOLID ENERGY GENERATION SYSTEMS

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In a set of energy-intensive technologies the usage of lumpy fuel from wood, non-certified fuel (straw, energy vines, elevator waste, sawdust, wood chips) successfully competes with natural gas and electricity. According to the Ukrainian Academy of Agrarian Sciences, due to the biomass the agricultural enterprises of Ukraine can become completely self-sufficient in generating thermal energy for the rural population. Together with the production of biofuels for internal combustion engines, this can be a significant contribution to the energy balance of Ukraine and can create thousands of additional jobs [1].

The drying process of grain is the most energy-consuming and energy-intensive component of further transportation, storage and its processing. It is impossible to store grain without bringing it to a predetermined moisture value, therefore, this process should take

place with strict observance of technological requirements to not reduce the quality characteristics of the grain.

The final cost of grain drying (P_{drying}) consists of the cost of fuel (P_{fuel}), electricity (P_{elect}), its transportation ($P_{trans.}$), storage (P_{stor}) and the salaries of operators (P_{sal})

$$P_{drying} = P_{fuel} + P_{elect.} + P_{trans} + P_{stor.} + P_{sal} \ . \quad (1)$$

The fuel cost component (P_{fuel}) essentially depends on the type of fuel. Diesel, propane-butane, natural gas are the most commonly used types of fuel in elevators for drying grains.

Let us consider the possibility of using pellets and grain wastes to reduce operation costs of drying. Compare the costs of fuel (Table 1). The table shows the market value of each fuel, the efficiency of boilers, the calorific value and fuel consumption at humidity reduced by 1 % for 1 ton of grain and the cost of fuel in UAH at humidity reduced by 1 % for 1 ton of grain.

This table shows that despite the decrease in boiler efficiency and increased fuel consumption, the cost of pellets and non-certified fuel is significantly lower. Thus, the total cost of grain drying will be reduced by the cheap component of P_{fuel}. And the use of adjustable actuators will reduce the electricity consumption of P_{elect}.

The vast majority of grain dryers are equipped with gas burners, and the use of pellets and elevator wastes requires conversion of grain complexes to solid fuel heat generators. The approximate cost of re-equipment for 2000 kW will be UAH 3.5 million. These costs will pay off in less than 100 days of operation of the complex when using the waste of the elevator, and for 150 days of work on pellets. From these calculations the economic feasibility of re-equipment of the complex [1].

Our proposed technology for the conversion of grain dryers has passed production tests and is successfully operated at four elevators in the Kiev, Ternopol and Chernihiv regions.

Table 1

Comparison of costs for different types of fuel for drying cereals

№	Title	Diesel fuel (L)	Propane-butane (L)	Natural gas (m^3)	Pellets (kg)	Uncertified fuels (kg)
1	Heat generation (kW)	10.4	7.25	8.3	4	2.8
2	Boiler efficiency	0.89	0.92	0.92	0.85	0.85
3	Energy cost	25	12	10.2	2.8	0.5
4	Fuel consumption at humidity reduced by 1 % for 1 ton of grains	1.53	2.14	1.87	4.13	5.16
5	Fuel cost (UAH) at humidity reduced by 1 % for 1 ton of grains	38.31	25.67	19.06	11.56	2.58

Conclusions. The proposed technology allows to reduce the cost of drying grain crops by 7 times, provided that non-certified fuel is used in thermal energy generation systems, as well as by rationalizing the automated operation modes of a grain dryer and a biofuel-fired solid-fuel generator.

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ECONOMIC EVALUATION OF ENERGY SAVING MEASURES FOR RESIDENTIAL BUILDING

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High energy consumption of the building sector is a pressing issue in Ukraine. Therefore, improving the energy efficiency of buildings is an important problem that needs to be addressed. The object of the study is a 213 apartments 9-storey residential building built in 2009. The construction was built on an individual project with 5 entrance, a roof boiler room and a non-heating basement. The building has a horizontal roof over the technical floor. Geometric parameters: heating area 15400m^2, heating volume 83600m^3. Heating system - two-pipe. The rooftop boiler works only during the heating period, hot water supply at the expense of electric boilers. The performed calculations of the efficiency of boilers on the direct balance showed that the reduced efficiency of existing boilers decreased from the passport value of 92% to the real 85%. During the work a detailed energy inspection was performed, which included: study of operating modes, refinement of geometric and thermal performance of fences, study of microclimate conditions, performing the necessary instrumental measurements and calculations, financial and economic analysis. A financial analysis of investments in equipment, installation and operation has been carried out and the economic impact of measures to improve the efficiency of the building in three packages (Table 1, 2) with a planning horizon of 15 years has been determined.

