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New solutions to the problems of stripping of ore bodies using inclined workings driven downward in conditions of increased water cut

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ABSTRACT
The authors of this paper describe the face transport system that ensures the stripping of ore bodies using the underground development method with inclined narrow workings driven downward, including in conditions of increased water cut. The face transport system will allow the preparation of a new 500-thousand-ton mine with minimum general construction and mining construction works as well. The article contains an engineering study of the transition of the road heading to blastless continuous-flow methods of rock development using hydraulic impulse or mechanical shock machines, which are under development. For deep and ultra-deep developments starting from 250-300 m and deeper, a new technical solution is given for the construction of a downhole mine airlift with the lowest capital and operating costs and sufficiently high reliability and productivity. New technical solutions will ensure the radical transition of the technological concept of mining production from the drilling-and-blasting cyclic to blastless continuous-flow one.

Keywords: stripping of the deposit, inclined working, hydraulic impulse gun, breaking, hydraulic pipeline, air lift.

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Introduction

This research contains an engineering study of transition of road heading to blastless continuous-flow methods of rock development using hydraulic impulse or mechanical shock machines, which are under development. New rock cutting machines are designed for blastless continuous breaking of hard and hardest rocks right in the face [1, 2, 3, 4]. These new tools give the opportunity to use the most efficient and safe pipeline transportation on inclined drives to deliver the developed rock from the face to the surface [5, 6, 7]. The developed new technical proposals and methods of mining operations are aimed at technical and technological support of the replenishment of the mineral resources in the Republic of Kazakhstan and the preservation of the industrial potential of processing enterprises with due account for the current trend of depletion of large deposits.

At the territory of Kazakhstan, mainly in undeveloped areas, there are several thousands of small gold, and rare metal deposits, which due to their limited reserves, geological conditions of occurrence, and the composition of useful components are classified either as marginal or unrecoverable ones.

One of the main tasks of the mining industry, specializing mainly on hard ores and rocks, is the technical and technological support of the transition from cyclic technologies to continuous-flow ones using new technical means that can make mining enterprises commercially more efficient [8, 9, 10, 11].

Over the past decades, the situation with the replenishment of raw materials of the Republic of Kazakhstan has significantly worsened. Mining of numerous deposits with small or hard-to-recover reserves using such traditional technologies as drilling and blasting has practically no economic prospects.

There arose a long-felt need for significant modernization of the exploration, stripping and development of polymetallic and other deposits.

Developing a face of inclined working

During several years the Mining Institute after D.A. Kunayev has been searching for new technological solutions to reduce the cost of mine construction and, therefore, the mining cost. At the same time, the emphasis is placed on the mining of small deposits of valuable ores and metals that are not yet developed.

This requires new technical solutions that should significantly reduce capital and operating costs, for example, through the use of process charts for steeply inclined stripping by means of conveyorways equipped with a hydraulic pipeline transport capable of both driving these workings and stoping.

Currently, the work is carried out for creating equipment for fine-fraction breaking of hard ores and rocks using powerful impulse water jet devices, and for medium-hard rocks, using mechanical impact devices with an electromagnetic drive [1, 2, 3].

The creation of a new cost-effective process chart for stripping ore bodies, which can also be effectively used for their development, is based on the continuous-flow and safe driving of steeply dipping workings from the surface, including in the conditions of increased water cut in the rock mass.

Backtracking from the drilling and blasting method of roadheading and mining to the hydraulic impulse breaking using an electric drive will significantly reduce the amount of ventilation and ventilation means in full compliance with sanitary standards for the mine atmosphere due to the environmental friendliness of the process.

Figure 1 shows a drawing of the design of the GPE-1200 mud-pulse gun with a 600 kJ useful power of water jet. According to calculations, the technical performance of one GPE-1200 reaches 500 thousand tons per year, while the standard performance for a heading face when using a drilling and blasting method is 40 thousand tons per year [2]. Figure 2 shows a photo of an experimental sample of a small mud-pulse gun with a 24 kJ water impact power.

