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MASS DESTRUCTION OF STRONG ROCKS BY PERIODIC EMISSIONS OF HYDRO CHARGES

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Abstract. In underdeveloped areas of Kazakhstan, several thousand small gold and rare-metal deposits are located at a depth inaccessible for open mining, which in their limited reserves are either classified as off-balance or are not included in the register of reserves of the SCR (state Committee of reserves). This article discusses the creation and development of new technologies that are based on the use of fundamentally new technical means will be effective and able to reduce the cost of mining. The hydro impulse method of destruction of rocks of any fortress is offered that will allow reducing sharply volumes of capital and operational works at a considerable decrease in their Prime cost. Therefore, it will be possible to involve in the effective development of numerous off-balance gold and rare-metal deposits of Kazakhstan. For this purpose, a comparative analysis of the economic and technical efficiency of the hydro-pulse destruction of strong and abrasive rocks in the ore industry with respect to the existing drilling and blasting technology is given, the developed design of an environmentally friendly electric-discharge hydro-pulse gun GPE-1200 with a very high power of hydrofoil is described. The specific recommended design mechanisms, shut-off valves water gun, operating at ultrahigh hydrostatic inside aggregate pressures, which include how to combine the blasting of the rock mass in the excavation or clearing works and use the device for drilling wells.
Keywords: underground gasification, steep-falling layers, steam-air blast, steam generator, hydraulic shock compressor, hydraulic pulse drilling, steam-hydraulic turbine.

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ҚАТТЫ ТАУ ЖЫНЫСТАРЫНЫҢ ГИДРО ЗАРЯДТЫҢ КЕЗЕҢДІК ЛАҚТЫРЫСТАРЫМЕН ТАСҚЫНДЫ БҰЗЫЛУЫ

Түйіндеме. Қазақстанның аз игерілмеген аудандарында өзінің шектеулі қорлары бойынша не баланстан тыс не болмаса қорлардың мемлекеттік комитетінің қорларының тізіліміне мүлдем енгізілмеген бірнеше мың шағын алтын кені және сирек металл кен орындары ашық игеру үшін қолжетімсіз тереңдікте жатыр. Бұл мақалада жаңа техникалық құралдарды пайдалану негізінде тау-кен жұмыстарының өзіндік құнын төмендетуге қабілетті және тиімді болатын жаңа технологияларды жасау және әзірлеу қарастырылады. Кез келген бекіністің тау жыныстарын қиратудың гидроимпульстік тәсілі ұсынылды, бұл олардың өзіндік құны айтарлықтай төмендеген кезде күрделі және пайдалану жұмыстарының көлемін күрт төмендетуге мүмкіндік береді. Демек, Қазақстанның көптеген баланстан тыс алтын кенді және сирек металды кен орындарын тиімді өңдеуге тарту мүмкіндігі пайда болады. Осы мақсатта қазіргі бар бұрғылау және жарылыс техникасына қатысты кен өндіру өнеркәсібіндегі қатты және абразивтік жыныстардың гидро-импульстік бұзылуының экономикалық және техникалық тиімділігін салыстырмалы талдау ұсынылған, өте жоғары гидравликалық соққы бар ГПЭ-1200 экологиялық таза электр разрядты гидро-импульстік карудың әзірленген жобасы сипатталған. Тау-кен жұмыстары кезінде тау жыныстарының массасын өндіруді біріктіруді көздейтін, сондай-ақ бұрғылау ұңғымаларын бұрғылау қондырғысын пайдалануды көздейтін аса күшті гидростатикалық қысым кезінде жұмыс істейтін гидравликалық снаряд клапандарының арнайы ұсынылған конструкциялары келтірілген.

Түйінді сөздер: жер асты газдандыру, шұңқырлы бөгеттер, булардың ауа жарылысы, бу генераторы, гидропластикалық компрессор, гидрофильді бұрғылау, бу-гидравликалық турбина._

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ПОТОЧНОЕ РАЗРУШЕНИЕ КРЕПКИХ ГОРНЫХ ПОРОД ПЕРИОДИЧЕСКИМИ ВЫБРОСАМИ ГИДРОЗАРЯДОВ