Table 1

Economic evaluations

№	Name	Investments, \$/m^2	Save energy, [kW·h/year]	Payback period, years	NPV	NPVQ
1	Maximum	35	1130730	14	-5,8	-0,39
2	Optimal	6	588200	4,3	1,9	0,73
3	Minimum	1	286600	1,1	1,69	5,13

Table 2

Energy conservation measures

№	Name	Event Package		
1	frequency regulation of pumps	Minimum	Optimal	Maximum
2	insulation and sealing of the basement entrance			
3	weather regulation			
4	vestibule doors			
5	lighting upgrade and motion sensors			
6	recuperators			
7	boiler replacement			
8	replacement of windows			
9	insulation of the technical floor			
10	Insulation of exterior walls			
11	apartment heat accounting			
12	balancing the heating system			

The maximum package has a negative NPV value and cannot be recommended for implementation, but it does contain calculations for measures that will bring the characteristics of the enclosure structures to the norms [1] in force in Ukraine.

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INTERNATIONAL EXPERIENCE FOR IMPROVING THE ECOLOGICAL SAFETY OF THE AIR ENVIRONMENT IN UKRAINIAN CITIES

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In the XXI century, the rapid development of cities has made it possible for people to live with increasing comfort. However, along with the benefits, urban areas also have a negative impact on human health and the environment. And this influence is especially strong on the atmospheric air breathed by citizens. Thus, according to "National Geographic" and "World Health Organization" [2], 3.7 million people worldwide were prematurely killed by air pollution in cities and rural areas in 2012. And air pollution causes not only health problems for residents, but also much more complicated effects, such as reduced yields in surrounding areas. Therefore, in order to identify ways to reduce the negative impact on the air environment of Ukrainian cities, the experience of foreign countries in counteracting atmospheric pollution was analyzed.

The main ideas of the international community include the following measures – to encourage the development of public transport and the use of bicycles and even to ban the use of traditional vehicles. At the same time, if "incentive" measures have been already implemented in many cities today, the "penalty" measures are implemented gradually and give residents some time to adapt. The results of the opinion polls have shown that most of the citizens understand the need for both incentive and penalty initiatives in order to achieve good levels of environmental safety of the living environment, and therefore support them.

According to the "Guardian" [1] data, published in 2016, cars in many historic areas in Paris are banned over the weekends. In addition, the city administration provides free public transport access during large-scale environmental incidents. Bicycle incentives and car-sharing programs are also encouraged in the city. In the Netherlands politicians plan to completely ban the sale of all gasoline and diesel vehicles from 2025, allowing only vehicles that use electricity or hydrogen. Freiburg in Germany already has over 500 km of cycle routes, tramways and a cheap and efficient public transport system. Copenhagen (Denmark) also encourages cycling. There are now even more bicycles in town than people. Much of Copenhagen territory has been closed to vehicles for decades, and by 2025 the city plans to become completely carbon-neutral. Similar examples can be also found in Oslo, Helsinki, Zurich etc.

So, taking into account the presence of not only the ecological but also the economic crisis in our country, we consider the following measures as the most urgent for implementation in Ukraine – increasing the number of bicycle routes and controlling their targeted use; conducting social advertising campaigns to promote healthy lifestyles and use of

bicycles; introducing public transport discounts during peak times when motorways are overloaded; reducing the number of cars in places where the maximum permissible concentrations of air pollutants are constantly observed.

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BENCHMARK APPROACH FOR DEVIATIONS OF ENVIRONMENTAL PROTECTION ENGINEERING SYSTEMS

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The modern environmental protection engineering systems, as any complex system, are characterised by deviations as a kind of passage (or passages' set) inside of which the system is allowed operating. The engineering system staying in this passage is the warranty of system performance in principle. It is some analogy with error which corruptes the correct data and states a fact that the correct data are found in bounds of assured range. This deviation is always multidimentional one. It is formed by (min-max)-pairs which qualify the boundaries inside of which some parameters characteristic for the permissible regimes and behavioral characteristics exist. At the same time the Benchmark approach may be used for system's real features adjusting to some model with purpose of selection the desirable deviation.

An example of deviation evaluation is analysis of complex system behavior under conditions of sources and connectivities alterations - "figure-of-eight" model of environmental and engineering processes. Thus, if the increase of resource (effectiveness) occurs simultaneously with the connectivity (complexity) increase that correspond to the system's development, – the system operates adequately. If at any point in the trajectory there is a negative increase in the resource, it becomes a signal of an approaching crisis and the need to carry out a local artificial crisis for the purpose of adaptation, that is, to look for deviance, to new conditions or risk-based requirements. After that adaptation system may rise on higher level from point of view of resource and connectivity, i.e. scare up the adequately deviation. That provides longer and more effecient system's operating in conservation mode.

