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TO THE QUESTION OF THE VOLTAGE STABILITY ENSURING FOR COMPLEX MONITORING SYSTEMS OF METAL'S STATUS

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ABSTRACT

The paper considers one of the tasks that need to be solved when developing complex monitoring systems of metal's status, which is to ensure the stability of the supply voltage, and the results of compensatory voltage stabilizer development are given. The analysis results of the adopted circuit solutions correctness are shown and the conformity of the stabilized power supply parameters to the given conditions is proved.

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Introduction. The creation of new and improvement of existing high-tech control systems requires the rapid receipt of objective and most accurate information about the large number value of physical quantities, which characterize the state of the metal in the stressed state. Such approach implementation will increase the probability of metal's status monitoring in operating conditions. Today, integrated multichannel information and measurement systems are used to ensure the required accuracy and speed of measurements. A number of requirements are set for such systems, starting from ensuring the stability of their power supply. This work is devoted to solving this issue.

The results of research. The analysis peculiarities of building systems for metal products integrated monitoring based on the simultaneous use of two or more methods showed, that such tools should have a simple technical implementation, high informativeness and satisfactory speed of the control object technical condition information.

Based on the results of previous studies [1], we concluded this problem can be solved by combining the ultrasonic method and thermal control, which allows to record changes in energy flows which are generated in metal, and the values of the obtained informative parameters from contact microelectronic sensors high-speed and high-frequency ultrasonic transducers to establish the moment of the microcracks formation and its development.

Works that have to be done in order to improve the means of control [2] require addressing a number of new issues and approaches that will radically improve the characteristics of the existing system control of stress-strain state metal structures. The task of creating new measuring channels in the system requires making informed decisions on the structural, circuit and mathematical support of the control, which will further determine the reliability and the system metrological characteristics as a whole.

In the most modern information and measurement systems (IMS) measurement processes is based on the use of processes for transferring the values of measured physical quantities to change the voltage or current amplitude, frequency or phase of electrical signals. Therefore, the accuracy of measurements in such IMSs is determined not only by the perfection of these transfer processes technology, but also by the accuracy of the obtained changes measurements in the electrical signals parameters [3].

Analyzing the possible computerized system architecture for comprehensive monitoring in the light of finding approaches to ensure reliability and accuracy of control, among the first tasks is to provide the system with a stable power supply that prevents overload and surges or high voltage pulses. To date, a number of stabilized power supplies are known, which are used to reduce interference when turning the power on and off, as well as to increase the life of the connected equipment.

This paper presents the research and study results of the main characteristics of the developed stabilized power supply, which was performed in scope of student research.

In the solving problem of providing a control system with a reliable stabilized power supply, it was necessary to analyze fundamentally different methods of voltage stabilization: parametric and compensatory. In the parametric method, the destabilizing factor acts on the parameter of the nonlinear element, which in some way weakens the effect of the destabilizing quantity. Stabilizers of this type use elements with a nonlinear relationship between current and voltage. The principle of stabilization here is based on the change in the resistance of the nonlinear element that is part of the circuit, when changing the applied voltage or current flowing through it. As a result of currents and voltages redistribution between the individual circuit elements the stabilization of the output voltage is achieved. The advantage of the parametric method of stabilization is the scheme simplicity, which consists of a small number of elements. The main disadvantages are low efficiency and low stabilization factor [4].

The compensation stabilization method involves comparing the stabilized output voltage with the reference voltage. The voltage difference after comparison acts on the regulating element of the stabilizer so that it compensates the change in output voltage that occurred. The adjusting element of the stabilizer can operate in continuous (analog) or pulse (key) mode. Basing on this, stabilizers of the compensatory type are divided into continuous and pulsed.

Compensatory stabilizers have a significantly higher stabilization coefficient compared to the parametric and higher efficiency, reaching 70% (parametric not more than 40%) [5]. That is why the compensatory stabilization method was preferred.

The parameters of the stabilized power supply circuit calculations were performed basing on the following requirements: rated voltage in the network U_{nom} = 220V; network frequency f_m = 50 Hz; pulsation coefficient K_p = 0.1%.

To confirm the efficiency and evaluate parameters of the developed unit and voltage stabilizer of the compensatory type and the compliance of its characteristics with the initial requirements, its main parameters were determined using the circuit modeling program Micro-Cap.

Using main features of the Micro-Cap 9 program, the transients in the circuit when applying the supply voltage and the corresponding actions of arbitrary shape were analyzed, followed by plotting the variable states of the circuit.

Conclusions. The correctness analysis of the circuit solutions allows us to conclude that the parameters of a stabilized power supply based on a compensating stabilizer that works as a closed automatic control system with feedback and a sufficiently high stabilization factor (≈30%) and an efficiency of about 70%. The compensation stabilizer is mounted as separate unit. It is powered by a rectifier mounted also as a separate unit. Therefore, the developed stabilized power supply can be used in a computerized system for complex monitoring of metal products condition status in a stress-strain state.

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FEASIBILITY STUDY FOR THE APPLICABILITY OF APPLYING THE HOT RECYCLING TECHNOLOGY FOR REPAIR OF ASPHALT CONCRETE PAVEMENTS

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operational maintenance,
economic efficiency.

ABSTRACT

The main technological solutions for the current repair of non-rigid pavement in Ukraine are identified. The cost assessment of repair technologies was carried out depending on the cost of arrangement of the pavement and its maintenance. The technical and economic comparison of traditional technologies of current repair of asphalt concrete pavement and technologies of hot regeneration of asphalt concrete is carried out. An expert method and a method of comparison were used in the research. To calculate the comparative economic efficiency, the indicator of reduced costs was taken into account with the risk-free discount rate. Estimate calculations were performed using the software CMETA_8_Online. Based on the analysis of the obtained results, it is established when comparing only the cost of repairs, the most cost-effective methods of renovating the riding qualities of roads are surface treatment and hot recycling technology by the Reshape method. Technologies of hot regeneration of asphalt concrete and arrangement of wear layers from cast emulsion and mineral mixes are cost-effective when carrying out the comparison for interrepair (5 years for current average repair) period.

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Introduction. Taking management decisions during the implementation of new equipment, materials and technologies should be based on the results of their feasibility study. Feasibility study of design decisions involves two aspects of analysis: technical and economic. The technical aspect involves the development of a number of options that is possible in terms of their technical implementation. The economic aspect involves an economic evaluation of each of the options [1].

An important component of the strategy for the development and maintenance of the road network in Ukraine is measures to prevent the destruction of the road pavement which includes current repair.

Traditional technological solutions for the current repair of non-rigid pavement in Ukraine mainly include additional arrangement of pavement wearing courses: asphalt concrete layers, crushed stone-mastic layers, wearing courses of cast emulsion and mineral mixtures [1]. Fulfillment of such works allows renovating the riding qualities of the road but requires significant funds and reserve of road construction materials. Taking into account the tendency of increasing the cost on road construction materials, in particular on imported bitumen, the technology of their reuse is relevant.

One of the promising methods of renovating the riding quality of roads is the technology of hot regeneration of asphalt concrete based on the reuse of materials. Depending on the method of preparation, there is a technology of preparation of hot regenerated asphalt mixtures at the plant and directly on site. According to the world practice of road construction, technologies of hot recycling of paving asphalt concrete on site are classified depending on the type and purpose of work, manufacturing processes and application of regenerated mixtures as follows [2]:

- Reshape method – profiling;
- Repave method – profiling with the renovation of a wearing course;
- Remix method –regeneration with a change in the composition of the old asphalt concrete by adding new materials in the amount of up to 30% by weight;
- Remix Plus method –regeneration with a change in the composition of old asphalt concrete and simultaneous arrangement of a layer of new asphalt concrete mix in one passage.

Studies described in [3-6] have shown that by the use of hot recycling technologies on site an economic effect from 20% to 35% compared to traditional technologies of repairing asphalt pavements can be achieved. However, the authors of these works determined the economic effect without taking into account the costs on operation of the repaired areas which are very important factors.

Taking into account a fairly wide range of works on current repairs in Ukraine and insufficiently studied technology of hot regeneration of asphalt concrete, it is important to conduct a technical and economic comparison for choosing a rational option.

The object of research is the technology of current repair of asphalt pavement.

The purpose of the study is to evaluate the cost-effectiveness of technologies for hot regeneration of asphalt concrete in comparison with alternative technologies for repairing asphalt pavement.

The methodology of the study.

The efficiency of different repair technologies was determined by comparing the reduced costs per 1000 m^2 of road pavement consisting of the cost of repairs, the cost of materials, costs on operational maintenance during the comparative period (*T*). As a criterion for assessing the comparative efficiency of technology the minimum value of the integrated costs C_i which also includes the loss of road users during repairs was used [7].

The calculation of the reduced costs is carried out taking into account the risk-free discount rate *E*.

To compare the costs of different repair technologies the following formula was used [7]:

$$C_i = \sum_{i=1}^{n}\left[(C_{mr} \times (1+E)^t) \times n\right] + \sum_{i=1}^{m}\left[(C_{cmr\_om} \times (1+E)^t) \times m\right] + \sum L_{ru}^r \times (1+E)^t \quad (1)$$

where C_{mr} – the cost on current midterm repairs of pavement;

n – the number of current midterm repairs that are performed during the comparative period *T*;

C_{cmr_om} – costs for current minor repairs and operational maintenance of pavement;

L_{ru}^r – losses of road users during repair works.

m – the number of years of operational maintenance of road pavement by the selected option of work performance;

E – risk-free discount rate in relative units;

(1+*E*) – cost discount rate;

t – year of calculation.

The costs of repair and operational maintenance work were determined by the resource method in accordance with SOU 42.1-37641918-085: 2018 "Highways. Rules for determining the cost of current repair and operational maintenance.

The direct costs were determined on the basis of resource estimate norms DSTU B D.2.2-27: 2016 “Resource element estimate norms for construction works. Highways (Collection 27)”, DSTU B D.2.7-1: 2012 “Resource estimate norms of operation of construction machines and mechanisms”, SOU 42.1-37641918-034: 2018 “Road machines and mechanisms. Resource estimate norms of operation of construction machines and mechanisms”, SOU 42.1-37641918-035: 2018 “Roads. Resource element estimate norms for repair and construction works”.

There are no resource element estimate norms for works on hot recycling of road asphalt concrete on site by Reshape and Repave methods. Taking into account the above, individual estimate norms were developed for the relevant works, taking into account the requirements of DSTU-N B D.1.1-6: 2013 “Guidelines for the development of resource element estimate norms for construction works”.

For normalization the needs in labor and technical resources during the development of individual estimate norms, the calculation and research method was used [8]. It is based on the use of data obtained as a result of carrying out the special regulatory research (measurements, photo-timing).

Determination of the value of labor costs (V_{lc}) of construction workers is calculated by the formula [8]:

$$V_{lc} = \frac{A_{pc} * 100}{(100 - (PC_{p\_fw} + PC_{r\_pn} + PC_m)) * 60} \quad (2)$$

where A_{pc} – the amount of projected costs for the process meter, man-min;

PC_{p_fw} – projected costs for preparatory and final work, %;

PC_{r_pn} – projected costs for recreation and personal needs, %;

PC_m – projected costs for maintenance of machines and mechanisms.

The time of use of machines and mechanisms (T_m, mach.h) and labor costs of units servicing machines and mechanisms (LC_{usm}, man.h) were determined on the basis of the current standard working time of construction workers and the number of performers:

$$T_m = V_{lc} : N_w \quad (3)$$

$$LC_{usm} = T_m \cdot N_{us} \quad (4)$$

where N_w – quantitative composition of the construction workers, man.;

N_{us} – quantitative structure of the unit serving machines and mechanisms, man.

The scope and cost of certain types of work to be performed during the current minor repairs and operational maintenance of 1 km of public roads were determined taking into account the minimum maintenance standard according to [9].

During determining the cost of work on current minor repairs and operational maintenance, the conditions of operation of non-rigid pavement after repair work were taken into account. With this in mind, the following options for carrying out the current minor repairs and operational maintenance were selected [7]:

–the first option: without taking into account the work on the elimination of potholes after the repair of pavement;

–the second option: includes the whole complex of repair works.

When formatting the minimum value of the integrated costs indicator, the losses of road users during repair works were neglected, as they are insignificant and will not significantly impact on the research results.

The comparative period (T) is determined taking into account the inter repair time of road pavements operation for highways of category 3 in accordance with VBN G.1-218-050-2001 "Inter repair time of road pavements operation on public roads" and is 5 years.

Research results and discussion.

On the basis of the conducted analysis on the experience of application of the technologies of the current repair of the road pavement in Ukraine and of the expert assessment, the following main technologies of the current mid-term repair were chosen:

1) **Milling and construction of a new layer of asphalt concrete.** Including cold milling of asphalt concrete pavement by milling to a depth of 5 cm, preparation of asphalt concrete mixture and its transportation to the object, arrangement of a top layer of 5 cm thickness with a fine-grained asphalt concrete mixture by paver;

2) **Removal of potholes and arrangement of a new layer of asphalt concrete.** Includes patching, preparation of the asphalt mixture, transporting the mixture to the site and arranging the top layer of 5 cm;

3) **Milling and arrangement of a reclaimed asphalt layer.** Includes cold milling of asphalt concrete pavement to a depth of 5 cm, transportation of milled crumbs to the asphalt plant, preparation of asphalt mixture using regeneration additives and its transportation to the site, arrangement of a top layer of 5 cm thickness with fine-grained regenerated asphalt mixture by paver;

4) **Hot recycling technology using the Reshape method.** Includes heating and milling the pavment to a depth of 2 cm using a remixer, mixing the milled material in the mixer, paving and compacting the mixture. On top of the reclaimed layer, a wearing course of 10 mm thickness of cast emulsion-mineral mixture is laid.

5) **Hot recycling technology using the Repave method.**

Includes heating and milling of pavement to a depth of 4 cm using a remixer, mixing the milled material with simultaneous placement of a wearing course of asphalt concrete mixture and compaction of two layers in one passage.

6) **Hot recycling technology using the Remix method.** The method includes heating and milling the surface to a depth of 3 cm using a remixer, mixing a milled material with the addition of new asphalt mixture and bitumen (up to 1%), placement and compaction of the layer.

7) **Hot recycling technology by the Remix Plus method.** The method includes heating and milling of pavment to a depth of 5 cm using a remixer, mixing a milled material with the addition of bitumen (up to 1%) with simultaneous placement of a layer of 3 cm thickness of asphalt mixture and compaction of two layers in one passage.

8) **The technology of thin-layer pavement of cast emulsion-mineral mixtures.** This technology includes the elimination of potholes in the asphalt pavement and arrangement of a wearing course of cast emulsion-mineral mixture in two passages by a specialized machine. The total thickness of the layer is 3 cm.

9) **Surface treatment.** This technology includes the removal of potholes in the asphalt pavement and arrangement of a single surface treatment with spreading the crushed stone by a specialized machine.

Taking into account [10] determination of the cost of works for each of the selected technologies (Fig. 2), estimated calculations have been made with the use of the program complex SMETA_8_Online in current prices as of 15.04.2020.

According to [7], the annual costs of maintenance and current minor repairs of the national road of III category have been calculated. According to the first variant (without taking into account works on elimination of potholes of road pavement) expenses on 1000 m^2 of pavement make 31500,00 UAH, and for the second variant − 15011,63 UAH.

When estimating the costs, different terms of operation life cycle of road pavements repaired according to technologies 1-9 were also taken into account. An example of the calculation of costs for the current mid-term repair and operational maintenance of 1000 m^2 of the highway of the III category repaired by technology 1, is given in Table 1. Costs by technology are similarly calculated. The total costs of the current mid-term repair and maintenance for each option are compared in Tables 2.

