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Satbayev University

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ИЗВЕСТИЯ

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NEW TECHNOLOGY OF UNCOVER THE ORE HORIZON BY THE METHOD OF IN-SITU LEACHING FOR URANIUM MINING

Abstract. The article presents the main factors that reduce the formation permeability and the processes of artificial penetration of particles into the rock pores and cracks, as well as a list of equipment for wells drilling that convert the direct flow of drilling flush fluid into the reverse one in the bottom-hole zone. The traditional processes of preparing a well for operation and measures for processing the productive formation zone are described.

The article describes new drilling methods recognized by test work in the drilling company «Volkovgeologiya» JSC. Based on research studies and analysis of the regularities of the decline of wells, an airlift method of drilling an ore zone with a specially developed design is given, as a result of which a significant effect is formed by reducing the amount of repair and restoration work and funds spent on drilling operations. The implementation of the proposed idea at the facilities of drilling companies of «Volkovgeologiya» JSC arose on the basis of the analysis of drilling technological wells associated with uranium deposits and the identified complications during drilling through rocks of the sedimentary complex (clays, sands, with layers of bedrock - argillites, aleurolites, aleurites, sandstones, limestones, gypsum, etc.). When opening productive formations composed of fine-grained sands, almost often there is a violation of their natural filtration properties, which is expressed primarily in a decrease in the permeability of the near-wellbore zone rocks as a result of the formation of a colmatation zone - a section of the well into the pores of which particles of the dispersed phase of the drilling flush fluid have penetrated. One of the features of the proposed method was initially set the task of reducing the number of repair and restoration works and the costs of carrying them out, while simultaneously solving the issue of reducing the cost of drilling, construction and increasing the productivity of technological wells. The work presents a diagram of the technological equipment and tooling developed by the authors, as well as describes the drilling technology that allows preserving the initial filtration properties of the ore-bearing horizon by reducing the amount of infiltrate squeezed by the hydrostatic pressure of the column of flushing liquid into the bottom-hole zone, which is carried out with direct supply of flushing solution down the bottom..

Key words: airlift, productive layer, drilling, well, ore-bearing horizon, mud pump, compressor.

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УРАН ӨНДІРУ ҮШІН ЖЕРАСТЫ ҰҢҒЫМАЛЫҚ ШАЙМАЛАУ ТӘСІЛІМЕН КЕН ҚАБАТТАРЫН АШУДЫҢ ЖАҢА ТЕХНОЛОГИЯСЫ

Аннотация. Мақалада «Волковгеология» АҚ бұрғылау компаниясында сынақ жұмыстары барысында танылған бұрғылаудың жаңа әдістері баяндалған. Зерттеу ізденістері мен технологиялық ұңғымалар дебитінің төмендеу заңдылықтарын талдау негізінде арнайы жасалған конструкциясы бар кен аймағын бұрғылаудың эрлифт әдісі келтірілген, оны қолдану нәтижесінде жөндеу-қалпына келтіру жұмыстарының санын және бұрғылау жұмыстарын жүргізуге жұмсалатын қаражатты қысқарту есебінен елеулі әсер қалыптасады.

Технологиялық ұңғымалардың дебитінің төмендеу заңдылықтарын зерттеу және талдау негізінде кен аймағын арнайы дайындалған конструкциясы бар эрлифті бұрғылау әдісі ұсынылған, оны қолдану нәтижесінде жөндеу және қалпына келтіру жұмыстарының санын және бұрғылау жұмыстарына жұмсалатын қаражатты азайту арқылы айтарлықтай нәтиже қалыптасады. Ұсынылған идеяны «Волковгеология» АҚ бұрғылау компаниясының нысандарында енгізу уран кен орындарына арналған технологиялық ұңғымаларды және шөгінді кешеннің (саздар, құмдар, байырғы тау жыныстарының қабаттары бар - аргиллиттер, алевролиттер, алевриттер, құмтастар, әктас, гипс және т.б.) тау жыныстарын бұрғылау кезінде анықталған асқынуларға жүргізілген талдау негізінде пайда болды. Ұсақтүйіршікті құмдардан тұратын өнімді қабаттарды ашу кезінде олардың табиғи фильтрациялық қасиеттері дерлік бұзылады, бұл ең алдымен бітелу аймағының – кольматацияның пайда болуы нәтижесінде ұңғыма түп маңындағы тау жыныстарының өткізгіштігінің төмендеуінен, ұңғыма кеуектеріне бұрғылау ерітіндісінің дисперстік фазасының бөлшектері еніп кетуінен көрінеді. Ұсынылған әдістің ерекшеліктерінің бірі бастапқыда жөндеу және қалпына келтіру жұмыстарының санын және оларды жүзеге асыру шығындарын азайту, сонымен қатар технологиялық ұңғымаларды бұрғылау, құрылымдау және өнімділікті арттыру барысында шығындарын азайту мәселелерін шешу болып табылады. Жұмыста авторлар әзірлеген технологиялық жабдықтар мен құрал-саймандардың схемасы берілген, сондай-ақ, жуу сұйықтығының бағанының гидростатикалық қысымымен төменгі шұңқыр аймағына түсетін инфильтрат мөлшерін азайту арқылы кенжарға жуу ерітіндісін тікелей беру арқылы кен қабаттарының бастапқы сүзу қасиеттерін сақтауға мүмкіндік беретін бұрғылау технологиясы сипатталған.

