MODELING OF THE PROCESS OF MINING OF ZEOLITE-SMECTITE TUFFS BY HYDRO-WELL METHOD

Yevhenii Malanchuk
National University of Water and Environmental Engineering, Doctor of Technical Sciences, Professor of the Department of Automation, Electrical and Computer-Integrated Technologies, Ukraine

Sergiy Stets
National University of Water and Environmental Engineering, Candidate of Technical Sciences, Associate Professor, Associate Professor of the Department of Automation, Electrical and Computer-Integrated Technologies, Ukraine

Ruslan Zhomyruk
National University of Water and Environmental Engineering, Candidate of Technical Sciences, Associate Professor, Associate Professor of the Department of Automation, Electrical and Computer-Integrated Technologies, Ukraine

Andriy Stets
National University of Water and Environmental Engineering, Student, Ukraine

Abstract

The essence of the work is to study and model individual technological operations and determine the technological parameters of underground development of zeolite-smectite tuffs deposits by hydro-well method, taking into account the dominant factors of the process.

The work research the process of destruction of the massif under different conditions and methods of influence, identifies the main parameters that affect the process of hydrodynamic erosion of zeolite-smectite tuffs and established dependencies between the physical and technological indices of hydromonitor erosion of the massif rocks, determined the relationship between the indices of energy of erosion mineral consumption to optimize the extraction process.

The parameters of the technology of mining of the chambers of zeolite-smectite tuffs by hydro-well method deposits have been substantiated, the dependence of the flow transport ability on the flow rate of the hydromonitor under different conditions of movement of the destroyed tuff in the mining chamberhas been investigated and established. This will allow the effective extraction of zeolite-smectite tuffs for further use in various industries.

Introduction

Due to the widespread use of zeolite-smectite tuffs, the issue of using well hydrotechnology for their extraction is included in the state program of development of mineral resources of Rivne region [1-3].

To substantiate the parameters of well hydrotechnology for the production of zeolite-smectite tuffs in the work conducted research and proposed solutions that consist in establishing the laws of the process of erosion of rock, transportation in the flow of hydraulic mixture and the formation of mining chambers, which will be the basis of theoretical and technical solutions [4-7].

The novelty and the distinguishing features of the investigated and modeled methods of self-propelled hydraulic transport along the bottom of the extraction chambers is that the calculation is conducted with the condition of determining the qualitative and quantitative parameters of the erosion process: the amount of working agent required for erosion; the productivity of the erosion of the minerals, the coefficient of roughness of the bottom; radius and angle of the erosion sector.

Given that the creation of a common model of well hydrotechnology, mining is almost impossible due to methodological and technological difficulties, studies have been conducted for individual technological operations [8, 9].

Investigation of processes of erosion and fluidity of the hydraulic mixture

The movement of fluid in a jet is characterized by the movement of water particles in the absence of rigid boundaries of the channel. During the movement of a jet, when several liquids are mixed, different in density, as well as in multiphases, when the substance of the jet and the substance of the medium are in different physical states (in gaseous or dropping), and sometimes with the admixture of solids in the boundary layer of the jet, phenomena occur so complex that at the present stage there are no reliable methods for their analytical determination [10, 11].

The specificity of the formation of the jet in the well hydromonitor is such that as the flow of water to the nozzle, it meets on its way various supports that contribute to the turbulence and cavitation of the flow, which impair the quality and parameters of the jet. The final formation of the jet occurs in the nozzle, the purpose of which is to convert the static pressure of water into the kinetic energy of the jet, and as the cross section of the nozzle at constant flow of water increases its speed. At the same time, the pressure loss in the nozzle, which is proportional to the square of the flow velocity, increases. In the final section of the nozzle, the static pressure takes into account the velocity head, taking into account the pressure loss [12].

The study of the distribution of the axial dynamic pressure of the jet along its axis with the central and lateral nozzles of the monitor head showed that the axial dynamic pressure of the jet from the lateral nozzle at a distance of 100-150 mm is 45-55% of this value for the central nozzle. This is due to the large losses of head when water enters the side nozzle, which significantly degrades the hydrodynamic characteristics of the jet.

The speed of rotation of the head of the monitor was determined on the stand (Fig. 1). Analyzing the research data, the dependence of the speed of rotation of the hydromonitor head on the pressure at different angles of rotation of the lateral nozzle is established, which is shown in Fig. 2.