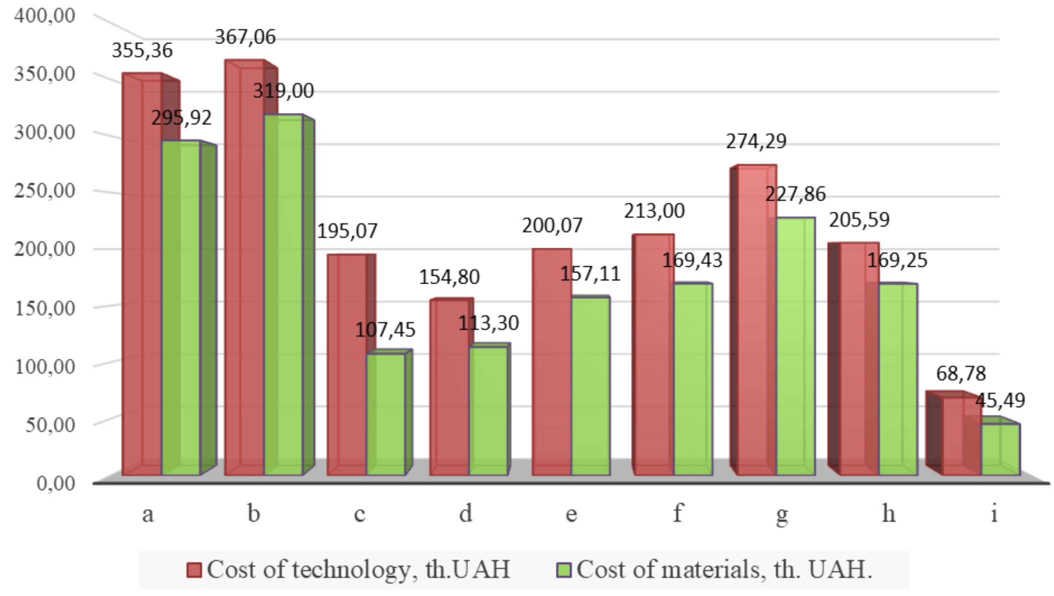

Fig. 1. Current repair cost of 1000 m² of road pavement by technology:
a - 1; b - 2; c 3; d - 4; e - 5; f - 6; g - 7; h - 8; i - 9

Table 1. Costs of current mid-term repair and maintenance of 1000 m² of category III road repaired by technology 1

Year	Discount factor	Costs, thousand UAH		Annual costs, thousand UAH	Accumulation of costs, thousand UAH
		C_{mr}	C_{cmr_om}		
0	1	355,361	-	355,361	355,361
1	1,05	-	13,344	13,344	368,705
2	1,103	-	14,011	14,011	382,716
3	1,158	-	14,718	14,718	397,434
4	1,216	-	15,452	15,452	412,886
5	1,276	-	34,048	34,048	446,934
Total	-	355,361	124,523	446,934	-

Table 2. Costs of current mid-term repair and maintenance of 1000 m² of category III road repaired by technology 1-9.

Year	Annual costs by за technology 1-9, thousand UAH								
	1	2	3	4	5	6	7	8	9
0	355,361	367,057	195,068	154,801	200,073	212,995	274,292	205,588	68,781
1	13,344	13,344	13,344	13,344	13,344	13,344	13,344	13,344	28,000
2	14,011	14,011	14,011	29,4	14,011	14,011	14,011	29,400	29,40
3	14,718	14,718	30,884	30,884	30,884	30,884	14,718	30,884	30,884
4	15,452	32,424	32,424	284,877	32,424	32,424	15,452	367,702	144,594
5	34,048	34,048	34,048	16,226	34,048	34,048	34,048	16,226	34,048
Total	446,934	475,602	319,779	529,532	324,784	337,706	365,865	663,144	335,707

On the basis of the data from Tables 2, a graphic representation of the given costs for the current mid-term repair and maintenance of the road, depending on the service life of the road, is made (Fig. 2).

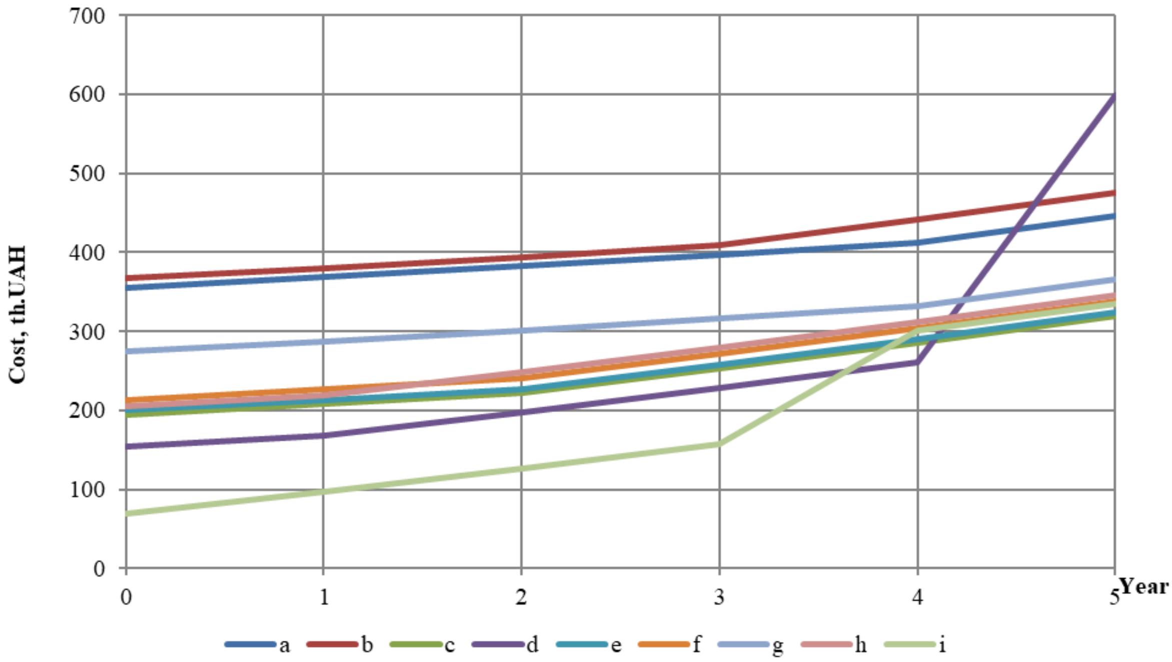

Fig. 2. Chart of annual reported costs for current mid-term road repair and maintenance, depending on repair technology:
a - 1; b - 2; c 3; d - 4; e - 5; f - 6; g - 7; h - 8; i - 9

Charts in Fig. 1 and Fig. 2 show that when comparing only the cost of repair, economically viable methods of restoring the riding qualities of roads is the surface treatment and hot recycling technology by Reshape method. However, the expert analysis and experience of application of such technologies show that the motor road repaired by the mentioned technologies requires the next current mid-term repair rather than the motor road repaired by alternative technologies. This, in turn, has also affected the minimum value of the integral cost indicator for a comparative period of 5 years.

The most expensive methods in estimating the minimum value of integral cost indicator for a comparative period of 5 years are "traditional" repair technologies with milling the old layer of the road pavement and arangement of a new layer, but at the same time, these technologies are the most qualitative and durable.

The technologies of hot regeneration of asphalt concrete and arrangement of wearing courses from cast emulsion-mineral mixtures have average cost of repair, but in the five-year perspective are the most economically advantageous.

Conclusions. It has been established that when comparing only the cost of repair, surface treatment and hot recycling technology using the Reshape method are economically viable methods of restoring the riding qualities of roads.

The technologies of hot recovery of asphalt concrete and arrangement of wearing courses from cast emulsion-mineral mixtures are economically advantageous when comparing them for the period between repairs (5 years for the current mid-term repair).

The cost of repair by any technology is too dependent on the cost of construction materials and the share of local materials at the facility, so in each case, when choosing a method of repair, it is necessary to conduct a pre-project technical and economic comparison.

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METHOD FOR USING SOLAR ENERGY TO GENERATE CLEAN ENERGY BASED ON VACUUM-ATMOSPHERIC POWER AMPLIFICATION TECHNOLOGY

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atmospheric energy,
solar energy,
gravity,
vacuum technologies.

ABSTRACT

New method of converting solar energy into useful work and generating clean energy based on the technology of vacuum-atmospheric power amplification has been developed. As an energy source this technology uses an external supply of potential energy of the atmosphere in the Earth's gravitational field, which exists everywhere and becomes useful when it is converted into the desired form for use.
In this case, clean energy is generated in the same way as in hydroelectric power plants. The main advantage of the proposed method is that the devices in which it is used generate energy stably, regardless of the time of day, weather and location. Clean energy absorbed from the atmosphere is independently generated with any necessary design capacity for a specific consumer in the desired location without the use of organic fuel and main power grids. The article presents a theoretical justification of the method of generating clean energy based on the VAPA technology. Examples of using this method in various devices are given.

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Introduction. The technology of vacuum-atmospheric power amplification (hereinafter – VAPA) is based on the use of the potential energy of the atmosphere in the gravitational field of the Earth. Until an apple stimulated Newton to create the Law of universal gravitation, no one thought about why a body without support necessarily falls down. When our 400 kg vacuum pump suddenly rose and began to "float" in the air relative to the support, we decided to investigate this phenomenon and find a practical application for it. Modern vacuum technologies have achieved significant development, which makes it possible to apply them in a fundamentally new direction – the generation of renewable clean energy by atmospheric-vacuum converters. This technology allows you to create environmentally friendly vacuum-atmospheric engines (hereinafter – VAE) with an external inclusive supply of non-thermal energy from a natural inexhaustible source – the potential energy of the atmosphere.

It is known that the surface of our planet constantly receives an average of 1.36 kW/m^2 of solar energy, a significant part of which is accumulated by the atmosphere. The atmosphere, as an open system, is a natural substance that stores solar energy, thereby maintaining the pressure and temperature gradient of the atmospheric layer in the Earth's gravitational field. [1;2]

Currently, the kinetic energy of the atmosphere is used for generating clean energy in the form of local winds at wind farms, which have a number of significant disadvantages. These include:

instability of the air flow, the huge size of turbines for generating relatively large capacities, stationary binding to the terrain. The VAE turbine is 750 times more efficient than a three-blade wind turbine, which can provide an average output of no more than 400 W/m^2, and a rotary VAE of similar power can consistently provide a performance of more than 300 kW/m^2 from the blade surface when the turbine rotates at 120 rpm (2 rpm), at any time of the day, regardless of the weather and location.

The purpose of this article is a theoretical justification of this method of generating clean energy and the possibility of practical use of the potential energy of the atmosphere as an external source of non-thermal energy for the production of useful work. The article describes the operation of various devices that use the potential energy of an atmospheric column, which is based on a work surface that separates media with different densities. In devices using this technology, work is performed on a vacuum-atmospheric continuous cycle with an external supply of non-thermal energy without the "dirty" technology of exclusive thermodynamic expansion of the working body, which is currently used.

Interaction of solids on the boundary of two medium with different density in a gravitational field.

On the border of two medium: water - atmosphere, in accordance with the law of Archimedes, it is possible to move loads in the gravitational field with a mass of 100 - 500 thousand tons that are in suspension state in water due to the compensating hydrostatic (Archimedean) lifting force. Using the lifting force of the atmosphere is more difficult. The air density is 1.29 * 10^{-3} g / cm^3, the lifting force acting on a ball with a volume of 1m^3 that is filled with hydrogen with a density of 9 * 10^{-5} g /cm^3 will be approximately 12 N. If a vacuum is created inside the shell of the ball, then the lifting power of the ball without taking into account the weight of the shell is 13 N.

As a special case of Archimedes ' law, we can consider a variant when the lifting force acting on the movable surface of the shell, which is located on the border of two media – the atmosphere and the vacuum, increases by several orders and can reach a value of 101,325 N per m^2.

Let's assume that the atmosphere at the Earth's surface is uniform, and the density is constant $\rho = const$ and the continuity condition is fulfilled $\frac{\partial \rho}{\partial t} = 0$. Then the atmospheric pressure forces (hereinafter referred to as APF) act on the body as the volume forces F_a for hydrostatic pressure in accordance with Euler's equations. In our case, for atmospheric pressure P_a, can be represented as:

$$\rho F_x = \frac{\partial Pa}{\partial x};\ \ \rho F_y = \frac{\partial Pa}{\partial y};\ \ \rho F_z = \frac{\partial Pa}{\partial z}. \qquad (1)$$

Or in vector form:

$$\rho F = \text{grad } P_a \qquad (2)$$

when $\rho = const$, in the absence of volumetric forces grad P_a = 0, the atmospheric pressure on all sides of the body is the same (Pascal's law). In the field of gravitational forces, the only force of gravity $F_t = mg$ acts. In order to transfer a body to a suspended state in the atmosphere, it is necessary to have a compensating force $F_a = F_{ks}$ (hereinafter referred to as CFAP) opposite to F_t, which can be done under certain conditions. [3]

Consider these conditions. The atmosphere, as a natural storage of solar energy, is an open system in which this process is implemented. The potential energy of a column of atmosphere with height h that falls on a surface with an area of $S_{eff,}$ is equal to:

$$E_p = S_{eff}\, g \int_0^h \rho(h) h dh = S_{tff}\, g \rho_0 \frac{1}{\lambda^2}[1 - \exp(-\lambda h)(\lambda h + 1)] \qquad (3)$$

in this case, a barometric formula is used for the density of air in the atmosphere, where, $\rho(h) = \rho_0 \exp(-\mu h)$, $\mu = Mg/RT$, M is the molecular weight of the gas, R is the gas constant, ρ_0 is the density of air at altitude h = 0, T is the absolute temperature.

If we assume that at the Earth's surface the atmosphere is uniform and the density is constant ρ_0= const, then the potential energy of the column of atmosphere that rests on the surface of the area S_{eff}, can be represented as:

$$E_p = S_{eff}\, g\, \rho_0 h^2/2 \ \text{[J]} \qquad (4)$$

This formula gives an expression for the natural potential energy of the atmosphere in the field of gravitational forces created by the energy of the Sun. It is used in the VAPA technology as an inclusive source of non-thermal energy for the production of useful work.

The VAPA technology uses the energy of a non-closed system, which continuously receives solar energy, so according to the Second principle of thermodynamics, the operation of devices produced by this method does not contradict the Law of conservation of energy.

Therefore, devices for generating renewable clean energy, which are based on the VAPA technology, do not belong to perpetual motion engines, they can work, as well as hydroelectric power plants, in continuous mode without supplying organic fuel.

The principle of converting the potential energy of the atmosphere in the VAPA technology is similar to converting the energy $E = mgh$ of a falling stream (column) of water into electricity in hydroelectric power plants. Formula (4) can be represented as: $E_p = \alpha m_a g h_1$, where $m_a = \rho_0 S_{eff} h$, is the mass of the atmospheric column with height h, which rests on a surface with area S_{eff}, h_1 – the height (distance)at which the atmospheric column descends, $\alpha=(h- h_1)2$ – a constant. It follows that the pressure force of the atmospheric column on the surface S_{eff}, is equal to $F_a = m_a g$.

Let us consider, as a special case of Pascal's law, the possibility of compensating the gravitational force F_t due to the oppositely directed force of atmospheric pressure $-F_{ks}$ and its use for performing useful mechanical work on a closed vacuum-atmospheric cycle (Fig. 1.). [4]

Let's assume that we have a sealed cavity 1 in the form of a cylinder whose side surface is elastic, for example, in the form of a bellows 3, the ends of which have an area of $S_{eff} = 1\ m^2$. One end of the bellows is rigidly fixed to the support surface 5. The body 7 is attached to the lower end 2, which has the ability to move freely up/down relative to the vertical supports 4.

