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ANALYSIS OF TEST RESULTS OF A HOUSEHOLD ABSORPTION REFRIGERATING APPLIANCE ON AN ELECTRIC AND GAS SOURCE OF THERMAL ENERGY

One of the biggest challenges for refrigeration systems is their conversion to environmentally friendly refrigerants. This attracts the attention of developers of household refrigeration equipment to absorption refrigeration devices (ARD), which include an absorption refrigeration unit (ARU). ARD working fluid consists of natural components – ammonia water solution with the addition of an inert gas (hydrogen). Therefore, the use of ARU can be considered as one of the options for transferring to environmentally friendly refrigerants. In recent years, in connection with the rapidly developing gasification of the population of Europe, an alternative has arisen – the operation of household ARD on natural gas. Natural gas can become an alternative to electrical energy in stationary operating conditions of household refrigeration appliances. Thus, the object of the study was a single-chamber household refrigerator with a low-temperature compartment «Kiev-410» (Ukraine).

In this paper, the study is aimed at comparing the thermal modes of operation and the costs of operating a household ARD on electric energy and natural gas. To solve this, it was necessary to determine the temperatures at the characteristic points of the refrigeration apparatus and in the chamber, as well as the energy consumption of the absorption-type apparatus in accordance with regulatory documents, at various values of the thermal load on the thermosyphon and various ambient temperatures.

The studies were carried out at elevated outdoor temperatures: 28–33 °C. The range of thermal loads on the ARU thermosyphon electric heater was 50–130 W. The range of numerical values of natural gas consumption in the burner was (2.8–8.8)$\cdot 10^{-6}$ m^3/s. In the process of conducting experimental studies of household ARD, results were obtained showing the economic prospects of working in stationary conditions on natural gas.

At the same time, ARD of increased useful volume (200 dm^3 and above) has the greatest prospects. The daily operating costs in them are 0.078...0.084 USD, which is 23...27 % lower than the case of using electricity. When the ARU thermosyphon is built into the heating and hot water supply system, it becomes possible to use the temperature potential of the waste products of combustion and completely eliminate operating costs.

Keywords: *refrigeration equipment, absorption refrigeration unit, environmentally friendly refrigerants, heat recovery.*

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1. Introduction

The transfer of refrigeration systems to environmentally friendly refrigerants attracts the attention of developers of household refrigeration equipment and to absorption refrigeration devices (ARD), which include an absorption refrigeration unit (ARU) [1]. ARU working fluid consists of natural components – ammonia water solution with the addition of an inert gas (hydrogen) [2]. Therefore, the use of ARD can be considered as one of the options for transferring to environmentally friendly refrigerants.

ARD have a number of such positive qualities as noiselessness, reliability and long service life, absence of vibration, magnetic and electric fields during operation, the ability to use several energy sources in one unit – both electrical and thermal [3, 4]. ARDs are practically insensitive to changes in the parameters of the current in the network in the voltage range 160–240 V [5].

The advantages of ARD should be attributed to the lower, in comparison with compression analogs, the cost, which in many cases is of decisive importance. ARD are effective when used as mini-refrigerators, minibars, in built-in and transport models of refrigerators, when the refrigerating capacity does not exceed 20 W and it is impractical to use compression refrigeration machines [6].

At the same time, ARD have an increased energy consumption in comparison with similar compression models, which limits their area of application and market share in household refrigeration equipment.

For this reason, works aimed at increasing the energy efficiency of ARD are relevant.

It is also important in modern conditions that the ARU working fluid – ammonia-water solution with the addition of an inert gas (hydrogen, helium or their mixture [7]) belongs to natural refrigerants. It is absolutely environmentally safe, since it has zero values of the ozone-depleting potential and the potential for the «greenhouse» effect [2].

ARDs also have a number of such unique qualities as [5, 8, 9]:

a) possibility of using several different sources of thermal energy in one apparatus – both electrical and alternative (heat of combustion of fossil fuel and biogas, solar radiation, exhaust gases of internal combustion engines);

b) ability to work with low-quality energy sources, including electrical in the range of network voltage from 160 to 240 V;

c) noiselessness, high reliability and long service life.

ARD equipped with burners are widely used by tourists and travelers, as there is no alternative to them in areas with a lack of electricity.

The advantages of ARD include the minimum cost among the existing types of refrigeration equipment of low refrigeration capacity, which in many cases determines their popularity among users.

In recent years, in connection with the rapidly developing gasification of the population of Europe, an alternative has arisen – the operation of household ARD on natural gas. And if devices operating on liquefied gas (propane) or kerosene are widely known on the market for household absorption refrigeration equipment, then the use of natural gas as a source of thermal energy has not yet been practiced. Natural gas can become an alternative to electric energy in stationary conditions of operation of household refrigeration appliances, especially in the presence of economic preferences.

The aim of this research is to compare the thermal modes of operation and the costs of operating a household AHP using electric energy and natural gas.

So, *the object of research* was a single-chamber household refrigerator with a low-temperature compartment «Kiev-410» (Ukraine).

2. Methods of research

When choosing the object of research, let's guide by the following consideration, the temperature and energy characteristics of the ARD and the influence on them of operating parameters and structural elements should be of both scientific and practical interest.