Түйін сөздер: эрлифт, өнімді қабат, бұрғылау, ұңғыма, кенді горизонт, бұрғылау сорабы, компрессор.

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НОВАЯ ТЕХНОЛОГИЯ ВСКРЫТИЯ РУДОНОСТНОГО ГОРИЗОНТА СПОСОБОМ ПОДЗЕМНОГО СКВАЖИННОГО ВЫЩЕЛАЧИВАНИЯ ДЛЯ ДОБЫЧИ УРАНА

Аннотация. В статье приведены основные факторы, снижающие проницаемость пласта и процессы искусственного проникновения частиц в поры и трещины горных пород, а также приведен перечень оборудования для бурения скважин, преобразующие прямой поток промывочной жидкости в призабойной зоне в обратный. Описаны традиционные процессы подготовки скважины к эксплуатации и мероприятия по обработке зоны продуктивного пласта.

В статье изложены новые методы бурения, признанные испытательными работами в буровой компании АО “Волковгеология”. На основе исследовательских изысканий и анализа закономерностей падения дебита технологических скважин приведен эрлифтный способ бурения рудной зоны со специально разработанной конструкцией, в результате применения которой образуется значимый эффект за счет сокращения количества ремонтно-восстановительных работ и средств затрачиваемых на проведение буровых работ. Внедрение предлагаемой идеи на объектах буровых компаний АО «Волковгеология», возникло на на основе проведенного анализа бурения технологических скважин, приуроченных к урановым месторождениям и выявленных осложнениях при бурении по горным породам осадочного комплекса (глины, пески, с прослоями коренных горных пород - аргиллиты, алевролиты, алевриты, песчаники, известняки, гипсы и т.п.). При вскрытии продуктивных пластов, сложенных мелкозернистыми песками, практически зачастую происходит нарушение их естественных фильтрационных свойств, что выражается прежде всего в уменьшении проницаемости пород приствольной зоны в результате образования зоны кольматации – участка скважины, в поры которого проникли частицы дисперсной фазы промывочной жидкости. Одной из особенностей предлагаемого способа изначально поставлена задача на снижение количества ремонтно-восстановительных работ и затрат на их проведение, при этом одновременно решается вопрос снижения затрат на бурение, сооружение и увеличение производительности технологических скважин. В работе приведена схема разработанного авторами технологического оборудования и оснастки, а также описана технология бурения, позволяющая сохранить первоначальные фильтрационные свойства рудоносного горизонта за счет сокращения количества инфильтрата, задавливаемого гидростатическим давлением столба промывочной жидкости в призабойную зону, который осуществляется с прямой подачей на забой промывочного раствора.

Ключевые слова: эрлифт, продуктивный пласт, бурения, скважина, рудоносный горизонт, буровой насос, компрессор.

Introduction. In-situ leaching (ISL) method of uranium mining was first used in the 1960s and accounted for 50% of world uranium production in 2019. The ISL method, in comparison with traditional methods, provides a lower production cost, has a lower negative impact on the environment and provides high performance in the field of industrial safety and labor protection. The processes of uncover a productive formation and its development during the construction of technological wells for in-situ leaching of uranium are decisive for obtaining a highly productive and durable technological well (Karmanov, 2021: 7, Chen, 2018: 9, Hu, 2017:7). The use of optimal technology in the process of carrying out these works significantly increases the efficiency of drilling such wells. The main condition for increasing the efficiency of drilling operations is the use of such methods of opening and developing a productive formation, which ensure the preservation of its natural porosity and permeability or contribute to their increase in the bottom hole area of the well.