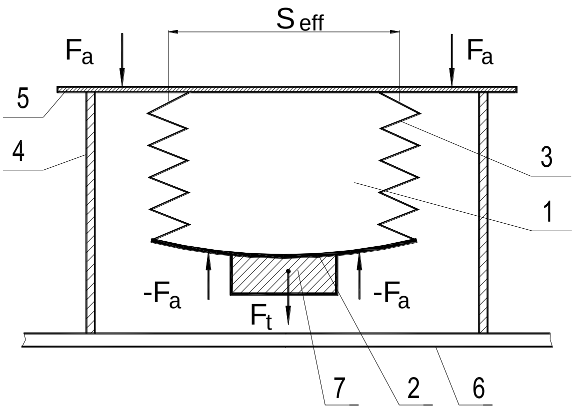

Fig. 1. Interaction of forces CFAP $F_{ks} = -F_a$ and force of gravity F_t

The atmospheric pressure on a surface area of $S_{eff} = 1\ m^2$ equals to 101325 Pa or 101 kN/m^2, and force F_a, with which atmospheric pressure P_a acts on a surface area of 1 m^2 equals to:

$$F_a = F_{ks} = P_a S = 101325\ Pa * 1m^2 = 101325\ \ [N] \quad (5)$$

If air is pumped out of the cavity 1, then, in accordance with Pascal's law, the compensating vertical component $-F_a = F_{ks}$, which acts on the surface of the end of the bellows 2, is also equal to 101 kN/m^2, This force, which will later be called the Pascal force, can lift a load 7 weighing 10,000 kg into a suspended (levitating) state relative to this support, if it is attached to the movable end face/platform of the vacuum cavity 2, which has an area of 1m^2 (hereinafter – PP). In this case, the body weight is redistributed to the support (4, 5).

CFAP is always normal at any point in the separation shell of two media with different densities, which is supported by an atmospheric column.

The Pascal force F_a inclusively acts in any direction in the atmosphere on a separation shell with an effective area of S_{eff}, which is located between two media-the atmosphere and a vacuum or between a liquid and a vacuum.

In General this physical phenomenon can be formulated:

The Pascal force equal to the weight of the atmospheric / liquid column, which rests on the opposite surface of this vacuum cavity with area S, fixedly mounted on the support, is inclusively *acting on the moving surface with area S of the vacuum cavity with an elastic side shell that is immersed in the atmosphere or liquid.*

On the basis of f. 5, it is obvious that the compensating force acting on the body, which is located on the PP vacuum cavity relative to the support, is the lifting force of Pascal F_{ks}, which significantly exceeds the pushing force of Archimedes F_{arh}.

The total pushing force F_{arh} on the submerged body is equal to:

$$F_{arh} = \rho_t \ g \ V_t \quad (6)$$

where ρ_t − is the density of the body, V_t − is the volume of the body, g − is the acceleration of gravity. [5]

As shown above, for a ball with a volume of 1m^3, from which the atmosphere is pumped out, the buoyancy force will be: F_{arh} =13 N

The potential Pascal force with which the atmospheric column presses on the PP of the vacuum cavity on a support that has an area of S_{eff} =1m^2, based on f. 4; 5 is equal to:

$$F_{ks} = \rho_0 \ g \ V_a = P_a \ S_{eff} = 101325 \ [N] \quad (7)$$

where ρ_0 – is the density of the atmosphere, V_a – is the volume of the atmospheric column above the PP with S_{eff}.

To create such a buoyancy force in the atmosphere, Archimedes will need an airship with a volume of 8436 m^3 filled with hydrogen.

It is obvious that a sealed cavity 1 in the form of a cylinder, in which the side surface is elastic, for example, in the form of a bellows 3 (Fig. 1), can provide a transition to a levitating state in the atmosphere relative to the support of physical bodies of almost any weight. This allows you to create simple vibration-isolating systems based on VAPA technology − vacuum-atmospheric stabilizers of objects relative to the horizon. [6]

The main provisions of the theory of VAPA technology

Obviously, under the influence of Pascal's force, the movable end surface of the vacuum cavity can produce inclusive useful work in a closed vacuum-atmospheric cycle due to the potential energy of the atmosphere. Useful work is done due to the interaction of gravity and atmospheric pressure and can become the basis for the development of a fundamentally new technology for generating clean energy.

Based on the above, it is possible to formulate the following provisions that determine the operation of the VAPA technology:

1. The mobile surface of a hermetically closed vacuum cavity, rigidly fixed to a support located in the external environment – atmosphere/liquid, is constantly affected by the force of atmospheric pressure – the Pascal force from this external environment. The Pascal force acting on the movable end surface is always directed in the opposite direction to the stationary end surface of the vacuum cavity with a flexible side shell. This force is directly proportional to the effective area of the stationary and mobile surface and is equal to the pressure difference between the external environment and the vacuum cavity.

2. The body may be in a suspended (levitating) state in the atmosphere (liquid) if it is attached to a hermetically sealed vacuum cavity with an elastic lateral surface fixed to the support in the external environment – the atmosphere (liquid). In this case, the force of gravity is compensated by an equal Pascal force.

3. The movable surface of the hermetically sealed vacuum cavity, which is on the support and divides two media with different density: the atmosphere-vacuum or liquid-vacuum, can produce useful work. This work is done from an external source of non-thermal energy, directly proportional to the volume of the vacuum cavity and the pressure difference in the cavity and the external environment.

This implies:

Consequence 1. *The Pascal Force acting inclusively on the mobile surface of a hermetically closed vacuum cavity, which has a lateral elastic shell and a support point in the external environment, can compensate for the force of gravity and keep the body in a suspended (levitating) vibration-insulated state in the atmosphere. The value of the compensating force is determined by the specified effective area of the fixed support surface and the pressure in the vacuum cavity.*

Consequence 2. *The movable end face of a hermetically sealed vacuum cavity, which has a point of support in the external environment, can continuously produce useful work under the action of Pascal's forces at the expense of the potential energy of the external medium in the atmosphere or liquid if the volume and pressure in the cavity continuously vary in a closed vacuum-atmospheric cycle.*

Consequence 3. *The energy that is spent to create a vacuum in the vacuum cavity in the vacuum-atmospheric cycle can be less than the potential energy of the external medium – the atmosphere or liquid expended for work, which is produced by the movable surface of the vacuum cavity.*

Consequence 4. *Conversion of the potential energy of the atmosphere into free clean energy can occur, provided that the energy spent on creating a vacuum is less than the energy absorbed from the atmosphere to produce useful work.* [7]

Practical application of the VAPA technology

It is practically possible to move a platform with a load under the action of a force F_a at a distance l relative to the support located on a solid underlying surface, if a cavity is formed between the platform and the support plane, in which a vacuum environment is artificially created (see Fig. 1.).

For example, a platform with an area of $S = 1m^2$ when passing a distance of $l = 1m$ under the influence of the force F_a of the atmospheric column, which presses on the effective area of the outside of the platform, will produce work:

$$A = F_a\, l = 101\ k\,N{*}1m = 101\ \ [kJ] \tag{8}$$

and can provide 100 KW of useful power per second.

$$N = A/t = 101\ \ [kW] \tag{9}$$

It is obvious that based on the expression (9), the useful power is determined by the pumping speed of the volume of the vacuum cavity $V = S\,l$, at $P_a = const$, while it is obvious that *1 liter of volume, due to the absorbed potential energy of the atmosphere, can generate 100 W/s of useful power.*

To return the platform to its original position, it is necessary to fill the vacuum cavity with atmospheric air in a natural way (by pressure) to compensate for the effect of the force F_a of the atmospheric column on the outside of the platform. Thus, a two-stroke vacuum-atmospheric cycle can be obtained: "pump out – air inlet". If it is possible to cycle the platform at a distance of $\pm\, l$ with a frequency of *10 Hz* (600 rpm), it can provide *1 MW* of power for mechanical work due to the absorbed potential energy of the atmosphere.

When converting the forward movement of the platform to the rotation of the shaft knees, the torque is defined as:

$$M_t = F\,r = S\,P_a\,l/2\ \ [Nm] \tag{10}$$

and the output power can be written as:

$$N = n\,P_a\,S\,r\ \ [W] \tag{11}$$

Where: n − the number of shaft speed; P_a − atmospheric pressure; S − the effective area of the external surface of the platform; r − the radius of the point of application of force.

This formula almost completely defines the main parameters of a power plant using the crank mechanism CM, in which the absorbed potential energy of the atmosphere is used as an external source of non-thermal energy.

For example, at normal atmospheric pressure $P_a = 1.013{*}10^5\ Pa$, the torque for the case in question will be:

$$M_t = 1{,}013{*}10^5\ S\,l/2 = 50650\ \ [Nm] \tag{12}$$

and the output power at n =10 will be:

$$N = 1{,}013{*}10^5\ n\,Sr = 500\ \ [kW] \tag{13}$$

To almost create a power plant it is necessary to solve three problems: to find a way of converting potential energy into kinetic atmosphere; to create the ability to produce mechanical work; to create an engine that will be able to work through external source of non-thermal energy pressure of the atmosphere. The solution of these problems allows using a fundamentally new source of clean energy, the operation of which does not depend on the action of the wind, the flow of falling water, the time of day and location (except for the height above sea level). At the same time, this energy source can be created with any given useful output power from 3-15 kW to 1-10 MW or more, which will work in accordance with the laws of conservation and thermodynamics as hydroelectric and wind power station.

The creation of a vacuum-atmospheric engine VAE and a device for generating electric energy, which uses the potential energy of the atmosphere as an external source of non-thermal energy, has been solved by us in several variants and is protected by patents of Ukraine and the EAPO [8;9], as well as a US patent [10].

Fig. 2. shows a scheme of a device that can perform mechanical work due to the potential energy of the external environment, while the vacuum system provides the necessary speed for pumping the working fluid (gas) from the vacuum cavity in a closed cycle without escaping into the atmosphere.

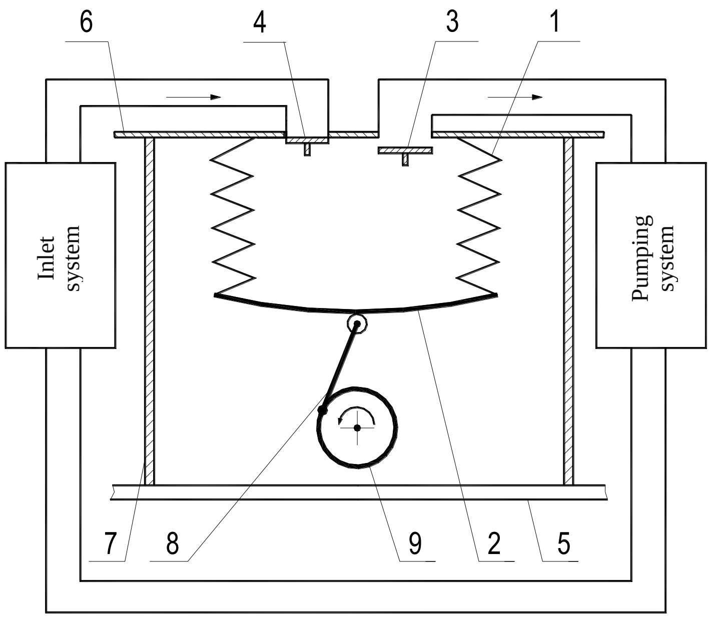

Fig. 2.

Where: 1 ‒ elastic lateral surface (bellows) of the vacuum cavity; 2 ‒ a moving surface (an end face of a bellows); 3; 4 ‒ evacuation / inlet valves; 5 ‒ underlying surface; 6 ‒ supporting surface; 7 ‒ stand support; 8 ‒ connecting rod; 9 ‒ a cranked shaft with a flywheel.

Fig. 3. shows a variant of the experimental sample with one working bellows. The device operates in a push-pule vacuum-atmospheric cycle mode. Shaft rotation is controlled by Hall sensors.

Fig. 3. Variant of the experimental sample with one working bellows

Thus, the power part of the plant that generates electricity from an external source of clean energy- the absorbed potential energy of the atmosphere, works in isolation and independently relative to the vacuum pumping that consume electricity, creating an artificial vacuum in the cavity. A positive balance between generated and consumed energy and will be the useful clean energy that is generated by the device. The choice of an effective vacuum system will determine power gain *Gp* of the concrete device. [8]

As an example, for calculating the *Gp* of the device, we take two versions of the standard oil-free dry vacuum system with a Roots pump (main) and a screw auxiliary pump with parameters:

a. productivity 300 l/s; power consumption 11 kW;

b. productivity 2500 l/s; power consumption 51 kW.

The work that this vacuum system performs to pump out a vacuum cavity with a volume of V_0 = 1[m^3] at a speed of v [m^3/s], at a power consumption of N [W] is defined as:

$$A = NV_0/v \text{ [J]} \quad (14)$$

For the example «a» with parameters v = 0,3 m^3/s, N =11*10^3 W, the work A_1 will be:
A_1 = 11x10^3*1/0,3 = 36,6 [kJ]

For the example «b» with parameters v = 2,5 m^3/s, N=51*10^3 W, the work A_2 will be:
A_2 = 51,5*10^3 * 1/2,5 = 20,6 [kJ]

Thus, 36.6 kJ and 20.6 kJ, respectively, were spent on pumping out at a given speed of the vacuum cavity with a volume of 1 m^3 by the vacuum system. It is very important that the *pumping is carried out due to work, for which the energy of a closed system is used from generating devices,* for example, through centralized power networks or from autonomous diesel power plants. However, the working mechanism of the power part of the installation with the volume of the vacuum cavity $V_0 = 1m^3$, *produces stable effective work* A_{ew} *directly from the energy source of the open system – the potential energy of the atmosphere, which is a continuous natural storage of solar energy*. This work is performed stably with the support in the vacuum cavity of the pressure $P_0 \leq P_{at}^{-2}$ equals to $A_{ew} = 101$ *J*.

It follows that the power gain Gp of the device depends on the parameters of the vacuum system and in this particular case will be equal to:

For example, «a» $Gp = A_{ew} / A_1 = 101 / 36.6 = 2.76$,

For example, «b» $Gp = A_{ew} / A_2 = 101 / 20.6 = 4.9$.

In a real device, *Gp* can be twice as high, as in the above calculations, it was not taken into account that during the working stroke the volume V_0 of the vacuum cavity is a variable.