The above can be illustrated by the example of municipal solid waste (MSW) management, which involves combining natural and man-made buffer zones into a single system. In Phase 1, the MSW was dumped into landfills where, most MSW components were returned to their natural state, which provided the circulation of substances in nature. However, the volume of MSW increases annually, which threatens to turn large regions into continuous sources of environmental pollution, and the natural decomposition of MSW is a

very slow process (the half-life of MSW decomposition is 50 years). When the landfill mass exceeded critical limits, Phase 2 of MSW management began – the construction of "landfills", which was characterized by fairly reliable isolation of MSW from the environment, filtrate removal systems and collection of gaseous MSW decomposition products for use as energy. But the number and capacity of the landfill sites continued to grow and a limit was approaching beyond which could not be increased. Therefore, it was necessary to move to a new model (Phase 3) – the construction of waste incineration plants (WIP), which provided the use of the organic constituent of MSW as a source of fuel resources. But WIPs use only about 50% of the organic constituents of MSW for energy generation. Therefore, now (Stage 4), combustion gas generators based on MSW pyrolysis are being developed, which allow to use up to 90-95% of the organic components of MSW, combined combustion and pyrolysis generators of heat and energy. MSW sorting system is improved at all stages of treatment, with the aim of using individual MSW components as recyclables. Above mentioned approach may be realized in case of admissible system (real model) behavior deviation search by means of Benchmark approach which follows from the decision making theory.

THE RATIO OF DIAMETERS OF TURBINE IMPELLERS OF SMALL HYDROELECTRIC POWER PLANTS

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Small hydropower plants with a pressure of 10 meters of water column are most appropriate to equip axial hydraulic turbines. The main advantages of such turbines are high speed, high efficiency and the ability to use all available pressure (even one below the plane or axis of the impeller). Typically, one to three hydro units are installed at one station. If the turbine is one, then it must be double-adjustable (in order to be able to change the angles of installation of the blades of both the working and directing apparatus). This is necessary in order to adjust the hydroelectric power plant to the flow of water in the river, which can vary within wide limits (depending on climatic conditions). The main drawbacks of the dual-adjusting turbine are its high cost and low reliability. Much more reliable and much cheaper are unregulated axial turbines (also called propeller turbines). There should be two or three such turbines at the hydroelectric power station, so that at least discretely adjusting to the flow of water in the river. The purpose of this article is to offer the best ratio of the sizes of geometrically similar propeller turbines of small hydropower plants.

The main size of a turbine is the diameter of its impeller. Suppose two turbines are installed at a small hydroelectric station. What should be the ratio of the diameters of their impellers? This is a difficult question, so it is necessary to decide what factors should be taken into account when solving it.

Modern low-pressure small hydropower plants with installed capacity of up to 200 kW are mainly networked, that is, they send all the generated energy to the common energy system. Therefore, they must be effective and environmentally friendly. If two small propeller turbines are to be installed at a small hydroelectric station, for environmental and economic reasons, the ratio of the diameters of their impellers should be $\sqrt{2}$:1. If these two turbines are geometrically similar, then at the same head, the ratio of water consumptions will be 2:1. It is the best ecological option for the layout of a small hydropower plant with two unregulated

turbines. It gives the opportunity to carry out a uniform discrete three-step control of water consumption by the station with the following characteristics: depth of control – 67%, discreteness of regulation – 33%. The relative water consumptions of a station may take the following values: 100%, 67%, 33% (100% – when both turbines are running, 67% – if only a large turbine is running, 33% – when only a small turbine is running).

If a small hydroelectric power plant is supposed to accommodate three propeller turbines, for environmental and economic reasons the ratio of the diameters of their impellers should be $2:\sqrt{2}:1$. This option of selecting the basic equipment for a small hydroelectric power station makes it possible to provide a uniform discrete seven-step control of water flow by a plant with the following characteristics: depth of control – 86%, discreteness of regulation – 14%. The relative water consumptions of a station may take the following values: 100%, 86%, 71%, 57%, 43%, 29%, 14%.

Therefore, in order for a low-pressure small hydro power plant up to 200 kW to be cheap, efficient, reliable and, most importantly, "friendly" to nature, it must be equipped with two or three different geometrically similar propeller turbines with the ratio of the diameters of their impellers $\sqrt{2}:1$ (two turbines) or $2:\sqrt{2}:1$ (three turbines).

MAINTENANCE OF THE ECOLOGICAL BALANCE BY CREATING A SYSTEM OF NATURE RESERVE AREAS

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The analysis of the frequency of anthropogenic ecological disasters and the overall state of the environment in recent decades have shown that humanity as a whole is paying greater attention to its own well-being, rather than to sustainable and symbiotic development with nature. According to [2] the number of the world natural catastrophes has also grown significantly from 1980 to 2018. So, the greater the environmental impact of humanity, the more important it is to maintain ecological balance. The expansion of the worldwide and national system of nature reserve areas is extremely important from the standpoint of such concepts as sustainable development, circular and green economics. And in our opinion, currently in scientific publications relatively little attention has been paid to the issues of extending nature reserve territories.