Резюме. В малоосвоенных районах Казахстана, на недоступной для открытой разработки глубине залегают несколько тысяч малых золоторудных и редкометальных месторождений, которые по своим ограниченным запасам отнесены либо к забалансовым, либо вообще не включены в реестр государственных комитета запасов. В этой статье рассматриваются создание и разработка новых технологий, которые на основе использования принципиально новых технических средств будут эффективными и способными снизить себестоимость горных работ. Предложен гидроимпульсный способ разрушения горных пород любой крепости, что позволит резко снизить объёмы капитальных и эксплуатационных работ при значительном снижении их себестоимости. Следовательно, появится возможность вовлечь в эффективную отработку многочисленные забалансовые золоторудные и редкометальные месторождения Казахстана. Приведен сравнительный анализ экономической и технической эффективности гидроимпульсного разрушения крепких и абразивных пород в рудной промышленности относительно существующей буровзрывной технологии, описана разрабатываемая конструкция экологически чистого электроразрядного гидроимпульсной пушки ГПЭ-1200 с весьма высокой мощностью гидровыстрела. Приведены конкретные рекомендуемые конструкции механизмов запорно-выпускных клапанов гидропушки, работающей на сверхвысоких гидростатических внутриагрегатных давлениях, которые предусматривают как комбайновую отбойку горной массы на проходке горных выработок или очистных работах, так и ипользования устройства для бурения скважин.

Ключевые слова: подземная газификация, крутопадающие пласты, паровоздушное дутьё, парогенератор, гидроударный компрессор, гидроимпульсное бурение, парогидравлическая турбина.

Introduction. The Republic of Kazakhstan is ranked 13th in the world among 70 mining powers as regards the total scope of solid minerals mining. The share of Kazakhstan in the world reserves of certain metals is as follows: 30% of world reserves of chromium ore, 25% of manganese ores, 10% of iron ores, copper and lead, 13% of zinc, iron ores is16.6%. The main mining scope can be provided by a more efficient non-explosive flow technology using hydro-impulse rock-cutting devices of the GPE-1200 specimen designed by the Institute of Mining named after D.A. Kunayev. At the territory of Kazakhstan, mainly in underdeveloped areas, several thousand of small gold and rare-metal deposits are located at an inaccessible depth for open-pit mining, which in their limited reserves are classified as either off-balance or not included in the register of reserves of the SRC (State Reserves Committee) due to inadequate exploration [1, 2].

Therefore, the study is aimed at the development and creation of new technologies that, based on fundamentally new technical means, will be able to reduce the cost of mining so that the development of such deposits has become effective.

The Institute of Mining named after D.A. Kunayev has been developing new solutions for underground non-explosive mining of ore bodies in the hard rocks using flow process technology based on hydro-impulse technique with increased power of hydraulic springs for a number of years [3, 4].

The new technology can provide a multiple increase in bottom hole performance due to continuous breaking and continuous conveyor transportation. Thus, drilling and blasting operations are completely excluded. The need for energy-intensive ventilation eliminates and the whole system of a specialized system of airway workings and at the same time ensures complete environmental safety. The volume and cost of fixing and maintaining mine workings is sharply reduced due to contour penetration and the exclusion of the harmful effects of explosions on the integrity of the boundary massif.

The capability to effectively work out with reverse bias hydro-impulse means under natural flooding of the bottom holes by the mine water with a clear delineation of the opening sections and preserving the integrity of the edge massif, indicates a practical way for the preferential transition to a steeply inclined ore bodies. This method is characterized by the shortest transport openings both in the inclined part and in the horizontal sections of the floor horizons. In addition, it is possible to mine ore bodies from top to the bottom with oblique layered panels by the most efficient methods for producing of expansion goaf stowing.

Currently, as the large deposits are developed, a rather urgent task is the involvement of numerous marginally profitable gold and polymetallic deposits into effective mining. The use of hydro-impulse technique for drilling large-diameter wells, for example, in preparation for steeply dipping coal deposits operating using underground gasification methods or for degassing coal seams is of particular interest [5, 6].

General part and discussion. The prototype of the hydro-impulse technology is the first and the only test specimen in the world of the KIV-1 tunnel borer with a hydro-impulse destruction body created by the DONGIPROUGLEMASH Institute in collaboration with the Donetsk State University. In 1985, KIV-1 had a hydro-impulse energy of 54 kJ and was intended for excavating in coal mines along the rocks of up to 6 units under professor Protodyakonov's scale [7-11].

