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SYSTEMATIZATION OF THE HARD ROCK NON-METALLIC MINERAL DEPOSITS FOR IMPROVEMENT OF THEIR MINING TECHNOLOGIES

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СИСТЕМАТИЗАЦІЯ НЕРУДНИХ РОДОВИЩ СКЕЛЬНИХ КОРИСНИХ КОПАЛИН ДЛЯ ВДОСКОНАЛЕННЯ ТЕХНОЛОГІЙ ЇХ ВІДПРАЦЮВАННЯ

Purpose. Systematization and allocation of basic non-metallic deposits of magmatic and metamorphic genesis for carrying out works on improvement and introduction of eco- and resource-saving technologies taking into account the spatial parameters of the investigated deposits.

Methodology. Statistical and analytical methods are used to obtain the results while processing the main parameters of operating non-metallic quarries of the raw materials for the production of crushed stone products, as well as logical methods for the division of quarries into groups according to their spatial dimensions and thickness of overburden rocks.

Findings. The main directions of resource-saving technologies for open pit development of hard rock non-metallic mineral deposits are analyzed. While systematizing, the deposit area and overburden thickness are accepted as characteristic criteria. These types of quarries are recommended as the main objects of research to improve ecological and resource-saving technologies for their development.

Originality. For the first time, non-metallic deposits of the igneous and metamorphic genesis of Ukraine’s rock-building materials are systematized according to the spatial dimensions of the quarry fields and the overburden thickness. As a result, the basic quarries as the main objects of further research are identified.

Practical value. The research results and received systematization of non-metallic quarries will allow improving existing ecological and resource-saving mining technologies, taking into account their specific spatial parameters which will ensure the rational natural resource use while developing deposits. The implementation of the results will improve the efficiency and environmental safety of mining operations. The given classification will allow developing a methodology for calculating the ultimate cost-effective mining depth of granite quarries with the internal location of overburden and waste which takes into account the mining and geological parameters that have the greatest impact on the efficiency of mining operations and economic indicators.

Keywords: *eco- and resource-saving technologies, non-ore deposits, quarry, open-pit field parameters, systematization, overburden thickness*

Introduction. Ukraine occupies one of the leading places in the world in the reserves of hard rock non-metallic minerals of raw materials suitable for building materials, including crushed stone products: limestone, dolomite, quartzite, sandstone, granite, migmatite, dense shale and other minerals.

Over 600 non-ore deposits of hard rock minerals have been explored in Ukraine. They are located in all its regions, except for Volyn and Chernihiv [1]. Over 85 % are granite deposits, as well as deposits of other hard rock minerals of magmatic, metamorphic and sedimentary origin, suitable for the production of building materials, mainly debris and crushed stone.

The non-metallic deposits of these minerals are confined to intrusive and effusive deposits of igneous rocks of Ukrainian crystalline Shield, as well as sediments of hard sedimentary rocks: limestones, sandstones, shales, and others. The rocks of sedimentary genesis occur mainly horizontally and are flat-lying, in the form of embedded and lenticular bodies. Igneous magmatic rocks unrestrictedly extend into the interior of the Earth crust, forming laccolites, batholiths, stocks and other deposits. Quarries of hard rock non-ore building minerals (granite and stone) operate in many regions of the state.

Most of the sedimentary building material deposits in Ukraine are worked out at full depth (80–120 m) to the seam floor using the technology with the internal dumping of overburden rocks. Deposits of magmatic rock formations are developed in average to a depth of 50–100 m, sometimes 140–150 m (Kriukivskyi and Kremenchutskyi granite quarries) with external dumping.

In the practice of designing quarries of hard rock building materials, their final development depth is limited by the following parameters and factors: the depth of explored mineral reserves; growth of groundwater inflows at great depths causing a sharp increase in water drainage costs; the degree of development of the area near the quarry fields limiting their spatial dimensions; increasing radioactivity of minerals with depth; small cross-sectional dimensions of igneous ore deposit.

Among more than 300 quarries of igneous hard rocks, about 60 % have reached their projected mining depth. There are no real opportunities for expanding the boundaries of open pit fields by means of extension of stocks on the sides. This is due to the need to transfer roads, buildings, structures, pipelines, as well as the allocation of new areas of privatized land. It remains to realize another way to develop mining operations in a depth with add new underlying reserves. At the same time, the scientific substantiation of the rational ultimate depth of development of such deposits with internal dumping formation of overburden rocks has not been executed. In this regard, it becomes important to establish the ultimate depth of development of non-metallic deposits of building materials, the solution should be based on the average parameters of typical quarries.

