(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 845 738 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
07.07.2021 Bulletin 2021/27

(21) Application number: **19854844.8**

(22) Date of filing: **26.08.2019**

(51) Int Cl.:
E21D 1/03 *(2006.01)*

(86) International application number:
PCT/RU2019/000595

(87) International publication number:
WO 2020/046175 (05.03.2020 Gazette 2020/10)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
KH MA MD TN

(30) Priority: **28.08.2018 RU 2018131076**

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(54) MINE SHAFT CONSTRUCTION METHOD AND SHAFT SINKING MACHINE

(57) Group of inventions relates to mining. The method includes face mining, erection of temporary lining and permanent lining with a backlog from the working face by an amount not lower than the level of conditional stabilization of the residual deformation of the rock walls, at which the load on the lining does not exceed the current bearing capacity of the lining. The level of conditional stabilization is determined by the nature of changes in deformations of the rock walls. For this purpose, directly at the working face, at one point, the conditionally initial position of the rock wall of the shaft is fixed and, as the shaft sinks to a specified level, the deformation of the rock wall relative to its conditionally initial position is measured, after which the nature of the change in the deformations of the walls along its full vertical extent from the level of fixation of the conditional initial position is established. The load on the lining is determined by the current value of deformation at the level of conditional stabilization of the residual deformation of the rock walls of the shaft based on the established nature of the deformation of its walls. Combine comprises mounting frame for erection of lining, and face frame, a panelized spacing ductile shell, in the form of a series of stoplogs installed around the face frames, connected with it by means of hydraulic jacks, an operating member for processing the cross section of the shaft, and a control system. Displacement measuring sensors are installed between a stoplog and one of the frames or both frames and / or between two adjacent frames. The control system includes a processing unit for the measurement result, which forms the ordinate of the level of conditional stabilization of the residual deformation of the rock walls from the working face, and a control unit for processing the cross section of the shaft by the operation member. As a result, the reliability and safety of workings on the construction of shafts in a wide range of mining and geological conditions and specific technological features of mining operations has increased. The operational reliability of the mine shaft and the speed of sinking have increased while the resource intensity of the workings has been reduced.

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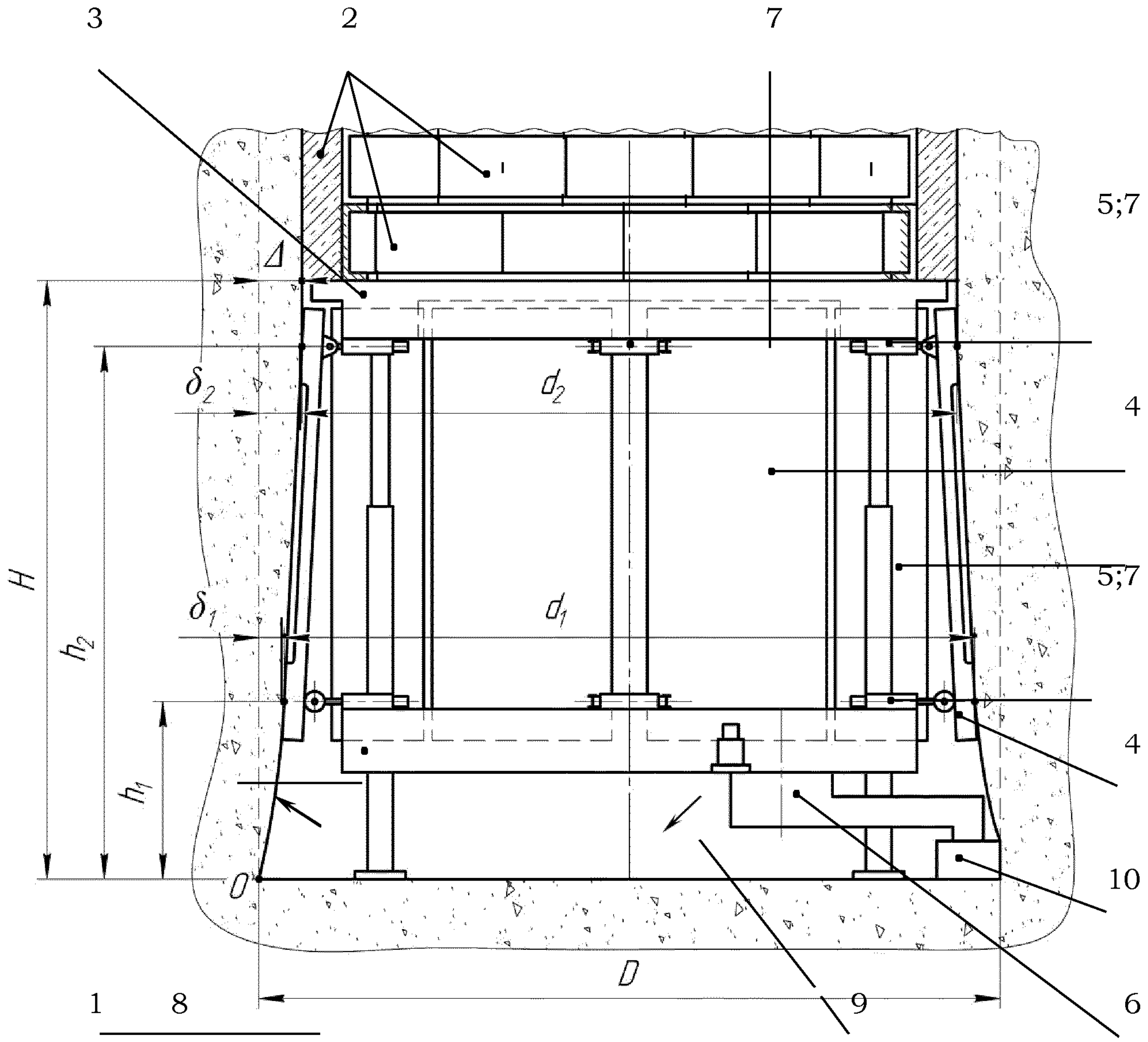

Fig. 1

Description

[0001] The group of inventions relates to the field of mining, namely to the technology of construction of vertical shafts of mining enterprises and to the mining equipment for its implementation.