In the exploration of mineral deposits, drilling of wells is one of the main types of work. A significant part of the wells is drilled in difficult geological and technical conditions: complete absorption of drilling fluid, unstable rocks, off-specification core recovery, remoteness and, as a result, difficult water supply for drilling units. Drilling in such conditions significantly reduces the technical and economic indicators of drilling operations due to the significant costs of supplying drilling units with flushing fluid, increasing the consumption of materials due to dealing with absorption of flushing fluid and issues in wells, downtime and re-drilling of mineral formations (Kuandykov T., 2020: 7, Kassenov A., 2016: 7, Kassenov A., 2020:5).

The current level of development of drilling equipment and drilling technology allows combining technological operations for completion of productive formations, while a positive effect is often achieved. The decisive factor in the choice of methods for completion of a productive formation is the stability characteristics of the rocks that make up the formations being uncovered. Unstable formations, usually composed of loose sands or similar rocks, are highly prone to collapse and deformation when penetrated by a well. The structure of the skeleton of a porous reservoir of such rocks can be destroyed under the influence of drilling rock cutting tools, as well as under the influence of hydrodynamic and hydrostatic pressure on the productive formation, 1.5–2 times higher than the formation pressure. This leads to a rearrangement of sand grains, to its compaction and a decrease in the permeability of the formation.

In the process of uncover a permeable formation by drilling, a clay mud is most often used to increase the stability of the wellbore walls and prevent the absorption of drilling fluid by the formation. At the same time, clogging of pores and cracks of the reservoir occurs, which reduces its permeability. (Khawassek Y., 2016: 11, Moldashi, 2021:9,)

The main factor that reduces the permeability of the formation is clogging, which manifests itself in the penetration of cuttings, dispersed phase (clay particles) and a mud filtrate into the pores and cracks of the formation, and the formation of a weakly permeable clay crust on the walls of the well. (Clogging is the process of artificial penetration of particles into the pores and cracks of rocks).

Materials and methods. In the conditions when the pores and cracks of the reservoir are clogged, as a result of which its permeability decreases a perspective way to solve this issue is a drilling backwash wells. Currently, a number of mechanisms have been developed for backwashing during well drilling: airlift pumps, bottom hole piston pumps, devices that convert the direct flow of drilling fluid in the bottom hole zone into a reverse flow, etc. However, the lack of substantiated recommendations on the choice of parameters for backwash mechanisms and a number of design flaws hinders the widespread practical application of this drilling method. In the process of preparing a well for operation when treating a zone of a productive formation with solutions of sulfuric or hydrochloric acids, the permeability of productive formations is restored by flushing the clogged near-filtration zone with acid solutions, transferring the products of clogging into a solution and carrying it out to the surface. In this drilling method, a low-clay solution can be used as a drilling fluid, which enters the bottom hole through the drill pipes, and the slurry formed during the drilling process rises to the surface along the gap between the borehole walls and the drill pipes using an airlift.

Uncover of aquifers with reverse flushing gives the greatest effect compared to the other methods, while maintaining the natural conditions of porosity and permeability of the formation. The presence of a liquid column in the borehole provides the necessary stability of the borehole walls. In the process of uncover productive formations due to the suction of the slurry from the bottom of the well, their natural conditions of porosity and permeability are preserved. Among of all modern methods, this method allows you to uncover productive formations with wells of large diameter (up to 500 mm and more).

On the basis of research studies and analysis of the regularities of the decline in the flow rate of technological wells, the air-lift method of boring the ore zone was proposed, which gives a significant effect by reducing the number of repair and restoration work and the funds spent on carrying out these works.

A schematic diagram of ore zone drilling by airlift method for uranium ore mining by in-situ leaching is shown in Figure 1. This method of drilling technological wells was tested on operating technological wells of Volkovgeologia JSC, with a total depth of 300-500 m on average.

To operate the airlift, compressed air is supplied from the compressor to the mixer into the annular space of the double drill string, while the mixer is located at the design depth of the well being drilled.