ARD manufactured at the Vasilkiv Refrigerator Plant (Ukraine) using serial technologies meets these requirements: this is a household single-chamber refrigerator with a low-temperature compartment (NLTC) «Kiev-410» АШ-160 (Fig. 1, Table 1) [10]. According to the normative document [11], the temperature is maintained in the LTC not higher than minus 18 °C, and in the RC – in the range of 0–5 °C.

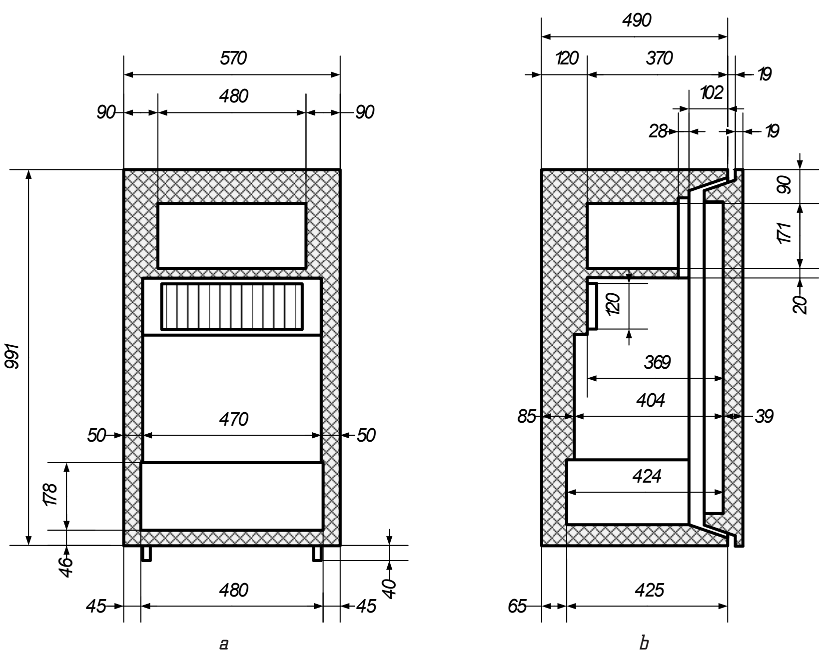

Fig. 1. Overall dimensions of the ASh-160 «Kiev-410» absorption refrigerating device with a low-temperature compartment: *a* – front view; *b* – side view

Table 1

The main characteristics of the research object

Model	Useful volume, dm^3		Overall dimensions, m			Distinctive design features
	general	LTC	width	depth	height	
ASh-160 «Kiev-410» absorption single-chamber refrigerator with LTC	160	14	0.58	0.65	1.03	The vertical evaporator is installed in a heat-insulated block in the opening of the rear wall of the cabinet

To solve this aim, it is necessary to determine:

a) temperatures at characteristic points of the refrigeration apparatus and in the chamber;

b) the amount of energy consumption of absorption-type devices in accordance with the regulatory documents [12], at different values of the thermal load on the thermosyphon (Q) and at different ambient temperatures.

The experimental setup contains a system for measuring and recording temperatures, a system for supplying, stabilizing and measuring electrical power, a system for supplying and measuring the flow rate of natural gas, and a sample of the refrigeration apparatus under study.

The experimental device is shown in Fig. 2.

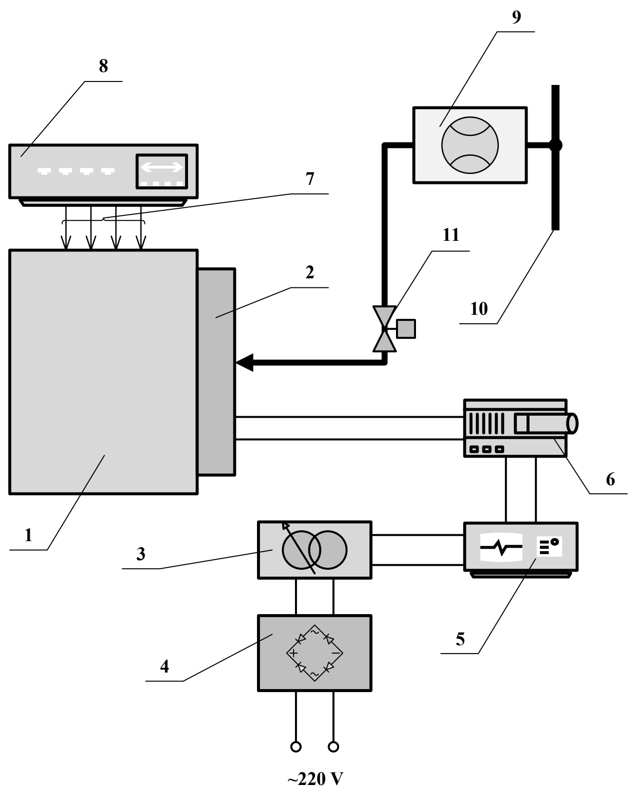

Fig. 2. Diagram of the experimental device:
1 – heat-insulated body of the refrigerating device; 2 – absorption refrigeration unit; 3 – adjustable autotransformer; 4 – voltage stabilizer; 5 – measuring complex; 6 – electric power meter; 7 – thermocouples; 8 – temperature measuring device; 9 – natural gas flow meter; 10 – gas main; 11 – gas flow regulator

The research object consists of a thermally insulated body 1 with ARU on the back wall 2.