The rock destruction in the bottom-hole was carried out in water portions of 1000 g each, thrown on the bottom-hole in the form of a jet with a diameter of d = 10 mm with a speed of up to 700-

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800 m/s. The relatively low power of the shot and the very low resource did not allow the new technology to gain a foothold in its field of destination, let alone expand it into strong rocks of the ore formation.

In subsequent periods to up to date, a full-scale study of the bulk rocks destruction in the massif with the clean high-energy hydro jets, the mining science did not pay enough attention.

As the main evaluating criterion of the methods of rocks destruction is the energy intensity of the process.

The mechanical method with a high-speed impact, which can be equated to an explosion, has a coefficient of energy intensity of about 0.07 and is, after an explosive, the smallest of all used in practice is among well-known methods.

The processes with a shock-impulse force loading of the surbottom hole of a destructible object during 0.003 - 0.008 s proceed as explosive and are characterized by the absolute energy intensity of the rocks destruction 0.6 kgs.m/cm^3 or 5.9 J/cm^3 (slightly dependent on the strength and more significantly on rock viscosity).

To compare with, during roller drilling, from 12.6 to 25.3 kgs. m / cm3 energy is expended (from 123.6 J/cm^3 to 248.2 J/cm^3). These data are fully supported by testing of the VNIITsvetMet Institute at the open mines of the East Kazakhstan oblast (Ridder-Sokolny, Tishinsky, Zyryanovsky mines).

The power parameters in the rocks destruction by the explosive method and the hydro-impulse coincide significantly to a greater extent in relation to the open work, where the bottom hole area ratio relative to the loading depth reaches a greater value. In this case, the clamping of the explosion by a lateral thrust is much less than in the bottom hole of the driving, and the specific consumption of explosives decreases sharply.

In our case, the penetration depth of a water tool deep into the rock packwall on the hard rocks is a relatively small value relative to the bottom hole area. The clamping is practically minimal; therefore, the calculated funnel area is the largest compared to the depth.

The specific energy consumption in this case will be even smaller than the above. However, the energy consumption of destruction is substantially taken into account, determined for borehole blasting in open pit mining, namely: for rocks with a strength of 8–12 units — 5.9 J/cm^3, for rocks 12–15 units — 7.2 J/cm^3, for rocks of 16-20 units - 8.8 J/cm^3.

The efficiency of the destruction process is as known to be directly proportional to the power of the energy pulse and is inversely proportional to the time of interaction with the object being destroyed.

A water tool in the process of immersion of the frontal part of the rock massif has a selective capability of breakdown of the layer at different speeds by penetrating natural fractures or those formed by impact, as well as destructible weak rock strata. In this case, the cross section of the water tool in the channel being punched expands with a powerful hydrostatic expansion, characterized by the rate of decreasing speed. This thrust pressure is the main factor in the funnel-shaped separation of the rock from the massif.

The process has some similarities with an explosion in a clamped medium with a very effective stemming of the hole collar, the role of which here is performed by the sharply directed inertness of a water tool.

Here, there are actually no losses from the reverse leakage of energy from the mouth of the section being punched, as well as unnecessary throwing of pieces from the zone of small resistance of the rock to tearing, since each depth level of the funnel clearly corresponds to the natural level of hydrostatic expansion.

The remaining constituent positive dynamics are obvious. The process is fully environmentally friendly, since the drive of the hydraulic gun is electric. Water tool has the lowest cost of all compared.

The estimated volume of destruction of the monolithic rock by a 3-kilogram water tool with a speed of impact with a bottom hole of 800 m/s is about 60 dm^3. Comparative values of the energy potentials of various types of combustible substances are given in Table 1 [12].

Table 1 - Comparative values of the energy potentials of various types of combustible substances [12].

Fuel	Energy capacity W		
	MJ/kg	kcal/kg	kWh/ g
1	2	3	4
Powder	3,8	900	1,06
Dynamite 75%	5,4	1280	1,5
Rocket fuel	4,2-10,5	1000-2500	1,17-2,85
Firewood	8,4-11,0	2000-2500	2,33-2,85
Top soil	10,5-14,5	2500-3500	2,1-4,0
Diesel oil	42,7	10200	11,9
Hydrogen	120	28600	33,36
Natural gas	41-49	9800-11700	11,46-13,07

The above reference data provide that explosives have the worst energy indicators, but due to the high speed of the release process of thermal energy (about 0.001-0.004 s), they have the greatest effect on the destruction of solid materials and therefore have found wide application in the mining industry.