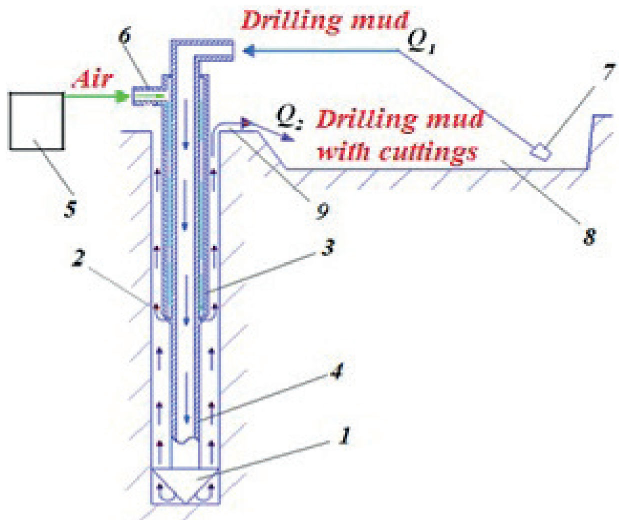

Figure 1 - Schematic diagram of airlift drilling
1-bore bit; 2-mixer; 3-double drill pipes; 4- drill-rod string SBT-63,5 mm; 5-compressor; 6 - shackle; 7 - coarse filter; 8 - sump.

To operate the airlift, compressed air is supplied from the compressor to the mixer into the annular space of the double drill string, while the mixer is located at the design depth of the well being drilled. Flushing fluid from the sump through the channel of the inner pipe of the double drill string and further along the inner channel of the single drill string SBT-63.5 is fed to the bottom hole using a mud pump.

The compressor pressure required to start the airlift into operation must be: (Karmanov, 2021: 7, Kenzhetaev, 2021:6)

$$P_{start} = \rho g h\left(1+\frac{d_{in}^2}{D_l^2}\right), \quad (1)$$

where: P_{start} – compressed air pressure, at the inlet for starting the airlift, Pa;
ρ – working fluid density, kg/m^3;
g – acceleration of gravity, m/s^2;
h – geometric immersion of the mixer, m;
d_{in} – inner diameter of the air duct, m;
D_l – lifting pipe diameter, m.

The working pressure of the airlift is determined by the formula:

$$P_{work} = \rho g\left[h-\left(\frac{\rho_p}{\rho}-1\right)\left(H_m-h\right)\right]-\Delta P_{feed}, \quad (2)$$

where: P_{work} – airlift working pressure, Pa;

ρ_p – pulp density, kg/m³;

H_m – liquid column height, m;

$\Delta P_{feed.}$ – pressure loss in connections and pipes, Pa.

The required air flow rate to ensure the specified airlift performance is determined by the formula (3).

$$q = \left(\frac{2}{\alpha} - 1\right)\left(1 + \frac{\rho g h}{2P_a}\right), \quad (3)$$

where: q – specific air consumption, m³/m³;

α – relative immersion of the mixer, 0,18;

P_a – atmosphere pressure, (P_a=101325 Pa).

The creation and maintenance of air pressure in the annular space between the walls of the well and the drill string from the above ratio is achieved by the design of the mixer. The mixer used in the implementation of the method is a branch pipe, in the side wall of which there are radial through-drilled holes of certain diameters.

The depth of running double drill pipes (Figure 2) is determined on base of the results of hydraulic calculations and the total depth of two drill strings (double TBDS-89 + SBT-63.5mm) should reach a mark 5-7 m above the ore-bearing horizon. This depth mark of the well must be prepared according to the technological regulations agreed by the contracting drilling company. Further drilling is carried out using a specially developed technology for each well, depending on the geological conditions of drilling.