The ARU electric heater is connected to a system for supplying, regulating, stabilizing and measuring electrical power.

The supply of electric power to the regulator 3, which is used as an adjustable autotransformer of the LATR type (Ukraine), is carried out through the voltage stabilizer LVT ASN-250 (Ukraine) 4. The electric load is registered using the measuring complex K-50 (Ukraine) 5, and the electric power – counter TurBZ-2 (Bulgaria) 6.

For operation on natural gas, a burner device was used, consisting of a standard sleeve for an electric heater, welded to the body of the ARU thermosyphon and a chimney. The chimney served to remove the combustion products and ran parallel to the vertical section of the ARU reflux condenser.

In the lower part of the sleeve, a heat source was installed – the flame of a gas burner.

The consumption of natural gas network was measured using a standard S6RL gas meter (Ukraine).

The temperatures at the characteristic points of the LTC and RC were measured using standard chromel-copel thermocouples 7. The thermocouples are switched through a recording device, which was a SH300 digital voltmeter (Ukraine) 8.

3. Research results and discussion

The results of experimental studies are presented in the form of graphical dependencies in Fig. 3, 4.

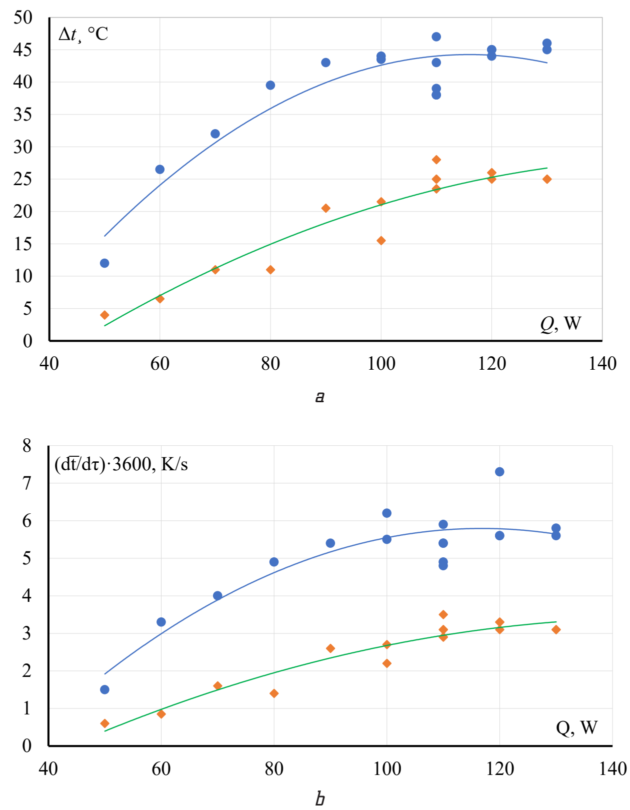

Fig. 3. Dependence of the thermal conditions of the Ash-160 «Kyev-410» refrigerator on the magnitude of the heat load of the electric heater: *a* – temperature difference between the environment and the temperatures in the chambers; *b* – average rate of change in the temperature difference over time; ● – low-temperature compartment; ◆ – refrigerating chamber

The studies were carried out at elevated outdoor temperatures: 28–33 °C. Under these conditions, according to the normative document [12], the operating mode of the ARD is continuous 1, that is, with a constant supply of heat load to the ARU thermosyphon.

The range of thermal loads on the ARU thermosyphon electric heater was 50–130 W. The range of numerical values of natural gas consumption in the burner was 2.8–8.8·10^6 m^3/s.

Fig. 3, *b*, Fig. 4, *b* shows the average rate of change in the temperature difference over time. This indicator characterizes the intensity of the cooling process of the chambers of the research object.

In the LTC, the maximum cooling intensity took place in the range of heat loads of the electric heater of 50–110 W, which is confirmed by the results of other works [13, 14].