Therefore, in order to develop a further strategy for the quarry development of debris and crushed stone productions, to determine the areas of application of existing environmental and resource-saving technologies, as well as to implement them at the design stage of quarries, it is necessary to carry out research on the systematization of indicated quarries on the basis of the spatial parameters of the open pit fields and the overburden thickness.

Mining of mineral raw materials should be carried out taking into account technologies that meet the following requirements [2]: minimal structure and fertility land disruption; electric and ecologically safe equipment use; application of state of the art dust suppression and dust removal methods during the production processes; implication of specific means and methods for blasting operations that will ensure minimization of dust and gas emission (or completely exclude them), seismic impact on the nearest objects from the blast block [3], shock wave and scattering of rock pieces in different directions; completeness of mineral extraction [4]; ensuring drainage of deposits and dredging works during extraction of raw materials in such ways that provide the natural or close to it hydrological regime to the greatest extent without significant changes in the direction of supplying enterprises and the population with volumes of drinking and technical water; carrying out reclamation and revitalization of disturbed lands by mining operations to the most ecologically acceptable landscapes of territories and their re-creations [5]. At the same time, the mineral extraction should be carried out taking into account the advancement of clean high technologies (CHT) for the development of deposits of various origin types and technology for their development [6].

The aboveme ntioned states determined the topicality of the problem of substantiating the ultimate depth of development of non-metallic deposits with internal dumping formation, as well as the need for the systematization of non-metallic hard rock deposits, which will improve the eco- and resource-saving technologies for their development.

Analysis of the recent research and publications. The works of such scientists as Mishchenko V. S., Symonenko V. I., Byzov V. F., Drizhenko A. Yu., Shlain B. I. and others are dedicated to solving problems in the quarry systematization.

The analysis of published results shows the diversity in the direction of the systematization of quarries. In scientific works of Simonenko V. I. it is shown that perspective resource-saving technologies for the development of the above-mentioned deposits should be investigated and implemented in the following areas: exploration of deposits through their gradual steep layers development; application of inner open pit storage of overburden and industrial wastes; detachment in the face of commercial products through the use of mobile and semi-stationary crushing and screening installations; mining out deposits to the maximum economically feasible depth within the quarry field; creation of technogenic deposits with accompanying mineral raw materials recovering in a mined-out space with possibility of their further mining; recultivation of disturbed lands for agricultural and forestry, as well as fish farming and other purposes.

The analysis of various literary sources of Symonenko V. I., Shlain B. I. in the field of mining technology of hard rock non-metallic mineral deposits allows us to conclude that the studies in the above-mentioned areas do not fully cover the existing deposits and some hardly have any results at all. Thus, the results of studies on the substantiation of the technology and its parameters for developing such deposits to the maximum economically feasible depth with the use of inner open pit overburden and industrial waste storage are practically unknown.

Knowledge on minimizing environmental damage from various production factors in open pit development and other topical issues in the field of extraction technology of non-metallic raw materials is also insufficient. Studies of indicated directions and tasks are carried out according to the thematic plans of the Ministry of Education and Science of Ukraine which consider the development of resource-saving technologies of the development of hard rock non-metallic mining in Ukraine. These studies are constrained by the lack of fully systematized groups of typical quarries for the extraction of raw materials for the production of crushed stone products.

Earlier in the works of Symonenko V. I., Byzov V. F., Drizhenko A. Yu., Shlain B. I. systematization of hard rock quarries of both ore and non-ore minerals was proposed according to the characteristics of final mining depth and the surface area of the open pit. These classifications are calculated for a high range of non-metallic deposits, the systematization of which also includes, apart from granite and stone quarries, quarries for the flux limestone production, dolomites, talc-magnesian raw materials and other non-metallic minerals. They differ from those considered by their size, the volume of the rock mass excavation, mining equipment, and mining and geological factors of the minerals occurrence.

In addition, similar tasks were solved in various papers, where deposits are divided into thin, medium, thick and very thick seam thicknesses by the number of formed quarry bench within the thickness of the developed bed. The classification data does not take into account specific values of the bench height or seam thickness, which was considered in the classification proposed by Shlain I.B. According to it, non-metallic deposits are divided into groups: very small ones – up to 15 m; small ones – 15–30 m; average ones – 30–60 m; large ones – 60–100 m; very large ones – 100–150 m and exceptionally large ones – over 150 m of thickness.