Analyzing peculiarities of maintaining the ecological balance, it is important to take into account the following. Firstly, the ensuring of the homeostasis in urban and natural ecosystems requires sufficient photosynthetic activity of autotrophic plants, reproduction of all the necessary components, preservation of various life forms on the planet, the ability to self-purification and development. This means that interaction between human society and the natural environment need to take place in conditions of the dynamic homeostasis and equilibrium. Carl Linnaeus even suggested that there is an "economics" of nature. By this, he meant the interconnections of all natural components upon which equilibrium in nature is based [1].

Secondly, further development of human society always leads to changes in the natural environment. At the same time, anthropogenic changes should not have a catastrophic character that leads to serious environmental crises. They must be gradual, ensure the proper distribution and strength of anthropogenic pressure and create the necessary conditions for

adaptation to them of both humans and nature. This state of dynamic homeostasis in the biosphere is called dynamic ecological balance.

It is important to state, that exploitation of nature always leads to environmental losses. From a purely environmental point of view, humanity consumes more than produces. In addition, in the process of using energy, people "spend" it (but do not destroy) turning it into an unusable type [3].

There was no absolute natural balance on Earth before the appearance of humans. Under such conditions, the development of the biosphere itself would be impossible. However, nature evolves over billions of years, and the changes that take place in it are almost imperceptible. Those ecosystems that are in equilibrium state undergo a series of stages characterized by changes in environmental performance, including some resistance to external influences.

Thus, when the intensity of anthropogenic environmental load has reached a critical limit, it becomes apparent the need to realize a complex set of tasks related to the requirements of optimization of resource use and utilization of natural resources potential, conservation and restoration of natural geosystems and environmental protection. This requires an effective public policy in the areas of resource use, environmental safety and environmental protection.

So, maintaining ecological balance and developing a strong system of nature reserve areas is not an easy task. Currently, there are a lot of methods and instrument aimed at achieving this aim. But in our opinion, a set of the instruments can be expanded by creating specialized soft products for different cases on the bases of T. Saaty's analytic hierarchy process in RStudio using "ahp" package. This method can be also used in order to assess the anthropogenic impact on the particular conservation area.

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SELECTION OF BOILER UNITS FOR SCHOOL HEATING

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Introduction. In recent years, it has been very common to introduce energy-efficient technologies to reduce the combustion of minerals. The transition to renewable energy sources and biofuels will help to solve the problem of environmental pollution and produce financially competitive thermal energy.

In Ukraine, budgetary and municipal institutions receive and produce heat using outdated and worn-out low-efficiency equipment that has reached the end of its operating life.

The building of School №121 has three floors and consists of two buildings. The total heated area is 3700 m^2. The total height of the building is 12.5 m. The glazing area is 500 m^2,

external walls – 1987 m^2, floor above the unheated basement and attic floor – 1119 m^2. The school is attended by 237 pupils, 42 employees.

The boiler room is designed for heating and hot water supply of the school during the heating period. It has two solid fuel boilers NIISTU - 5, which burn up to 185 tons of AKO grade coal, and is located in the basement, which is strictly prohibited [1]. Total thermal capacity of NIISTU-5 boiler is 325 kW, efficiency - 72%, emission level of nitrogen oxides - 96.82 kg/year; carbon oxides - 91.88 kg/year; carbon dioxide – 90224 kg/year. The actual efficiency of the boiler is 45-55% due to its unsatisfactory condition and improper storage of coal in the open air. The heating of the building consumes 540 Gcal/year of heat, which is 490 thousand UAH.

The work aims to substantiate the feasibility of installing a pellet boiler in the school heating system.

In order to reduce the heat consumption in the school, it is proposed to carry out thermal modernization of the building - 1085 thousand UAH, to introduce regulation of temperature regime in school premises and restore forced ventilation - 12 thousand UAH. The proposed measures will reduce heat consumption from 294 kW to 160 kW, and total energy saving costs up to UAH 1.1 million.

Connection to the district heating is not profitable: the network is at a considerable distance from the school and there are no other powerful consumers nearby. Therefore, it is proposed to leave the autonomous heat supply to the school, but to move the boiler room from the basement to another room on school premises. In order to determine the optimal fuel type and equipment for its combustion were considered:

1) gas condensing boiler:
   - Vaillant ecoTEC plus VU OE 806 / 5-5 [2];
2) solid fuel boilers:
   - Altep Trio 80 for burning wood and coal [3];
   - Metal-Fach Sokol SEG 150 - pellet boiler [4];
   - Marten Comfort MC-80 - boiler for long-term combustion on firewood [5].

Calculations were performed in the RETScreen software environment [6].