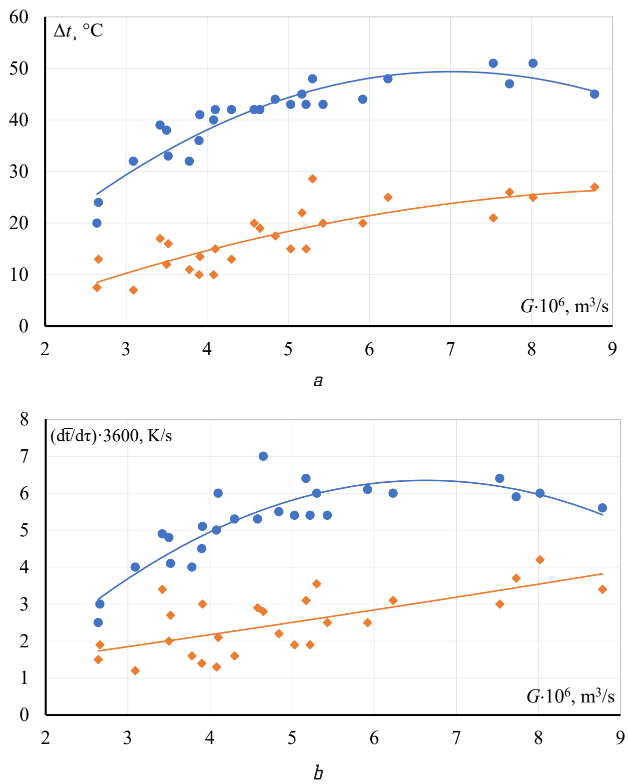

Fig. 4. Dependence of the thermal regimes of the ASh-160 «Kyev-410» refrigerator on the numerical values of the natural gas consumption: *a* – the temperature difference between the environment and the temperatures in the chambers; *b* – the average rate of change in the temperature difference over time; ● – low-temperature compartment; ◆ – refrigerating chamber

In the RC, the intensity of the cooling process is linear over the entire range of heat loads of the heater 50–130 W. The increase in the upper value of the thermal load of the thermosyphon can be explained by the margin of the heat exchange surface of the evaporator set in the RC.

When the AHP was running on natural gas in the LHC, the maximum cooling intensity took place in the flow rate range of $2.8–6.0 \cdot 10^6$ m^3/s.

In the HC, the intensity of the cooling process was also linear over the entire flow rate range $2.8–8.8 \cdot 10^6$ m^3/s. And, accordingly, the increase in the upper value of the thermal load of the thermosyphon is also explained by the margin of the heat exchange surface of the evaporator set in the HC.

It is advisable to evaluate the economic part for the maximum values of the refrigerating capacity of the research object.

So, with a heat load of an electric heater of 110 W, its daily power consumption will be 2.64 kW·h.

With a natural gas consumption of $6.0 \cdot 10^6$ m^3/s per second, its daily consumption will be 0.5184 m^3.

For the current pricing policy for energy resources in Ukraine in May 2021 – 1 kW·h costs 0.062 USD, and 1 m^3 of natural gas – 0.315 USD, the daily cost of operating ARD will be 0.164 USD (for electricity) and 0.163 USD (for natural gas).

It is necessary to remember that the above results are based on operating conditions at elevated outdoor temperatures. When the object of research is operated in the temperature range of 22–25 °C and there is an automatic control system, its daily power consumption is 1.63 kW·h [5]. In this case, the daily operating cost would be 0.101 USD.

Taking into account the thermal potential of natural gas (heat of combustion 31.8 MJ/m^3 [15]), the average daily heat load on the ARU generator in our studies was 191 W.

Recent studies [16] have shown that the optimal heat load of our research object in the presence of a control system is 75–80 W. In this regard, it is possible to predict the parameters of the daily cost of operating ARD on natural gas, about 0.111 USD.

The results obtained characterize the technical and cost parameters of household AHP of the average volume of cooling chambers (120...160 dm^3). For chambers of increased volume (200 dm^3 and above), when there are practically no restrictions on the mass and size characteristics of the ARU [17], it is possible to reduce gas energy consumption by 1.2...1.3 times by using regenerative heat exchangers [18].

In the case of mini-refrigerators with high requirements for weight and size characteristics, one should expect an increased gas consumption by a factor of 2.1...2.6 [18].

It should also be noted that the temperature of the combustion products at the level of 250...350 °C is sufficient for the ARU operation [19]. The theoretical temperature of natural combustion with an average value of excess air of 1.0 is 2050 °C [20], and in practice, on average, 1200 °C [21].

In this regard, it is advisable to embed ARD into the heating or hot water supply system of the house, which will additionally solve the problems of refrigerated storage of food products. In such a scheme, the ARD will operate in the mode of heat recovery from hot combustion products, i. e. there will be no operating costs.

Thus, the studies carried out have shown that:

a) of all types of household refrigeration equipment of the absorption type, the maximum economic benefits when operating on natural gas can be obtained for chambers of increased usable volume (200 dm^3 and above);

b) the cost of operating chambers with ARU of average volume (120...160 dm^3) is commensurate both for the case of using electric energy and natural gas;

c) from an economic point of view, natural gas should not be used for absorption refrigerators of small useful volume (30...50 dm^3).

4. Conclusions

In the process of conducting experimental studies of household ARD, results were obtained showing the economic prospects of working in stationary conditions on natural gas.

At the same time, ARD of increased useful volume (200 dm^3 and above) has the greatest prospects. The daily operating costs in them are 0.078...0.084 USD, which is 23...27 % lower than the case of using electricity.

When the ARU thermosyphon is built into the heating and hot water supply system, it becomes possible to use the temperature potential of the waste products of combustion and completely eliminate operating costs.

At the same time, there remains the potential for further thermal engineering improvement of the gas burner device, for example, with the help of a turbulizer for the flow of hot combustion products [17].

An important fact is the possibility of working with a household ARD both with an electric power source and with natural gas. This improves the reliability of the refrigeration appliance, especially in areas with problematic power supply.