[0002] The construction of mine workings and underground structures leads to the disruption of the balance existing in the rock mass. In the vicinity of outcrops, deformation and destruction of rocks occur. The normal and safe exploitation of mining operations and underground structures is ensured by the lining that prevents displacements and collapse of rocks inside the workings. Displacing rocks meet its resistance, lining interacts with the rock mass, as a result of which a new balance state is established. The magnitude of the stresses arising at the contact of the lining with the rock mass and the rock displacement value depend both on the properties and initial stress state of the rocks, and on the type of structure, mechanical characteristics of the lining and the technology of its construction [N.S Vulychev. "The mechanics of underground structures. Textbook for high schools." - M., Nedra, 1982, 270 p.]. Traditionally, the stresses at the contact of the lining with rock mass is often called the load on the lining.

[0003] It is obvious that the stress-strain state of the rock mass in the balance state is static. But during the construction of the shaft, partial unloading of its surface from radial stresses occurs, which causes elastic deformation and displacement of the rocks into the mine. Meanwhile, the pressure on the lining due to the creep behavior of rocks caused by this process develops over time and depends on the load history, that is, on the sequence and duration of technological operations. Moreover, the most intense change in stresses and, as a consequence, the deformation of the walls of the shaft are in the immediate vicinity of the face. In this section, a slight increment of the function argument leads to a significant increase in the value of the function. However, with distance from the face the function flattens out (tends to a straight line), that is, even augmented increment of the argument does not lead to a significant increase in the value of the function. In relation to the considered problem, the flattering of the function under the given conditions means the conditional stabilization of the convergence of the rock walls.

[0004] It has been experimentally revealed that the load on the lining sharply increases during shaft sinking. So, for example, during the erection of a monolithic concrete lining following the movement of the face, significant deformations arise due to the convergence of the enclosing rocks, which adversely affect the not yet completely hardened lining and lead to its deformation or destruction. To reduce the operating stresses in the lining, it is necessary to erect it at a certain distance from the face and make it loaded within the normative strength [V.E. Volikov, S. A. Rybak, I. A. Ozornin. "On the issue of shaft sinking in a tectonically-stressed rock mass" // Mountain Information and Analytical Bulletin (scientific and technical journal). - 2014. - No. 10. -163-171 pp.]. In this case it's not guaranteed that the lining will immediately have its maximum load-bearing capacity, but on the contrary, as a rule, it requires some time to acquire the necessary strength. Similar processes, albeit to a lesser extent, are also the characteristic of tubing lining, mainly due to the need to tamp the tubing space. The nature and duration of acquiring by the lining its normative strength depends on the properties and type of such lining.

[0005] It is important that at the initial moment of installation (erection) of the lining the load on it shall not exceed its initial strength, and that with further sinking the increasing stresses shall not exceed the load-bearing capacity the lining has acquired for the time given. Taking into account that creep deformations are caused only by additional (relievable) stresses caused by the construction of the shaft (see N. S. Vulychev, "Mechanics of Underground Structures"), the calculations should include not complete but residual deformation (at the level of conditional stabilization of residual deformation of rock walls). That is, a deformation arising as a result of the additional stresses occurring when the distance from the face is incremented by a conventional value (conventional unit). The distance from the face at which the residual deformation does not exceed the value of the current bearing capacity of the lining of a given type with known properties under given mining conditions is the level of conditional stabilization of the residual deformation of the rock walls.

[0006] There is a step-multilayer lining [Description of the utility model to patent of the Russian Federation No. 134216 dated April 23, 2013, IPC E21D 1 1/00, E21D 5/00, publ. on January 10, 2013, Bull. No. 31], which constitutes the layers of fixing material (concrete, reinforced concrete, spray concrete, polymers) sequentially applied both to the fixed rock outcrops and on top of each other, and the number and / or thickness of the stepped layers get smaller in the direction of the face, and the number of layers is equal to the number of steps, with the length of each layer sequentially applied after the next face advance is equal to the length of the restraining influence zone of the face, and the length of the step in the layer is equal to the length of the next face advance.

[0007] The disadvantage of this lining is a rather narrow scope of application. For example, under conditions of strong convergence of the rock walls, the layers closest to the face having a small thickness, will deform not having time to gain strength sufficient to resist the generated stresses. Thus, the scope of application of such lining shall be limited to relatively stable rocks at sites with well-known geology and well-developed technology for mining workings. In other conditions, the use of this technical solution is unsafe and reduces the reliability and durability of the shaft.

[0008] There is a method of sinking vertical shafts into soft watered rocks [Description of the invention to patent of the Russian Federation No. 2398967 dated July 23, 2009, IPC E21D 1/00, E21D 1/12, publ. on July 10, 2010, Bull. No. 25], that includes freezing of rocks and drilling and blasting operations, while drilling and blasting operations determine the position zone of the face with the maximum possible impact force of elastic waves acting on the freezing columns relative to the contact boundaries of two rocks with different physical and mechanical properties, after which rocks are getting destroyed in these zones in a mode providing the magnitude of stresses in freezing columns, created by elastic waves, equal to or less than the maximum allowable magnitude.

[0009] The disadvantage of this method is that it is strictly linked to the technology of rock freezing, which narrows the scope of its application. In addition, in the considered method the drilling and blasting method is used as the main method of rock destruction, which has a number of significant drawbacks, among which low productivity, danger, and the fundamental impossibility of accurate determination of the nature and magnitude of deformation of the work may be underlined, that is, the safety of the freezing columns in the case of the drilling and blasting method cannot be guaranteed. This, in turn, reduces the reliability, safety, and economic viability of shaft sinking.

[0010] There is a method of sinking deep shafts into soft watered rocks [Description of the invention to USSR copyright certificate No. 1126698 dated September 29, 1983, IPC E21D 1/12, publ. on November 30, 1984, Bull. No. 44], which includes preliminary determination of the elastic and strength characteristics of rocks in a frozen state, artificial freezing of rocks to create a temporary ice-rock enclosure, shaft sinking by pass and erection of lining, while the value of the ice-rock enclosure displacement during shaft pass is controlled in such a way that it do not exceed a predetermined limit value, depending on the thickness of the ice-rock enclosure, distance of sinking, rock pressure, and rheological parameters of the frozen rock mass and some technological features. Upon reaching the maximum value of the ice-rock enclosure displacement, a permanent lining is erected.