One of the applications of F_a in a closed vacuum-atmospheric cycle can be carried out in a device where two PPs in the form of movable cylinders rigidly connected through a crank form a power pair and move back and forth along a push-pull cycle. Fig. 4. shows a diagram of such a device using a cylinder-piston group and a crankshaft. In this case, each clock cycle of the device is operational. If one cylinder carries out a working stroke, pumping out of its cavity occurs and Pascal force acts on its end face, then the second cylinder idles, the atmosphere is naturally poured into the cavity, the pressure on both ends is the same and the Pascal force does not act. During the reverse stroke, the cavity of the second cylinder is pumped out, and it makes a working stroke, and the first cylinder idles, while the atmosphere is poured into its cavity in order to compensate (neutralize) the Pascal force. [9]

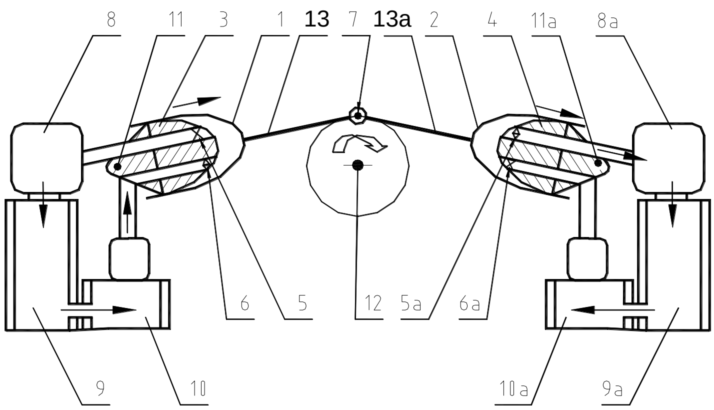

Fig. 4. Scheme of the device with movable cylinders

Where: 1, 2 − movable cylinders; 3, 4 − pistons with the ability to swing on the axes 11, 11a; 5, 5a, 6, 6a − inlet / exhaust valves; 7 − the axis of the crank; 8, 8a, 9, 9a − pumping system; 10, 10a − the inlet system; 12 − an axis of the crankshaft; 13, 13a − rods connecting movable cylinders with the eccentric axis of the crank.

Due to the fact that F_a during the working stroke is constant in absolute value, the use of the crank mechanism, on which up to 50% of the power is lost, is not rational in high-power generation devices. Therefore, in this method of generating large powers, it is optimal to use a VAT vacuum-atmospheric turbine, which can operate on the basis of VAPA technology as part of a vacuum-atmospheric rotary power amplifier (hereinafter − VARPA).

Principle of VARPA.

As it was shown above, so that the Pascal force F_a acts on the moving surface in a closed cycle, it is necessary to create a pressure difference in the vacuum cavities that this surface separates. To ensure the movement of the surface that separates the vacuum cavities, it is necessary that the volumes of these vacuum cavities simultaneously increase / decrease (see Fig. 4.).

This vacuum-atmospheric cycle of supplying the absorbed potential energy of the atmosphere to obtain mechanical work in one housing is implemented in a vacuum-atmospheric turbine (hereinafter − VAT), which is shown in Fig. 5. [10].

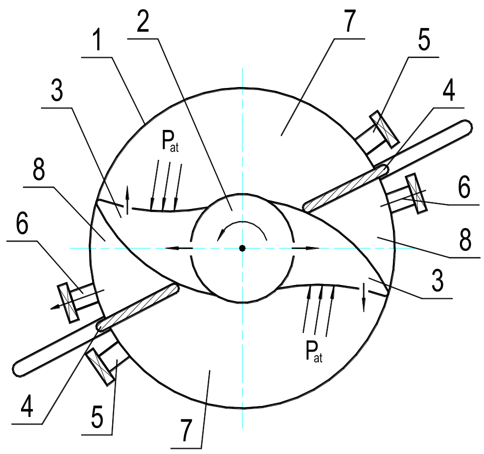

Fig. 5. VAT radial section

VAT contains a cylindrical housing 1, in which the rotor 2 is located, mounted in the housing of the device. The rotor is equipped with at least two streamlined blades 3, the ends of which are in contact with the inner surface of the housing with the possibility of vacuum tight sliding on this surface. Movable plates / dampers 4 − are built into the casing. They are installed diametrically opposite in the VAT casing and divide its volume into two equal vacuum cavities formed by the outer surface of the rotor with blades and the inner surface of the casing. Atmosphere is inflated and evacuated through valves 5; 6. The dampers provide separation of the vacuum cavities 7; 8, they touch their ends with the outer surface of the rotor and the blades with the ability to slide vacuum tightly on this surface. As the blades rotate, which are affected by atmospheric pressure, the volumes of the vacuum cavities simultaneously increase / decrease. To ensure continuous atmospheric inlet into the constantly expanding cavity 7, the rotor shaft and rotor blades are made hollow. On the surfaces of the rotor blades there are nozzles of the "Laval nozzle" type (shown by arrows) through which the atmosphere enters the cavity 7. At the same time, the decreasing volumes of the cavities 8 are continuously evacuated, in which the pressure $P_0 \ll P_a$ is maintained by the vacuum system, which ensures a given pressure difference.

The rotation of the rotor is ensured by the direct influence of the Pascal force F_a on the surface of the blades in the cavities 7 while evacuating the atmosphere from the cavities 8. The blades are diametrically opposed relative to the rotor, which makes it possible to perform mechanical work with constant torque. On the rotor there can be more opposing blades more, which is determined by the design features of the VARPA to obtain the necessary parameters of the VAT. [11]

VAT is much more efficient than a three-bladed wind turbine, which can provide an average output of no more than 400 W/m² from the flooded area, and the VARPA rotary amplifier provides *continuously stable energy generation, for example, more than 300 kW/m² from the surface of the blade when the turbine rotates only at 120 rpm/min (2 rpm), at any time of the day, regardless of weather and location.*

As an autonomous clean energy generator, VARPA can compete in all respects and completely replace diesel power plants, for example, in the range of capacities of 0.1−3 MW, which are in demand on the market mainly as autonomous standby sources of electricity. As a rule, they consume fossil fuels up to 200−400 liters / hour and cannot work on an ongoing basis. VARPA practically does not consume fuel and can generate electricity in constant mode for an unlimited time. Savings in fuel costs alone can be up to $ 3,000,000 per year per installation.

The dimensions of the VARPA with a design reserve capacity of about 2 MW will be approximately the same with diesel power plants of the same power, and the weight, even taking into account the vacuum system, will be significantly less, so VARPA can be performed in a mobile version, for example, in a standard container.

2. Calculation of the delivered power of the VARPA device for 2 MW with the following parameters:

- the diameter of the rotor D_1 = 0.3 m;
- inner diameter of the housing D_2 = 1.3 m;
- the length of the blade along the axis of symmetry of the rotor h = 1 m;
- the length of the rotor with 4 blades 2.5 m;

the total surface area of the four rotor blades will be $S = 2$ m².

Substituting these parameters in the calculated formula of the device's power, we get the power output of the device at 120 rpm/min (2 rpm):

$$N = \pi/2\ P_a\ Sn = 3{,}14/4*101300*2*2 = 636\ [\text{kW}] \quad (15)$$

If, according to the patent, we increase the surface area of the four blades in two chambers of the rotor to S = 5m², (D_2 = 2.3 m; h = 1.6 m; D_{av}= 1.3 m), then the power output of the two-chamber device at 180 rpm/min (3 rpm) increases to 2.38 MW. At the same time, the rotor length of the power unit increases to 3.5 meters, and the diameter of the camera bodies up to 2.5 meters.

The torque on the power shaft of two chamber installation, in which the rotor has four blades, will be:

$$M = 4Fr = 2F\ D_{aw} = 101300*1{,}3*2 = 263380\ \ [\text{Hm}] \quad (16)$$

Such a torque ensures the stability of rotation of the rotor of the generator at even the maximum variable load.

To obtain the required pressure difference, it is necessary to ensure pumping of the working chambers and constantly maintaining a pressure in the pumped parts of the vacuum chambers of about 100−10,000 Pa. Modern dry vacuum pumps of serial production provide the necessary speeds for individual pumping of the vacuum cavities of the working chambers.

The optimal use of VARPA is possible as a powerful autonomous offshore source of clean electricity, in trucks, trunk locomotives and marine power units.

Due to the fact that the torque does not depend on the rotor speed and there are practically no thermal and mechanical losses, the VARPA power plant with these parameters can provide the required speed of a vessel with a sufficiently large displacement without the use of fossil fuels.

For example, for a ship, in this case, the rotor rotates at an average speed of 180 rpm, therefore, a power shaft with a propeller can be connected directly to the rotor without loss of power in the transmission. The rotational speed and stop of the rotor are regulated by the electronic controller by changing the rate of inlet and exhaust of the atmosphere.

Obviously, with the use of VARPA in a marine power plant, we can obtain, ceteris paribus, fuel savings of about 10 times, which is very important for long-term autonomous navigation. At the same time, VARPA will provide minimal vibration and noise of the power unit. Similar fuel economy can be obtained by using VARPA in the power unit of the main locomotive and truck.

Conclusions.

1. The potential energy of the atmosphere is a natural unlimited source of non-thermal clean energy and can be used to obtain useful work.

2. It is shown that modern vacuum pumping systems make it possible to create devices that provide a transition to a suspended state in the atmosphere relative to the support of physical bodies of almost any weight.

3. A method for converting solar energy into useful work is theoretically substantiated, on the basis of which a vacuum-atmospheric power amplification technology is developed − VAPA technology, as a new promising direction in renewable energy. VAPA technology can have a great advantage over other methods of generating clean energy, which use the energy of the Sun. It can be widely used for non-thermal autonomous generation of clean energy due to the absorbed potential energy of the atmosphere.

4. Based on the VAPA technology, it is possible to create compact, almost silent autonomous devices for generating clean energy of any power, operating on an implosive non-thermal vacuum-atmospheric cycle, which can be effectively used in the energy sector and as part of environmentally friendly power units of vehicles.

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ON THE METHOD OF DETERMINING LEARNING DESCRIPTIONS TO FORECAST NATURAL DISASTERS WITH THE PATTERN RECOGNITION SYSTEM

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ABSTRACT

To forecast natural disasters (floods, mud-slides) in the fixed region and in period T0 with SPRL – the System of Pattern Recognition with Learning (elaborated by us) it is necessary to have the data of the previous 12 months of period T0 and learning descriptions (LDs). To identify this latter, the fact of occurrence or non-occurrence of disasters in the same region and the period T0 should be known in other years and also, the above mentioned 12-month date for each year. Determining LDs based on them is the aim of the article. For this purpose, the method which will be included in the first model of the SPRL is elaborated. The SPRL comprises: 1) preliminary elaboration of the initial information, 2) learning and 3) recognition models. This system is implemented on a PC. It is verified on the basis of the real data to recognize objects of different classis. Primary, additional and formal additional parameters are determined in the method given in the article. On the basis of their values in correlation with the aforementioned 12 months two matrices are determined. The first of them corresponds to the fact of occurrence of disasters and the second one – of non-occurrence. By using these parameter values given in these matrices LDs will be determined. The best LDs will be given to the learning model of the SPRL for transformation and increasing of informativity. Based on the LDs obtained after the transformation, the learning model will make knowledge and data bases.

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Introduction. One of the important problems is forecasting the natural disasters (floods, mud-slides) [1,2]. To forecast natural disasters with the System of Pattern Recognition with Learning (SPRL) [3,4] in the fixed region in the given period T_0, it is necessary to have initial learning descriptions. In case of objects, learning description [5,6] is the sequence of parameter values (characteristics) of an object for which the class, the object presented by this sequence belongs to, is known beforehand. The sequence of parameter values is also called realization [3, 4, 7], vector of *m* component (*m* – the number of parameters) [8]. In case of a natural event, occurrence or non-occurrence of such a natural event should be known in the fixed region and the given period T_0. Let us call this period learning zero block and the sequence of parameter values characterizing the natural event in the first and second case separately in the previous 12 months of period T_0 – learning description.

We have elaborated the System of Pattern Recognition with Learning – SPRL [3, 4]. It includes: 1) model of preliminary elaboration of the initial information, also 2) learning and 3) recognition models. These models include the methods and algorithms of solving 21 main objectives. The SPRL was implemented on a PC. The system is verified on the basis of the real data to recognize objects of different classes. This system can recognize new objects from the list of the given classes even in case when descriptions corresponding to the objects of one and the same class differ from each other more than descriptions corresponding to the objects of different classes.

In order to forecast this or that natural disaster using SPRL (e.g. floods, mud-slides, etc.) in the given year in the fixed region and the particular time period T_0 (let us call this period a zero block), the data for this previous 12 months of this very year should necessarily be known in advance. These data should be presented as a sequence i.e. description of parameter values of the corresponding natural event. In the indicated data must be implied the existing real data – parameter values (characteristic features). They can include characteristic features determining occurrence as well as non-occurrence of natural disasters.

In addition, before the system forecasts whether this natural event will occur or not in the given year in the fixed region and period T_0 (zero block), it should preliminarily elaborate the data about occurred and not occurred natural disasters in previous years in the same region and period T_0. These data should correspond to the sequences of characteristic features determined on the basis of the data of the previous 12 months in each year in the same region and period T_0 (learning zero block) in case of occurrence and non-occurrence of the natural event. Meanwhile, these data should be given in respect to the learning zero block of the given natural event in case of occurrence and non-occurrence separately. It means that it is necessary to have the learning zero block and its corresponding learning descriptions in case of occurrence as well as non-occurrence of disasters. Elaboration of the learning descriptions is the aim of this article. We have elaborated the method which determines learning descriptions in correlation with the previous 12 months of the learning zero block. It will be included in the first model of the SPRL. Let us call the learning descriptions which correspond to such learning zero block in which a natural disaster has occurred, learning descriptions included in the first class; if a natural disaster has not occurred in the learning zero block – the second class. After determination of the learning descriptions, the best of them will be passed to the learning model. After transformation of the learning descriptions, the model will determine knowledge and data bases for each class separately.

Primary and formal additional parameters. Before learning descriptions are determined, first of all, on the basis of the data of the previous 12 months, for the corresponding natural event should be chosen its corresponding characteristic initial parameters. For example, in case of flood, we can presumably consider the following initial parameters in the fixed region and period: the average air temperature ranges from 12 noon to 12 midnight and from 12 midnight to 12 noon of the next day. From these time intervals, let us call the first of them the first part of the time interval and the second one – the second part of the time interval. Also, we should consider the mean values of air atmospheric pressure, air humidity and wind speed in the same region and in both time intervals. As these parameters are presumable, they can be specified later. For instance: maximum temperature, direct and scattered solar radiation, air relative humidity [2], etc. can be considered as initial parameters (the article deals only with 4 parameters listed above). Obviously, changing or adding the parameters, certainly, will not lead to serious changes in the elaborated method. The changes that will be provoked in correlation with the specificity of forecasting natural disasters, should be considered in the recognition model of the SPRL.

If we separately discuss 4 parameters corresponding to each part of the time interval, we will get the sequences consisting of 8 parameters in correlation with the learning zero block that corresponds to the previous 12 months of the given period and region. Let us call so defined parameters primary parameters. Under this learning zero block (period) we can imply any month of a year.

It is also possible that the values of the primary parameters chosen from the beginning (in our case of 8 parameters determined according to the first and second parts of the time interval indicated above) or the parameters even after their specification are not enough to determine informative learning descriptions and, consequently, to forecast natural disasters. Taking into consideration this fact, we considered it expedient to determine additional parameters. They look as follows:

$$P_1 = \max y_v + \min y_v;\; P_2 = \max y_v - \min y_v;\; P_3 = \frac{1}{m}\sum_{j=1}^{m} y_j = \bar{y};\; P_4 = card\alpha;$$

$$P_5 = card\beta;\; P_6 = \sum_{j\in\{j/y_j<\bar{y}\}} y_j;\qquad P_7 = \sum_{j\in\{j/y_j>\bar{y}\}} y_j;\qquad P_8 = \frac{1}{m}\sum_{j=1}^{m}(\bar{y}-y_j)^2,$$

where y_j denotes the data given in j th period, m – the number of data in j th period. α corresponds to the set of data of above the average values of the data given in the j th period, β corresponds to the set of data of below this average values. Let us determine four parameters based on the formulas given above. Let us mark them with P_9, P_{10}, P_{11} and P_{12}, and call them formal additional parameters.

$$P_9 = p_1 / p_2,\; P_{10} = p_3 / p_8,\; P_{11} = p_4 / p_5 \text{ and } P_{12} = p_7 / p_6 .$$

If we add these formal additional parameters to the sequence of 8 primary parameters, we will get the sequence consisting of 12 parameters.