Boiler	The amount, pcs.	The cost, thousand UAH	EFFICIENCY, %	Total power, kW	Type fuels	Heat of combustion, MJ/m^3 (MJ/kg)	Fuel consumption, m^3 / year (kg / year)	At fuel, hrn / m^3 (Grn / kg)	Payback period, years.
Vaillant ecoTEC plus VU OE 806 / 5-5	2	206	99	160	gas	33,4	33205	6,55	4,7
Altep Trio 80	2	154	80	160	briquettes	13	86210	3,4	10
Metal-Fach Sokol SEG 150	1	280	90	150	pellets	16,4	70566	3,2	4,9
Marten Comfort MC-80	2	135	85	160	firewood	16,7	67110	2	3,6

The table shows that the Marten Comfort MC-80 boiler, which burns wood, has the shortest payback period for replacing the boiler with the proposed energy-saving measures. But this boiler has no automatic fuel supply. Among automatic - gas condensing boiler Vaillant ecoTEC plus VU OE 806 / 5-5 and pellet Metal-Fach Sokol SEG 150 we choose the latter, because the school has no gas supply.

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ON ONE SIMULATION METHOD OF TURBULENT FLOWS

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Modeling of turbulent flows is a task that has not yet been fully resolved. Natural and technological processes are often accompanied by turbulent flows of liquid and gas. The problem of the turbulent vortices originating and it analysis is highly relevant in our time. This knowledge has many practical applications that will be useful for engineers of different technological fields.

Today, there are many approaches to the calculation of turbulent flows. Recently, a large number of different software systems have appeared, solving a huge range of tasks. The examples of these kinds of programs are: FlowVision, ANSYSFluent, OpenFOAM, COMSOL Multiphysics®, Solidworks, etc. However, they have a number of shortcomings: they take up a lot of space on a computer, are very expensive, require installation and license. It was therefore necessary to create a software product without the above-mentioned disadvantages, albeit to a lesser functionality.

Mathematical model that describes the process of viscous liquid flowing around bodies in which turbulence is modeled by one-, two-, or three-parameter model in the form of an algebraic expression was proposed. Based on this model, a computer simulation system of the tested process was developed.

Let's consider the simplest variant of the problem of viscous liquid flowing around bodies. Liquid flows into a pipe of $R \times H$ size with initial velocity V_0.

At a distance l from the input flow there is a cylinder of diameter d perpendicular to the flow direction. At the other end of the pipe, the flow is free to flow out. Thus, the area is conditionally infinite in one direction. The geometry of the problem is shown in Figure 1.

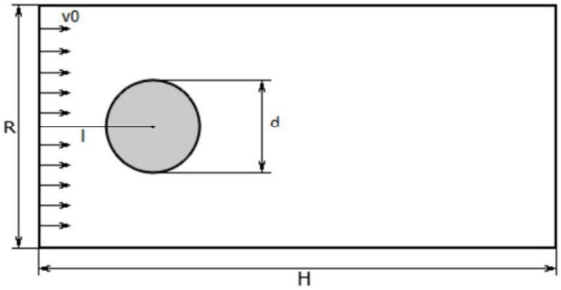

Figure 1. Geometry of flowing around bodies

It is necessary to create a mathematical model of viscous liquid flowing around bodies based on the turbulent nature of liquid movement, to implement the numerical studies of the flowing process around bodies of different shapes with visualization of the calculation results, to show the adequacy of the model created at the qualitative level.

The problem was implemented in Cartesian coordinates. For the calculated area we choose half of the axial cross-section of the pipe, i.e. the problem is reduced to two-dimensional.

The computational area is a rectangle. We break the computational area into basic cells with a uniform chessboard grid. We will need the out of boundary layer of cells to arrange the initial and boundary conditions. A peculiarity of this grid is that the points in which scalar and vector values are set or calculated are separated in space: scalar - in the center of cells, and vector – on the faces (fig. 2).

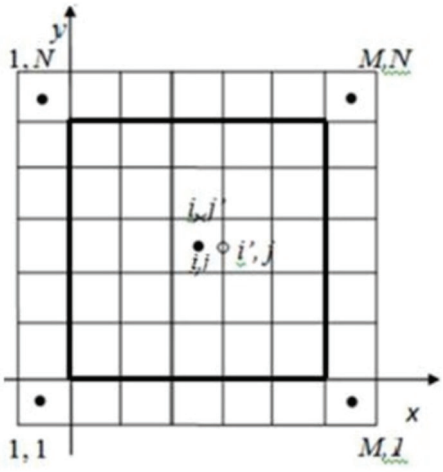

Figure 2. Calculation grid

Liquid motion is described by the Navier-Stokes equations:

$$\frac{\partial \vec{v}}{\partial t} = -(\vec{v} \cdot \nabla)\vec{v} + \nu \Delta \vec{v} - \nabla p', \quad (1)$$

$$\vec{\nabla} \cdot \vec{v} = 0, \quad (2)$$

where:

v – speed of the liquid;

p' – pressure normalized, to density;

ν – kinematic viscosity coefficient.