[0011] The disadvantage of this method is the narrow scope of application, due to its binding to the rock freezing technology. In addition, to implement the method it is necessary to first determine in laboratory conditions the characteristics of rocks in a frozen state, which requires a detailed study of the geology of the site, without which the method cannot be considered safe, and the constructed shaft - reliable and durable.

[0012] There is a method of sinking a shaft [Description of the invention to USSR copyright certificate No. 1286774 dated August 20,1985, IPC E21D 1/00, E 1D 1/12, publ. on January 30,1987, Bull. No. 4], including the formation of an ice-rock enclosure using freezing columns placed behind the shaft contour, a cyclic extension of the face by the sinking distance, erection of lining within the sinking after determining the moment of the beginning of the decrease in the bearing capacity of the ice-rock enclosure, which is determined using acoustic sensors placed in pre-drilled blast holes in an ice-rock enclosure by observing the development of an elastic area in the ice-rock enclosure, and the moment of the beginning of the decline of the ice-rock enclosure bearing capacity is defined as the time of reaching by elastic area the freezing columns.

[0013] The disadvantage of this method is the narrow scope of application due to its binding to the technology of rock mass freezing, as well as the need for preliminary operations (drilling blast holes for placement of acoustic sensors), which reduces the productivity of work, as well as the availability of additional instruments and devices for conducting numerous measurements.

[0014] There is a method of measuring the loading of a vertical shaft [Description of the invention to USSR copyright certificate No. 1288302 dated December 12 1984, IPC E21D 5/00, publ. on July 02, 1987, Bull. No. 5], which involve assessing the difference in the magnitude of deformations at the moment of tearing off the formwork and at the end of concrete setting and comparing this value with a permitted value.

[0015] The disadvantage of this method is the need for additional equipment for measurements. In addition, the loading of the shaft is determined only after fixing the workings, that is, there is no possibility of a quick response to emergency situations. Thus, the method is applicable for mining operations at sites with well-known geology and proven mining technology.

[0016] There is a method of constructing a vertical mine workings by drilling and blasting method (Description of the invention to RF patent No. 2493367 dated July 6, 2012, IPC E21D 1/03, published on September 20, 2013, Bull. No. 26], including drilling of soil or rock by means of a drilling machine with a manipulator, blasting rocks, excavating of soil or rock using an excavator bucket, erection a tubing lining using a self-propelled sinking stages.

[0017] The disadvantage of this method is the use of drilling and blasting technology for the destruction of rocks, which reduces the reliability, safety and economic efficiency of shaft sinking. As a rule, this and similar technologies are developed for theoretical, refined passing conditions, which do not include, in particular, the non-horizontal position of rock formations with different physic-mechanical properties, when the shaft passes through easily deformable adjacent rocks and, on the contrary, very stable rocks within a single level or through formations that lay clearly at a slant. The lining erected under such geological conditions sustains a non-normative load and is potentially subject to premature wear.

[0018] There is a shaft-sinking combine that includes a mounting frame for erecting a reinforcing lining and a face frame, panelized spacing ductile shell in the form of a series of stoplogs installed around the perimeter of the mounting and face frames and connected to it by means of spacing advancing hydraulic cylinders, an operating member for processing the sectional drawings (diameters) of the shaft made with the possibility of axial and radial movement in relation to the face frame, and a control system [Description of the invention to RF patent No. 2600807 dated September 09, 2015, IPC E21D 1/03, publ. on October 27, 2016, Bull. No. 30].

[0019] The disadvantage of the combine is the impossibility to control the process of erection a reinforcing tubing and / or concrete lining, depending on the operational changes in mining and geological conditions or if such conditions do not correspond to previously performed geological surveys.

[0020] The task to which the group of inventions is directed and the achievable technical result is to increase the reliability and safety of the construction of resource-intensive and complex engineering structures, such as mine shafts, in a wide range of geological conditions - from easily deformable to very stable rocks, including within one geological horizon, and specific technological features of mining operations, such as, for example, the presence or lack of preliminary shaft freezing, the presence of the primary lining and / or anchorage et al. This also resolves the task of improving the operating reliability of a shaft and performance of the shaft sinking; resource-intensity of mining is getting reduced.

[0021] In order to accomplish the task and to achieve the claimed technical result in the method of shaft constructing, including mechanical mining of the face, construction of temporary lining and the further construction of a permanent lining with a backlog from the working face not less than the level of conditional stabilization of residual deformation of the rock walls, at which the load on the lining does not exceed the current bearing capacity of the lining, the level of conditional stabilization of the residual deformation of the rock walls, at which the load on the lining does not exceed the current bearing capacity of the lining, is estimated by the nature of changes in the deformation of the rock walls, for which purpose, directly at the working face, at least at one point, the conditionally initial position of the shaft rock wall is fixed and, with the shaft sinking to a predetermined level, at least at one point, the measurement of the deformation of the rock wall occurs, in relation to its conditionally initial position, after which the nature of the change in the deformation of the shaft rock wall along the vertical extent from the fixation level of the conditional initial position of the shaft wall is established, and the load on the lining is determined by the current deformation at the level of conditional stabilization of the residual deformation of the created walls, by reference to the established nature of the deformation of the shaft walls.

[0022] Besides:

- the change in deformations of the rock walls is defined as the difference in the diameter of the shaft at the level of the working face at the point of the conditionally initial position of the rock wall of the shaft at a given level;
- the change in deformations of the rock walls is defined as the difference in the perimeters of the shaft at the level of the conditionally initial position of the shaft rock wall of the shaft at the face and at a given level;
- conditionally initial position of the rock walls of the shaft is fixed at the working face by assigning its processing diameter;
- measurements of deformation of rock walls are made at a given level simultaneously at several points along the perimeter of the shaft cross section and the nature of the change in deformation of the shaft rock is established according to the point with maximum deformation.

[0023] In order to accomplish the task and to achieve the claimed technical result displacement measuring sensors are installed between at least one stoplog and one of the frames or both frames and / or at least between two adjacent stoplogs in the shaft sinking combine. The shaft sinking combine includes the mounting frame for mounting the lining and the face frame, panelized spacing ductile shell in the form of a series of stoplogs installed around the perimeter of the mounting and face frames and connected to it by means of spacing hydraulic jacks, an operating member for processing the cross section of the shaft made with the possibility of at least radial movement in relation to the face frame, and a control system, which in turn includes a measurement result processing unit forming the ordinate of the conditional stabilization level of the residual deformation of the rock walls at the working face, and also a control unit for the processing of the cross-section of the shaft by the operating member.