Matrix 1 and Matrix 2. Using the primary and formal additional parameter values learning descriptions will be determined with the proposed method, on the basis of the previous 12-month data of the learning zero block (let us assume – January).

At first two matrices (matrix 1 and matrix 2) are made to determine these learning descriptions. The first matrix refers to occurrence of natural disasters and the second one – to non-occurrence.

In order to make these matrices (when January corresponds to the learning zero block), we should consider the following sequence of one-month period of the previous 12 months of the respective learning zero block: December, November, October, September, August, July, June, May, April, March, February, January (the latter refers to the next year). The months in the matrices are given in such sequence. In this case, each of these months should be divided into small periods with respect to days. Let us call them learning blocks because the fact of occurrence or non-occurrence of a natural disaster in the corresponding learning zero block is known in advance.

Since the number of days in each month does not coincide with each other, the above-mentioned months in correlation with the days will be presented in the form of sequences of the following intervals (learning blocks): the months containing 31 days will be divided into the following intervals [31-24], [23-16], [15-8], [7-1]. The months containing 30 days will be presented in the following form [30-23], [22-15], [14-8], [7-1]; for February, if it belongs to a leap year, intervals will be presented in the following way [29-22], [21-15], [14-8], [7-1], but if the year is not leap, intervals will be presented in the following way [28-22], [21-15], [14-8], [7-1].

Thus, from the corresponding 12 months, each month will be divided into 4-4 learning blocks (short periods). From each matrix 48 learning descriptions will be determined in relation to the corresponding parameters, both parts of the time intervals, each month, and the learning blocks included in it.

In the first row of the matrix 1 is given the name of the parameters, in the next 48 rows are given the average values of the corresponding parameter values in correlation with the parts of the time interval and then in correlation with the learning blocks which is included in the month of the corresponding sequential number. Consequently, the matrix element A_{ij}^{t} is denoted by the average of the values of i th parameter which is determined at first with respect to the first part of the time interval (is implied data from 12 noon to 12 midnight) and then according to t^{th} learning blocks of j th month. B_{ij}^{t} is determined analogically but in respect to the second part of the time interval (is implied data from 12 midnight to 12 noon of the next day). Out of the 8 primary elements of the matrix 1, A_i, $i=\overline{1,4}$ and B_{i+4} of indices correspond to one and the same parameter but they have different meanings (loading) according to different parts of the time interval what is expressed with different markers A and B. The same applies to the elements of the matrix 2.

Out of the 48 aforementioned rows, each of which is a learning description, in the article are given only the first 4 rows. It refers to all periods divided into small periods of only the preceding 12th month of the corresponding learning zero block, with respect to parameter indices and the parts of the time interval.

The month, in which occurrence or non-occurrence of natural disaster should be forecasted in the next years, which is a learning zero block for the matrix, is denoted by $\mathbf{0}_k$. The index k indicates the sequential number of the corresponding month of the learning zero block whose each month from the corresponding previous 12 months is divided into aforementioned 4-4 short periods (learning blocks).

In one upper line of the matrices is given the name of the preceding 12 months of the learning zero block, in the followed row – sequential numbers of these months, and in the top line of the matrices, along the name of the matrix (in brackets), in the same line is given the name of the learning zero block.

Dec.	Nov.	Oct.	Sep.	Aug.	July	June	May	Apr.	March	Feb.	Jan.
12	11	10	9	8	7	6	5	4	3	2	1

Matrix 1 (learning zero block 0_1 - January)

$$\begin{array}{cccccccccccc}
\boldsymbol{A_1} & \boldsymbol{A_2} & \boldsymbol{A_3} & \boldsymbol{A_4} & \boldsymbol{B_5} & \boldsymbol{B_6} & \boldsymbol{B_7} & \boldsymbol{B_8} & \boldsymbol{P_9}, & \boldsymbol{P_{10}}, & \boldsymbol{P_{11}}, & \boldsymbol{P_{12}} \\
A^1_{112} & A^1_{212} & A^1_{312} & A^1_{412} & B^1_{512} & B^1_{612} & B^1_{712} & B^1_{812} & P^1_{912} & P^1_{1012} & P^1_{1112} & P^1_{1212} \\
A^2_{112} & A^2_{212} & A^2_{312} & A^2_{412} & B^2_{512} & B^2_{612} & B^2_{712} & B^2_{812} & P^2_{912} & P^2_{1012} & P^2_{1112} & P^2_{1212} \\
A^3_{112} & A^3_{212} & A^3_{312} & A^3_{412} & B^3_{512} & B^3_{612} & B^3_{712} & B^3_{812} & P^3_{912} & P^3_{1012} & P^3_{1112} & P^3_{1212} \\
A^4_{112} & A^4_{212} & A^4_{312} & A^4_{412} & B^4_{512} & B^4_{612} & B^4_{712} & B^4_{812} & P^4_{912} & P^4_{1012} & P^4_{1112} & P^4_{1212}
\end{array}$$

$\overline{\boldsymbol{A}}{}^{\boldsymbol{t}}_{\boldsymbol{ij}}$ and $\overline{\boldsymbol{B}}{}^{\boldsymbol{t}}_{\boldsymbol{ij}}$ are determined analogically in matrix 2, but non-occurrence of natural disasters is implied in this matrix. In matrix 2, as in matrix 1, after the first row out of 48 rows are given only the first 4 rows of the 12th month.

Matrix 2 (learning zero block 0_1 - January)

$$\begin{array}{cccccccccccc}
\overline{\boldsymbol{A_1}} & \overline{\boldsymbol{A_2}} & \overline{\boldsymbol{A_3}} & \overline{\boldsymbol{A_4}} & \overline{\boldsymbol{B_5}} & \overline{\boldsymbol{B_6}} & \overline{\boldsymbol{B_7}} & \overline{\boldsymbol{B_8}} & \overline{\boldsymbol{P_9}}, & \overline{\boldsymbol{P_{10}}}, & \overline{\boldsymbol{P_{11}}}, & \overline{\boldsymbol{P_{12}}} \\
\overline{A^1_{112}} & \overline{A^1_{212}} & \overline{A^1_{312}} & \overline{A^1_{412}} & \overline{B^1_{512}} & \overline{B^1_{612}} & \overline{B^1_{712}} & \overline{B^1_{812}} & \overline{P^1_{912}} & \overline{P^1_{1012}} & \overline{P^1_{1112}} & \overline{P^1_{1212}} \\
\overline{A^2_{112}} & \overline{A^2_{212}} & \overline{A^2_{312}} & \overline{A^2_{412}} & \overline{B^2_{512}} & \overline{B^2_{612}} & \overline{B^2_{712}} & \overline{B^2_{812}} & \overline{P^2_{912}} & \overline{P^2_{1012}} & \overline{P^2_{1112}} & \overline{P^2_{1212}} \\
\overline{A^3_{112}} & \overline{A^3_{212}} & \overline{A^3_{312}} & \overline{A^3_{412}} & \overline{B^3_{512}} & \overline{B^3_{612}} & \overline{B^3_{712}} & \overline{B^3_{812}} & \overline{P^3_{912}} & \overline{P^3_{1012}} & \overline{P^3_{1112}} & \overline{P^3_{1212}} \\
\overline{A^4_{112}} & \overline{A^4_{212}} & \overline{A^4_{312}} & \overline{A^4_{412}} & \overline{B^4_{512}} & \overline{B^4_{612}} & \overline{B^4_{712}} & \overline{B^4_{812}} & \overline{P^4_{912}} & \overline{P^4_{1012}} & \overline{P^4_{1112}} & \overline{P^4_{1212}}
\end{array}$$

Thus, two matrices are obtained: matrix 1 and matrix 2.

Any row from the second row of these matrices is the primary learning description. This is caused by the fact that these rows are given in the form of sequences of parameter values characterizing a natural event (these sequences include primary parameter and formal additional parameter values). In addition, at the same time, in their respective learning zero block the fact of occurrence of a disaster is known in advance in case of the matrix 1, and in case of the matrix 2 – the fact of non-occurrence of the same natural disaster. This means that according to the data from the previous 12 months corresponding to the learning zero block can be determined by the appropriate learning descriptions, also, the descriptions corresponding to the zero block, i.e. when the fact of occurrence or non-occurrence of the disaster in the zero block is not known.

Choosing learning descriptions. For each sequence (learning description) let us calculate the differences between each fixed $\boldsymbol{i}$ th parameter value in respect to the both parts of the time interval separately and for t th learning block of $\boldsymbol{j}$ th month. Let us indicate these differences with $\boldsymbol{d^{X\,t}_{ij}}$, $\boldsymbol{d^{X\,t}_{ij} = X^{\,t}_{ij} - \overline{X}{}^{\,t}_{ij}}$, where under X is implied A or B primary $\boldsymbol{i}$ th $\boldsymbol{i = \overline{1,8}}$ parameter values in correlation with the first or second part of the time interval consequently or P $\boldsymbol{i}$ th $i = \overline{9,12}$ – formal additional parameter values in corresponding correlations.

$$\begin{array}{cccccccccccc}
d^{A1}_{112} & d^{A1}_{212} & d^{A1}_{312} & d^{A1}_{412} & d^{B1}_{512} & d^{B1}_{612} & d^{B1}_{712} & d^{B1}_{812} & d^{P1}_{912} & d^{P1}_{1012} & d^{P1}_{1112} & d^{P1}_{1212} \\
d^{A2}_{112} & d^{A2}_{212} & d^{A2}_{312} & d^{A2}_{412} & d^{B2}_{512} & d^{B2}_{612} & d^{B2}_{712} & d^{B2}_{812} & d^{P2}_{912} & d^{P2}_{1012} & d^{P2}_{1112} & d^{P2}_{1212} \\
d^{A3}_{112} & d^{A3}_{212} & d^{A3}_{312} & d^{A3}_{412} & d^{B3}_{512} & d^{B3}_{612} & d^{B3}_{712} & d^{B3}_{812} & d^{P3}_{912} & d^{P3}_{1012} & d^{P3}_{1112} & d^{P3}_{1212} \\
d^{A4}_{112} & d^{A4}_{212} & d^{A4}_{312} & d^{A4}_{412} & d^{B4}_{512} & d^{B4}_{612} & d^{B4}_{712} & d^{B4}_{812} & d^{P4}_{912} & d^{P4}_{1012} & d^{P4}_{1112} & d^{P4}_{1212}
\end{array}$$

Thus, we get such sequences of differences that will allow us to choose the best sequences (consequently, learning descriptions from matrices). They will be chosen with the help of the following algorithm which comprises 4 stages:

1. For each of the above sequences, let us choose the maximum and minimum values from the values contained in it. Let us denote them with $\max \boldsymbol{d}_{ij}^{Xt}$ and $\min \boldsymbol{d}_{ij}^{Xt}$, and call them characteristics of their sequences (corresponding learning descriptions). By using them and the vector-optimization method of choice of the best variants [9], let us determine the best sequences i.e. such sequences which belong to Pareto set. Let us mark the set of such sequences with $\boldsymbol{D_1}$.

2. For each sequence, let us determine the average meaning of the values included in it. Let us determine the set of the best sequences the same way as given in the stage 1, but here the average value and maximal value are considered as characteristics of sequences. Let us mark this set with D_2.

3. The procedures given in the stage 2 will be used in this stage, but minimal and average meaning will be used as characteristics (vector components) of sequences. Let us mark this set with D_3. Thus, we will get 3 sets $\boldsymbol{D_1}$, $\boldsymbol{D_2}$, $\boldsymbol{D_3}$ of the best sequences. Let us denote their united set with $\boldsymbol{D}$. It should contain various differences (consequently, matrices should contain different learning descriptions).

4. If so determined set for $\boldsymbol{D}$, $cardD < 40$, then, on the basis of the characteristics of the sequences of differences remained beyond set $\boldsymbol{D}$ for each difference, we will calculated vector lengths. According to the value of these lengths, we will fill set $\boldsymbol{D}$ so that is should contain 40 sequences. Consequently, 40 learning descriptions will be chosen from each matrix. As the statistics of using the SPRL has shown (in case of recognitions of objects) this quantity is enough to make knowledge and data bases for the learning model. Thus, such learning descriptions are obtained, that will be passed to the learning model of the SPRL. The learning model will transform them, increase informativity and define the knowledge and data bases in the process of machine learning [10].

To increase the informativity of learning descriptions, the learning model uses: from combinatorial mathemetics balanced and partially balanced incomplete block-designs and tactical configurations of (v,b,k,r,λ,μ) type [11,12], geometrical configurations [13] and the vector-optimization method of choice of the best variants. Namely with their help the learning model determined new artificial (formal) parameters, functions which show the internal hidden connections between the primary characteristic parameters of the natural event which really exist between them, but are not explicitly given in the primary learning descriptions. At the same time, thus defined parameters will increase this number in case of their small number and, but in case of large quantity of parameters – it decreases [3]. Besides, with their help are determined such characteristics, values of these functions (parameters) and their combinations which are characteristic to only one (i.e. each different) class. After this, learning descriptions will be recorded in the language (new codes) from which the learning model determines data bases for each class separately in case of occurrence of a disaster as well as in case of its non-occurrence.

The knowledge base contains all those formulas (functions), values which are used for transformation of learning descriptions and the language (new codes) in which learning descriptions will be recorded.

The data base which is determined on the basis of the above mentioned knowledge base contains the characteristic features of the both classes: single characteristic features, feature pairs, triplets and specific combinations (groups) of characteristic features. These groups contain combinations of characteristic and non-characteristic features of classes. The triplets as well as these combinations are determined using the aforementioned combinatorial schemes without exhaustive search. This fact significantly decreases the quantity of triplets and these combinations due to what their use becomes possible.

Using the method for determining learning descriptions, was discussed that case when occurrence or non-occurrence of natural disasters should be forecasted in January according to which matrix 1 and matrix 2 were determined, and on their basis – learning descriptions. The same method is used for each month separately.

For this purpose, the corresponding matrix 1 and matrix 2 will be made for each month (which we consider as a learning zero block). On the basis of these matrices, the same procedure will be used that was used for January.

Thus, to determine learning descriptions, besides the method given in this article, only the two models of the SPRL are used. After determination the learning descriptions to forecast disasters it is necessary to use the third (recognition) model of the SPRL, but it was considered only for object recognition. This is caused by the fact that in the SPRL elaborated by us is considered recognition of only objects (satellite types, aircrafts, diseases, schedules, irises etc.) and is not considered the specifics of forecasting (recognition) of natural disasters, events.

Unlike recognition of any object, the specificity of recognition of a natural event (disaster) is as follows: a natural event is not forecasted by using such learning descriptions that correspond directly to the learning zero block and on the basis of these descriptions do not determine knowledge and data bases (as it happened in case of objects). In case of a natural event, based on the data of the previous 12 months of the learning zero block, learning descriptions (from which the control descriptions are separated by the first model) must be determined.

In this case at first the conditions of the previous period of this learning zero block should be studied the first model separates control descriptions from the initial learning descriptions from the very beginning. That is why it is implied that the fact of occurrence (non-occurrence) of a disaster in the learning zero block is not known to them. At the same time, it is obvious that control descriptions do not participate in making the aforementioned knowledge and data bases. Therefore, for them, the learning zero block has the role of the zero block, while the control descriptions play the role of new descriptions that are determined on the basis of the data corresponding to the previous 12 months of the zero block.