The tasks of classification, division of non-metallic igneous and metamorphic deposits into groups were solved in the work of the VNIPIstromsyrie Institute. The classification is given according to the following criteria:

- the strength of composing deposit rocks;
- fracturing, weathering of rocks in the field;
- orographic confinedness;
- the form, size, and volume of field reserves;
- characteristics of minerals and rocks of overburden;
- the water content of a deposit.

The given classification is designed for a wide range of non-metallic deposits with a predominant number of horizontal dense beds of the Midland of Russia and has a number of shortcomings.

For example, in terms of area, the fields are divided into the following groups: very small ones – up to 0.1 km^2, small ones – from 0.1 to 0.2 km^2, medium ones – from 0.2 to 0.5 km^2, large ones – from 0.5 to 2.5 km^2 and very large ones – over 2.5 km^2. This classification does not take into account the fact that in Ukraine there are practically no deposits of non-metallic igneous and metamorphic rocks whose area exceeds 1.2 km^2. According to the thickness of overburden it is divided into 6 corresponding groups. This classification has too many types of deposits and uneven distribution of the exponents of the overburden thickness. For example, the first type of deposits with overburden thickness of up to 2 m cannot be found in Ukraine, despite the fact that in Ukraine there are many deposits on a significant area of which there are no deposits (located on the floodplains of rivers on the crystalline shield).

Unsolved aspects of the problem. The above mentioned deposit systematizations were made for certain direction of research activities not related to development and improvement of eco-, land- and resource-saving technologies for mining of building materials.

Therefore, to substantiate an effective resource-saving technology for the development of primarily domestic non-metallic igneous and metamorphic deposits, it is necessary to correct the previously proposed works by Symonenko V. S. and Shlain B. I. in the systematization of deposits.

This systematization will allow developing a method for calculating the ultimate economically effective depth of mining of magmatic and metamorphic genesis of rock building materials in Ukraine with the internal location of overburden and mining waste. It is characterized by the consideration of mining and geological parameters that have the greatest effect on the efficiency of mining operations and economic indicators, which limits the achievement of maximum effect.

Objectives of the article. The purpose of the work is to identify the basic non-metallic hard rock deposits of igneous and metamorphic deposits as the main objects of the study, which will allow carrying out research on improving the ecology and resource-saving technologies for the development of deposits for the production of crushed stone products.

Presentation of the main research. In the investigated (developed) technique for optimizing the mining depth of non-metallic deposits with internal storage of overburden and industrial waste, the spatial dimensions of the deposit (area) and the overburden thickness are determined indicators [4]. Both parameters are taken into account to determine the final depth of the minefield. They are proposed to be used as a generalizing feature in the systematization of open pit fields of non-metallic deposits into groups.

For the foregoing purposes, it is necessary to solve the following problems: to analyze the parameters of non-metallic deposits where stone raw materials are extracted for the production of crushed stone products; to group them by area and overburden thickness, taking into account the results obtained in the works of Symonenko V. I. and Shlain B. I. on the substantiation of the rational ultimate depth of mining operations within the boundaries of existing mining fields; to establish the main parameters of the basic quarries of Ukraine for their application as objects of research.

The main task of systematization is stipulated by the need to divide the deposits into groups, from which it is possible to exclude the basic quarries as objects of our further research. Taking these approaches to systematization, we will analyze it in relation to Ukraine granite quarries more thoroughly.

As a result, 117 non-metallic igneous and metamorphic deposits [1] for the production of crushed stone products have been analyzed and investigated. Their spatial parameters are the length of the quarries from 290 to 1650 m, the width of the quarries from 220 to 1000 m, the area of the fields from 6.1 to 141 ha. Analyzing these parameters, it is proposed to distinguish 3 main groups of quarries by area (Table 1, Fig. 1), which will uniformly separate the spatial dimensions of the deposits, which will positively affect further studies and the simplicity of the choice of the mining technology.

One of the most important factors affecting the implementation of resource-saving technology for the development of the above-mentioned deposits in the case of internal overburden is their thickness. Analyzing the parameters of the overburden thickness in the existing quarries of Ukraine, we see that this parameter ranges from 4 to 45 m (the average overburden thickness of the deposit).