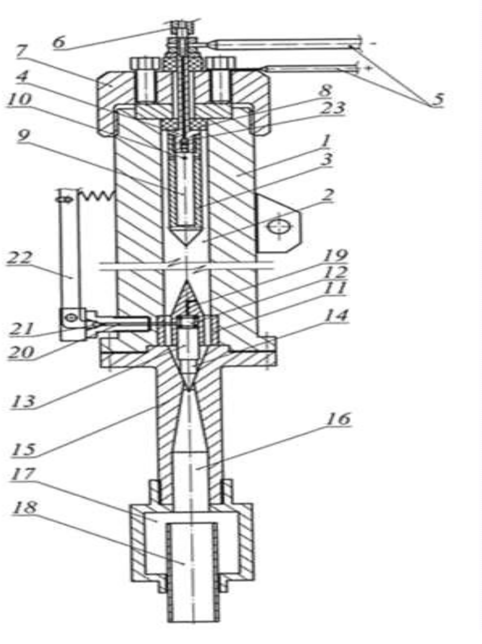
It is possible to simulate an explosive process using mechanical or hydraulic impulses artificially creating the capability for the instantaneous release of accumulated energy inside the working units.

Based on the above, the design of the GPS-1200 hydro-impulse gun is based on a powerful accumulator of super-high-pressure water vapor energy, obtained within 3-4 seconds of evaporating and overheating up to 1600 °C or more using an electric discharge in a thin layer of aqueous electrolyte with a subsequent overheating by electrothermal devices. As a result, in direct proportion to the amount of electrical energy expended, the required reserve of thermal energy is generated in a compressed volume of vapor-ion sublimation superheated to 1700–1800 °C. In this case, the hydrostatic pressure in the cavity of the water gun can reach 6-7 thousand atm. [13, 14, 15, 16]. The capability of accumulating a sufficient amount of thermal energy to destroy the strongest rocks is limited by the strength characteristics of the trunk material, which corresponds to ultrahigh pressure and temperature. An important factor in the accumulation of energy is also the volume of charging water when limiting hydrostatic pressure, the compression of which determines the expanded volume of vapor-ion sublimation in the process of overheating.

Ultrahigh intraaggregate pressure creates a rather acute problem for the instant opening of the shutoff valve of nozzle release.

Figure 1 is a diagram of the design of a GIP-1200 hydro-impulse gun. The thermal energy reserve in the compressed volume of vapor-ion sublimation will be about 2400 kJ under a power supply transformer of 630 kW in 4 seconds of overheating.

The efficiency will be about 0.5 in the heat dynamic process of converting thermal energy into kinetic energy of a water charge with a coefficient of expansion of sublimation k = 6. With a water charge mass of 2.5 kg, its flow rate from the nozzle is about 850 m/s. The impact energy of the jet on the bottom hole at the maximum will be up to 1200 kJ, which will be able to destroy up to 90 dm^3 of the strongest and most abrasive rock.



1 - water gun shaft; 2 - compression space of a weak electrolyte; 3 - electro-discharger; 13 - shut-off valve set pressure; 15 - aero-hydrodynamic channel; 17 - silencer;
18 - water jet formation nozzle

Figure 1 - Diagram of the GIP-1200 hydro-impulse gun device

Technical speed of mine excavation workings with a section of 12.5 m^2 in rocks with strength of 16-18 units on a prof. M.M. Protodyakonov's scale by GIP-1200 hydro-impulse gun is estimated to reach 50 running meters per day under a 10 1 / min shots of frequency. The annual capacity of one hydraulic gun at 100% load can reach 350 thousand of m3 of strong rocks in the bearer.

New equipment carries out continuous rock breaking in the bottom hole, together with its continuous shipment both at tunneling and mining operations. At the same time, the most labor-intensive drilling and blasting cycle in the mining industry is completely excluded, the cross-sectional areas of capital transport and ventilation workings are significantly reduced, and the costs for their construction and maintenance are reduced accordingly. Overall costs for ventilation of mine workings are sharply reduced and the quality of mine atmosphere is improved. Also, there is no stoppage in work due to explosion and airing.

The exclusion of rock-breaking technological explosions in the excavation and mass explosions in production with full conveyor of broken rock mass with the same performance can reduce the volume of ventilation workings by three and 2-2.5 times reduce the sections of transport workings. The operational stability will increase since the aquifer rock massif is not subjected to dangerous deformations from the powerful explosions.