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**Sergiy Oveckiy,
Yurii Melnychenko,
Lesia Moroz,
Yaroslav Yakymechko**

DEVELOPMENT OF MARINE GAS HYDRATE DEPOSITS WITH ALTERNATIVE USE OF THE POTENTIAL OF THE GAS TRANSPORT SYSTEM ON THE EXAMPLE OF UKRAINE

The object of research is the use of a pipeline system for the production of methane and utilization of carbon dioxide. One of the most problematic areas in this scheme is the substantiation of the effectiveness and the possibility of using the existing pipeline system of countries that are gradually moving towards carbon neutrality of the economy based on the principles of sustainable development. In this case, these principles are implemented through the consumer's access to clean energy by burning gas obtained from offshore hydrate fields at thermal power plants with the simultaneous utilization of carbon dioxide.

In the course of the study, the methods of mathematical modelling of the development of offshore gas hydrate fields were used, which were developed earlier in the study of methane production from hydrate deposits by the replacement method. Comparison of the block diagram of the development of offshore gas hydrate fields using the existing pipeline system by means of logical analysis made it possible to establish not only the economic, but also the environmental effect.

Data have been obtained that the gas transmission system, provided that carbon dioxide is transported, can be effectively used at various stages of the development of offshore gas hydrate fields. This is due to the fact that the proposed development block diagram has a number of design features, in particular, the possibilities of using the gas transmission system at the stage of development, production and decommissioning of wells are taken into account.

This makes it possible to efficiently use carbon dioxide transported from power plants using the existing transport system to the development site of offshore hydrate deposits. Compared with similar known methods of carbon dioxide utilization, this provides the following advantages: alternative use of the existing pipeline system for the purpose of greening the technology of methane production from offshore hydrate deposits.

The principles considered in the work make it possible to dispose carbon dioxide in the form of a hydrate under the seabed. The achieved economic effect can be considered as income received from the sale of electricity produced at power plants, and quite obvious environmental effect.

Keywords: *development of offshore hydrate deposits, greening of natural gas production technology, utilization of carbon dioxide.*

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1. Introduction

The problem of using the gas transportation system in the world arose 10–15 years ago, when there was a need to move to carbon neutrality of the economy [1]. One possible use of the gas transmission system in the future is the utilization of carbon dioxide [1] (Ireland) or the delivery of hydrogen obtained by various means to the consumer [2] (Great Britain). The prospects of using a pipeline system for biomethane transportation are also considered [3]. Some researchers [4] (United States of America) point out the significant socio-economic risks due to the insufficient load of the existing gas pipeline system due to the transition of the economy to a low-carbon basis. Especially valuable for both the world and Ukraine is the study [5] (Belgium) on the possibility of using the gas transmission system for gas utilization and storage and the connection of this process with electricity generation. In Ukraine, where there are a large number of thermal power plants, developed gas transmission systems and the Black Sea with highly promising natural gas resources in hydrate fields, we can offer an interesting comprehensive solution that will be attractive to many countries.

The opening of the Nord Stream 2 gas pipeline can have very difficult consequences for Ukraine, as about 3 % of gross domestic product provides for the transit of Russian gas to Western Europe through Ukraine [6]. The cessation or even reduction of gas transportation volumes may lead to the bankruptcy of GTS Ukraine Operator LLC (Kyiv, Ukraine) in the near future. However, there are opportunities to reduce or eliminate such consequences by alternative use of the potential of the gas transmission system [7]. One of the possible prospects for such an application of the gas transmission system is the transportation of carbon dioxide [1], in order to dispose of it as the main environmentally harmful waste from large producers, in particular, thermal power plants.

An option that will bring not only environmental but also economic effect is the use of carbon dioxide to extract hydrocarbons, for example, to maintain reservoir pressure in the process of field development [8]. Another alternative to the use of carbon dioxide is the possibility of replacing methane in the crystalline structures of gas hydrates [9] of the Black Sea bottom. In this case, the volumes of utilized carbon dioxide and methane obtained in the process of replacing can be ten times larger than when using the technology of maintaining reservoir pressure. Therefore, the development of the technological process of methane extraction from gas hydrate fields is an urgent issue, if it is based on the use of the pipeline system of Ukraine for the transportation of carbon dioxide.

Thus, *the object of research* is the use of a pipeline system for methane production and carbon dioxide utilization. And *the aim of research* is to substantiate the possibility of using the gas transmission system for the development of offshore gas hydrate fields.

2. Methods of research

The research on the development of offshore gas hydrate fields is based on the methods described in [10]. The main hypothesis of the study is that the gas transportation system of Ukraine under the condition of carbon dioxide transportation can be effectively used at different stages of development of marine gas hydrate fields [11].

The following scientific methods were used in the study:

– method of classification – in determining the objects of energy and transport infrastructure for the implementation of the developed block diagram;
– method of functional-cost analysis – in the study of the conceptual model of development of marine hydrate deposits at the stages of development, production and decommissioning of wells.

3. Results of research and discussion

The conceptual model of marine hydrate field development (Fig. 1) begins with the stage of obtaining data through geological exploration.

Exploration of marine gas hydrate deposits is based on the bottom manifestations of natural methane discharge, the largest of which are bottom mud volcanoes. Near such manifestations, as a rule, bottom or under the seabed hydrate deposits are found at a slightly greater depth [12].