For the numerical solution of equations (1)-(2) we use a three-stage scheme of the physical factors according to division method:

$$\mathrm{I}\tilde{\vec{v}} = \vec{v}^n + \tau(-(\vec{v}^n \cdot \nabla)\vec{v}^n + \nu' \Delta \vec{v}^n + \vec{F}^m)$$

$$\text{II}\Delta p' = \frac{\nabla\tilde{\vec{v}}}{\tau} \quad (3)$$

$$\text{III}\vec{v}^{n+1} = \tilde{\vec{v}} - \tau\nabla p'$$

We're going to simulate the turbulent behavior of the motion by algebraic expression - three-parameter model for effective kinematic viscosity coefficient [5]:

$$\nu' = \nu + \frac{\Delta}{Re_\Delta} v_\Delta + l^2 \left|\frac{\partial v}{\partial y}\right|, \quad (4)$$

where:

$\nu = \mu/\rho$, μ– dynamic viscosity;

Re_Δ – Reynolds' grid number;

l – mixing-length– model parameters;

Δ – grid cell size;

v_Δ – velocity within the cell;

y – variable that parameterizes the axis perpendicular to the flow direction.

Expression (4) takes into account the carrying of turbulent vortices of scale along the flow and conditions of vortex initiation. It is known from numerical experiments that Reynolds' grid number equal to 2 keeps the calculated scheme on the stability threshold. For the pressure at all borders the second kind of conditions are accepted:

$$\vec{n} \cdot \vec{\nabla} p|_s = 0.$$

The system of equations (3) with effective kinematic viscosity index simulated by expressions (4) is supplemented by the following boundary conditions.

On hard surfaces:

- for the velocities perpendicular to the surfaces leakage condition: $V_\perp = 0$,
- for parallel surface velocities is free sliding condition: $\left.\frac{\partial V_{||}}{\partial \vec{n}}\right|_s = 0$.

In the incoming and outgoing flow there is a condition of free fluid flow: $V_\perp = V_0$ – flow speed and $\left.\frac{\partial V_\perp}{\partial \vec{n}}\right|_s = 0$ respectively.

For the pressure at all borders the second kind of conditions are accepted:

$$\vec{n} \cdot \vec{\nabla} p|_s = 0.$$

We approximate the model equations and boundary conditions to them on a uniform chessboard grid. Since the instability of the difference schemes and the turbulent nature of the motion are the same physical nature, the summands introduced into the scheme to ensure its stability, model turbulence in a certain way.

Based on the described model the system of computer simulation of liquid and gas flow problem Continuum Mechanics Simulation (CMS) was developed. A numerical experiment in the flow of bodies of different shapes was carried out. The system allows working with any geometry of the task, supports models on the level of plug-ins, which allows connecting them dynamically, has wide possibilities of visualization of calculation results. The environment allows you to save and resume the task, supports recording animation with visualization of calculations. From additional features of the system we can distinguish: the system takes up little space, does not require installation, has a user-friendly interface, does not require system resources, has a higher speed compared to, for example, with FlowVision.

At numerical problem modeling of bodies flowing of the various shapes in CMS system the following results were received.

By means of arrows, speeds at an initial stage of a body flow of the cylindrical form are shown in figure 3. Two vortices begin to form right behind a body. They occur because there

is a low pressure zone behind the body. As a result, the upper layers act on the lower ones, which cause the fluid layers to move. At the beginning of the calculation, there is a symmetrical displacement of the layers.

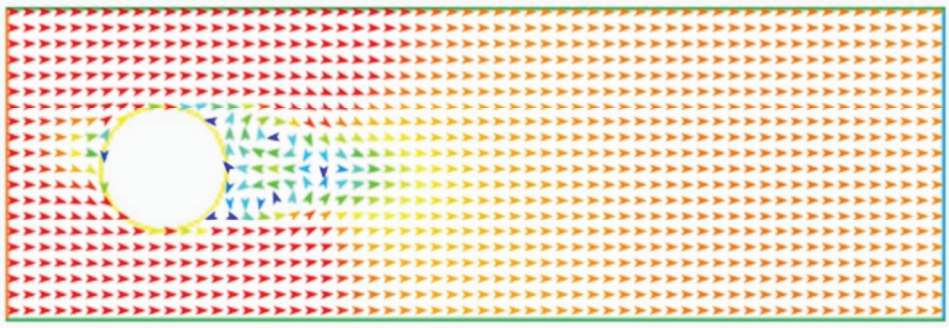

Figure 3. Distribution of speeds at a time of 1.4 s.