The ability to pass 100% workings using the smooth-wall method in the most cases will eliminate the use of heavy monolithic supports. Where monolithic concrete was required for drilling and blasting, it will be sufficient to mount with gunite. Where gunite was required, the excavation can be operated without fastening.

In addition to high performance, the water impulse method provides a number of technical, technological, and environmental benefits with regard to drilling and blasting. For example, regarding electricity in comparison with explosives (detonit No. 1) in the development of 1 m^3 of rock with a strength of up to 18 units according to the prof. Protodyakonov's scale savings amount to $ 4.0.

These advantages for the newly constructed mine represent a very significant savings in capital and operating costs, which can be calculated only from the data of a specific project for the construction of a new mine.

Speaking about, the concomitant savings of funds, material and labor costs are also not taken into account and are assumed as an additional reserve of the effectiveness of the use of the flow-line blasting production method. And the most important effect is the elimination of severe injuries associated with drilling and blasting.

Ultra-high intra-unit pressure creates a rather acute problem for instant opening of the shut-off valve of nozzle release and control of hydraulic shots. In this regard, below are solutions of the shut-off valve of the hydraulic gun with external and internal control of shots.

In the drawing (Figure 2), a constructive execution of the valve of the hydraulic gun, operating at intracavitary hydrostatic pressure from 2000 to 2500 atm, with external control relative to the cavity of the hydro-impulse gun by hydro-charging shots, is given.

In the drive housing, valve 1 contains polished drilling and three longitudinal ribs that are pressed into the broadening of the stem cavity. The valve 2 is slidly mounted in the drilling of the housing with back pressure of the spring 3 and with the conical overlapping of the feed channel of the nozzle 4 in the normal position. The diameter of a valve housing ground in the valve body exceeds the diameter of its conical part by 5-6%. The spring chamber of the valve body is connected to an external device (Node No. 2) with a channel d = 8 mm, and with a cavity shaft by d = 1 mm channel. The nozzle 4 is sealed with a wedge-shaped steel ring 5 and fixed by means of the supporting end plate 6 with a cap end nut 7. At the same time, the absolute hydrostatic pressure on the end wall of the cavity performs the absolute seal of the nozzle apparatus from the barrel cavity. The shot control is performed using an externally located device (Node No. 2), which sets the final value of the hydrostatic pressure in the barrel cavity.

The device is fed with compressed air with a pressure of 0.6-0.7 MPa, opposed to high hydrostatic pressure in the barrel due to the difference in the areas of the interacting parts - the air membrane of the device and the cone section of the hydraulic outlet channel blocked by a needle from the spring chamber in the valve body. Shock energy of a shot with a mass of hydro-charging 2.5 kg with pressure from 200 to 250 MPa from 35 to 45 kJ.

When charging the barrel with water with a pressure up to 10 MPa, water penetrates through the channel d = 1 mm into the spring chamber and more tightly than the spring force, presses the conical part of valve 2 into the conical part of the nozzle 4 channel. Reliability of sealing increases accordingly with pressure in the barrel.

With the achievement of the design pressure in the barrel, overcoming the force of the membrane

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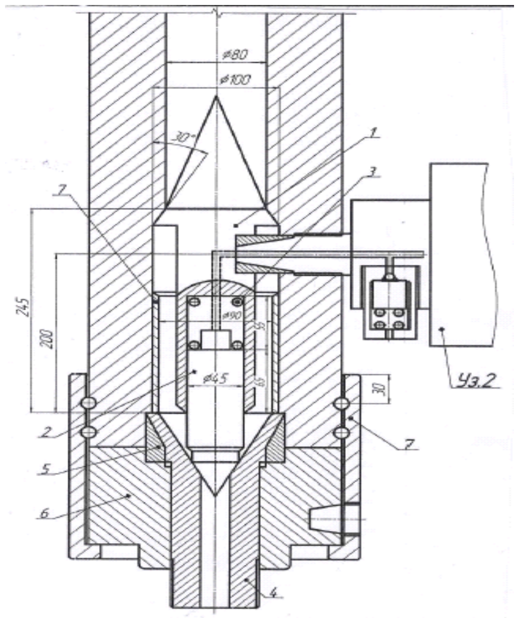
acting on the shut-off needle, some of the water is thrown out of the spring chamber of the valve body into a special follower. The energy of this release pusher through a cork valve (not shown) opens the exit to compressed air above the membrane device and the water from the spring chamber is completely released into the atmosphere. The excess of the ross-sectional area of the valve 5 over the overlapped area of the nozzle forces it to instantly move inside the spring chamber. In this case, at the very beginning of this movement, the channel d = 1 mm is closed and the access to water in the spring chamber (is blocked during the shot). A water charge is released into the nozzle channel and further onto the object to be destroyed. The advantage of the design should include convenient maintenance of the external mechanism of the control device and the ability to adjust the power of the shots by increasing the pressure of the compressed air supplied to its diaphragm.