Transfer of formation fluids to the surface should be carried out by means of wells. The depth of sea hydrates under the bottom does not exceed 1200 m. The depth of the water area in the Black Sea for the existence of hydrates – from 500 m. Then the total length of the water column and the bottom of the casing will be approximately 1700 m.

Features of drilling wells for the development of hydrate deposits are determined by the need to preserve the uncased wellbore through the dissociation of hydrates in the bottomhole area, taking into account:

1) increase in temperature due to friction of the tool and the drill string;

2) exposure to chemically active components of drilling mud.

These issues are solved by regulating the composition of the drilling fluid, namely the introduction of lubricating admixtures that reduce the coefficient of friction on the ice-like surface of the hydrate and limiting the use of mineralized compositions of drilling fluids.

Further tactics for the development of hydrate deposits are associated with the presence of underwater mud volcanoes.

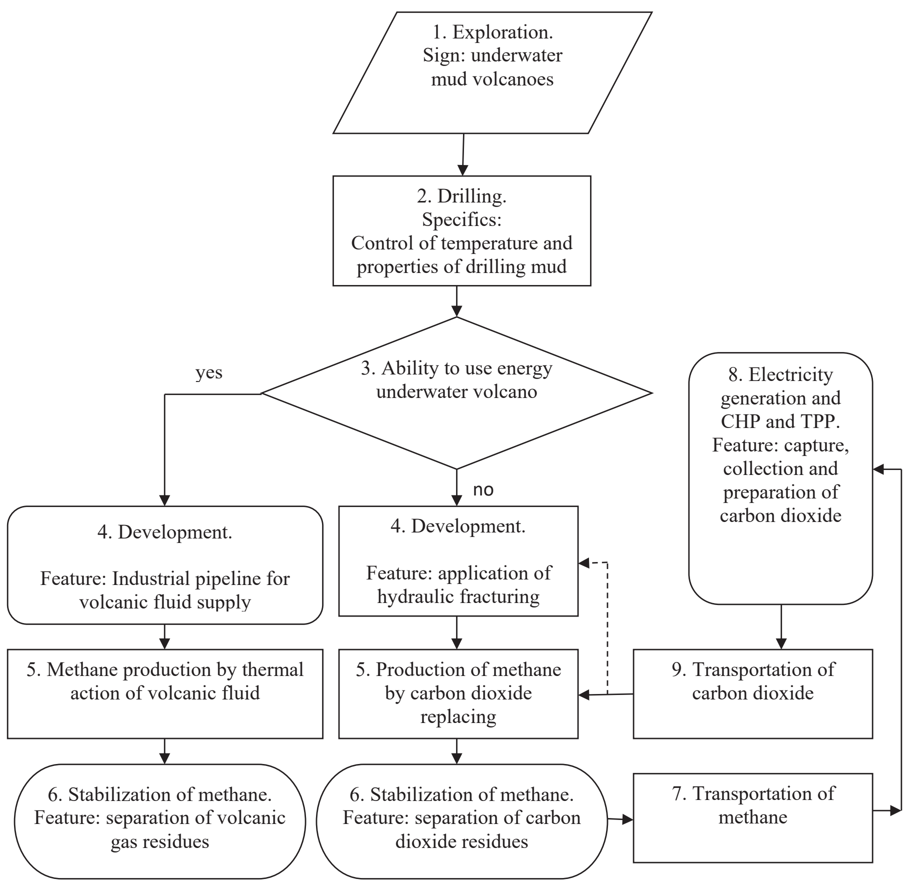

Fig. 1. Conceptual block diagram of the development of marine gas hydrate fields

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The technology of supply of these fluids by industrial pipelines to the surface bottom outlets of gas hydrates for their dissociation can be used if:

– such volcanoes have high fluid productivity;
– fluid temperature is quite high;
– distance to the deposit is small and allows the supply of fluid with allowable heat loss.

It should be borne in mind that to limit the ingress of suspended particles of mud of the volcano to the deposit drilled in the mouth of the volcano wells of small depth, must be inclined in the mouth. The authors of [10] hypothesized that under certain hydrodynamic conditions surface bottom hydrates can serve as a non-permeable seal rock for free methane output, so with sufficient methane flow rates it is possible to operate these deposits without drilling special wells.

If it is impossible to use the energy of underwater volcanoes to dissociate bottom and under the seabed deposits of hydrates, due to the long distance, too low temperature of volcanic fluid, etc., it is necessary to use other production methods. The main among these methods for marine deposits was the method of replacing [11], which has a number of advantages, in particular:

– preservation of the rock skeleton with the elimination of the risk of bottom landslides, because sea hydrates, in contrast to the land have a much lower content of solid impurities and their crystals act as the main structure-forming matter;
– control of the main filtration characteristics by determining the appropriate technological parameters of the replacement process.

The technological process of development involves the use of fracturing in the case if the main deposit is at a depth of more than 500 m, which makes it possible to avoid artificial gas griffins on the bottom surface. The purpose of fracturing is traditional – to create a network of artificial cracks to increase the total inflow of methane, as well as increase the area of contact with the replacement gas. In this case, as a proppant can be used not only sand but also hydrate-forming gas [13], which at a sufficiently high pressure and low temperature can form hydrates of fixation. In the process of well development by hydraulic fracturing, hydrogen sulfide hydrates [11] have the advantage of being more resistant to pressure drop and temperature increase. However, currently there is no necessary equipment to increase the concentration of hydrogen sulfide obtained from deep water. Hydrogen sulfide is formed at a depth of 200–300 m in inland seas with anomalous gas regime in some countries, including Ukraine. Therefore, for the most part, most countries in the world will now have to use carbon dioxide as a substitute gas in the extraction of methane from gas hydrate fields.