Over time, vortices gradually become asymmetrical. It could be concluded that the process is smoothly transitioned from laminar to turbulent, which is typical for a non-stationary process. This is because the pressure field behind the body becomes irregular.
Then the process completely becomes turbulent. Detachable vortices appear which follow the streamlined body in two rows, which is typical for the turbulent nature of fluid movement. These results clearly show the established Karman vortex street.
The color gradient (fig. 4) shows the distribution of the absolute velocity field. It shows the periodic separated vortices that follow the body, which indicates the adequacy of the calculation results.

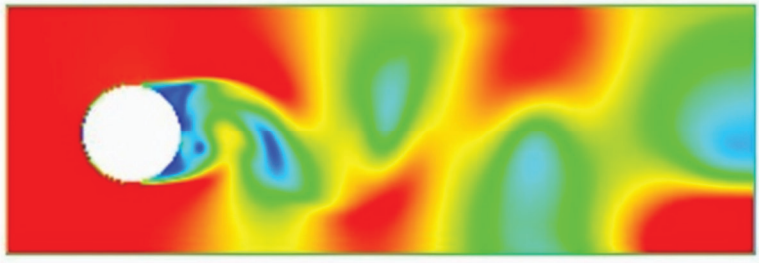

Figure 4. Distribution of speed modules

This paper describes a mathematical model of the problem of flowing around bodies of different shapes with a viscous liquid and presents the results of numerical studies. A three-parameter model of turbulence, which is an algebraic expression, was used to model the turbulent nature of motion. To visualize the results of calculations, the system of liquid and gas movement computer simulation of problems Continuum Mechanics Simulation (CMS) was developed.
During the numerical experiments, the so-called "Karman Vortex street" was obtained, which appears as a result of the flowing around bodies at high Reynolds numbers, which determine the turbulent nature of the movement of viscous liquid. The system allows working with any geometry problem, supports models at level of plug-ins, allows to connect them dynamically, has wide possibilities of calculation results visualization, the environment allows to save and restore a target problem, has support of record of animation with calculation visualization. From the additional characteristics of the system we can distinguish the following: the system takes up little space on the computer, does not need installation, has a user-friendly interface, does not contain high system requirements, has a high speed (as opposed to FlowVision system).

The received numerous results of calculations are confirmed experimentally that allows speaking about adequacy of mathematical model and allows to model successfully similar phenomena.

ASH AFTER COAL BURNING AS A POTENTIAL USE OF RAW MATERIAL RESOURCES

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In Poland, the main material for electricity production is coal. However, over time, this type of fuel has become less popular due to the formation of a large number of combustion products - ash. Waste has not been considered important for many years. This was a mistake because waste always accompanied people and the environment was polluted many times. All waste collected by us is regulated by law. Pursuant to the Act of 27 April 2001 on waste (Journal of Laws of 2007 No. 39, item 251) waste means any substance or object belonging to one of the categories listed in Annex 1 to the law that it disposes of (or required to dispose of) [1]. Until the use of this fuel is abandoned in Poland, environmental protection will be a goal and a priority.

One of the reasons for the increased level of environmental pollution is the use of low-quality coal with a high ash content. As a result of burning coal, most of the artificial carbon in the form of CO2, about 50% SO2, 35% NOx and dust is emitted into the atmosphere. Exhaust gases also contain CO (carbon monoxide, carbon monoxide) and toxic organic compounds, including benzapirene (C20H12), dioxins, fly ash, sulfur oxides SOx (sulfur oxides IV and sulfur VI), nitrogen oxides NOx (nitrogen oxides NOx) (II) and oxides (IV) oxides), some fluorine compounds and gaseous products of incomplete combustion of fuel. Exhaust emissions containing ash particles easily spread over considerable distances and fall into the human lungs and are very dangerous.

The importance of research into how solid waste is used by energy producing companies (including ash) is due to the need to reduce the environmental burden caused by man by coal-fired power plants by using heat energy in technologies. The prospect of using fly ash is dictated by its properties and low cost, potential economic and environmental effects.

From the point of view of the rational use of nature, slag materials are extracted from the viscera of the earth, transferred to another territory and unused raw materials, capable of meeting many industry needs. It is known that ashes are 98–99% composed of Si, Al, Fe, O, Ca, Ti, Mg, S, K, Na. These elements are called ash (macroelements). Almost all other elements of the periodic table are present in ash at 0.1% and less, these are trace elements.

In world construction practice, both unclassified ash and ash are widely used after their initial enrichment or separation into components [2]. Thus, ash can be used to build pavement foundations, to reconstruct worn upper asphalt layers, such as tar, tar, tar, to create planning mounds, etc. The use of ash for these purposes should be justified in tests of suitability and safety, taking into account mechanical stress and weather and climate factors. It is necessary to assess the chemical safety of ash use in terms of groundwater contamination with toxic ash leaching substances.