Process charts for stripping ore bodies

A process chart is proposed for stripping new deposits by means of a pair of steeply inclined conveyorways with a cross section of no more than 10 m^2 each (Fig. 3 and 4), at that with the sections of a lowered height for the purpose of more convenient maintenance of the working roof and its fastening, mainly with rods and a grid.

During the roadheading period, both inclined workings are equipped with a pair of looped hydraulic pipelines moving after the radheading to deliver the rock mass from the bottom to the surface (Figures 5 and 6).

Ore body 1 is stripped by means of two inclined workings 1 and 2 with two-sided lateral circumference of ore body 3 along the host rocks. The slope of workings is 30 - 35^0.

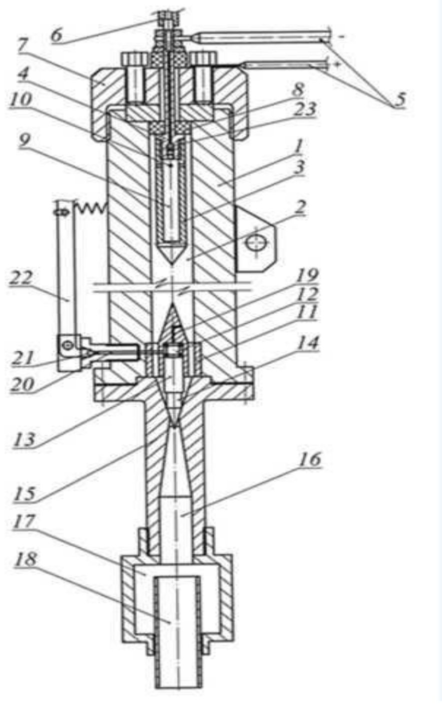

Figure 1 - Drawing of the design of the GPE-1200 mud-pulse gun

1 — Gun tube; 2 — Compression space of weak electrolyte; 3 — Spark gap; 13 — Set pressure stop valve; 15 — Aerohydrodynamic channel; 17 — Muffler; 18 — Water charge nozzle

For the operation, one of them is equipped with a ring hydrotransport pipeline to deliver the flow of waste rock to the surface. The working 2 is equipped with a pipeline for supplying material from the surface to the mining areas for backfilling.

Hydraulic pipeline transport

The main problem when driving underground mine workings using continuous-flow method is the transportation of the broken rock mass from the face to the surface, or to the general mine, i.e. mainline vehicles. The problematic link here is the build-up of the transport line following the advance of the heading face while a point of unloading of the rock mass is situated at one permanent place.

The predominant type of transport equipment for horizontal tunneling and stoping is roller belt conveyors, which can only be docked if a load is overturned, which poses many associated problems. The belt conveyors are completely unsuitable for downward driving of inclined workings with a slope of over 30^0, often in conditions of high water inflow into the face.

Figure 2 - Experimental sample of a mud-pulse gun

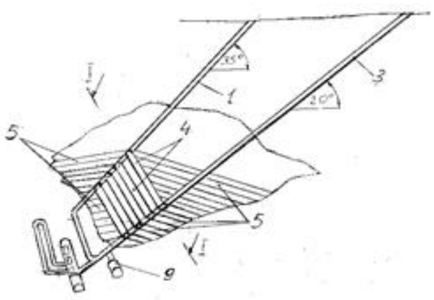

Figure 3 - Process chart for stripping and preparation of a compact ore body

1-Ventilation steeply inclined shaft;
3- Conveyor steeply inclined shaft;
4- Orts; 5- Panel steeply inclined stub headings; 9- Freezers' compartment.