Methane obtained from gas hydrate fields is used to generate electricity at thermal power plants (TPP) or combined heat and power (CHP) plants. The carbon dioxide formed in the production process is captured and sent in the opposite direction for substitution in the marine gas hydrate deposit. Methane and carbon dioxide form hydrates of the first type, filling large and small cavities of crystals [11], which, given the difference in molecular weight, theoretically allows to utilize 2.75 times more mass of carbon dioxide than methane.

Transportation of carbon dioxide to the marine deposit of hydrate is a technically difficult task, primarily due to the aggressiveness of this gas in relation to the equipment of existing pipelines, in particular its sealing elements.

It is necessary to solve the problems of carbon dioxide utilization on the principles of sustainable development – to get the maximum satisfaction of consumer needs without harming the environment, so let's define the features of this process on a specific example in Ukraine.

The nearest promising gas hydrate field can be considered deposits located near the volcano Odessa (Ukraine), Fig. 2. Laying of underwater pipelines to this area is possible with the use of already developed and unrealized projects of the pipeline transport system. In particular, to the Odessa gas field partly according to the design options of the route 2, 3, 4, 5, or using long-term plans for the development of hydrocarbon fields near the Zmiyinyy Island.

At the first stages of development, especially during the development of wells, there is enough capacity of Odessa CHP, with an electric capacity of 68 MW (natural gas consumption of about 6800 cubic meters). If to use the existing pipeline system, you will have to lay no more than 50 km of land section of the pipeline. When increasing the flow rate, it is necessary to use the nearest power plants (Fig. 3) – Zaporizhzhia TPP with a capacity of 2400 MW (consumption of about 240 thousand cubic meters of natural gas). Otherwise, it is possible to use Trypillia TPP with a capacity of 600 MW (consumption of about 60 thousand cubic meters of natural gas).

These TPPs are in close proximity to the main routes of the pipeline system of Ukraine (Fig. 4), so they will not require laying long sections of supply pipelines and can be effectively used for the proposed scheme (Fig. 1).

In addition, the calculation of the economic efficiency of this technological solution must be carried out not only taking into account the amount of electricity produced, but also a certain environmental effect from the utilization of carbon dioxide.

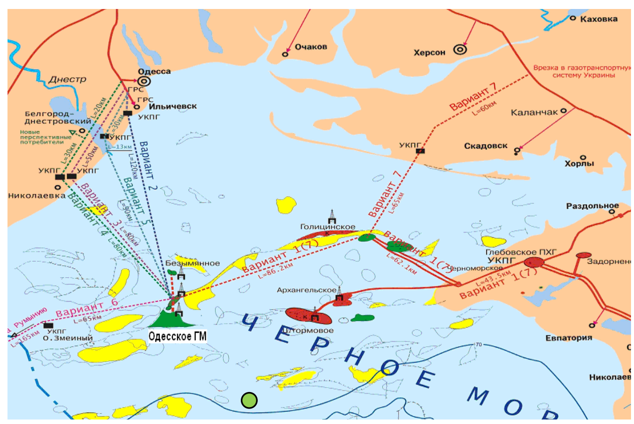

Fig. 2. Location of a promising area around the mud volcano Odessa (marked with a green circle)

Fig. 3. Location of power plants of Ukraine [14]

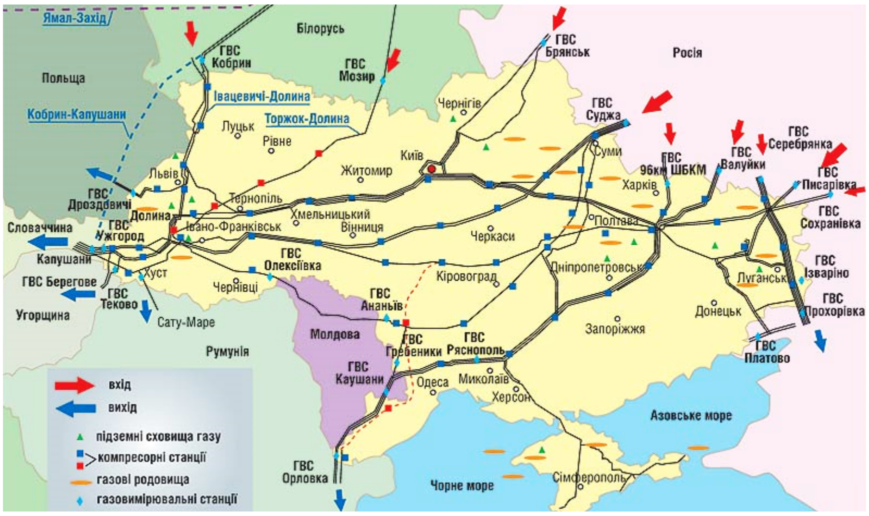

Fig. 4. Scheme of the pipeline system of Ukraine [15]

For this purpose, for example, the approaches of the Kyoto Protocol [16] can be used, according to which a country that reduces emissions can sell its excess quota to other countries. Ukraine managed to do it at a price of more than 4 euros per ton of carbon dioxide.

