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FEATURES OF TECHNOLOGICAL FACTORS OF WELL CONSTRUCTION BASED ON THE EXAMPLE OF OIL AND GAS FIELDS

Purpose. Comprehensive study of geological and technological factors of drilling, flushing during drilling, stabilization of wellbore walls, as well as opening of productive horizons in difficult mining and technical development conditions at different stages of hydrocarbon deposits.

Methodology. When carrying out the research, basic methods of mathematical and physical modeling, bench experimentation, as well as methods for processing the results of laboratory and industrial research in the EXCEL and MATNCAD environment were used. Measurements of the parameters of compositions of special process liquids were carried out using appropriate control and measuring equipment and materials.

Findings. Laboratory and production data on the analysis of well bottom deepening indicators and the use of special agents in wells – flushing fluids, cementing systems in tandem with buffer fluids are proposed for consideration. These agents make it possible to rationalize the drilling process, as well as prevent the active development of deterioration in the filtration properties of reservoir rocks and create a reliable transport channel for hydrocarbons.

Originality. Based on the study of the results of research into well construction processes, the following important circumstance has been proven. The solution to the problem of improving the quality of field development, in this case hydrocarbon fields, lies in the use of integrated approaches to the organization of downhole circulation processes of special technological fluids.

Practical value. The obtained comprehensive results of laboratory and industrial research can be taken as the basis for creating modern methods for designing processes for deepening the face, as well as flushing when drilling and casing wells, the construction of which is carried out in sedimentary rocks.

Keywords: *well, drilling, flushing fluid, reservoir rock, cementing, filtration properties*

Introduction. The necessity to develop oil and gas deposits (deposits of other minerals are no exception) is indisputably confirmed by the existing urgent needs of industry and households of various organization levels in the availability of high-quality fuel and chemical raw materials of the relevant groups for consumption. However, at present, it is necessary to conduct a conversation about the further profitable development of already exploited, or rational involvement in the development of new deposits, with the obligatory consideration of the presence, for the given circumstances of the significant complication factor of geological-and-technical conditions for the construction of boreholes, an indispensable channel for obtaining reservoir liquids [1].

We need to focus on some important aspects for a correct understanding of the problems of boreholes construction processes. In the process of deepening the boreholes, rock layers are exposed to it, which differ quite significantly in their physical-mechanical (quite relevant at present is the issue of increasing the mechanical speed of drilling in waste rocks, which will significantly reduce the time of well construction) and filtration-capacitive properties (this is important for reservoir rocks). In addition, drilling in the zone of productive layers has a certain peculiarity. It consists in the fact that when the zone of the productive object is opened, the physical-and-chemical processes that take place around the wellbore become quite important, that is, the primary mechanical and physical-and-chemical state of the reservoir rock and the moving (liquid or gaseous) rock phase (formation liquid) contained in the deposit is disturbed [2].

It should be noted that the efficiency of the development of oil and gas fields is significantly affected by the state of the formation bottom hole zone (BHZ) both during the deepening period and when the boreholes are completed (in particular, this includes fastening and subsequent cementing operations). In the process of formation of BHZ, there is an active redistribution of stresses in the rock, the interaction of drilling liquids with formation liquids, the penetration of the filtrate from the specified liquids from the borehole into the formation, physical-and-chemical processes in the walls of the wellbore (osmotic phenomena, diffusion, and others) [3].

Hydrodynamic interaction of the drilling liquid with the reservoir liquid occurs during the pressure in the borehole exceeds the reservoir pressure. Under the in-

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fluence of excessive pressure, the solid phase penetrates the rocks together with the drilling liquid and its filtrate, which contributes to a significant deterioration of the reservoir rock permeability. Let us emphasize, that the physical-and-chemical processes in the walls of the borehole under construction can significantly intensify the processes of filtrate precipitation from the washing liquid [4].

The time of interaction of the drilling liquid with the reservoir rock during the period of static and dynamic repression will also have a significant influence on the process of BHZ formation (we would like to add some more detailed explanation here: repression drilling is the method in which the pressure of the column of the flushing liquid in the borehole exceeds the formation pressure of the liquids). It should be noted that the most acceptable way to reduce the specified time is the stable provision of a high mechanical velocity of the hole deepening.