The rotating motion of the head gives the centrifugal components of the reaction forces of the jet from the side nozzles. The speed of rotation of the head n was determined at different angles of rotation of the central jack nozzle relative to the axis of the head and at different values of the head of water H_0 at the inlet to the head. During the studies, the angle of rotation of the conveyor nozzle remained constant at α_2=15°.

Studies have also found that with increasing pressure from 0,4 to 1,1 MPa, the pressure loss on the sections of the telescopic shaft of the monitor is practically absent. The telescopic shaft also serves as a straight section that stabilizes the flow of water before the nozzle. Water costs for hydro screwdriver at the nodes of the telescopic shaft units were 15-18%.

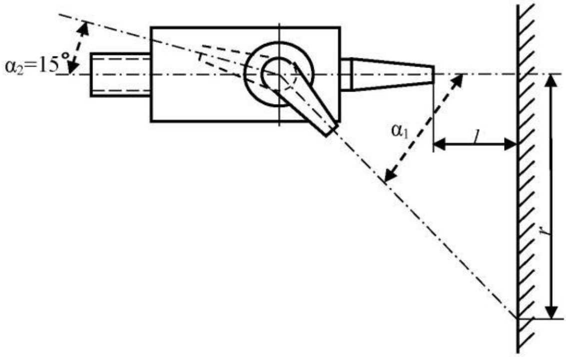

Fig. 1. Scheme of a stand for research of a hydromonitor head

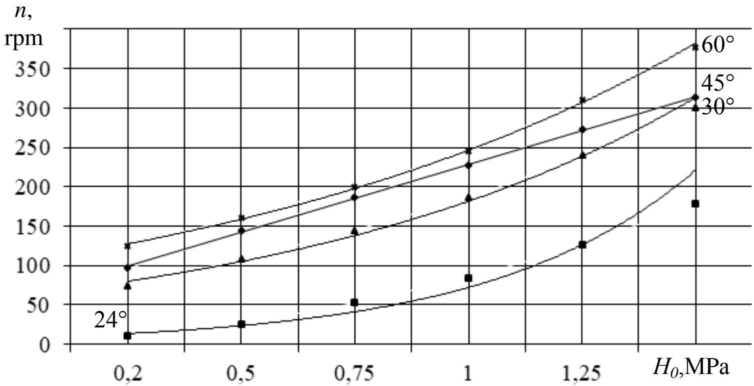

Fig. 2. Dependence of speed of rotation of the monitor head on the water head at different angles of rotation of the side nozzle $n=f(H_0)$

According to geological studies tuffs lie above the water saturation zone [1, 13]. In this regard, in our studies, we considered unfilled medium jet hydromonitor (1MPa - 4MPa) pressure.

When the action of the jet on a flat wall, located perpendicular to its axis, the impact force was calculated by the formula

$$P_0 = \rho_в \omega_0 V_0^2\,, \qquad (1)$$

where $\rho_в$ - is the density of water, V_0– is the velocity of the jet at the outlet of the nozzle, and ω_0 - is the cross-sectional area of the jet.

In chambers, the erosion of the jet acts on a flat wall with a one-way outlet. The impact force of the jet in this case

$$P_0^I = P_0 K' , \quad (2)$$

where K'- is the coefficient taken within 1,3-1,4.

The specific pressure of the jet on the obstacle in all cases was determined by the formula

$$p_0^i = P_0^i / \omega_0 . \quad (3)$$

Pressure water jet has no solid particles, so as it moves away from the nozzle, it changes all its initial parameters – shape, diameter, speed, pressure. The reasons for this change are air resistance; aeration of the jet by air and its spraying, accompanied by an increase in diameter; the action of compressed air inside the jet; the presence of turbulent formations inside the jet; the effect of gravity.

The maximum pressure along the cross-section of the pressure water jet, ie axial dynamic pressure, as shown by studies, for all values, of the diameter of the nozzle and the pressure of water decreases with increasing distance from the nozzle and for low-pressure and medium-pressure water jets is determined by dependency

$$p_l^{oc} / p_0 = (l / l_n)^{-k'} , \quad (4)$$

where p_0 - is the jet pressure at the outlet of the nozzle, k' - is the coefficient characterizing the intensity of jet decay (for low-pressure water jets with a nozzle d_0=50-190 mm k'=0,5; for medium-pressure ones - k'=0,85).