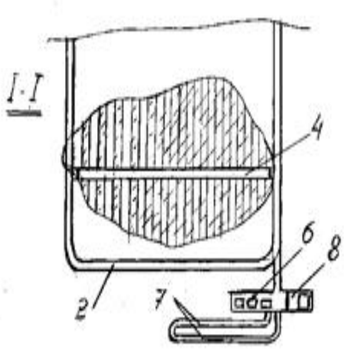

Figure 4 - Cross section of the stripping plane 1-1

1- Annular drift; 4 – First transport ort;
6- Pump chamber; 7- Water collector; 8- Electric substation chamber.

The solution to the problem may lie in the creation of an efficient hydraulic pipeline transport, for example, with ball separators of bulk cargo, which simultaneously acts as pistons and scrapers. By means of water-jet washing such separators can avoid jamming in the places of loading and discharging [5, 6].

To increase the performance of hydrotransportation from deep horizons, it is possible to use high-pressure air boost along the route.

A technical problem of the hydro-pipeline transport is that the broken rock must be lump, and this is rather successfully solved by using rock cutting mud-pulse equipment.

According to Fig. 4 and 5, the unit is located in a steeply dipping working 1 with the face 2 flooded with water and includes a pair of looped pipelines 3 with half-ring connections 4 and 5.

The pipeline is sectioned using nipples 6 ensuring unhindered sliding of the annular pipeline following the advance of the working face along the metal linings 7. Gravity movement of the pipeline system, depending on the slope angle, from the stop in the face 2 or from any pusher on the surface is not shown.

Free floating hollow ball scrapers8 made of fiberglass (for instance) are placed in the pipeline cavity. The upper semicircle 5 in the empty branch has an unloading slot 9 above the receiving hopper for the transported material. The lower semicircle of the pipeline 5 along its inner perimeter is tightly connected to the annular conduit 10. Inside its cavity, there is a freely rotatable hoop 11 equipped with blades 12.

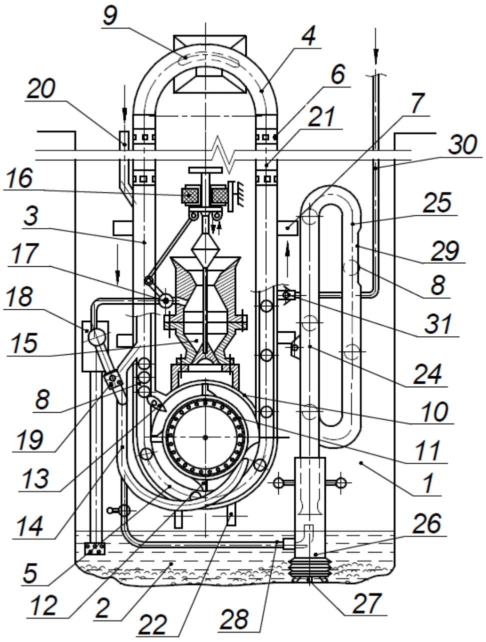

Figure 5 - Face transport system in plan view

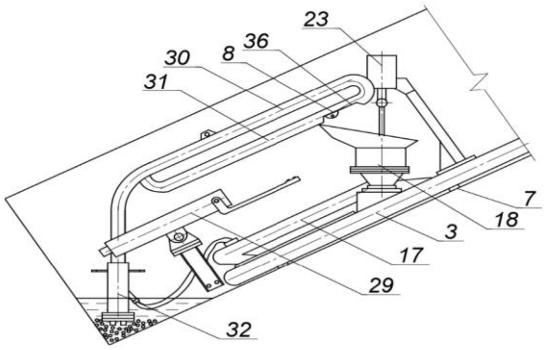

Figure 6 - Face transport system in side view

At the place of coupling of the empty branch of the annular pipeline 7 and the annular conduit 10, a limited-swing spring-loaded retainer 13 is mounted to fix the ball scrapers8 that can simultaneously interact with the blades 12.

The section of the empty branch above the fixed ball scrapers8 is connected using a bypass pipeline 14 with the cavity of the annular conduit 8 near its second coupling point with the dumping branch of the pipeline 3.