1 - valve drive housing; 2 - valve; 3 - valve spring; 4 - nozzle; 5 - ring seal; 6 - end plate; 7 - cap nut; Node number 2 - the control unit hydraulic shots

Figure 2 - Shut-off valve with external control of shots

The disadvantage of the design is the presence of rigid mounting edges of the valve body in the area of high-speed flow of hydraulic charge. This dramatically reduces the power of the shot.

The control unit in the design of the hull structure contains a communication channel between the spring chambers of the shut-off valve of the hydraulic gun and the over membrane space with a significantly developed area (Figure 3).

The membrane 1 is made of plastic material and rests on the hard drive 2. The hard drive 2 in the center contains a tide 3, ground in the lower part of the body 4 and ends with a needle 5. The needle normally blocks the connecting channel 6 from the spring chamber. The lower part of the housing 1 is equipped with a pusher mechanism 7, 8, 9, controlling the release of compressed air from the over membrane cavity. The over membrane cavity is constantly fed with compressed air through a thin channel d = 1.5 mm, which opposes high hydrostatic pressure in the barrel due to the difference in the areas of the interacting parts — the device membrane and the conical section of the hydraulic outlet channel from the spring chamber.

When the calculated hydrostatic pressure in the cavity of the barrel is determined by the ratio of opposing forces of compressed air and hydrostatic pressure in the spring chamber and, consequently, in the cavity of the barrel, the needle moves up and the pressurized water enters the mechanism of ejection of compressed air from the over-membrane cavity. The pusher 7, 8, 9 acts on a standard cork valve (not shown) mounted on the housing cover 10. As a result, the hydro-channel opens completely, all the water from the spring chamber is released into the atmosphere and the hydraulic gun is shot. The figure 4 below shows the shut-off valve with internal control of hydraulic shots.

The design differs from the M1 modification in that the valve 1 is made integral

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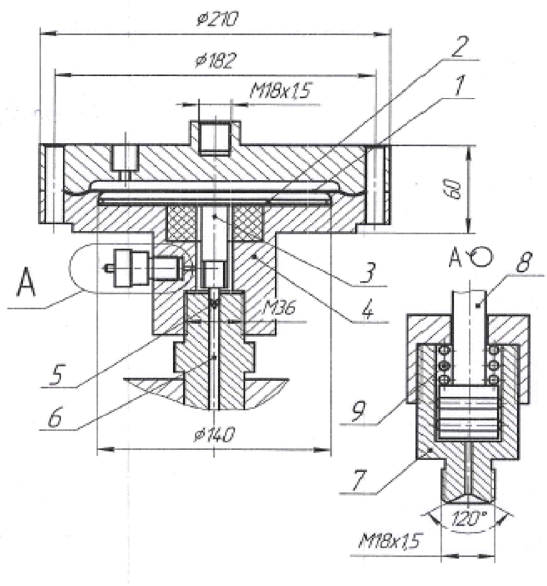
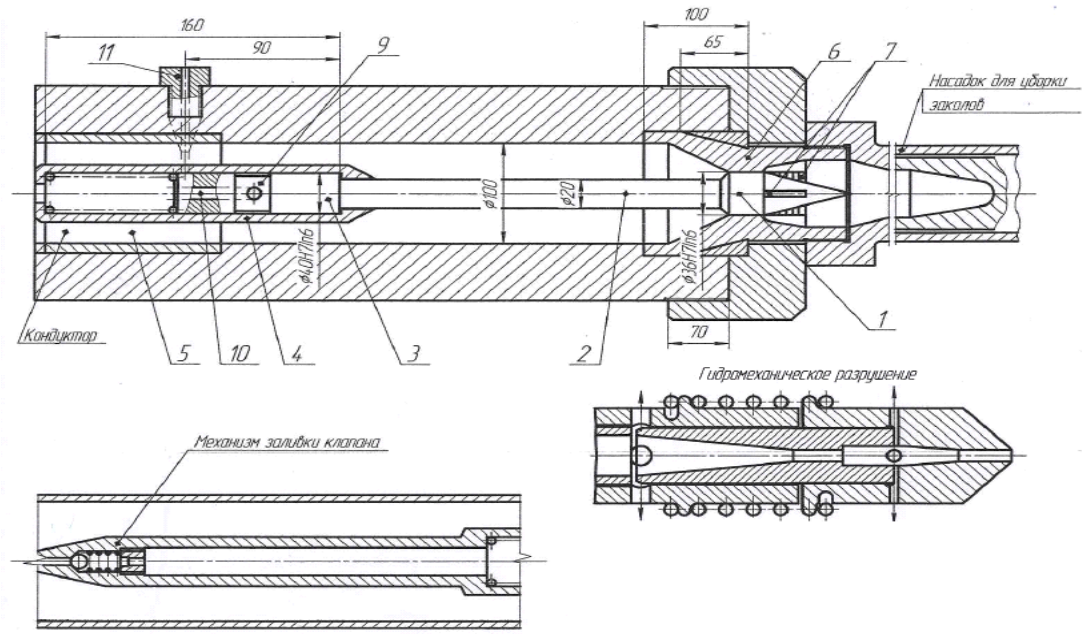
with a thin rod stem 2, terminated by a ground valve piston 3, placed in cylinder 4, which in turn is rigidly connected to the conductor 5. The conductor is also rigidly fixed on the back side of the water charge, i. e. outside the zone of high-speed fluid flow. The valve 1 is made in the form of a ground-up cylinder, moving inside the orifice of the nozzle apparatus 6 until it is fully extended, its ribs 7 are longitudinal to the liquid flow and fixed at their end. The axial nozzle is also equipped with a priming mechanism when charging with a ball valve 8. The valve piston has an annular groove 9 and