Based on the analysis of our own experimental data and literary sources, it is possible to create new technologies for the production of building materials from secondary raw materials (ash) (Fig. 1) to improve the environmental safety of the area, which will allow the use of dry ash from heaps of ash in the production of aerated structures and gradually to reduce the accumulation of ash in the granaries also allows to reduce cement consumption by up to 50% in aerated concrete production technologies.

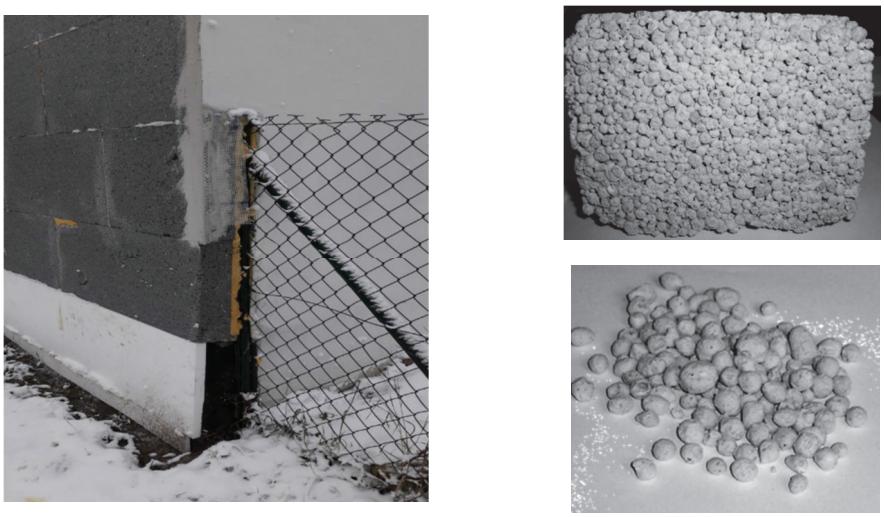

Fig. 1. Samples of ash-based materials and methods of use

Conclusions: The implementation of the project results in the production of porous heat-insulating materials in production plants, and then the preparation of raw materials for the production of basic mixtures will allow to obtain social and environmental effects: create new jobs, increase employment, reduce the human burden on the environment. resources will lead to a significant economic effect.

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PHASE TRANSITION HEAT ACCUMULATOR

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Ensuring stable load on the grid is an urgent problem in the energy sector. The daily schedule of electricity consumption in the grid is characterized by a sharp increase in load in the morning and evening hours and a significant decrease at night. In this case, the most imbalance of the load creates for the power generating companies, because the capacity to maneuver their capacity is very limited. This is especially acute for nuclear power, which, for example, in Ukraine for 9 months of 2019 produced 53.0% of electricity. The utilization rate of installed capacity of Ukraine's nuclear power plants is on average about 67%, while the global average is 87%. Given these facts, there is an urgent need to create new buffer consumers, which would allow to increase the utilization rate of the installed capacity of

Ukraine's nuclear power plants, which will allow to smooth the average daily energy consumption schedule.

In order to partially offset the daily schedules of grid load in Ukraine, as in several European countries, a preferential night tariff for electricity was introduced, which aims to increase its consumption at night. One of the most promising and economically viable areas of nighttime electricity consumption is its accumulation using different principles. Accumulation allows you to save energy at night at a discounted rate and then use it during the day. Among the various types of heat accumulators, batteries using phase transition materials are promising. Their advantage is the ability to provide high energy density in the narrow temperature range with a slight change in the volume of the heat storage material during the phase transition.

High-density polyethylene can be used as the heat-storage material of the phase-transition batteries. Low thermal conductivity is a major disadvantage of polyethylene, but it can be offset. We propose to increase the thermal conductivity of high density polyethylene by introducing metal into the heat storage system. Moreover, the metal is introduced in the form of a metal shell deposited directly on the phase transition material (polyethylene). The metal shell is formed as a result of metal deposition in chemical reduction solutions on the activated polyethylene surface. This allows to obtain a material that is evenly covered with a layer of metal. This method provides easy introduction of the metal into the heat storage system, thus forming a homogeneous system with a uniform distribution of metal in the volume of polyethylene.

To investigate the possibility of using the developed material as a basis for the creation of thermal accumulators with a phase transition, a pilot plant was used to model the operation of the thermal accumulator. The main units of the developed installation are the control unit and the directly measuring cell. The measuring cell is located inside the insulating shell at the bottom of which the slots are made to allow air circulation during the discharge of the battery. To intensify the circulation of air, a fan is placed at the top of the insulating jacket. The measuring cell consists of a metal container that houses a phase transition material, a heater and two thermocouples, to measure the change in material temperature during charge and battery discharge.

The preliminary findings suggest that the use of metallized polyethylene as a basis for the generation of phase-shifted heat accumulators is promising. The time required for charging and discharging the battery is significantly shorter than the original polyethylene, which indicates a higher thermal conductivity of the metal-filled system.