In this direction, it is also proposed to distinguish 3 main types, which will differ in the average thickness of the covering rocks (Table 2, Fig. 2).

Analyzing Tables 1 and 2, we can carry out general systematization of non-metallic hard rock mineral deposit for the production of crushed stone products (Fig. 3).

Considering that in each group the deposit is mined by one basic quarry, as a result, nine types of basic quarries are distinguished (Table 3), the averaged parameters are given in Table 4.

Having processed the parameters of the investigated deposits (analytical and statistical methods), we can analyze the range of changes in the parameters influencing the ultimate mining depth for each type of deposits given in Table 4.

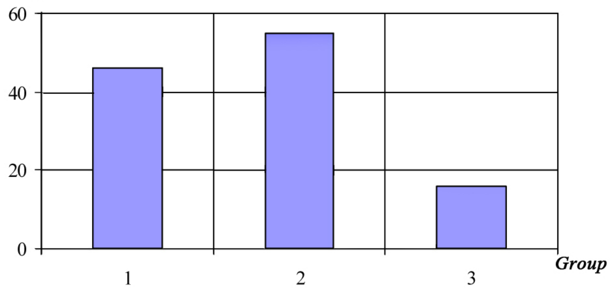

Fig. 1. Classification of investigated quarries by square:
1, 2, 3 – groups of quarries by spatial dimensions

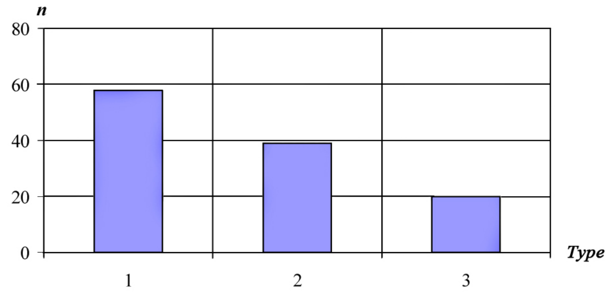

Fig. 2. Classification of investigated quarries by overburden thickness:
1, 2, 3 – types of quarries by overburden thickness

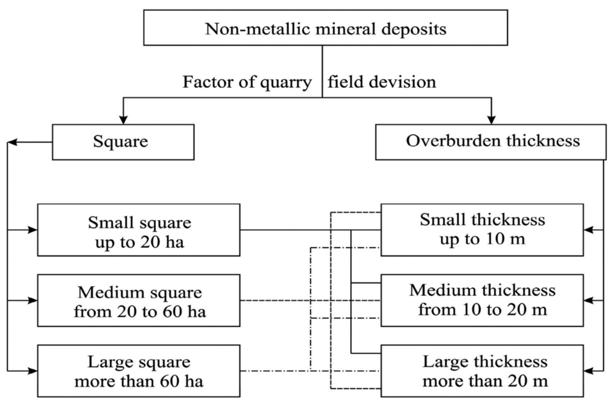

Fig. 3. Systematization of non-metallic quarry fields

Table 1

The selection of the groups of quarries according to their spatial dimensions

Group of quarries by area	Name	Square, S, ha	Quantity	Dimensions of the quarry field, m		
				Length, L_q, m	Width, B_q, m	Square, S, m
Group 1	Small area	up to 20	46	290 ÷ 610	220 ÷ 390	6.1 ÷ 19.7
Group 2	Medium area	20 ÷ 60	55	480 ÷ 1200	320 ÷ 760	20.2 ÷ 59.3
Group 3	Large area	over 60	16	860 ÷ 1650	600 ÷ 1000	66.6 ÷ 141

Table 2

The selection of the groups of quarries according to their overburden thickness

Quarry type by overburden thickness	Name	Overburden thickness, h_o, m	Quantity	Overburden thickness in investigated deposits, h_o, m
Type 1	Small thickness	up to 10	58	4 ÷ 10
Type 2	Medium thickness	10 ÷ 20	39	11 ÷ 20
Type 3	Large thickness	over 20	20	20 ÷ 45

Conclusions and recommendations for further research. The author of the work carried out research and analysis of parameters of 117 non-metallic deposits of magmatic and metamorphic origin. In the development of systematization, the area of deposits and the thickness of overburden were accepted as the main classification criteria. As a result, three main groups of quarries were identified according to the area of deposits: large, medium and small. Analyzing the indicators of the thickness of overburden in existing quarries, three basic types were distinguished, which differ in the average thickness of the covering rocks: small, medium and large.