Literature review. Statistical data about the boreholes drilling in the Dnipro-Donetsk depression showed that the mechanical velocity of drilling is constantly correlated with the parameters of the drilling liquid [5], and the main indices of the properties of the latter (density, viscosity, filtration index) depend, first of all, on the component composition. There is no material or reagent for drilling liquids that only selectively affects their parameters. Let us give a specific example: with an increase in the content of the solid phase, the density of the washing liquid naturally increases, but the filtration index decreases; treatment of flushing liquids with polymers, with the aim of reducing filtration rates, is accompanied by an increase in viscosity; dilution of the washing liquid, as a rule, contributes to a decrease in density and creates prerequisites for an increase in the filtration rate. Therefore, the main parameters of the technological properties of washing liquids are interconnected, and by combining reagents, it is possible to only partially regulate the indices of any parameter in the absence of significant influence on others. The question of the nature of the influence of the flushing liquids parameters on the operations efficiency and boreholes drilling velocity requires detailed research [6]. We focus our attention on the fact that the nature of the dependence of the mechanical penetration velocity on the parameters of the flushing liquids indicates the following: the mechanical velocity (in this case, the operating efficiency of the bit) decreases with an increase in the density and viscosity of the flushing liquid, as well as the content of the solid phase in it and increases with increasing filtration; however, these dependencies are not equivalent.

Interrelated with the considered issues are the processes of fastening and cementing, which consist in filling the annular space of the borehole, formed by the outer wall of the casing pipes and the rock massif, with a suspension of special binding materials and appropriate reagents, which is able to thicken at rest and turn into so-called tamponage (cement) stone with certain mechanical properties [7]. According to existing practices, after drilling the productive layer, it is fixed with an operational string of casing pipes and cemented; later, in order to connect the inner part of the casing with the productive layer, holes are formed in the column itself and the cement column.

The process of cementing pursues a fairly large number of tasks, among them, the most important are following: reliable isolation of permeable horizons, unloading of the casing string and its protection from the action of aggressive formation liquids, elimination of defects in the borehole fixing [8]. This can be done only on the condition of high-quality performance of the entire complex of operations on preparation of the wellbore for injection of cementing slurry and the presence of the latter with all the necessary technological properties.

Thus, we can state that the creation of rational modes for the opening of productive horizons, followed by the proper execution of the operations of fastening and cementing of casing strings [9], is a rather urgent problem from the point of view of preserving the natural reservoir properties of rocks.

Unsolved issues of the problem. Today, there is a significant increase in scientific and practical work on the study of problematic issues of well technologies. Such issues include a significant intensification of downhole processes of rock destruction. This will reduce the likelihood of a violation of the integrity of the wellbore. This can be explained by the emergence of a real possibility of reducing the time required to drill certain geologically complicated well intervals [1]. It should be noted that the opening of a productive layer (for hydrocarbon deposits) is considered a complex of operations, the proper execution of which is aimed at ensuring a reliable hydrogas-dynamic connection of the operational column of the borehole with the productive layer (oil, gas, gas condensate); moreover, based on the analysis of relevant research, we proved that the productivity of boreholes largely depends on the perfection of the reservoir opening [10]. It is the circumstance that can explain the significant interest of scientists and practitioners in the issue of high-quality completion of the boreholes.

At present, according to the available and accepted scientific-and-practical works for analysis, it is possible to distinguish drilling (the process of passing a productive horizon with a rock-crushing tool) and perforation (the process of forming a filtration connection between a borehole and a rock reservoir) during the opening of productive horizons (so-called primary and secondary disclosure) [11].

It is well-known that productive layers of hydrocarbon raw materials can be opened by drilling to the design depth of the borehole under construction, or after completing a cycle of drilling and fastening the wellbore to the roof of the productive layer (for example, installing a filter column). However, the methods for forming the filtration zone of the borehole by perforating casing pipes cemented in the interval of the productive layer are implemented in more than 90 % of the boreholes, which explains the active interest in the issues under consideration and the necessity to improve these technological methods.

According to the results of previously conducted research, the following was established: in the process of opening rock strata, there is constant filtration of drilling liquid into permeable layers. The nature of the depth and amount of filtrate penetration into the productive horizons is variable over time and depends on a complex number of factors: the filtration rate of the flushing liq-

uid, the presence of a clogging component for the latter, the filtration and capacity properties of the collectors, the existing hydrodynamic processes in the borehole being constructed. In addition, it is shown that the filtrate of the drilling liquid, and partly the solution itself, penetrating into the productive layer, sharply reduce the permeability of the latter for oil and gas, which leads to a number of irreversible processes, that is, the prerequisites are created for blocking the movement of the liquid. It can be considered proven that from the point of view of the necessity for qualitative disclosure of productive horizons, technological requirements should require keeping the filtration index within minimum limits [12].