Therefore, at first, it is necessary to recognize the condition of the previous periods of this zero block. The learning model first transforms these learning descriptions in order to increase informativity. Then, with their help, it determines the knowledge and data bases separately using the data from all previous years (at least 5 years) on the basis of the determined learning descriptions. These bases determined in different years will be transferred to the recognition model. After this, in the learning process, control descriptions should be recognized by using different knowledge and data bases determined in the different previous years. Namely on the basis of the results of the recognition of these control descriptions will be recognized occurrence or non-occurrence of a disaster in the zero block, because these results of recognition show how correctly these bases correspond to the fact of occurrence or non-occurrence of a disaster, to what extent it is possible to recognize new disasters in the same region and period on the basis of the knowledge and data bases determined in the learning process. This leads to a number of changes to the recognition model (change of the decision-making criteria, etc.).

When the initial information is given or it can be presented in the form of the learning descriptions, we can set the objective of forecasting natural disasters in terms of pattern recognition with learning. This, in its turn, conditions necessity of determining the learning descriptions corresponding to natural disasters to solve the aforementioned objective. This fact is caused by the fact that after determining such learning descriptions it is possible to use all three models of the SPRL but after modification of the recognition model (what is a separate objective). At the same time, the data in relation with the previous 12 months of the zero block should necessarily be given.

Conclusions. To forecast natural disasters (floods, mud-slides) with the system of pattern recognition with learning – SPRL (elaborated by us) in the given region and period T_0, besides having the data of 12 months prior to this period, it is necessary to have learning descriptions – LDs. For their determination it is necessary to have the data of the previous 12 months in the same region and period T_0 of other years in case of occurrence and non-occurrence of disasters. Determining LDs based on the given last data is the aim of the article. For this purpose, the method which will be included in the model of preliminary elaboration of the initial information (the first model of SPRL) is elaborated. First of all, primary, additional and formal additional parameters are determined in the method. On the bases of these parameter values, two matrices are determined. The first of them corresponds to the fact of occurrence of disasters and the second one – of non-occurrence. The values of the parameters are given in these matrices. On the basis of them LDs are determined in correlation with the parts of the time intervals, each month of the previous 12 months and the learning blocks included in each month. Thus the determined LDs are passed to the learning model (the second model of SPRL) for further transformation and for making knowledge and data bases. For this purpose, the learning model uses balanced and partially balanced incomplete block-designs, tactical configurations of (v,b,k,r,λ,μ) type [11, 12], geometrical configurations and the vector-optimization method of choice of the best variants.

Thus, to determine learning descriptions, besides the method given in this article, only the two models of the SPRL are used. The learning model transfers the bases determined in different years to the recognition (third) model to forecasting a disaster only after this model is modified (what is a separate objective).

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PHYSICS AND MATHEMATICS

ЗАВИСИМОСТЬ СТРУКТУРЫ ЗОН ПОЛУПРОВОДНИКОВ ОТ СКОРОСТИ РЕКОМБИНАЦИИ МЕЖДУ ЗОНАМИ

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ABSTRACT

This article researches the dependence of recombination processes that occur in semiconductors on the structure of semiconductor zones. The advantages of using faulty zonal semiconductors in the development of solar cells have been substantiated.

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Потребность в электроэнергии ежегодно повышается на 5 процентов в связи с ростом населения и развитием экономики Узбекистана. К 2030 году в нашей стране потребуется довести производственную мощность электроэнергии до 25000 мегаватт или годовой объем производства электроэнергии до 120 миллиардов часов.

Для удовлетворения потребностей в электроэнергии важное значение имеет поиск и эффективное использование альтернативных источников энергии. Из альтернативных источников энергии можно выделить солнечную энергию, энергию ветра, морской воды и биогаза.

Особое место среди них занимает солнечная энергия. Во-первых, солнечная энергия, которая преобразует солнечную энергию в электрическую, отличается от других альтернативных источников энергии простотой своей структуры, безопасностью, экологической чистотой и возможностью его использования в долгосрочной перспективе.

Во-вторых, специалисты утверждают, что земная поверхность ежедневно получает от солнца количество энергии, равное 174 петаваттам. Наша страна, где в году 300 солнечных дней, очень удобна для применения технологий получения электрической энергии от солнечных лучей.

К 2030 году в нашей республике планируется запустить солнечные и ветровые электростанции мощностью 3500 тысяч мегаватт. В ближайшие 10 лет в Узбекистане будет запущено 25 солнечных электростанций.

В настоящее время электроэнергия, производимая солнечными батареями, во много раз дороже электроэнергии, производимой на тепловых, атомных и гидроэлектростанциях. Поэтому перед учеными и инженерами, производящими солнечные элементы, стоит проблема совершенствования солнечных элементов и снижения себестоимости электроэнергии.

Основная стоимость электроэнергии, получаемой от солнечных элементов, зависит от дороговизны полупроводниковых материалов, работающих на солнечных батареях. Основным полупроводниковым материалом, работающим на солнечной энергии, остается кремний.

Все усилия, прилагаемые современными учеными, направлены на получение недорогого кремния, который не очень подходит для солнечных батарей. Это, в основном, поликристаллы и аморфный кремний, достаточно тонкие пленки, насыщенные водородом и опылённые до проницаемой основы. Еще один способ удешевления солнечных элементов — это упрощение технологии. Особенно дорого обходится отказ от высокотемпературной диффузионной операции. При этом мы также избавляемся от сокращения времени жизни носителей заряда. В этом случае диффузионная длина носителей заряда уменьшается.

Наконец, еще одним способом снижения себестоимости основных элементов солнечных батарей может стать использование новых рабочих принципов. Или же можно использовать концентраторы солнечной энергии с целью выбора более дорогого полупроводникового материала. Был проведен ряд научно-исследовательских работ по удешевлению солнечных батарей и повышению их коэффициента полезного действия за счет отказа от высокотемпературных диффузионных процессов, в которых технологические процессы являются дорогостоящими, а также увеличения времени жизни носителей заряда. В работах авторов [1-5], [6-12] изучено, что чувствительность полупроводниковых солнечных элементов к свету зависит от скорости рекомбинации, которая происходит в полупроводниках, и времени жизни носителей заряда.

В данной статье исследуется связь скорости рекомбинации в полупроводниках со структурой зон полупроводников.

Как известно, по структуре зон полупроводников выделяются 2 типа:

1.Полупроводники с прямой зоной,

2.Полупроводники с непрямой зоной.

Если нижняя часть зоны проводимости (E_c) и верхняя часть валентной зоны (E_V) соответствует друг другу, то такие полупроводники называются полупроводниками с прямыми зонами.

Вначале рассмотрим процессы рекомбинации для полупроводников с прямыми зонами (Рис.1).

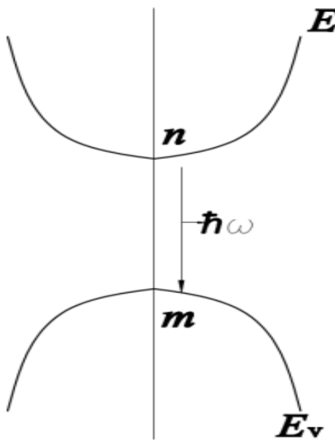

Рис. 1. Процесс рекомбинации в полупроводниках с прямой зоной

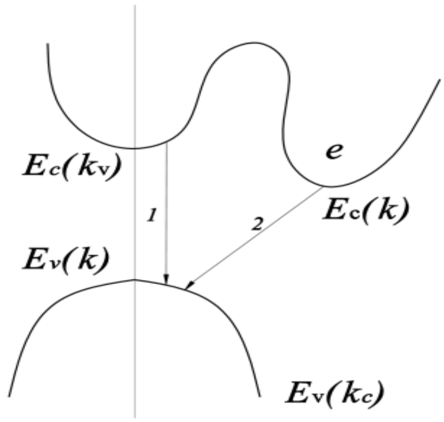

Рис. 2. Процесс рекомбинации в полупроводниках с непрямой зоной через прямое оптическое проникновение

Закон сохранения для рекомбинационных процессов выражается следующим образом:

$E_V = E_c - \hbar\omega$ – закон сохранения энергии

$\overrightarrow{k_V} = \overrightarrow{k_c} - \vec{g}$ – закон сохранения импульса

здесь, $k = \frac{\pi}{a} = 10^8$ см$^{-1}$–волновой вектор электрона, $g = \frac{2\pi}{\lambda} = 10^4 \div 10^5$см$^{-1}$ – волновой вектор фотона. Вероятность перехода из зоны электронной проводимостью в валентную зону $(n \to m)$

$$W = W_{nm}[1 - f(E_V(\vec{k})]$$

Вероятность существования в валентной зоне дырки k, равное волновому вектору $f[E_V(\vec{k})]$, вычисляется по следующей формуле

$$W = \frac{4}{3}\frac{e^2\omega}{4\pi\varepsilon_0\hbar c}\frac{|< k_c|P|k_V >|^2}{(mc)^2}[1 - f_p(E(k)]$$

Здесь ω – циклическая частота световой волны, m – масса электрона, P – элемент матрицы при переходе электрона из состояния k_c в состояние k_V.

$$W = \gamma_r \cdot P, \quad \frac{P}{N_V} = 1 - f(E_V(k))$$

$\gamma_r = \frac{4}{3}\frac{e^2\omega}{4\pi\varepsilon_0\hbar^2}\frac{|<k_c|P|k_V>|^2}{(\omega c^2)N_c}-$ коэффицент рекомбинации.

Оценим эти выражения при значениях $|< k_c|P|k_V >|^2 \approx mv$, $T = 300^0C$, $N_V = 10^{19}$см$^{-3}$, $\omega = 2\cdot 10^5$см$^{-1}$, $\gamma_r = 2\cdot 10^{-13}$см^3/с, $n = 10^{16}$см$^{-3}$, когда времени жизни носителей заряда будет равна $\tau=\frac{1}{\gamma_r\cdot n} = 5\cdot 10^{-4}$сек. Если $n = 10^{19}$см$^{-3}$, то τ=0,5 мкс.

Теперь ознакомимся с процессами рекомбинации, возникающими в полупроводниках с непрямой зоной.

При переходе электрона из состояния $E_c(k)$ в состояние $E_V(k_c)$ $[E_c(k) \to E_V(k_c)]$ а так же из $E_c(k_V)$ в состояние $E_V(k)$ $[E_c(k_V) \to E_V(k)]$ вероятность прямого оптического проникновения будет малым (рис.2).

Вероятность перехода путём прямого оптического проникновения электрона из зоны проводимости в валентную зону будет выглядеть следующимобразом

$$W = \frac{n\cdot p}{N_V\cdot N_c}e^{-\frac{E_c(k_V)-E_c}{kT}}\cdot e^{-\frac{E_V-E_V(k_c)}{kT}}$$

При оценивании вышеуказанной вероятности у полупроводников с непрямой зоной используются значения $E_c(k_V) - E_c \approx 0{,}5$ эВ, T=300 K, вероятность прямого перехода электронов относительно полупроводников с прямой зоной будет $\approx 2\cdot 10^9$раза меньше.

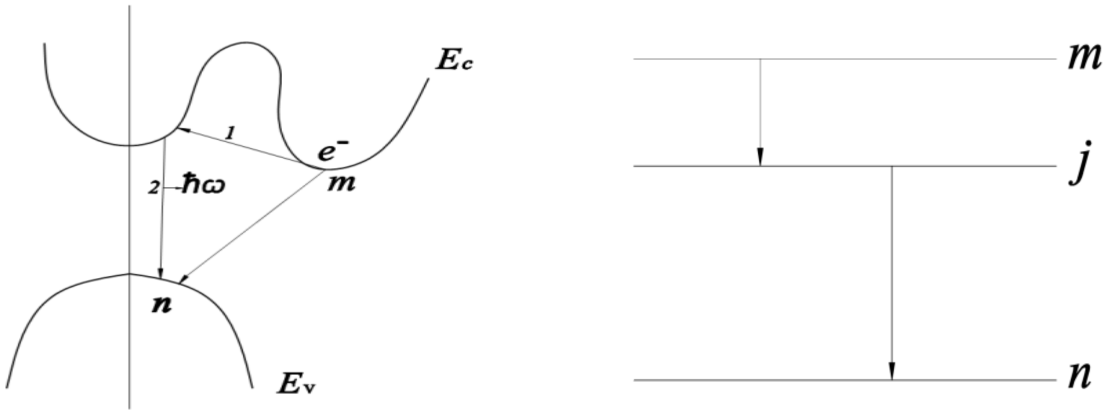

Рис. 3. Процесс рекомбинации у полупроводников с непрямой зоной через промежуточные состояния

Процесс рекомбинации в полупроводниках с непрямой зоной осуществляется и посредством промежуточных состояний (Рис. 3). Через промежуточное состояние электрон переходит из зоны проводимости в валентную зону. Согласно закону сохранения, для осуществления процесса рекомбинации электрон поглощает или выделяет фонон. Следовательно, законы сохранения будут следующими:

$\vec{k}_n$=$\vec{k}_m + \vec{g} \pm \vec{k}_{\text{фонон}}$ – закон сохранения импульса

$E_n = E_m - \hbar\omega \pm E_{\text{фонон}}$ – закон сохранения энергии

Вероятность перехода электрона из состояния m в состояние n выражается следующим образом:

$$W_{mn} = \sum_{j\neq m}\frac{< m|H|j >< j|H|n >}{E_m - E_j}$$

Вероятность у полупроводников с непрямой зоной ниже, чем у полупроводников с прямой зоной. Скорость рекомбинации у полупроводников с непрямой зоной также ниже, чем у полупроводников с прямой зоной. Следовательно, время жизни носителей заряда у полупроводников с непрямой зоной больше по сравнению с временем жизни зарядов у полупроводников с прямой зоной.

Таким образом, для создания солнечных батарей с высокой чувствительностью к освещённости на основе полупроводниковых материалов целесообразным является использование полупроводников с непрямой зоной.

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CHEMISTRY

CHEMICAL TYPIFICATION AND GENETIC CRITERIA FOR THE COMPOSITION OF GEORGIAN PETROLEUM

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ABSTRACT

The results of investigation of molecular composition of biological markers of Eastern Georgia crude oils by methods of GLC, MS, GC/MS, genetic and geochemical aspects of their chemical composition, the main geochemical criteria for making various genetic correlations are presented. It was established that though these crude oils belong to different chemical types they all belong to a single genetic type. High concentrations of isoprenoid alkanes, ratio $iC_{19}/iC_{20} > 1$, were revealed. In fractions higher than 420°C amongst the main biomarkers — steranes and triterpanes (C_{27}–C_{33}) – prevail hopanes of the 17αH-hopan series ($C_{30}H_{52}$); steranes (C_{27}–C_{29}) are represented by α-sterans and iso-sterans. Based on the main geochemical criteria the degree of catagenesis of oils and the probability of biodegradation of some of them was determined. In some crude oils polymethylsubstituted decalines, the relict type hydrocarbons (C_{14}-C_{16}) have been identified.