[0024] In addition, at least a portion of the displacement measuring sensors are located on or integrated into the spacing hydraulic jacks.

[0025] The group of inventions is illustrated by a drawing, which shows a general view of a shaft-sinking combine at the face of a shaft with a scheme for stabilizing its rock walls.

[0026] In this description, there are terms that require some special explanation.

[0027] The term "level of conditional stabilization of residual deformation of rock walls" shall be understood as the level at which the load on the lining due to deformations of the rock walls resulting from sinking operations will not exceed the current bearing capacity of the lining.

[0028] The term "the given level of shaft extension" shall be understood as movement of the shaft sinking combine in the axial direction into the shaft up to a face processing step, which is usually taken as a multiple of the height of the operating body.

[0029] The shaft-sinking combine includes a mounting frame *1* for erecting a temporary (omitted for clarity) and permanent lining *2* and face frame *3*, a panelized spacing ductile shell in the form of a series of stoplogs *4* installed around the perimeter of the face frame, connected to it by means of spacing hydraulic jacks *5*, an operating member *6* processing the cross section of the shaft, made with the possibility of radial and, possibly, axial movement in relation to the face frame *3*, and a control system (omitted for clarity). In this combine, at least between one stoplog *4* and one of the frames - frame *3* or frame *1* or between both frames *1* and 3 and / or, at least between two adjacent stoplogs *4*, the displacement measuring sensors *7* are installed, and the control system includes a result measurement processing unit, which forms the ordinate of the level *H* of the conditional stabilization of the residual deformation of the rock walls *8* at the working face 9, and the control system also includes a control unit for the processing of the shaft cross-section by the operating member *6*. It shall be noted that some of the displacement measuring sensors *7* installed between the stoplogs *4* and frame *3* or frame *1*, or between both frames *1* and *3*, are connected to or integrated into the advancing hydraulic cylinders 5.as a matter of convenience

[0030] Structurally, this shaft-sinking combine is one of many options for implementing the original method of constructing a shaft, which includes mechanized development of the face *9*, the erection of temporary lining (for example, spray concrete) and the further erection of a permanent lining *2* with the lag from the working face 9 not less than the level *H* of the conditional stabilization of the residual deformation Δ of the rock walls 8, at which the load on the lining *2* does not exceed its current bearing capacity, and the level *H* of the conditional stabilization of the residual deformation Δ of the rock walls 8 is determined by the nature of the changes in the deformations of the rock walls *8*, for which, directly at the working face *9*, at least at one point *O* the conditionally initial position of the shaft rock wall 8 is fixed, and, with the shaft sinking to a predetermined level, at least at one point h_1, the change of deformations δ_1 of the rock wall 8 relative to its conditionally initial position is measured, and then the nature $a=f(\delta, h)$ of the change in deformation of the shaft rock walls 8 is established by height of the shaft wall 8 from the fixation level of the conditionally initial position (point O), and the load on the lining is measured by the current deformation value δ_i; at the level *H* of conditional stabilization of the residual deformation of the rock walls *8* according to the established nature of the deformation of these walls *8*.

[0031] Change in deformations $\delta_1, \delta_2, \dots \delta_i$ of the rock walls 8 are defined as the difference in shaft diameters at the working face *9* at the point *O* of the conditionally initial position of the shaft rock wall *8* of the shaft -diameter *D* - and at a given level $h_1, h_2, \dots h_i$ - diameter $d_1, d_2, \dots di,$ - and / or a change in the deformations δ of rock walls *8* is defined as the difference in the perimeters of the walls *8* of the shaft at the conditionally initial position of the shaft rock wall *8* at the working face *9* and at a given level, and the conditionally initial position of the shaft rock wall *8* is fixed at the working face *9* by setting the diameter *D* of its processing.

[0032] The deformations δ of the rock walls *8* are measured at a given level simultaneously at several points along the perimeter of the cross section of the shaft, and the nature of the change in deformations δ of the shaft rock walls 8 is determined at the point with maximum deformation (i.e., the "worst" of the measurements , for example when the shaft is passing through rock strata with different physical and mechanical properties).

[0033] Using the obtained data for the displacement of the shaft walls *8* at a known distance from the working face *9*, it is possible to restore the nature of the function that describes the deformation Δ of the walls of the unlined shaft during sinking depending on distance *h* to the working face *9*. Such function (see the book by N. S. Vulychev "Mechanics of underground structures" and the article by V. E. Bolikov and et al. "On the issue of sinking shaft in a tectonically stressed rock mass"), can be described as a curve representing one of the parabola branches, that is, as the following quadratic function;

$$y = ax^2 + bx + c,$$

where:

y (h) - distance from face,
x (Δ) - face walls deformation,
a, b and *c* - some coefficients.

[0034] The extreme point of this hypothetical parabola is the point at which the deformations Δ of the walls and the distance *h* from the face are equal. It is logical to assume that point *O* is the origin in the coordinate system when considering the problem, at which the deformation of the shaft walls 8 is zero, as well as the distance from the face *9*. That is, the origin and extreme point of the function of the considered function in this case coincide (coefficients *b* and c are equal to zero). We take this point as the conditionally initial position of the rock wall 8. Then the general form of the quadratic dependence can be transformed as follows:

$$y = ax^2.$$

[0035] Coefficient *a* characterizes the function and fully describes the combination of the meaningful factors (mining-geological and technological) in the considered sinking area.

[0036] Having obtained, by measuring, a deformation value δ_i of the shaft walls 8 at least at one point at a known level h_i relative to the level of the conditionally initial position, the nature of the whole dependence may be established by obtaining the value of coefficient *a* from the following formula

$$a = \frac{h}{\delta^2}.$$

[0037] The lining shall be erected at the level *H* of the conditional stabilization of the convergence of the rock walls *8*, when the increment of the distance value *h* from the face does not lead to a significant increase in the deformations δ of the of shaft walls.