The top of the conduit 8 is tightly connected to a single-compartment loading and displacement chamber 15 containing a pair of opposed valves controlled by a reciprocating drive 16 and a high-pressure water injection system 17 to inject water into its cavity.

To supply water into the displacement chamber 15 at the time of displacement of bulk cargo from it into the annular conduit with pressure higher than the working pressure in the transport pipeline 3, the pressure system 17 from the pump of control water pumping point 18 from the face is equipped with a throttle valve 19.

The upper part of the empty branch of the annular pipeline 3 is equipped with a pressure pipe 20 connected to a hydraulic pump (not shown in the drawing), ensuring a supply of powerful stream of clarified water into the cavity of pipeline 3.

In the descending order, next after the half-ring 4, there are telescopic pipes 21 for building up the transport pipeline with new sections of pipes as the drifting face 2 moves forward. The lower half-ring 5 is equipped with holes 22 for attaching the hydraulic mud-pulse driving gun 23 (Fig. 1).

To rehandling the broken fine-fraction ore or rock from the flooded face 2 into the receiving chute of the displacement chamber 15, a suspension device is used consisting of the main pipeline 24 and a looped part 25 as well as a freely rotatable manually controlled pipe 26 telescopically mounted at the face end. The suction end of the pipe 26 is equipped with fingered rippers 27, and a water jet nozzle 28, which is connected to the cavity of the annular pipeline 3. Similar ball scrapers8 are placed inside the looped pipeline 24 and 25, while its annular branch 25 is equipped with a discharge slot 29.

For deep horizons, the dumping branch of the hydrotransport pipeline is located along the length of the route and is equipped with a high-pressure pneumatic pipeline 30 with normally closed valves 31 with pressure exceeding the local hydraulic one. The valves 31 can be either automatic, triggered by mechanical expansion of the bulk cargo, or with remote control.

The work of the transport system is managed by 3 operators. The operation begins with the development of the wall face of the inclined working with a hydraulic mud-pulse device 21. One operator controls the operation of the hydraulic gun, the second one controls the reloader, and the third one controls the operation of the loading chamber.

The clarified water blower on the surface dynamically moves the water flow with the developed rock and the ball scrapers 8. The latter ones can have different speed of movement in the empty branch and get accumulated on the retainer 13. When they are retained the water flow in the bypass pipeline 14 sharply increases, which rotates the hoop 11 with the blades 12 in the annular conduit 10. The blades periodically interact with the loading and displacement chamber 15. At the same time, each blade together with the rock pushes the retainer 14 and let the next ball scraper 8 into the annular part 5 of the pipeline and further along the dumping branch.

To reload the broken fine-grained rock or ore from the flooded face 2 into the receiving chute of the loading and displacement chamber 15, the pressure water is supplied to the suspended tubular device 30, 31 from the bypass pipeline 14 using a flexible sleeve 28 into the telescopic pipe 26.

The water jet forces the ball scrapers 8 to move ringwise resulting in the suction of a mixture of bottomhole water and bulk material, which is made moved by pins 27 of the rotary nozzles 32 manually or mechanically. Through the clear opening 29, the water-rock mixture is discharged into the chute, while the water is drained back into the face and removed by the pump 18 located on the surface along the dumping branch of the transport pipeline 3.

To increase the efficiency of the unit operating at great mining depths, the dumping branch of the pipeline is connected to the pneumatic injection pipeline 30 with a compressed air pressure higher than the local hydraulic pressure in the transport pipeline and is separated from it with a back pressure valve 31.

To drive inclined workings in dry face conditions, it is possible to use, with some modernization, existing continuously operating rock loading machines, for example, 1PNB-2 by the Kopeysk machine plant (RF).

The modernization includes the remodeling of one of the swinging arms to the opposite movement of both shoveling arms, the replacement of the scraper conveyor with a shortened belt conveyor and the installation of a pressure blade conveyor above the main conveyor belt, which fixes the load on the main conveyor belt.