1 - flexible membrane; 2 - hard drive; 3 - central tide; 4 - housing; 5 - needle; 6 - connecting channel; 7, 8, 9 - pusher mechanism

Figure 3 - Driver for external control of the valve of the hydraulic gun



1 - valve; 2 - stock rod; 3 - valve piston; 4 - cylinder; 5 - conductor; 6 - nozzle; 7 - guiding ribs; 8 - ball valve; 9- ring groove; 10 - axial channel;
11 - radial channel; 12 - trunk wall.

Figure 4 - Shut-off valve of the hydraulic gun with the internal control

an axial channel 10 with the possibility of connecting the radial channel 11 in the side wall of the barrel 12 with the atmosphere. The diameter of this piston exceeds the diameter of the valve body lapped. This achieves a sequential exit of the valve body from the orifice of the nozzle apparatus when the calculated hydrostatic pressure is reached before the annular groove of the valve piston coincides with the radial channel with exit to the atmosphere. When combined with the radial channel of the exit to the atmosphere, part of the water from the spring-loaded piston cavity is released into the atmosphere. The valve instantly occupies the extreme position "open nozzle". A shot is made. Then the valve mechanism springs back to the "closed" position and the cavity of the barrel is filled with pressurized water and simultaneously the cavity of the valve mechanism.

The advantages of the modification are the wide possibilities for increasing the power of shots due to the increase in the hydrostatic pressure in the barrel cavity and the possibility of using the device as a drilling tool for drilling large diameter wells.

Findings. The main result of the new solutions is a significant reduction in the cost of mining, which is achieved by reducing the actual volume of the mine underground construction, as well as due to the high performance of mining rock mass. Due to the environmentally friendly process, specialized ventilation systems with mine workings are reduced or completely eliminated. It becomes possible to complete the conveyor of ore and rock to workings of the smallest section. In addition, the cost is reduced due to the elimination of associated excavation of waste rock, since all the preparatory mine workings are carried out on the ore. This will dramatically reduce the time of construction and mining.

A new result is also the achievement of the full omnify of the mining system with the underground method, both for shallow ore bodies and deep-seated ones. In this case, the cost of production in its main part will depend only on the depth of development, where the main thing is the costs of electric power to drive conveyor transport to different heights.New technical and technological solutions will allow unifying the systems of opening and mining of compact ore bodies for different depths. In addition, high environmental and technological safety of underground works is achieved. Many deposits designed for open pit mining can be completely redesigned for underground mining, as more efficient and not requiring significant reclamation costs.

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