[0038] The above discussion is only an example of interpretation of the obtained measurements data. In fact, a mathematical description of the effect of the distance *h* from the face on the displacement δ of the rock walls due to convergence is a problem that currently has many solutions described by various functional dependences - exponential, logarithmic, etc. (see, for example, the work of N.S Vulychev. "Mechanics of underground structures. Textbook for high schools". - M., Nedra, 1982. 270 p.; G.A. Krupennikov, et al. "Rock masses Interaction with the vertical mine workings lining". - M., Nedra, 1966. - 315 p.; N.N Fotieva. "Calculation of lining for underground structures in seismically active areas".. - M., Nedra, 1980. - 221p.; K.V. Ruppeneit "Deformability of fractured rock masses". - M., Nedra, 1975. - 223 p. and other works). The use of these dependences implies the use of empirical coefficients, and its determination will require numbers of preliminary measurements, in contrast to the proposed method, in which, theoretically, to carry out one measurement will be sufficient. In any case, none of the existing mathematical descriptions is prevailing and at the same time all of them include the guaranteed margin of safety arising from the impossibility to obtain an accurate geological picture of the shaft. On the other hand, measurements made directly during the sinking allow, in particular, to reduce the unnecessary margin of safety of the erected lining without decreasing the reliability of the erected structure.

[0039] The essential features of the group of inventions have been analyzed.

[0040] When constructing all the shafts, the lining *2*, in theory, one shall erect the lining 2 at a level not lower than the level *H* of the conditional stabilization of the residual deformation Δ of the rock walls *8*, and this value is determined in advance by known theories. In practice, this is achieved either by erecting the lining 2 at a level that is reliably above the theoretical level *H* of the conditional stabilization, or by erecting the lining *2* at a "convenient" distance from the face *9* with an indubitable increase in the margin of safety of the lining 2. In all cases the diameter *D* of the shaft section "in sinking" and, accordingly, the materials intensity of lining 2 shall be increased.

[0041] When constructing the shaft in accordance with this invention, the level *H* of nominal stabilization of the residual deformation Δ of the rock walls 8 is actually measured directly during the course of the shaft sinking, for which a measurement interval acceptable for a given sinking speed is set (as a rule, such speed occurs at the stage of shaft extension or face processing) and the level *H* of nominal stabilization of the residual deformation Δ of the rock walls 8 is reliably determined. This allows, in particular, to reduce the diameter D of the cross section of the shaft "when sinking" and, accordingly, to reduce the materials intensity of lining *2* without compromising its margin of safety.

[0042] As an additional information, the mining enterprise receives a factual description of the physic and mechanical properties of the shaft along its full vertical extent, which, if desired, may be compared with previously performed geological surveys and, if necessary, adjusted the technological specification sheet of upcoming repair and restoration works.

[0043] The change in deformations δ of rock walls *8* is defined as the difference in shaft diameters at the working face *9 - D,* at point *O* of the conditionally initial position of the shaft rock wall *8* and d_i, at a given level h_i or, as the difference in the shaft perimeters at "zero" level of the conditionally initial position of the shaft rock wall *8* at the working face *9* and at a given level h_i. These measurements can be carried out with high accuracy by simple and common methods, for example, by using displacement measuring sensors 7 (or indirect methods, for example, using omitted for clarity pressure sensors, etc.), for which the perimeter of the shaft cross section is lined with a panelized spacing ductile shell in the form of a series of stoplogs *4* installed around the working face of the face frame. In addition to locating the boundaries of the shaft walls 8, which makes it possible to take a reading of a sufficient number of averaged deformation values δ of the walls *8*, stoplogs *4* also protect the face area *9* from uncontrolled rock collapse.

[0044] The above measurements of deformations δ require comparison with a certain conditionally initial position of the shaft rock walls *8*. This position is successfully fixed at the working face *9* by setting the diameter *D* of its processing, which is carried out by the specified work program of the operating member *6* of the shaft-sinking combine for processing the cross section of the shaft. Depending on the design, the operating member *6* is made capable of radial movement in relation to the face frame *1*. If necessary, the axial movement (shaft extension, face processing) of the operating member *6*, for example, a milling cutter (cutting drum) *10*, is provided either with its own axial movement, or movement in pair with the face frame *1*.

[0045] In order to increase the accuracy of measurements, deformations measurements δ_i of the rock walls *8* are performed at a given level h_i at more than one point, which would be sufficient for rocks with the same physical and mechanical properties (the so-called ideal conditions), but at the same time performed at several points along the perimeter of the cross section of the shaft, and the nature of the change in the deformations is established not by the average value of the deformations $\delta_{i\,av}$, but by the point with the maximum deformation δ_{imax}. by "the worst" of measurements.

[0046] The design of the shaft-sinking combine is characterized in that the stoplogs *4*, which are tightly adjacent to the shaft rock walls *8*, are equipped, as mentioned above, with one or more displacement measuring sensors *7*. Theoretically, one sensor *7* is sufficient between one of the stoplogs *4* and one of the frames - face frame *1* or mounting frame *3* or between two adjacent stoplogs *4.* However, considering rather large dimensions of the shaft, it is more efficient to carry out the measurements by several sensors *7* and at several levels, for example , by the number of stoplogs *4*, if the sensors *7* are located between the stoplogs *4* and the face frame *1* and the mounting frame *3*, or, if the sensors *7* are located between adjacent stoplogs *4*, - at its lower and upper sections. Displacement measuring sensors *7* between parts of the combine, installed at one level, for example, at level h_1, converting these measured displacements to deformation values, for example, Δ_1 values of the rock walls *8* at the same level, it is desirable to duplicate the same at another level, for example at level h_2 , assigned to some removal from the first or several, for example, three or more spaced levels, if necessary. In practice this can be achieved by placing the sensors *7* at the level of the face frame *1* and at the level of the mounting frame *3* or so, if the sensors *7* are placed between adjacent stoplogs *4*, and the metal structures of frames *1* and *3* restrict access to them for some reason. The use of multiple sensors *7* at different levels h_i allows to increase the accuracy of measurements of deformation δ_i of the rock walls 8 and to more reliably identify and establish the level *H* of the conditional stabilization of the residual deformation Δ of rock walls *8*, at which the load on the lining *2* is guaranteed not to exceed its current bearing capacity.

[0047] There are three possible options for neutralizing excessive deformations:

1 - increasing the diameter of the shaft processing;
2 - using preliminary lining (spraying, anchoring, etc.);
3 - shifting the works on installation of the lining *2* along the vertical extent of the shaft.