Taking into account accepted classification criteria, 9 basic (typical) quarries are distinguished, the average parameters of which are presented in Table 4. These types of quarries are proposed as the main objects for further research of resource-saving technologies and the development of a methodology for determining the ultimate cost-effective mining depth with internal overburden and industrial waste storage, taking into account mining-geological and mining-engineering parameters which influence the effectiveness of mining operations the most.

The application of the proposed base quarries of granite and stone raw materials ensures carrying out of studies with the great convergence of the theoretical and practical results obtained, which is important while applying resource-saving technologies on operating and commissioned mining enterprises for the extraction of building materials.

The received systematization will allow carrying out further research studies to improve the environmental, land and resource-saving technologies for the development of igneous rock deposits for the production of crushed stone and building materials.

Table 3

Systematization of non-metallic deposits of building materials for crashed stone production

Group of quarries by spatial dimensions			Type of quarries by overburden thickness			Quarry parameters				
						Thickness		Dimensions of quarry fields		
№	Name	Quantity	№	Name	Quantity	Useful minerals, H_m, m	Overburden rocks, h_o, m	Length, L_q, m	Width, B_q, m	Square, S, ha
1	Large area	16	1	Small thickness	6	50–84	6–9	1000–1350	600–1000	66.6–120
			2	Medium thickness	6	60–99	12–20	860–1650	600–800	64.5–112
			3	Large thickness	4	54–100	29–45	900–1120	600–900	72–141
2	Medium area	55	4	Small thickness	28	43–90	4–10	480–900	345–760	20.2–59.3
			5	Medium thickness	15	40–85	11–19	500–1200	350–560	22.7–55
			6	Large thickness	12	57–100	20–35	560–950	320–640	21–52.5
3	Small area	46	7	Small thickness	24	34–85	6.2–10	290–600	220–360	6.1–18.4
			8	Medium thickness	18	35–80	11–20	340–610	200–390	8.8–19.5
			9	Large thickness	4	40–54	20.1–31.3	420–570	240–358	10–19.7

Table 4

Parameters of basic non-metallic quarries for crashed stone production

Group of quarries by square	Type of quarries by overburden thickness	Thickness		Dimensions of quarry fields		
		Useful minerals, H_m, m	Overburden rocks, h_o, m	Length, L_q, m	Width, B_q, m	Square, S, ha
Large square	Small thickness	67.3	7.6	1198	774	92.7
	Medium thickness	71.0	15.6	1263	690	86.8
	Large thickness	73.3	35	1197	770	93.2
Medium square	Small thickness	62.3	7.4	615	493	30.8
	Medium thickness	60.5	14.8	711	446	31.5
	Large thickness	74.4	25.4	700	471	33.4
Small square	Small thickness	48.9	8.3	426	311	13.42
	Medium thickness	48.6	14.1	465	313	14.6
	Large thickness	49.5	23.8	509	300	15.3

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Мета. Систематизація та виділення базових нерудних родовищ магматичного й метаморфічного генезису для виконання робіт з удосконалення та впровадження еколого- й ресурсозберігаючих технологій, що враховують просторові параметри родовищ, які досліджуються.

Методика. Для отримання результатів використовувались методи: статистичний і аналітичний – при обробці головних параметрів діючих нерудних кар'єрів з видобутку сировини для виробництва щебеневої продукції, логічний – при поділі кар'єрів на групи за просторовими розмірами й потужністю порід розкриву.

Результати. Проаналізовані основні напрями ресурсозберігаючих технологій відкритої розробки нерудних родовищ скельних корисних копалин, запропонована систематизація родовищ з виділенням базових (типових) кар'єрів. При розробці систематизації визначальними критеріями прийняті: площа родовища й потужність розкривних порід. Дані типи кар'єрів рекомендовані в якості основних об'єктів дослідження з удосконалення еколого- й ресурсозберігаючих технологій їх розробки.

Наукова новизна. Уперше систематизовані нерудні родовища магматичного й метаморфічного генезису скельних будівельних матеріалів України за просторовими розмірами кар'єрних полів і потужністю розкривних порід, унаслідок чого виділені базові кар'єри в якості основних об'єктів подальших досліджень.