As the distance from the nozzle pressure water jet due to the occurrence of transverse velocities and interaction with the air expands and its diameter increases. To calculate the diameter of the jet d_l at a distance l from the nozzle used the expression

$$d_l = d_0 \mu^{0,5} (l / d_0)^{0,115} (p_0 / p_l)^{0,25} , \quad (5)$$

where μ=0,93-0,96 - is the nozzle flow factor, p_l - is the average dynamic jet pressure at a distance l from the nozzle, calculated by the average pressure at the outlet of the nozzle

$$p_l = p_0 \cdot \varphi_l . \quad (6)$$

The following formula is used to calculate the parameters φ_l

$$\varphi_l = 320 / \left[(l / d_0)^{1,5} \sqrt[4]{H_0 + 320} \right] . \quad (7)$$

where H_0 - is the initial head.

The average velocity of the jet V_l at a distance l from the nozzle was calculated by the formula

$$V_l = 1{,}4 p_l^{0{,}5}. \tag{8}$$

Solving the flight range of a jet is of great practical importance, especially when determining the location of a hydromonitor with respect to a slope.

The theoretical jet flight range (excluding aeration and air resistance) was determined by the formula

$$L_{cmp}^{T} = (V_0^2 / g) sin 2\alpha_3, \tag{9}$$

where α_3 - is the angle of inclination of the jet to the horizon, deg.

From the conducted researches it follows that the maximum flight range of the jet will be at the angle of inclination of the jet monitor to the horizon α_3=30-45°.

To destroy rocks, the pressure of the jet on contact with the rock must be greater shear resistance.

For cemented tuffs and similar rocks the shear resistance is expressed by the Coulomb formula

$$\tau = c + (\sigma - p_\Gamma) \cdot tg\varphi_в, \tag{10}$$

where σ - is the total normal voltage; p_Γ - is a neutral voltage equal to the hydrostatic pressure of water in the pores; c - clutch coefficient (for loose tuffs it is possible to accept: c=0); $\varphi_в$ - is the angle of internal friction.

The decrease in shear resistance of zeolite-smectite tuff rocks during vibration is due to the change in stress state, as well as due to changes in the angle of internal friction or coefficient of friction. As a result, there is a violation of the structure of the rock due to the displacement of individual unstable particles. When the vibration is affected, there is a process of constant dilution: the first impulse changes the upper layer, which in turn causes the unloading of the lower layers and their transition to a rarefied state in subsequent vibrations [14, 15]. The dilution zone is constantly moving, extending into the depth of the layer.

Modeling of the process of pulp hydrotransport in the extraction chamber

The displacement of the hydromonitor tuff destroyed by the jet to the absorber of the dispenser occurs in the stream along the bottom of the chamber by self-propelled or pressure flow of water. In addition, self-propelled delivery can be effectively used on the surface, from minning wells to a map of the inwash or pumping dredge pump [16-19].

The erosion of the camera is carried out by sectors, which causes the presence of different specific costs of the working agent along the length of transportation and leads to variability of flow rates. Ultimately, the factor of variability of specific costs and velocities influences the transport capacity of the stream, which is minimal near the slope and increases in the direction of final production. On the other hand, the amount of minerals destroyed is maximum near the slope of the mining chamber and minimum near near of final production. Therefore, the loss of minerals near the slope is large enough, even at the first meters of the blasting radius of the extraction chamber, increasing (due to the imposition of previous floods) as the slope is advanced. Over time, this makes it impossible to transport the reflected mineral without repeated erosion the entire area of the sector. Increasing the transport capacity of the stream near the slope by increasing by increasing the work agent cost will not only lead to a significant cost overruns, but also to an increase in the productivity of hydroerosion. This creates the same problem - the inability to arrange at the periphery of the extraction chamber (near the slope) such flow rates that would allow the transport of all the amount of reflected minerals [20-22]. This significant difference is the basis of studies and calculations of hydraulic transport of mining in hydro-well.

The process of hydrotransporting the pulp to an automated well monitor or outlet is a separate element of the system, so the reliability of this link determines the efficiency of the entire technological complex. Knowledge of the nature and basic laws of this element will allow you to choose the optimal conditions of transportation of the hydraulic mix [23, 24].