[0048] The latter method of neutralization in the absence of technological contraindications is the most preferred.

[0049] Thus, having received a comprehensive information on the level *H* of stabilization of the residual deformation Δ of the rock walls *8*, it is possible to start erecting the lining *2* from this section or above. In practice, a two-level (i.e., having a face frame *1* and mounting frame *3)* combine is constructed in such a way so that the distance between the face frame *1* and mounting frame *3* is guaranteed to overlap the level H of nominal stabilization of the residual deformation Δ of the rock walls *8*, for example, by one meter for an eight-meter shaft diameter. This is facilitated by the corresponding dimensions of the stoplogs *4* in height and its ductility (the ability to operate metal structures within elastic deformations, including through the use of spacing hydraulic jacks 5, makes it possible to take independent values from each of the sensors *7* spaced apart along the vertical extent.

[0050] The measurement of displacements between adjacent stoplogs 4 is carried out on account of the presence of a guaranteed gap between them.

[0051] Long stoplogs *4* has one more advantage - they prevent the uncontrolled shedding of the rock walls 8 between the face *9* and the level of the factual installation (erection) of the lining *2*. This is very important when on the face frame *1* or on the combine a variety of planned activities can occur , from equipment repairs to brigade changes, etc.

[0052] As mentioned above, the stoplogs *4* are connected to the face frame *1* and the mounting frame 2 by means of spacing hydraulic jacks *5*. This makes it possible to install measurement sensors *7* on all or part of the spacing hydraulic jacks *5*, which greatly simplifies the design of the shaft-sinking combine without compromising the structure reliability .

[0053] If it turns out that on a certain level the level *H* of conditional stabilization of the residual deformation of the rock walls *8* is higher than the level of the mounting frame *3*, then the control system will warn about this. In this case, a series of measures is taken to reduce the deformation of the walls 8 of the shaft near the face *9* (spraying, anchoring, increasing the treatment diameter etc.). In addition, it is possible to use an additional suspended scaffold above the mounting frame *3.* It should be noted that such cases are not so typical during shaft sinking.

[0054] In practice, the possibility to track the level *H* of conditional stabilization of the residual deformation Δ of the rock walls 8 allows to intervene in the sinking process - the control system, for example, commands the operating member *6* to switch to the processing mode of the cross-section of the shaft, - the diameter *D* of the shaft "in sinking" decreases, but not less than the value of necessary "inner" diameter of the shaft , taking into account the thickness of the lining *2*, otherwise the diameter *D* of the shaft "in sinking" increases.

[0055] It should be noted that the controlled "taper" of the shaft near the face 9 contributes to the displacement of the shaft-sinking combine by another step deeper into the face with minimal energy consumption.

[0056] The control of the deformation δ_i in the case of stopping the sinking operations allows to track the displacements of the rock walls 8, which are dangerous for the shaft-sinking combine and can lead to its jamming in the shaft, which is a consequence of the parametric reserve of technological capabilities of the combine. Existing shaft sinking technologies include special, rather laborious works to exclude the possibility of such situation.

[0057] It is definitely true, that the method of constructing a shaft using the claimed technology can be structurally carried out on combines of a different design than described above, but this shaft-sinking combine is structurally and in terms of manufacturing and operating costs is optimal for a comprehensive solution of the problems of construction of shafts .

[0058] As can be seen, the design and technological features of the claimed technical solutions increase the reliability and safety of the shafts construction workings

- resource-intensive and complex engineering structures - in a wide range of geological conditions - from easily deformed to very resistant rocks, including within one geological horizon. This practically makes it possible to significantly reduce or eliminate the influence of specific technological features of mining operations, such as, for example, the presence or lack of preliminary freezing of the shaft, the presence of primary lining and / or anchoring, etc. This allows to optimize the shaft sinking process and the thickness of the lining *2* decreasingly. In practice, this may look, in particular, as a decrease of the volume of wasted rock and, consequently, as an increase in sinking speed with the same volume of wasted rock, and as a saving in concrete for the erection of lining *2* while increasing the operational reliability of the shaft. As a result, consumers will obtain a modern mining enterprise with optimal resource costs.

[0059] The invention is illustrated by the following Examples:

Example 1 is a general case of a shaft sinking.

[0060] The elements of the combine are mounted in a pre-sink zone (short section of the shaft, mounting or launching chamber) using cross-functional crane equipment. All necessary communications are connected (electricity, water, air). As a result, the mounting frame *1* and face frame *3* are located inside the "skirt" of the stoplogs *4*, which contact the stoplogs *4* by means of spacing hydraulic jacks *5.* The mounting frame *3* can be connected to the face frame 1 in any known manner, for example, as described in RF patent No. 2600807 dated September 29, 2015.

[0061] The control system is adjusted to the diameter of the shaft "in sinking" in accordance with data previously obtained from mining and geological surveys.

[0062] After installing the equipment and checking its performance at idle, the treatment process of the face *9* begins.

[0063] The operating member *6* of the processing of the cross-sectional diameter of the shaft, made, for example, in the form of a cutter (cutting drum) *10*, begins to operate in the face *9.* The destroyed rock is carried up to the surface.

[0064] After developing the first layer of rock, the combine, together with the stoplogs *4*, is shifted over the respective sinking distance. The control system starts to analyze the data obtained from the displacements measuring sensors *7* for measuring the displacements (deformations) of the rock walls *8* and compare it with the conditionally initial position (zero points) at the face *9.* The maximum of the values of the measurements made is selected - the so-called. "Worst" measurement. It becomes possible to establish the first as yet approximate value of the level *H* of conditional stabilization of residual deformation Δ of the rock walls *8.*

[0065] As the shaft sinks, the control system starts to analyze the values of the measurements taken at different levels, on the basis of which there can be made a fairly reliable picture of determining the level of conditional stabilization of the residual deformation Δ of the rock walls *8*, at which the load on the lining *2* will not exceed its current bearing capacity. At the same time, each subsequent measurement confirms the conclusions of the primary measurements or quickly reveals trends of deformations δ_i of the rock walls.

[0066] In accordance with the technological regulations, installation of concrete, tubing, combined or some other type of lining *2* is started.