Практична значимість. Результати дослідження та отримана систематизація нерудних кар'єрів магматичного й метаморфічного походження дозволить удосконалити існуючі еколого- й ресурсозберігаючі технології розробки досліджуваних кар'єрів, ураховуючи їх конкретні просторові параметри, що забезпечить раціональне природокористування при розробці родовищ. Впровадження отриманих результатів дозволить підвищити ефективність і екологічну безпеку ведення гірничих робіт. Дана класифікація дозволить розробити методику розрахунку граничної економічно ефективної глибини відпрацювання гранітних кар'єрів із внутрішнім розташуванням розкривних порід і відходів гірничого виробництва, що відрізняється врахуванням гірничо-геологічних параметрів, які найбільшою мірою впливають на ефективність гірничих робіт, і економічних показників, що обмежують досягнення максимального ефекту.

Ключові слова: *еколого- й ресурсозберігаючі технології, нерудні родовища, кар'єр, параметри кар'єрного поля, систематизація, потужність розкривних порід*

Цель. Систематизация и выделение базовых нерудных месторождений магматического и метаморфического генезиса для выполнения работ по усовершенствованию и внедрению еколого- и ресурсосберегающих технологий, учитывающих пространственные параметры исследуемых месторождений.

Методика. Для получения результатов использовались методы: статистический и аналитический – при обработке главных параметров действующих нерудных карьеров по добыче сырья для производства щебеночной продукции, логический – при разделении карьеров на группы по пространственным размерам и мощности пород вскрыши.

Результаты. Проанализированы основные направления ресурсосберегающих технологий открытой разработки нерудных месторождений скальных полезных ископаемых, предложена систематизация месторождений с выделением базовых (типовых) карьеров. При разработке систематизации определяющими критериями приняты: площадь месторождения и мощность вскрышных пород. Данные типы карьеров рекомендованы в качестве основных объектов исследования по усовершенствованию эколого- и ресурсосберегающих технологий их разработки.

Научная новизна. Впервые систематизированы нерудные месторождения магматического и метаморфического генезиса скальных строительных материалов Украины по пространственным размерам карьерных полей и мощности вскрышных пород, вследствие чего выделены базовые карьеры в качестве основных объектов дальнейших исследований.

Практическая значимость. Результаты исследования и полученная систематизация нерудных карьеров позволит усовершенствовать существующие эколого- и ресурсосберегающие технологии разработки, учитывая их конкретные пространственные параметры, что обеспечит рациональное природопользование при разработке месторождений. Внедрение полученных результатов позволит повысить эффективность и экологическую безопасность ведения горных работ. Данная классификация позволит разработать методику расчета предельной экономически эффективной глубины отработки гранитных карьеров с внутренним расположением вскрышных пород и отходов горного производства, отличающуюся учетом горно-геологических параметров, в наибольшей степени влияющих на эффективность горных работ, и экономических показателей, которые ограничивают достижение максимального эффекта.

Ключевые слова: *еколого- и ресурсосберегающие технологии, нерудные месторождения, карьер, параметры карьерного поля, систематизация, мощность вскрышных пород*

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EXPERIMENTAL AND INDUSTRIAL RESEARCH ON FOAMGENERATING DEVICES

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ЕКСПЕРИМЕНТАЛЬНІ ТА ПРОМИСЛОВІ ДОСЛІДЖЕННЯ ПІНОГЕНЕРУЮЧИХ ПРИСТРОЇВ

Purpose. Finding out and researching rational constructive parameters of foamgenerating devices**.** The purpose is achieved through implementation of the following tasks:

- carrying out computer research on multi-nozzle foamgenerating devices and choosing rational geometric parameters and modes of their work that would provide high efficiency of washing wells with foam;
- finding out relation between geometrical shapes, parameters, work modes of foamgenerating devices and the efficiency of foam creation while performing experimental and industrial research;
- developing and explaining the rational scheme of strap in equipment and devices for washing oil and gas wells with foam in the process of industrial studies.

Methodology. It includes:

- experimental definition of the main parameters and work modes, considering the construction change of foamgenerating device;
- computer modelling of foam generating was performed with the purpose of optimizing its internal constructive elements.

Findings. Relations between geometrical shapes, parameters, work modes of foamgenerating devices and the efficiency of foam generating have been established.

Originality. Experimental studies on streaming of liquid, air and foam and their mixture through constructive elements of the equipment allow establishing regularities of the relation of the efficiency of foam generating with parameters and work modes of foamgenerating devices.