It is worth noting another important fact: studies of hydrotransportation in related industries were carried out, as a rule, with the invariance of the flow of working fluid, whereas the hydrotransportation of the mixture under these conditions occurs at a variable flow of water. In addition, all known studies were carried out in the transportation of material that has no initial velocity (fixed on a trench or the bottom), which is significantly different from the conditions of erosion and hydraulic transport to the bottom of the chamber. Here, the eroded minerals have a considerable amount of kinetic energy when they fall to the bottom of the chamber. With a certain flow of working fluid and a sloping bottom, the initial speed of the hydraulic mix can have a predominant effect on the subsequent transportation at the bottom of the chamber.

It is characteristic that in the majority of studies the task of active interference in the process of formation and preservation of the dynamics and kinematics of the movement of the mixture was not put in order to obtain optimal conditions for self and forced hydraulic transport. The solution to the problems of hydrotransportation was basically to determine the transport capacity of the stream. This approach to the calculation of hydrotransportation under the conditions of well hydrotechnology is unacceptable, since the ability of hydrotransportation is based on the possibility of hydro fracture [25].

The absence of analogues and the need for efficient hydrotransportation require the identification and establishment of the following dependencies: the effect of water flow on the flow capacity of the stream; the influence of the slope of the bottom of the camera on the transport capacity of the stream; the effect of the roughness of the bottom of the camera on the transport performance; detecting the effect of the initial energy of the particles on the technological losses [26, 27].

The potential energy of the open flow of the pulp is spent on the interaction of: the working agent with the bottom and walls of the camera; fluid particles with each other (friction in a liquid); particles of moving rock with each other and overcoming local resistance. It is not possible to quantify energy consumption individually for each interaction, so the method of cumulative estimation of flow performance is adopted. The total work is expressed by the maximum transport capacity of the solid flow at a given inclination of the bottom of the chamber of extraction and consumption of the working agent [27].

It is extremely difficult to investigate the parameters of the technology of mining of minerals from the camera, so experiments were carried out in a laboratory on a model stand (Fig. 3). It is practically impossible to perform absolutely appropriate modeling of well hydraulic production of tuffs, so the results of the studies are only quantitative.

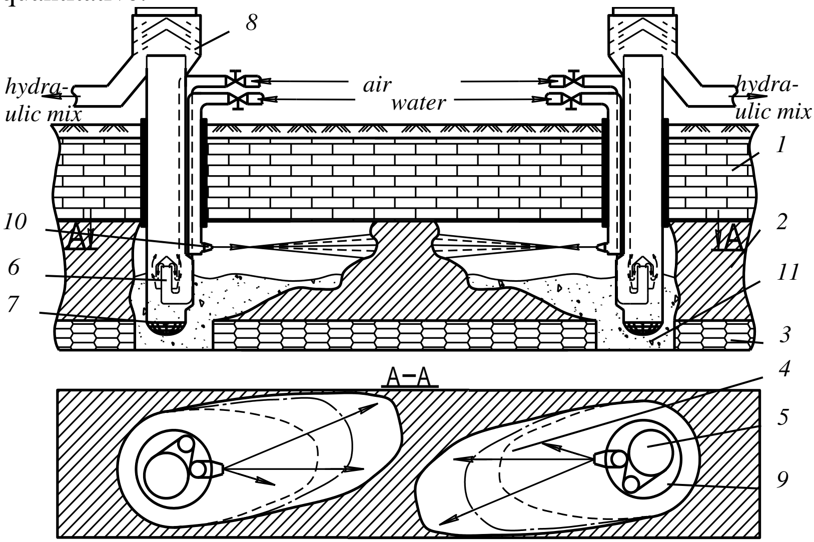

Fig. 3. Scheme of the stand for studying the technology of working out of the extraction chambers: *1* - rock of the roof; *2* - layer of zeolite-smectite tuff; *3* - the underlying rock; *4* - mining chamber; *5* - erlift; *6* - erlift nozzle; *7* - suction pipe; *8* - air separator plate type; *9* - casing string (well); *10* - a hydraulic monitor; *11* - hydraulic mi

The purpose of the research on the choice of the scheme of working out of the camera was to determine the most effective way of destruction and extraction of rock, the choice of the method of carrying out excavation works, as well as to determine the characteristics of the extraction equipment. Three schemes of working out of the chamber were studied: counter, back slope and circulating flow.

According to the first scheme, the extraction works were carried out by sectors around the production well.