[0067] In rocks with the same physical and mechanical properties, the control system in no way "intervenes" in the treatment of the face *9* by the operating member *6*. However, as soon as the properties of the rock begin to change, the control system displays a different level of conditional stabilization of the residual deformation Δ of the rocks 8. If this level stays within the level of the mounting frame *3*, the installation of the lining *2* continues. If it goes up beyond the level of the mounting frame *3*, then the lining 2 is installed using additional instruments, such as a suspended scaffold.

[0068] Depending on the strength (hardness) of the processed rock, a control signal is generated to the operating member *6* - for harder and more resistant rocks the processed shaft diameter is reduced, for less hard and resistant rocks it is increased. Correspondingly, the thickness of the lining 2 is changed while maintaining the given "inner" diameter of the shaft.

[0069] The effect of the use of the inventions will be greater, the greater the depth of the shaft, and this is many hundreds and even thousands of meters.

Example 2 - continued construction of the shaft using new technology.

[0070] When sinking a certain shaft, instability of the rock walls is revealed, requiring additional work to study the stability of the rocks and its strengthening. As a result, the costs of erecting lining significantly increased with the speed of sinking decreasing.

[0071] A decision is made on the technological combination of the process of measuring current displacements (deformations δ_i) of the rock walls and, accordingly, identifying the level *H* of conditional stabilization of its residual deformation Δ, at which the estimated lining loads will not exceed the current bearing capacity of the rock walls *8.* If it is not possible to equip the existing combine with an appropriate control system for implementing this method, a decision is made to dismantle it and deliver another shaft-sinking combine equipped with the function of on-line monitoring of the level *H* of conditional stabilization of residual deformation Δ of rock walls.

[0072] A pre-sink section (starting chamber) is prepared at the working face *9* and a shaft-sinking combine, designed in accordance with the invention, is installed thereto.

[0073] After installing the equipment and checking its operability at idle, the treatment of the face *9* starts according to Example 1

[0074] As a result, the volume of wasted rock decreases along with the volume of concrete used for erecting the lining, and the shaft sinking speed increases along with its operational reliability.

Example 3 - sinking a pre-frozen shaft.

[0075] The existing experience of pre-frozen shafts sinking revealed the problem of periodic damage to the cooling pipes and the associated high costs of its repair or, if permissible, the localization of damage.

[0076] As described above, the presence, as well as the lack of freezing of the shaft for a shaft-sinking combine that implements the claimed method of construction (sinking), does not distort the picture of objective monitoring of the level *H* of conditional stabilization of residual deformation Δ of the rock walls *8* for erection the lining *2*, in which the load on the erected lining *2* will not exceed its current bearing capacity. The effect of using the claimed inventions is to reduce the volume of the waste rock and, as a result, the possibility of reducing the "inner" diameter of the shaft processing and increasing the distance from the cutter *10* to the cooling pipes, which reduces the likelihood of its damaging. Practice shows that, for example, for a shaft having an "inner" diameter of 8 m, the diameter "in sinking" can be reduced by 0.5 m, which provides a "margin" for processing to cooling pipes of an average of 0.25 m. This, in practice, guarantees trouble-free passage of the shaft to the entire depth of the mine.

[0077] In addition, damage to the cooling pipes can occur if decisions are not made or untimely made to neutralize deformations of the rock walls 8 of the shaft, since its convergence can lead to a significant distortion of the cooling pipes, which will impair its integrity and operability. In such a situation, it is extremely useful to control the magnitude of deformations δ of the rock walls 8. So, the magnitude of deformations δ of the rock walls 8 reaches, for example, 80% of the permissible deformation rate of the cooling pipes, measures should be taken to eliminate these deformations, for example, using anchoring and / or primary lining, for example, spray concrete.

[0078] Shaft sinking is carried out similarly to Examples 1 and 2.

[0079] As a result of the use of inventions, the reliability and safety of shaft construction in a wide range of mining and geological conditions have increased - from easily deformable to highly resistant rocks, including within the same geological horizon - and the specific technological features of mining workings, such as, for example, the presence or lack of preliminary freezing of the shaft, the presence of primary lining and / or anchoring, etc. The operational reliability of the shaft has increased sinking productivity while reducing the resource intensity of mining workings.

Claims

1. The method of constructing a shaft, including mechanical mining of the face, construction of a temporary lining and further construction of a permanent lining with a backlog from the working face by an amount not lower than the level of conditional stabilization of the residual deformation of the rock walls, at which the load on the lining does not exceed the current bearing capacity of the lining, **CHARACTERIZED IN THAT** the level of conditional stabilization of the residual deformation of the rock walls, at which the load on the lining does not exceed its current bearing capacity, is determined by the nature of changes in deformations of the rock walls, for which purpose, directly at the working face, at least at one point, the conditionally initial position of the rock wall of the shaft is fixed and, as the shaft sinks to a predetermined level, at least one point is used to measure the deformations of the rock walls with respect to its conditionally initial position, after which the nature of the change in the deformation of the rock walls of the shaft along its vertical extent from the level of fixation of the conditionally initial position of the wall of the shaft is established, and the load on the lining is determined by the current deformation value at the level of conditional stabilization of the residual deformation of the rock walls based on the established nature of the deformation of the shaft walls.

2. The method according to claim 1, **CHARACTERIZED IN THAT** the change in the deformation of the rock walls is defined as the difference between the shaft diameters at the working face level at the conditionally initial position of the rock wall of the shaft and at a given level.

3. The method according to claim 1, **CHARACTERIZED IN THAT** the change in deformations of the rock walls is defined as the difference between the perimeters of the shaft at the conditionally initial position of the rock wall of the shaft at the working face and at a given level.

4. The method according to claim 1, **CHARACTERIZED IN THAT** the conditionally initial position of the rock wall of the shaft is fixed at the working face by assigning a diameter for its processing.

5. The method according to claim 1, **CHARACTERIZED IN THAT** the measurements of the deformations of the rock walls are made at a predetermined level simultaneously at several points along the perimeter of cross-section of the shaft and establish the nature of the change in the deformation of the rock walls of the shaft at a point with maximum magnitude of deformation [according to the worst of measurements].