Vertical stripping

For deep mining, as an example of an innovative solution related to the delivery of rock mass to the surface, a new design of a borehole pneumatic lift is proposed, which differs from other designed modifications with rolling elastic seals.

Attempts to create an effective pneumatic lift were undertaken at the design stage by many Institutes of the former USSR. However, all solutions related to effective sealing between the pneumatic carriage and the shaft walls were hindered by practically impossible technical conditions and requirements to contact surfaces, which were made of antifriction polymeric materials up to the shaft lagging. The actual operating conditions of mine shafts and lifts do not allow the use of such solutions.

The result of the proposed solution is a pneumatic lift (Fig. 7 and 8) with a balanced circuit, which includes two vertical transport mine workings 1 and 2 connected at the bottom with a linkage 3. Air blowers 6 are mounted between bridges 4 and 5 in linkage 3 with the possibility of alternate suction or injection into workings 1 and 2.

Each of the workings is equipped with the same type of cargo platforms in the form of cylindrical walls 7 and 8, respectively, with a sealed top floor 9 and a sealed bottom floor 10 equipped with a normally open hatch 11. Due to this, the cavities of the platforms can be used as an emergency exit onto the surface. Moreover, the opening in the bottom floor 10 is used for the maintenance of the unit. In this case, the mine vehilces 12 are mainly dumpers on the floors 9.

The side walls 7 and 8 of the platforms are equipped with at least two pairs of mutually parallel annular grooves 13. Each pair of grooves 13 contains toroid ends of elastic rolling seals 13 made mainly of synthetic polyurethane elastomer. Each seal in the area of the grooves contains a circle of fixing balls 15, mainly made of lightweight plastic materials.

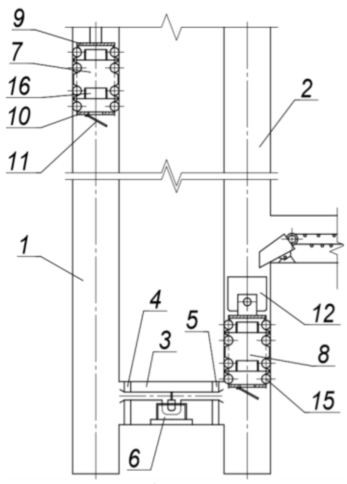

Figure 7 - Overview drawing of the balanced pneumatic lift

Walls of cylinders and grooves in the zone of interaction with the rolling seals must be covered with anti-friction materials or polished.

The inner parts of the platforms are equipped, for example, with annular water collectors 16 that have a hydraulic connection 17 with the friction surfaces of the rolling seals 14, with the surfaces of the grooves and walls of the platform cylinders. Water here serves both as a lubricant and a coolant of friction surfaces.

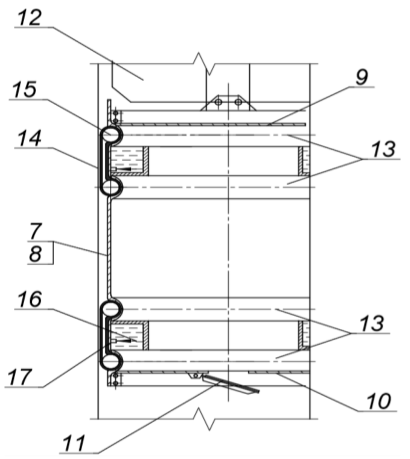

Figure 8 - Side elevation of the pneumatic lift's platform

An unusable liquid or gaseous medium is pumped into the cavity of rolling seals 14 with a thrust pressure on the walls of the enclosing mine that is higher than the working air pressure under the platforms created by the blowers 6.

When the blowers 6 are switched on to inject air into one of the workings and, accordingly, to suck from the other one, there arises a lifting force, which raises the loaded platform onto the surface and simultaneously lowers down the empty platform.