In the second scheme, the drilling first occurred by beating the wells with a channel and then expanding it. In this case, the well hydromonitors work on each other, creating favorable conditions not only for the destruction, but also for the transportation of rock in the chamber, as the jet energy is used most rationally in the coincidence of the movement of the hydraulic mixture and the promotion of the slope.

The third scheme is close to the first and provided for the formation of the primary chamber is not over the entire radius of effective action of the jet. The gradual and continuous rotation of the nozzle of the hydromonitor creates a circular circulation of the hydraulic mix in the bottom zone of the chamber. In this case, the jet energy is also used to transport the mixture to the dispenser.

The experiments were carried out at diameters of nozzles hydromonitor d_0 equal to 4,2 and 6,0 mm, changing the water pressure H_0 from 0,2 to 0,7 MPa and reservoir power 0,08-0,19 m. erlift performance 5 and density hydraulic mixtures 11 were measured by measuring capacities. Model layer 2 is represented by zeolite-smectite tuffs from the basalt quarry of the village of Ivanchi, selected from a depth of 15,2 m. Roof 1 and the bottom 3 of the reservoir were made in accordance with basalts and lavobreccia. The walls of the laboratory unit were made of transparent glass to accurately determine the shape and size of the chamber 4. The clamping lining created the ability to load the layer.

Averaged data of studies of tuffs by counter- slope are shown in Fig. 4.

Studies have shown that increasing the diameter of the nozzle and the water pressure increase the erosion rate and increase the efficiency of the extraction chamber (Fig. 4, Charts *1,2,3*), but the increase in efficiency is limited by the performance of the dispenser. Increasing the water pressure in the nozzle of the hydromonitor creates an increase in the density of the hydraulic mixture only up to a certain limit (ρ_h=1,3 g/cm^3).

Analysis of the results of the studies showed that of working out of layers from top to bottom in a single-well production scheme creates favorable conditions for the flow of hydraulic mixture to the dispensing device. The scheme of working out of the chambers by a back slope is promising only for the extraction of the rock in pillars. A limitation to its application is the small angle of deviation from the erosion axis.

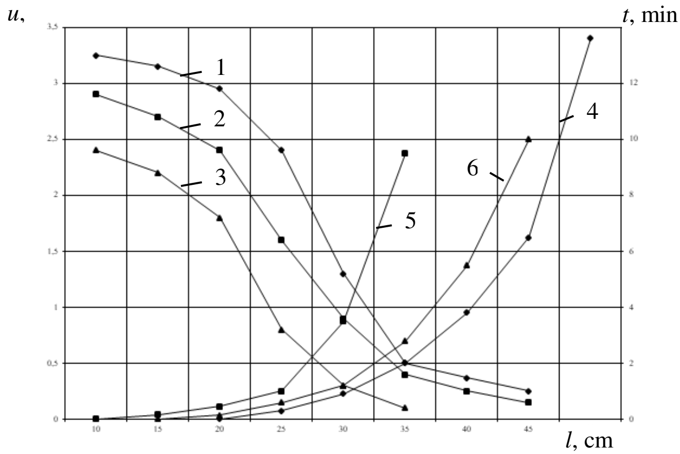

Fig. 4. Dependence of speed and time of erosion on the range of the slope: *1,2,3* - dependence of the speed of erosion u on the range of the slope*l*; *4,5,6* - dependence of the erosion time t on the range of the slope*l*; *1,4* - d_0=4,2 mm, H_0=0,7 MPa; *2,5* - d_0=6,0 mm, H_0=0,2 MPa; *3,6* - d_0=4,2 mm, H_0=0,2 MPa

The erosion of the reservoir and working out of the chambers by the circulation flow showed that, regardless of the power of the waste layer of rock, water pressure and diameter of the nozzle development stopped at a rotation of the nozzle 25° from the initial position.

The process of working out the chamber with undercutting the bottom was less effective due to the collapse of the ore and disturbance of the circulation flow. In the circulation scheme, it is preferable to increase the pressure on the nozzle to increase the working out. Flooding the camera dramatically reduces the efficiency of the discharge. Layered extraction by circulating flow under equal conditions reduces the working time of the camera of the same size by about 25%.

The circulation pattern is very sensitive to changing modes of operation of the hydromonitor and erlift and therefore it is advisable to apply it to the rock with a granulometric distribution. Due to the limitation of production sizes and low circulation stability in the bottom zone, the circulation scheme is less efficient compared to the previous two. Its effectiveness was noted only at the beginning of the formation of the extraction chamber.