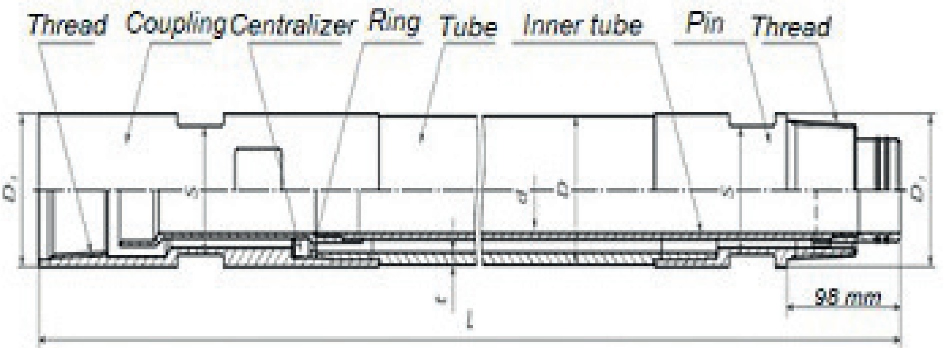

Figure 2 - Double drill pipes TBDS-89

In the process of launching the airlift in space at the level of the air mixer, bubbling (passing of air through the liquid layer) of air and flushing liquid with sludge will occur, the specific gravity of the liquid column at a certain interval facilitates the volume of drilled rock (sludge), which leads to the movement of this column to the surface. According to the law of continuity of the liquid, the underlying layers of liquid rush after the moving column, as well as the liquid from the sump 8 with the help of a mud pump, through the sleeve, a two-way swivel 6 along the central channel of the drill string rushes to the bottom. The circulation of the flushing agent begins to clean the cuttings from the bottom of the well. The most important thing is that no excess pressure of the drilling fluid is created on the bottom hole filtration zone of the well, due to the compensation of the back pressure of the rise of the liquid column in the space between the drill string and the walls of the well by airlift.

After the circulation of the drilling fluid is restored, the drill string is set in rotary motion with the help of a rotor (not shown in the diagram), slowly lowering the bit 1 to the bottom, the process of drilling and driving of the ore interval of technological wells begins. With an excessive air supply, suffusion of the sandy walls of the well can occur, therefore, the volume of injected and backwash fluid is kept strictly in equilibrium. Further development of the technology of the proposed method can be supplemented during drilling operations in production.

Results and discussion. Today, “NAC “Kazatomprom” JSC includes 13 uranium mining enterprises, including 3 enterprises that provide services for the extraction and processing of uranium, with 21 operating mines in the Turkestan, Kyzyl-Orda and Akmola regions of the Republic of Kazakhstan.

In accordance with contractual obligations, uranium mining enterprises annually form the volume of uranium production, based on the volume of uranium production, a APMPW (Annual Plan of Mining Preparatory Works) is formed. The APMPW plans the number and purpose of technological wells (pumping, injection, observation, etc.), which form a map of drilling operations of “NAC “Kazatomprom” JSC.

With the idea of introducing technological equipment and rigging for the drilling method while preserving the original filtration properties of the ore-bearing horizon, an analysis was made of the map of boreholes associated with uranium deposits, which are the objects of the drilling companies of Volkovgeologia JSC. The analysis showed that drilling is carried out on rocks of the sedimentary complex (clays, sands, with interlayers of bedrock rocks - mudstones, siltstones, silts, sandstones, limestones, gypsums, etc.) of II-V categories of drillability, with insignificant interlayers of rocks VI-VIII categories of drillability. Drilling units BPU-1200 (equipped with a drilling rig ZMO 1500 (ZIF-1200 AMR) and a mud pump NB-32 (or NB-50) are used for drilling operations. During drilling, as a rule, drill pipes SBT 50, sleeve-and-tool joints are used. As a rock-cutting tool, pico-drills Ø132, Ø151 or Ø161 mm are used, roller cone 3-blade carbide bits Ø161 - Ø294 mm or PDC drill bits.

Uncover of productive horizons during the construction of technological wells for water supply of ISL metals - uranium, is one of the measures to increase productivity and service life of wells, reduce operating costs. During uncovering productive strata composed of fine-grained sands, their natural filtration properties are almost always disturbed, which is expressed primarily in a decrease in the permeability of rocks in the near-wellbore zone as a result of the formation of a clogging zone - a section of the well, into the pores of which particles of the dispersed phase of the drilling fluid have penetrated. There are two zones of clogging: the zone adjacent to the near-wellbore part of the well, caused by the penetration of particles of drill cuttings and FF (flushing fluid), as well as the zone of mud filtrate, most often clay mud, into the rocks of the productive horizon. The formation of a clogging zone is inevitable if solid particles are present in the fluid and drilling is carried out with drawdown. The size of the clogging zone depends on the pressure drop during drilling, the duration of drilling and on the ratio of the size of the solid phase of the FF and the size of pores and cracks. When solid particles enter the pores and cracks of the productive formation, their cross-sectional area decreases, which leads to a sharp decrease in permeability. The depth of penetration of clay solution into the pores of the productive horizon depends on the properties of rocks and clay solution. With an increase in the zone of intense clogging, the complexity of its destruction also increases.