When the platforms move, expanded elastic seals 13 of the friction walls of the vertical workings roll around them without slipping, while slipping on the polished and water-moistened side surface of the grooves and cylindrical walls of the platforms. At this, the seals are securely fixed due to the aligned grooves and balls inside the elastic shells.

Conclusions

The use of a pneumatic lift with rolling seals will ensure underground mining at unlimited depth with the least wear-out of the seals and high reliability of their operation. Here, the requirements to the quality of the surfaces of borehole walls, fixed, for example, with smooth-walled tubing, and the requirements to the axial deviations of the boreholes themselves are significantly lower.

New means and methods for preparing ore bodies for underground mining will significantly simplify the mining technology and considerably decrease the amount of work for the development of mines' surface and the physical volume of mining operations. Consequently, the productivity of the mine as well as environmental and industrial safety will be significantly enhanced.

Conflicts of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Кенжарлардың суланған жағдайында жоғарыдан төменге қарай көлбеу қазбалармен кен денелерін ашу проблемаларының жаңа шешімдері

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ТҮЙІНДЕМЕ

Мақалада жер асты әдісімен жоғарыдан төменге, оның ішінде жоғары сулану жағдайында өтетін кіші қималы көлбеу қазбалармен кен денелерін ашуды қамтамасыз ететін кенжар-көлік кешенінің сипаттамасы беріледі. Кенжар-көлік кешені жалпы құрылыс және тау-кен құрылыс жұмыстарының ең аз көлемімен өнімділігі 500 мың тоннаға дейінгі жаңа кеніштi қазуға дайындауға мүмкіндік береді. Мақалада жобалық әзірлеуде тұрған гидроимпульсті немесе механикалық соққыш машиналардың көмегімен тау-кен массасын игерудің жарылғыш емес әдісіне көшуі техникалық тұрғыдан негізделген. 250 - 300 м және одан да терең тереңдікте тау-кен жұмыстарын жүргізу үшін жеткілікті жоғары сенімділік пен өнімділікті қамтамасыз ете отырып, ең аз күрделі және пайдалану шығындары бар ұңғымалық шахталық пневматикалық көтергішті орнату бойынша жаңа техникалық шешім ұсынылды. Жаңа техникалық шешімдер түбегейлі түрде тау-кен өндірісінің технологиялық тұжырымдамасын бұрғылау-жару циклінен жарылғыш емес өндіріске ауыстыруға мүмкіндік береді.

Түйін сөздер: кен орнын ашу, көлбеу қазу, гидроимпульсті зеңбірек, ұсақтау, гидравликалық құбыр, пневматикалық көтергіш.

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Новые решения проблем вскрытия рудных тел наклонными выработками сверху вниз в условиях обводнённости забоев

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АННОТАЦИЯ

В статье дается описание забойно-транспортного комплекса, обеспечивающего вскрытие рудных тел подземным способом наклонными выработками малого сечения, проходимыми сверху вниз, в том числе и в условиях повышенной обводнённости. Забойно-транспортный комплекс позволит с минимальными общестроительными и горностроительными объёмами работ подготовить к отработке новый рудник с производительностью до 500 тыс. т. В статье технически обоснован переход проходческих работ на безвзрывные поточные методы разработки горной массы с помощью гидроимпульсных или механоударных машин, находящиеся в конструкторской разработке. Для глубоких и сверхглубоких разработок, начиная от 250 - 300 м и глубже даётся новое техническое решение по устройству скважинного шахтного пневмоподъёмника, имеющего наименьшие капитальные и эксплуатационные затраты при обеспечении достаточно высокой надёжности и производительности. Новых технические решения позволят в своей основе изменить технологическую концепцию горнодобывающего производства с буровзрывной циклической на безвзрывную поточную.

Ключевые слова: вскрытие месторождения, наклонная выработка, гидроимпульсная пушка, дробление, гидротрубопроводный, пневмоподъёмник.

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