Thus, as a result of the conducted research, it is established that the most effective and promising application of mining in hydro-well of zeolite-smectite tuffs is a single-well production scheme with a counter-slope in which the erosion occurs in sectors and round-shaped extraction chambers are formed. And considering that the roof of the zeolite-smectite tuffs are powerful layers of basalt, the most rational system of development is a chamber system with an open treatment space in which the extraction of tuffs will be carried out by layers. Layers should be designed with a slope sufficient for the self- propelled movement of the destroyed rock.

Studies have also found that for large particles (size 8-10 mm), the impact of flow growth occurs only until the liquid level increases to the height of the particle, that is, until it is fully immersed in the liquid. Further increase in flow creates a much smaller effect on the intensity of the action on the particle, since the surface of the liquid does not collide with the plane of the particle perpendicular to the velocity vector, and has an effect only on the flow plot. It can be assumed that with a further increase in the cost of transportation will increase, but the magnitude of the increase in cost will cause only a slight increase. This leads to the conclusion that there is a limit to the impact of increasing the cost of transporting particles of destroyed tuff.

The effect of falling pulp flow on the transport capacity of the stream was also investigated in the experiment. It is revealed that the initial energy of the falling pulp during the erosion intensifies the turbulence of the flow in the bottom space and thereby reduces the probability of sedimentation of the particles, creating an initial velocity of the incident particle. As a result of the blow, the particles of the reflected tuff rise, the pulp density increases and, as a consequence, the ejection force increases, which reduces the adhesion forces of the particle to the bottom.

When the level of the pulp in the bottom space of the chamber was high enough, the energy of falling particle with this layer was exhausted and the sedimented particles could not move. In other words, there must be turbulent motion at the periphery of the extraction chamber and the level of pulp optimal in terms of particle wear.

To create a level playing field transportation along the entire length of the displacement of the reflected mineral in the extraction chamber, it is necessary to maintain a constant flow rate equal to the speed of reliable transportation. In this connection, it is necessary to create a rational, scientifically sound profile of the bottom of the extraction chamber, which must meet the following requirements:

- to create the optimum (effective in turbulence conditions) flow depth at the slope. If the depth of the pulp in the extraction chamber is large enough (as observed at small angles of inclination of the bottom), then the energy of the reflected particle of the rock will be exhausted upon fall and the deposited particles will not be able to be drawn into motion;
- to create the maximum force of rolling;
- have the optimum length of transportation of the reflected mineral.

Therefore, a rational profile should provide:

- constant flow velocity equal to the speed of reliable transportation;
- minimum losses of minerals during forming;
- the inability to settle the minerals at the bottom of the extraction chamber.

Analyzing the research data it is established that the flow transport properties are in most cases described by exponential dependencies or polynomials of the first order, ie linear functions, and the study of the transport capacity of the flow when changing the flow rate of the hydromonitor and the inclination of the bottom of the extraction chamber indicate that this process is approximated to an equation of this kind

$$Q_n(i, Q_{mp}) = 0{,}41 \cdot Q_{mp} \cdot i + 0{,}032 \cdot Q_{mp} + 15{,}7 \cdot i + 0{,}3. \tag{11}$$

The maximum permissible relative error of approximation does not exceed 10%.

Conclusions

The process of hydraulic fracturing of the massif during the development of the zeolite-smectite tuffs deposit in the rivne-volyn region by the mining of zeolite-smectite tuffs by hydro-well method was investigated under various conditions and methods of influence and the dominant parameters affecting the hydrodynamic erosion technology were identified

In the erosion of the breed, the residence time in the rarefied state is determined by the thickness of the layer, its water permeability, the change in pores volume in the process of compaction, the placement of drainage and the duration of the dynamic load, destructive structure.

As a result of studies of the transportation process, it is established that the pulp falling to the bottom of the extraction chamber intensifies the turbulence of the flow in the bottom space by creating an initial speed of movement of the pulp to the suction nozzle of the dispenser, which reduces the subsidence of tuffs particles in the stream, the maximum height of which does not exceed two altitudes times the size of the largest fractions of the destroyed rock.

It is established that the dependence of the flow capacity on the flow rate of the hydromonitor and the slope of the bottom of the chamber for the destroyed zeolite-smectite tuff is linear in nature and directly proportional to the specified parameters.

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