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Introduction. Organic geochemistry is a scientific direction in chemistry of natural biological compounds, the main task of which is study of composition and chemical evolution of organic molecules in sedimentary rocks [1]. These fossil molecules, chemofossils (relict hydrocarbons) of plant and animal origin, after being deposited in rocks, remained almost unchanged. They are unique as they preserved identity or underwent insignificant change in composition and structure of the carbon skeleton of the original biological molecules that took part in the processes of oil formation [2]. These relicts are considered as the most important biomarkers or geochemical labels that are used in understanding of biological conditions and many problems of oil genesis. Any regularity in their distribution in samples is geochemical criterion and allows to understand the nature and origin of the source of raw material, its age, degree of decomposition and catagenetic maturity. This information is used to carry out various geochemical correlations, genetic and chemical typifications of oils and to solve various problems of petroleum geochemistry [3]. The composition and molecular-mass distribution of chemofossils in oils determine the genetic type of oils. In contrast to the genetic type, the chemical type (composition) is changed with time under the impact of thermobaric, catalytic factors, water-oil contact and post-genetically changes of oils (biodegradation and migration) [4]. The role of hemofossils in perception of oils in general is invaluable. The most important biomarkers are normal and isoprenoid alkanes, cyclic hydrocarbons with one to five cycles per molecule, C_{19}-C_{35} sterane and terpane hydrocarbons, sesqui-, di- and triterpane series, terpenes, steroids, porphyrins and relatively little-studied aromatic hydrocarbons with relict type structure [5]. Currently, more than 1000 different biomarkers have been identified in oils and organic matter of rocks. Among them, new representatives of the hemofossils, characteristic of the most ancient organisms belonging to the natural habitat of Bacteria, Archaea, Eucarya, have been discovered [6]. Biomarkers along with isotopic composition of carbon are the main source of information about the bios during the ancient periods of the Earth [7].

In this article are presented the results of the study of molecular composition of relict hydrocarbons of some Georgian crude oils, are considered genetic and geochemical aspects of their chemical composition, the main geochemical criteria that give a possibility to make various genetic correlations.

Purpose of the study: chemical and genetic type of Georgian Petroleum.

Materials and methods. All used chemicals were of analytical grade. The HPLC/GC grade methanol, n-pentane, benzene, and petroleum ether were purchased from Sigma-Aldrich and Merck (Germany) companies. Activated fine silica gel (0.07–0.15 and 0.2–0.3 mm) was supplied by Labstatus (Ukraine) and ChemReactiveSnab (Almaty, Kazakhstan) companies. The coarse silica gel (0.4–2.5 mm) was supplied by Salavat catalyst plant (Russia). Carbamide- CaS Number 57-13-6; Beilstein Number 635724; Sigma-Aldrich (Germany) and thiourea – from Biochem (France). Carrier gas - hydrogen (CB Index: 87; Product Catalog: 9628, Customer Evaluation: 6, CAS: 1333-74-0; Remarks: Brand: Sigma-Aldrich / Product Number: 295396 / Purity: ≥99.99%). Apiezon L Ultra High Vacuum Grease, Silicone & Halogen Free, CAS #8009-03-8 were supplied by Sigma-Aldrich (Germany).

The following methods were used for the study: distillation, liquid adsorption chromatography, gas-liquid chromatography; deparaffinization by carbamide; three stage thermal diffusion; extraction by thiocarbamide, mass spectrometry and chromatography-mass spectrometry.

The gas-liquid chromatographic separation of the studied fractions was carried out on capillary columns in the following conditions: the fraction 50-200°C(column 100m × 0.25mm, linear programming of temperature from 50 to 200°C with a speed of 2°C/min); the fraction 200-350°C, the VIII fraction of thermodiffusion separation (column 200 m x 0.25 mm with dimethylpolysiloxane, liner programming of temperature from 40°C to 280°C with a speed of 2°C/min, hold 70 min) and filtrates of the thiourea adducts with the mixture of IX+X thermal diffusion fractions (column 50m × 0.25mm, linear programming of temperature – from 100°C to 280°C with a speed of 2°C/min); fractions 200-420°C (column 100m × 0.25mm, 50 thousands of theoretical plates, linear programming of temperature – from 100°C to 320°C with a speed of 2°C/min); the fraction >420°C – the same column, temperature of thermostat 290°C; liquid phase – Apiezon L.

Chromatography-mass spectrometry analysis was performed on the LKB-2091 instrument. The ion source temperature was 50°C and the ionization potential was 70 eV. Stainless steel column 40 x 0.4mm; 50 thousands of theoretical plates; programmed temperature according to samples.

Experimental part.

For the study of molecular composition of relict hydrocarbons, samples of crude oils from the main oil and gas regions of Eastern Georgia – Samgori, Teleti, Shromis-Ubani, Norio, Ninotsminda, Mirzaani, Taribani, Satskhenisi [8] were studied. These oils belong to a single sedimentation basin, are of different chemical type, have close geological age of the host rocks and a different depth of bedding.

The objects of the investigation were saturated hydrocarbons of fractions 50-200°C, 200-350°C, 200-420°C and >420°C, that were dearomatized on activated fine and coarse silica gel; fractions 200-350°C and >420°C were as well deparaffinazed by conventional method; the components of composition was studied by GLC.

In the light fractions (50–200°C) of the studied oils, over 100 individual hydrocarbons of C_5-C_{11} composition were identified. Interesting regularities were found in the composition of cyclopentanes and cyclohexanes; in addition, when studying distribution of isomeric nonanes and decanes the highest levels of 2,3- and 2,6-dimethylalkanes, as well as of 2-methyl-3-ethylheptane, the main relicts of light fractions of oils, were found.

Chromatogram of the thermodiffusion fraction VIII (the 200-350°C fraction of Taribani oil) is shown in Figure 1. Complex study of MS data and GC retention indices made it possible to divide isomers, which in itself is a great difficulty in the process of compounds identification. The main components of the VIII thermodiffusion fraction, as it was expected, are C_{11}– C_{22} isoprenoid alkanes. Among them the predominant are 2,6,10,14-tetramethylpentadecane (pristane, $C_{19}H_{40}$) and 2,6,10,14-tetramethylhexadecane (phytane, $C_{20}H_{42}$), the well-known biomarkers of oil. Cyclopentanes, cyclohexanes and decalines having retention times from 89 to 95 minutes (Figure 1) were characterized by low intensity.

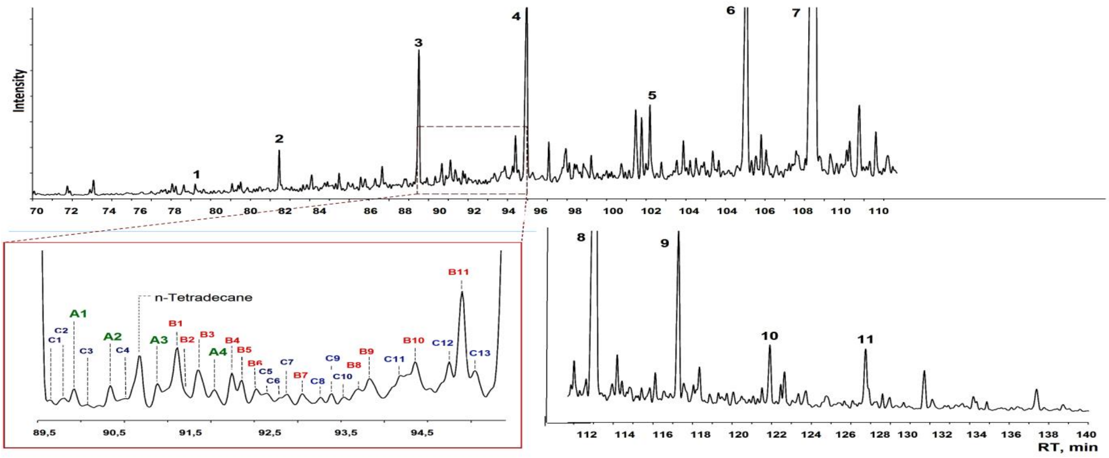


Fig. 1. GC of concentrate VIII obtained after thermal diffusion: Isoprenoides: 1-Undecane 2,6-dimethyl-(C13); 2 -Dodecane 2,6-dimethyl-(C14); 3-Dodecane, 2,6,10-trimethyl-(C15); 4-Tridecane 2,6,9trimethyl-(C16); 5–Tetredecane 2,6,10-trimethyl-(C17); 6 – Pentadecane 2,6,10-trimethyl-(C18); 7 – Pristan-(C19); 8 - Pristan-(C20); 9 -Heptadecane 2,6,10,15-tetramethyl-(C21); 10 – Octadecane 2,6,10,15-tetramethyl-(C22); 11 – Nonadecane 2,6,10,15-tetramethyl-(C23).

Among bicycloalkanes the content of the relict-type structures – the long-chain derivative of perhydroindan – 1-(2-methyl, hexyl)-perhydroindan and polymethyl derivatives of decalin – were determined. Typical structures and corresponding mass-spectra are presented on Figure 2. [9].

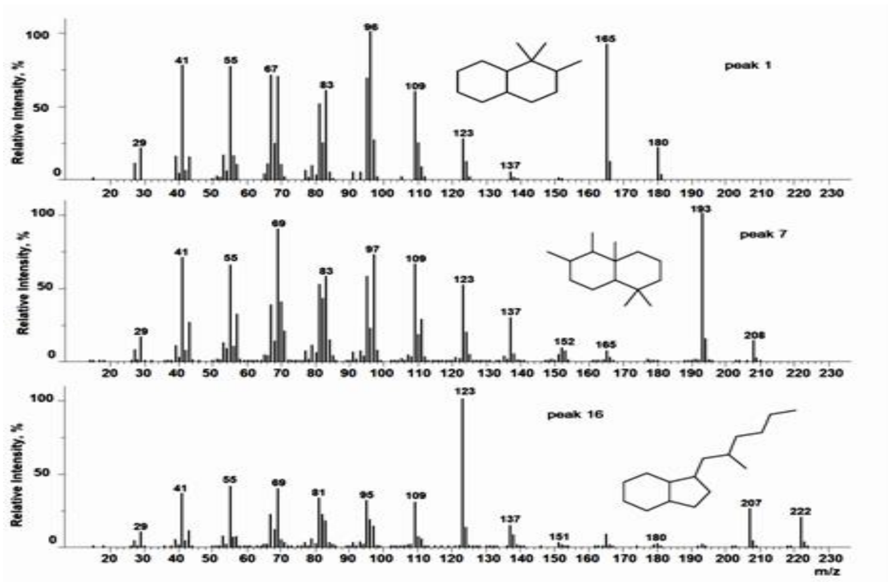


Fig. 2. Mass spectra of (c) 1,1,2-Trimethyldecaline (peak 1), 1,2,3,7,7-Pentamethyldecaline (peak 7) and 1-(2-Methylhexyl)perhydroindane (peak 16).

Based on the study of relative distribution of the main relict hydrocarbons — normal C_{12}-C_{32} and isoprenoid C_{14}-C_{22} alkanes in middle fractions boiling away at a temperature of 200–420° C, "the chemical typification" of oils was carried out on highly efficient capillary columns according to the method of prof. Al.A. Petrov [10]. From the chromatograms for all the above listed oils the mentioned above ratios were calculated and the corresponding diagrams were plotted. Relative distribution of normal and isoprenoid alkanes in oils of the type opposite to Taribani A^1 and Satskhenisi B^2 oils is shown on Figures 1 and 2[11]. Based on the diagrams, the geochemical isoprenoid coefficients Ki = ΣiC_{19}-iC_{20}/ ΣnC_{17}-nC_{18} and catagenetic coefficients K = ΣnC_{13}-nC_{15}/ΣnC_{25}-nC_{27}), the values of which are related to the biodegradation and catagenetic transformation of oils, as well as geochemical criteria – the ratio of pristane to phytane iC_{19}/iC_{20}, which are used to carry out various geochemical correlations are determined. On the basis of these characteristics the studied oils are confined to various chemical types: Samgori- A^1, Ninotsminda-A^1, Shromis-Ubani-A^2, Mirzaani-B^2, Norio-B^1, Teleti-B^1, Taribani-A^1, Satskhenisi-B^2. Oils of A^1 type by group composition correspond to paraffin oils; B^2 oil – to naphthenic oils. The oils of A^2 and B^1 types have intermediate characteristics of chemical composition. The study of the individual composition of oils showed that normal alkanes were present in large quantities in oils of A type. But a characteristic feature of all types of Georgian oils is high concentration of isoprenoid structures, especially of regular isoprenoids (iC_{19} and iC_{20}), moreover, with a large predominance of pristine. Relative distribution of normal and isoprenoid alkanes in 200–420°C fraction of Taribani and Satskhenisi oils are shown in Figures 3 and 4. Therefore, for almost all oils, the ratio iC_{19}/iC_{20} is higher than 1. This indicator ($iC_{19}/iC_{20}>1$) is an important geochemical characteristic associated both with the origin and with transformation of oil during the processes of biodegradation and catagenesis [12]. Norio oil is an exception: iC_{19} and iC_{20} are completely absent in it, and iC_{14} and iC_{16} are present in high concentrations. Characteristics of the studied oils are given in table 1.

Table 1. Characteristics of Georgian Petroleums

Name of the Crude oil, well No.	Depth of Bedding, m	Age of the enclosed rocks	Density (kg/ m^3)	Tars and asphaltenes, %	S, %	Chemical type	Genetic mark iC_{19}/iC_{20}
Samgori,.7	2800	Middle Eocene	886.0	18.2	0.25	A^1	2.2
Ninotsminda,.27	2800	Middle Eocene	892.0	18.5	0.23	A^1	2.2
Shromis-Ubani, 1	3000	Late Miocene	927.0	32.9	0.37	A^2	1.6
Norio, 35	1400	Middle Sarmat	924.0	21.5	0.15	B^1	1.9
Teleti, l 8	500	Middle Eocene	876.0	18.4	0.18	B^1	1.7
Mirzaani, 109	1100	Lower Pliocene	875.5	14,72	0.22	B^2	0.3
Taribani, 23	2374	Late Sarmat	838.6	14.84	0.25	A^1	1.7
Satskhenisi, 4	1400	Late Oligocene	836.1	32.68	0.26	B^2	2.2

By the method of mass spectrometry for the hydrocarbons in the paraffin-cycloparaffin part of all studied oils, the structural group composition of the middle (200-420°C) fractions – the relative distribution of alkanes and mono-, bi-, tri-, tetra- and pentacyclic naphthenic hydrocarbons, inherited by oils from the original organic matter, was determined. From the geochemical point of view, this characteristic is one of the genetic characteristics, which indicates both the distribution of naphthenic hydrocarbons and the single genetic type of Georgian oils (the so-called "naphthenic passport"). This characteristic shows that the cyclic compounds in various Georgian oils are represented in high concentrations.

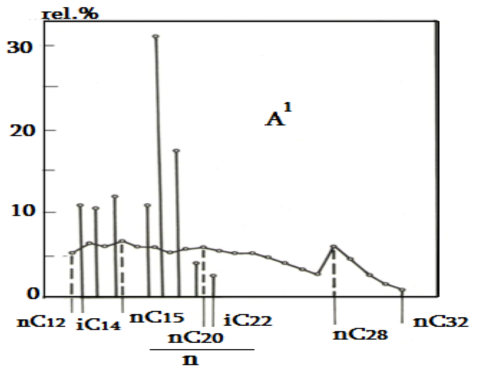


Fig. 3. Relative distribution of normal (C_{12}-C_{32}) and isoprenoid (C_{14}-C_{22}) alkanes in the fraction 200 – 420°C of Taribani oil.
n – number of carbon atoms in alkanes

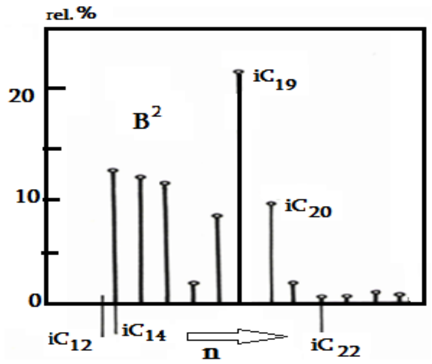


Fig. 4. Relative distribution of isoprenoid (C_{14}-C_{22}) alkanes in the fraction 200–420°C of Satskhenisi oil
n – number of carbon atoms in alkanes

Fractions 200-350°C and > 420°C that contained mainly polycycloalcanes were subjected to thermal diffusion with the aim of separation of concentrates from them. By using of thermal diffusion method with selection of optimal conditions (temperature gradient, separation time) and column efficiency it becomes possible to extract successfully concentrates of different hydrocarbons from oil fractions. In this study large and micro-TDF columns were used. The height of the large columns was 1500 cm, the volume of the annular space – 50 ml, the clearance – 0.3 mm with a coil in the working space. Stainless steel microcolomns of the original design had a volume of 3, 4 and 4.5 ml. These columns are of the Melpolder's columns type, their efficiency factor in dividing the model mixture of cis- and trans-decalines (1 : 1) is maximum S = 99% in 8-10 hours. Their height is 110 mm. These columns were designed and manufactured at the Petre Melikishvili Institute of Physical and Organic Chemistry, Laboratory of Petroleum Chemistry [13]. The columns have 10 drain cocks that provide separation of mixtures into ten equal-volume fractions. For extraction of naphthenic concentrates, saturated fractions of 200-350°C and >420°C were subjected to two-fold thermal diffusion (temperature gradient 130°C–150°C, separation time – 100 hours). At the end of the process a mixture of fractions (IX+X) – naphthenic concentrates was taken [14].