4. Conclusions

The study shows the principles of alternative use of the existing pipeline system of Ukraine in order to green the technology of methane extraction from marine hydrate deposits, which allow to dispose carbon dioxide in the form of hydrate under the seabed. The achieved economic effect can be considered as the profit received from the sale of electricity obtained at power plants, and the obvious environmental effect. The developed block diagram can provide zero-waste electricity production by Zaporizhzhia TPP with utilization of more than 240 thousand cubic meters of carbon dioxide and Trypillia TPP with utilization of more than 60 thousand cubic meters of carbon dioxide per day.

The results of the study will be useful for countries that have coasts washed by deep waters of the seas and oceans (more than 500 m deep), in the implementation of the main stages of development of offshore hydrate gas fields, which can use carbon dioxide for production and development of wells. The developed methodology allows to assess the adequacy of the available capacity of thermal power plants and the existing gas transmission system of a particular country for economically and environmentally efficient production of gas from marine hydrate fields.

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INVESTIGATION OF THE ACCURACY OF THE MANIPULATOR OF THE ROBOTIC COMPLEX CONSTRUCTED ON THE BASIS OF CYCLOIDAL TRANSMISSION

pages 6–14

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The object of research is modern robotic systems used in hotspots. In their arsenal, such mobile works are equipped with manipulators with high-precision hinges, which provide accurate positioning of the gripper (object of manipulation). Considering ground-based robotic complexes with a wheel or caterpillar base, the implementation of the process of manipulation on a stationary basis, a number of problem areas were identified that affect the accuracy of positioning.

In the course of research and analysis of modern robotic complexes, their circuit and design of components and mechanisms that provide the necessary qualities and parameters. The problem of developing high-precision hinges is central to the creation of efficient ground-based robotic systems.

The methodology of kinematic research of rotary hinges of the manipulator for the ground robotic complex is stated. The analysis of influence of deformations of material of impellers of not involute transfer on accuracy of positioning of a final subject is carried out. A kinetostatic analysis of the manipulator circuit was performed and the maximum moments acting in the hinged units on the drive unit were determined, which allowed to make a quantitative assessment using the Solidworks software package.

The mathematical model of construction of transfer and definition of accuracy of a rotary knot for a ground robotic complex, with use of cycloidal transfer without intermediate rolling bodies is investigated and developed. Mathematical modeling and taking into account the features of mechanical processes occurring in the manipulator, allows to increase the technical level of robotic complexes.

Ways of improvement are defined for maintenance of a progressive design of the manipulator that not only will satisfy necessary technical characteristics, but also will allow to simplify manufacturing technology.

Modern technologies and materials (stereolithography, carbon fiber, superhard materials) make it possible to implement advanced designs of spatial drive systems. Therefore, work in this direction is relevant, as robotic mechanical complexes for special purposes are widely used when performing work in emergencies.

Keywords: manipulators with high-precision hinges, rotary unit, stress-strain state of cycloidal transmission, high-precision hinge.

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IMPROVEMENT OF THE EXTRUDER BODY DESIGN IN ORDER TO INCREASE RELIABILITY AND QUALITY OF EXTRUSION

pages 15–19

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The article highlights one of the ways to improve the design of the extruder body in order to increase the reliability and, at the same time, the quality of extrusion. The object of research is a single-worm extruder. One of the most problematic areas of the extruder is the body. The main disadvantage of the extruder is the wear of the body surfaces due to corrosion or abrasion and requires regular replacement. This is due to the abrasive properties of the polymers and, accordingly, due to the friction of the polymer material against the body and the worm, especially due to contamination in the recycled material. In various sources, the replacement of the extruder worm with a more advanced design is widely covered. And scientists do not pay enough attention to improving the body of the extruder, which indicates the relevance of this study. That is why the problem of increasing the reliability of the extruder body is completely unsolved and urgent. In the course of the study, we used an analysis of the structural features of the extruder body, a literature-patent review of existing methods for improving the body of a single-worm extruder to increase the reliability and, at the same time, the quality of extrusion. As a result of the literature and patent review, the option of improving the extruder body based on the prototype of the split body, which additionally contains an inner surface of steel ribbed plates, was selected. It was found that the ribbing of the plates on the inner surface of the body increases the wear resistance of the body and promotes more intensive advancement of the polymer used material to the extruder head. This is due to the fact that the proposed improved body of the extruder has a number of features: steel ribbed plates rigidly fixed inside it are installed with overlap of the parting line of the extruder body. This makes it possible to increase the wear resistance and, accordingly, the reliability of the extruder body and, additionally, the extrusion quality. Compared with the known one-piece structures of the extruder body, the design of the body is detachable with steel rigidly mounted ribbed plates on the inner surface, which will simplify maintenance during repairs and, at the same time, improve the quality of extrusion.

Keywords: extruder, improvement of the extruder body, finning of the plates, extrusion quality, wear of the extruder body, extruder worm.

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