Removing the crust from the wellbore wall using mechanical reamers and hydraulic washing is not very difficult, but removing clay particles completely from the formation presents significant difficulties. The impact of the LF filtrate on the formation causes the following changes in the rocks of the productive horizons:

• the presence of chemicals contained in the liquid filtrate leads to a decrease in the effective sections of pores and channels of productive layers, as well as their permeability due to an increase in the hydrophilicity of rocks and the thickness of hydration shells;

• clay minerals contained in productive formations hydrate under the influence of water filtrate and increase in volume, which also contributes to a decrease in permeability;

• the presence of dissolved chemical elements in the FF filtrate contributes to the formation of insoluble sediments when interacting with the substances of the productive formation.

Thus, the impact of filtrate on the formation leads to a decrease in its permeability. This decrease is comparatively less than in the case of colmatation. To increase the permeability of the ore-bearing formation, it is necessary to reduce the impact of the filtrate on the formation, since the depth of penetration of the filter into the formation is many times greater than the thickness of the colmatation zone. With the airlift drilling method described in this work, the preservation of the initial filtration properties of the ore-bearing horizon of technological wells occurs due to a reduction in the amount of infiltrate crushed by the hydrostatic pressure of the column of drilling fluid into the bottomhole zone, which is carried out with direct supply of the drilling solution to the bottomhole (Rakishev, 2019 a:8, Rakishev, 2019, b:5, Rakishev, 2020, c:6).

Based on the mining and geological, hydrogeological and hydrodynamic conditions of the uranium deposit, the drilling technology provides for the drilling of vertical wells, rotary method, using direct circulation of the flushing fluid (FF). A low-clay drilling fluid, based on bentonite powder, or lumpy bentonite clay, with the addition of chemical reagents, is used as a flushing fluid. The composition, quantity, parameters and formulation of drilling mud for each type of field, drilling site and each well is developed separately, based on mining and geological, hydrogeological, hydrodynamic and a number of other technological characteristics. The analysis showed that the technology described above and the developed design of the drilling equipment are fully suitable for use in drilling, construction, and development of technological wells for the development of uranium deposits by the ISL method (Yussupov, 2017, a:3, Yussupov, 2021, b:6, Yussupov, 2021, c:4).

Conclusion. The advantage of the proposed technology for drilling technological wells is that there is no need for a complete retooling of the drilling rig equipment. The proposed technology is applicable in conjunction with existing equipment in the interval of the ore-bearing horizon. The advantage of the proposed drilling method is the preservation of the natural porosity and permeability of productive formations during their uncovering.

As the results of production tests show, with a decrease in the flow rate of a group of wells by 50%, respectively, their work is stopped from 3 to 5 days to carry out repair and restoration work (RRW). During the year, such RRW events can be carried out from 6 to 10 times. The use of the proposed technology will reduce the performance of the above mentioned works, and the productivity of wells will increase.

Until now, all the technologies used in other companies have been aimed at solving the issues of increasing the efficiency of workover operations in existing wells drilled using the traditional method. With high clogging, repair and restoration work, as a rule, was reduced to the treatment of the productive formation zone with solutions of sulfuric or hydrochloric acids, thereby the products of clogging are transferred into the solution and carried to the surface. This method is costly and causes enormous harm to the environment.

The proposed method initially sets the task of reducing the number of workover operations and the costs of their implementation, while simultaneously resolving the issue of reducing the costs of drilling, construction and increasing the productivity of technological wells. With the airlift method of drilling, due to the reduction of the amount of infiltrate crushed by the hydrostatic pressure of the column of flushing solution into the bottomhole zone, which is carried out with the direct supply of flushing fluid to the bottomhole, it allows preserving the initial filtration properties of the ore-bearing horizon of technological wells, and also due to depressions on the ore-bearing horizon, a decrease in collimation occurs and improving the filtration properties of the ore-bearing horizon. The drilling technology used in production, using the direct circulation method, does not allow drilling a high-quality well, these wells have a high degree of clogging, which leads to an increase in the number of workover operations. Airlift drilling will provide savings compared to reverse circulation drilling in obtaining a quality well, increasing drilling productivity, reducing the amount of workover, and increasing the content and amount of uranium mined.

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