According to data of MS analysis in concentrates of fraction 200–350°C mainly (~90%) tri-, tetra- and pentacycloalkanes of compact structure and bicycloalkanes of C_{14}–C_{16} composition were present. Concentrates, obtained from the 200-350°C fraction in order to hydrocarbons that form adducts were treated with thiocarbamide (conditions: thiocarbamide: fraction = 1 : 1; activator-methanol; diluent-benzene; time 25h; temperature 6°C) [15]. In the residual filtrates of concentrates from Taribani, Satskhenisi, Norio and Teleti oils the relict bicycloalkanes – the polymethylsubstituted decalines of C_{14}–C_{16} composition were identified. Hydrocarbons (1–6) were determined in Taribani, (2, 3, 6) in Satskhenisi and (2, 4) in Norio and Teleti oils [16]. On chromatograms of the filtrates (Fig.5) peaks corresponding to the said hydrocarbons are marked with numbers 1′–6′ (for Taribani oil) and 1–3 (for Satskhenisi oil). Composition and structure of the said hydrocarbons is determined by chromatography-mass spectrometry analysis. The characteristic peaks of mass-spectrometric destruction, the assumed structures and gross formulas of the identified polymethylsubstituted decalines are presented in Table 2.

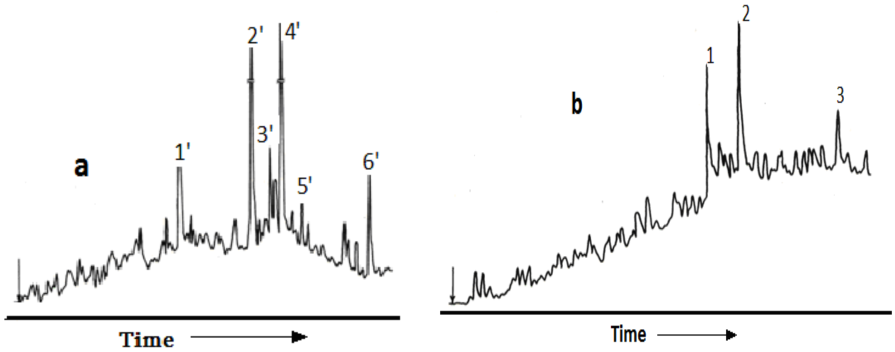
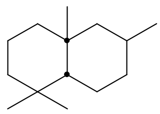
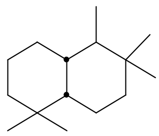
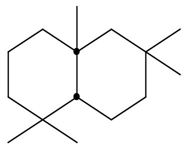
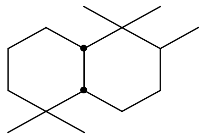
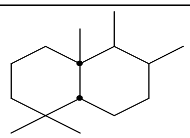
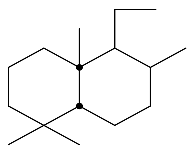


Fig. 5. Chromatogram of bicycloalkanes from the 200–350 °C fractions (a) of Taribani and (b) Satskhenisi Crude Oils

Table 2. Polymethylsubstituted decalines, identified in Georgian Petroleum

# of hydrocarbon In samples[a]				Name of Hydrocarbon	Structural and brutto-formula	Characteristic peaks in mass-spectra (intensity in % of the maximum peak) m/z (I, rel %)
I	II	III	IV			
1	-	-	-	cis-1,3,7,7-tetramethyl-trans-bicyclo-/4,4,0/decane	 $C_{14}H_{26}$	194(M^+;21), 180(8), 179(72),138(7), 137(16), 122(18), 121(68), 110(45), 109(69), 97(37), 96(23), 95(75), 83(43), 82(32), 81(100), 69(72),55(40)
2	2	2	2	trans-2,3,3,7 7-pentamethyl-trans-bicyclo-/4,4,0/decane	 $C_{15}H_{28}$	208(M^+;16), 194(15), (100), 179(6), 163(9), 149(10), 138(6), 137(35), 124(11), 123((48), 111(21), 110(12), 109(48), 97(27), 96(15), 95(52), 83(52), 82(23), 81(26), 69(55), 57(27), 55(26)
3	3	-	-	1,3,3,7,7-pentamethyl-trans-bicyclo/4,4,0/-decane	 $C_{15}H_{28}$	208(M^+;34), 194(9), 193(75), 179(14), 178(10), 177(24),165(24),164(10),163(27), 151(20), 150(9), 149(22), 138(12), 137(33), 124(35), 123(67),111(25),110(25), 109(100), 97(65), 96(43), 95(85), 83(69), 82(41), 81(73), 70(42),69(83), 57(43),55(55)
4	-	4	4	cis-2,2,3,7,7-pentamethyl-trans-bicyclo-/4,4,0/decane	 $C_{15}H_{28}$	208(M^+;20), 194(7), 193(100), 179(6), 177(7), 165(11), 163(6), 151(9), 150(9), 149(25), 137(32), 135(12), 124(25), 123(49), 149(51), 97(31), 96(25), 95(85), 83(31), 82(29), 81(61), 70(71), 69(65), 68(13), 67(26), 58(26), 57(29), 55(36)
5	-	-	-	trans-cis-1,2,3, 7,7-pentamethyl-trans-bicyclo /4,4,0/decane	 $C_{15}H_{28}$	208(M^+;27), 194(6), 193(41), 165(4), 139(2), 138(13), 137((32), 124(17), 123(100), 109(26), 97(7), 96(4), 95(35), 83(9), 82(11), 81(27), 79(2), 69(25), 68(4), 67(16), 57(8), 55(22)
6	6	-	-	1,3,7,7-tetramethyl-2-ethyl- trans-bicyclo /4,4,0/decane	 $C_{16}H_{30}$	222(M^+;37), 207(15), 194(5), 193(56), 177(10), 138(20), 137(37), 124(21), 123(100), 111(8), 110(14), 109(63), 97(18), 96(13), 95(58), 83(25),82(6), 81(58), 69(51), 70(12), 67(26), 57(25),55(40)

[a] Oils from I - Taribani, II - Satskhenisi, III - Norio, IV - Teleti deposits.

From the geochemical point of view large molecules of relict type saturated hydrocarbons – tetra- and pentacyclic naphthenes, namely steranes and triterpanes, the predecessors of which are considered to be natural steroids and triterpenoids found in various geological objects are of particular interest [17]. Steranes and triterpanes of the saturated hydrocarbon fractions of Georgian oils Norio, Teleti, Mirzaani, Sartichala, Ninotsmindai, Shromis-Ubani, boiling away above 420°C have been studied [18]. Saturated hydrocarbons were separated from oil fractions residues by chromatography on

ASK silica gel. In case of paraffinic oils the normal alkanes were removed by treatment with thiourea. Concentration of tetra- and pentacycloalkanes was carried out by the method of thermodiffusion. Analysis of concentrates and qualitative identification of the main gas-chromatografic peaks was carried out by gas-liquid chromatography and chromatography-mass-spectrometry methods. The results of the studies are presented in Tables 3 and 4.

Table 3. Relative concentration of 17αH-hopane series hydrocarbons of Georgian oils in fraction with boiling point > 420°C

Grude Oil deposit	Number of carbon atoms						Σ hopanes, in mass % (per oil)
	27	29	30	31	32	33	
Norio	2,5	11,0	31,2	25,8	16,7	12,8	0,60
Teleti	6,6	10,3	35,9	21,7	14,5	11,0	0,20
Mirzaani	8,2	12,7	30,6	22,7	18,4	7,4	0,20
Samgori	7,7	12,3	33,3	23,3	13,6	9,8	0,40
Ninotsminda	7,9	9,7	26,7	22,1	17,2	16,4	0,35
Shromis-Ubani	1,8	14,7	32,1	26,2	14,2	11,0	0,10

Table 4. Relative concentration of sterane hydrocarbons in fraction with boiling point > 420°C

Crude oil Deposit	Cholestanes C_{27}			Ergostanes C_{26}			SitostanesC_{29}				ΣHopanes/ ΣSteranes	ΣSteranes mass%
	iso	α	Σiso + α	iso	α	Σiso + α	iso	α	Σiso + α	α/iso		
Norio	21,2	6,6	27,8	26,9	14,5	41,4	24,9	5,9	30,8	0,24	2,3	0,30
Teleti	27,6	6,9	34,5	23,6	10,6	34,2	23,7	7,6	31,3	0,32	1,1	0,20
Mirzaani	28,2	7,2	35,4	36,5	6,4	42,9	17,6	4,1	21,7	0,23	0,8	0,25
Samgori	35,1	5,7	40,8	26,9	6,2	33,1	20,4	5,7	26,1	0,28	1,1	0,40
Ninotsminda	28,7	7,3	36,0	25,9	10,8	36,7	17,7	9,6	27,3	0,54	1,2	0,30
Shromis-Ubani	21,1	9,8	30,9	25,5	11,1	36,6	20,3	12,2	32,5	0,60	2,8	0,03

The research results. The structure of polymethylsubstituted decalines from fractions 200-350°C is determined by chromatography-mass spectrometric degradation method according to their characteristic peaks. When determining the location of the alkyl substituent it was taken into account that the presence of two geminal CH_3 groups led to a sharp increase of $/M\text{-}15/^+$ ion peak intensity in the mass spectra in contrast to the simultaneous presence of geminal and angular groups. In spectra corresponding to hydrocarbons 2, 3 and 4 (Table 2), there are low-intensity peaks of molecular ions M^+(m/z 208) and maximum intensity peaks of ions $(M\text{-}CH_3)^+$ with m/z 193 (tearing of methyl from molecular ion). At the same time, there are no fragments with a mass corresponding to tearing of the ethyl- (M^+-29) and propyl- or isopropyl group (M^+-43). The hydrocarbons under study are bicycloalkanes with many methyl groups. In hydrocarbons (1, 5, 6) with one geminal group, the peaks of M^+ ions are insignificant. Hydrocarbons (2, 3, 4) were attributed the structure of the sesquiterpane type, the composition of $C_{15}H_{28}$ [19], and hydrocarbons (1, 5, 6) – of polymethyl-substituted trans-decalines. The peculiarity of the structure of these hydrocarbons indicates the generality of their genesis [20]. They have a clearly relict character and most probably are genetically associated with important relicts – the hopanes [21].

The results of the study of relative distribution of the main biomarkers of oils – steranes and hopanes, make it possible to establish that the studied crude oils belong mainly to the 17αH-hopane series [22]; the yield of the sum of hopanes per oil is from 0.1 to 0.6%, and the sum of steranes - from 0.03 to 0.4%. At the same time, 17αH-hopane itself ($C_{30}H_{52}$) is present in maximum concentration.

Triterpanes (C_{27}-C_{33}) are represented mainly by hopane homologues. Steranes (C_{27}-C_{29}) in crude oils are represented by α-sterananes and isosteranes. They are characterized by cis-coupling of C/D cycles and constitute the main mass of steranes. Mirzaani oil is an exception. There is predominance of sterane structures. The distribution of steranes and hopanes make it possible to determine important geochemical parameters that carry genetic information about the degree of catagenetic conversion of oils, the chemical composition of the oil-producing biomass, etc. [23]. Based on the studied relicts, various genetic correlations were carried out [24]. It was established that despite the difference in chemical composition of oils they belong to a single genetic type in terms of geochemical parameters - the ratio of the main relict hydrocarbons: pristan/phytan (iso-C_{19}/iso-C_{20}), ∑hopanes/∑steranes (Tables 1, 3, 4), as well as distribution of n-, iso- and cycloparaffin hydrocarbons in fractions 200-420°C ("naphthenic passport"). To reveal catagenetic maturity of oils, other indicators were calculated, for example: concentrations of secondary steranes of C_{27} composition, ratio α-steranes/iso-steranes, etc. The highest degree of catagenesis was determined for Samgori oil, and the lowest one – for oil from the Shromis-Ubani deposit. The possibility of probable biological degradation of some of these oils in pools is assumed. Although, their different chemical composition may be stipulated to different conditions of bedding and biological oxidation. Formation of B^1 and B^2 type oils – Teleti, Norio, Mirzaani, Satskhenisi and Shromis-Ubani (A^2) – is based on biological oxidation. High concentrations of n-alkanes, isoprenodic alkanes and monocyclic naphthenes in oils of the primary generation A^1 – Samgori, Ninotsminda, Taribani – indicate that they almost did not undergo biodegradation. Biological oxidation probably affects only normal alkanes, leaving isoprenanes unchanged. The data of biological conditions in the oil pools explain the characteristic feature of all types of Georgian oils – the presence of high concentrations of isoprenoid alkanes in them.

Conclusions.

1. Appliance of Georgian oils to different chemical types was determined: Norio, Teleti – B^1; Mirzaani, Satskhenisi – B^2; Samgori, Ninotsminda, Taribani – A^1, Shromis-Ubani – A^2. It was established that despite the differences in chemical composition the studied oils were genetically similar by ratios iC_{19}/iC_{20}, Σhopanes/Σsteranes, as well as by "naphthenic passport". The characteristic feature of Georgian oils is revealed – high concentrations of isoprenoid alkanes, pristane (iC_{19}) and phytane (iC_{20}) with high predominance of pristane so the ratio $iC_{19}/ iC_{20} > 1$.

2. Polymethylsubstituted decalines, a relict type hydrocarbons the so-called sesquiterpane hydrocarbons of C_{14}-C_{16} composition have been identified in the middle fractions of Taribani, Satskhenisi, Norio and Teleti oils.

3. In high-boiling fractions > 420°C, big tetra- and pentacycloalkane molecules (C_{27}–C_{33}) — steranes and triterpanes with the predominance of hopanes belonging to the 17αH-hopan ($C_{30}H_{52}$) series have been identified. Hopane itself as 17αH-hopane is present in maximum concentration. It has been shown that oil steranes (C_{27}–C_{29}) were represented by α-steranes and thermodynamically more stable isosteranes, which constitute the main mass of the steranes studied. The degree of catagenetic conversion of oils was determined according to the ratios ΣnC_{13}–$nC_{15}/\Sigma nC_{25}$–nC_{27}, $\Sigma isoC_{19}$-$isoC_{20}/\Sigma nC_{17}$-nC_{18}, α-isosteranes, etc.

Studies of relict hydrocarbons of Georgian oils have revealed the presence of known biomarkers – saturated relict structures, peculiarity in composition, quantitative and relative distribution of individual biomarkers and their various geochemical ratios that give reason for a more thorough study of the genetic code of Georgian oils.

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