6. A shaft-sinking combine that includes a mounting frame for erecting a lining and a face frame, a panelized spacing ductile shell, in the form of a series of stoplogs installed around the face frames, connected with it by means of hydraulic jacks, an operating member for processing the cross section of the shaft, made with the possibility of at least radial movement in relation to the face frame, and a control system, **CHARACTERIZED IN THAT**, at least between one stoplog and one of the frames or both frames and / or at least between two adjacent stoplogs, displacement measuring sensors are placed, and the control system includes a processing unit for the measurement result, which forms the ordinate of the level of conditional stabilization of the residual deformation of the rock walls from the working face, and the control system also includes a control unit for processing the cross section of the shaft by the operation member.

7. The combine according to claim 6, **CHARACTERIZED IN THAT**, at least, a part of the displacement measuring sensors is located on or integrated into hydraulic jacks.

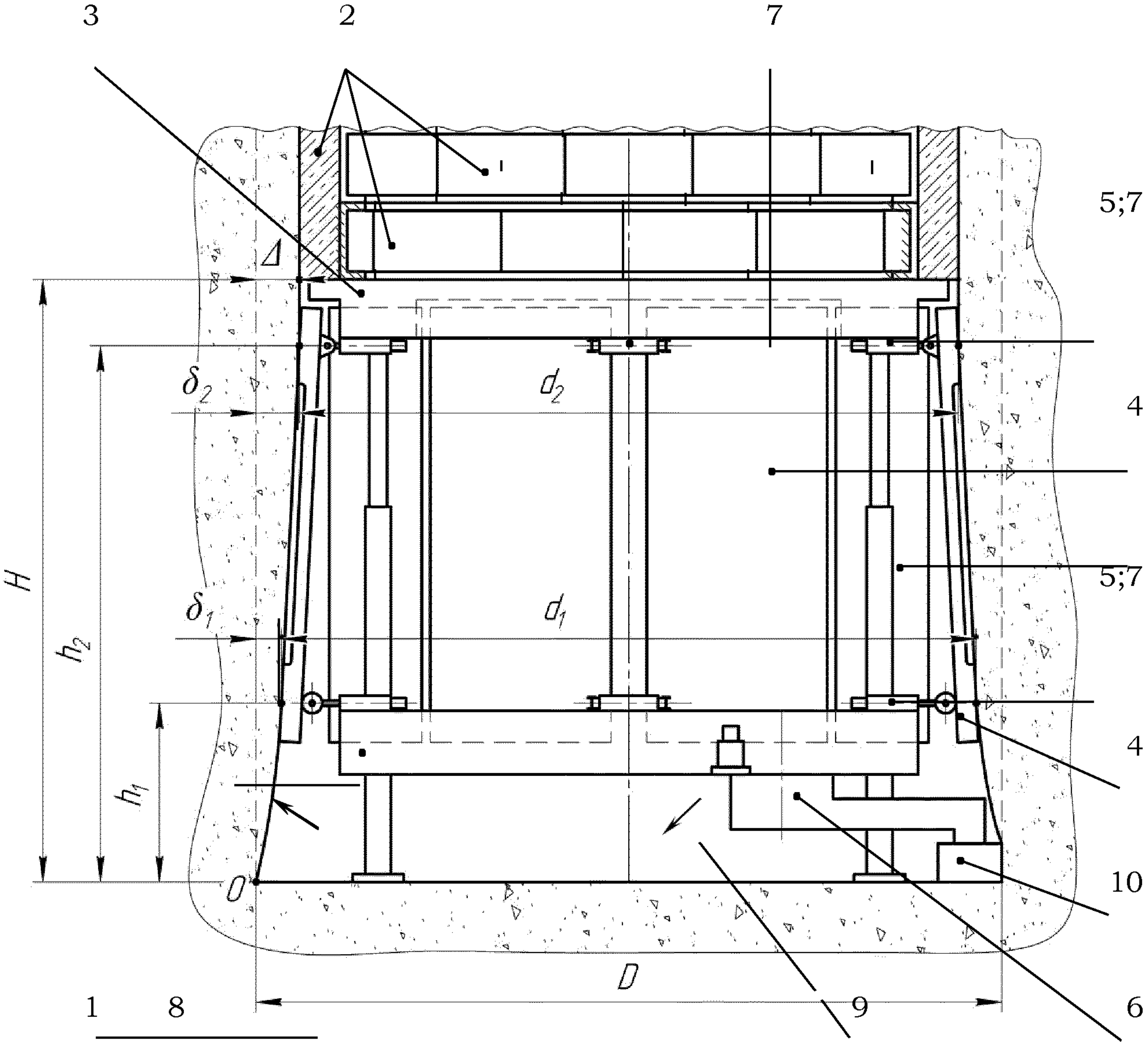

Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/RU 2019/000595

A. CLASSIFICATION OF SUBJECT MATTER

E21D1/03 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21D 1/00-1/16, 5/00-5/12, 9/00-9/02, 11/00-11/40

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, Information Retrieval System of FIPS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	RU 2060394 C1 (INSTITUT GORNOGO DELA SO RAN 20.05.1996, p. 4, left column, lines 47-right column, line 3	1-7
D, A	RU 2600807 C1 (OBSCHESTVO S OGRANICHENNOI OTVETSTVENNOSTJU "SKURATOVSKY OPYTNO-EKSPERIMENTALNYI ZAVOD") 27.10.2016, p. 8, lines 6-22, 29-34, 44 -p. 9, line 16	1-7
A	SU 1606698 A1 (VNIPKI PO OSUSHENIJU MESTOROZHDENII POLEZNYKH ISKOPAEMYKH, SPETSIALNYM GORNYM RABOTAM, RUDNICHNOI GEOLOGII I MARKSHEIDERSKOMU DELU) 15.11.1990	1-7
D, A	SU 1288302 A1 (VNII GORNOI GEOMEKHANIKI I MARKSHEIDERSKOGO DELA) 07.02.1987	1-7
D, A	RU 2398967 C1 (GOSUDARSTVENNOE OBRAZOVATELNOE UCHREZHDENIE VYSSHEGO PROFESSIONALNOGO OBRAZOVANIYA MOSKOVSKY GOSUDARSTVENNY GORNY UNIVERSITET) 10.09.2010	1-7
A	US 2519041 A (GLUCK GEORGE S) 15.08.1950	1-7

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 December 2019 (09.12.2019)	12 December 2019 (12.12.2019)
Name and mailing address of the ISA/ RU	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)

REFERENCES CITED IN THE DESCRIPTION

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