It is impossible to ignore the following undoubted factor considered in the sources of information: from the standpoint of ensuring high-quality primary opening of liquid-saturated horizons, the main place is occupied by such an index of influence on reservoir properties as the time of contact of the drilling liquid with the rock. According to the available information, the application of a highly effective rock-destructive tool is considered a rational direction that ensures a positive minimization of the contact time. It is also important to design such formulations of drilling flushing liquids that would prevent the negative phenomena of active physical and chemical interaction of these liquids with rocks [13].

It is also emphasized that significant additional hydrodynamic loads on formations, including permeable and productive ones, occur during lowering and lifting operations [3]. The impact of these loads can be significantly reduced if high-resistance bits are applied, which allow you to pass significant intervals and open the productive layer in a minimum number of trips [14].

Quite a large number of scientific-and-practical studies consider in detail the problems of improving the quality of operations on fastening and subsequent cementing of boreholes, and, as a priority direction, the conditions of complex assurance of the manufacturability of the execution of the specified operations (wellbore preparation processes using special techniques and methods, application adapted technological liquids and corresponding materials and reagents) [15]. Currently, a fairly common technology for improving the quality of well casing work is special cleaning techniques. Such measures can be effectively carried out using process fluids and special devices. Process fluids clean the wellbore due to their inherent viscosity properties and velocity pressure. Special devices operate mechanically or activate flows of flushing liquids. The task of cements is to create durable cement stone. This can be achieved by using special additives that prevent, for example, acid corrosion of cement stone and its further destruction. The aforementioned works show the directions of further innovative development of the technical and technological foundations of boreholes operations on fastening and cementing, which consist in the introduction into widespread application: instrumental methods of processing borehole walls, especially in their complicated areas (caverns), designed to minimize the possibility of getting into cement mixture extraneous impurities [16]; effective buffer systems, the purpose of which is the reliable separation of the contact surface of washing and cementing slurry liquids (in order to prevent mixing), increasing the completeness of their mutual replacement, destruction and subsequent transportation in the liquid flow of clay crusts and sludge pastes [17]; special tamponage mixtures, the physical and chemical properties of which allow reliable formation of a strong and impermeable cementing slurry stone [18, 19].

The reference information presented by us categorically substantiates the existence of an extremely necessary essential requirement for comprehensive research of individual processes of the borehole construction cycle, especially in terms of solving the issues of ensuring the quality of productive horizons opening and creating an operational channel for transporting hydrocarbon raw materials from the earth's depths to the surface.

Research objective. An interconnected study of basic geological and technological factors logically related to the processes of constructing exploration and production wells in difficult mining conditions using the example of hard-to-recover hydrocarbon deposits.

Statement of the main research material. The category of boreholes includes mine workings of circular cross-section, constructed in the layer of rocks and intended for the search, exploration and extraction of hydrocarbons (oil, natural and associated gas, gas condensate, etc.) [20]. The borehole construction cycle consists of a large number of sequentially performed operations, among which the following main ones can be singled out: direct drilling of rocks, removal of destruction products, fixing unstable walls of the production and creation of a reliable operational channel with correspondingly high rates of oil and gas extraction from productive layers.

It should be noted that the rational method of drilling exploratory and exploitation boreholes for oil and gas, as well as the technological measures corresponding to it, should ensure an unobstructed (that is, with the exception of, for example, the phenomena of shedding of the borehole walls, the sticking of the drilling tool, the release of reservoir liquids under high pressure, absorption drilling liquid) to achieve the goal in the shortest possible time [21]. Among other things, this can be achieved through the application of progressive structures of the rock-destructive tool (drill bits) and the creation of operating modes for it that correspond to geological-and-technical conditions (axial load, amount of supplied flushing liquid, rotation frequency, etc.) [22, 23].

The research has proven that there are several ways to increase the mechanical drilling speed. This result may be a consequence of the additional imposition of a dynamic load of some intensity on the downhole rock destruction tool. This is implemented using several techniques. These include the use of hydraulic or pneumatic impact drill projectiles with the effect of mechanical destruction of the peripheral part of the well. Additionally, hydraulic or pneumatic impact machines can be included in the drilling rigs. This was confirmed by studying the process of rock destruction (Fig. 1). The conditions for conducting experimental studies were the use of shock pulses on a rock-cutting tool (operation of a hydraulic impact machine). The destruction process was simulated on a sandstone block in the presence of circulation of a washing liquid containing a surfactant – sulfonol.

Analyzing the above research results (Fig. 1), we can conclude the following. Adding surfactants to drilling

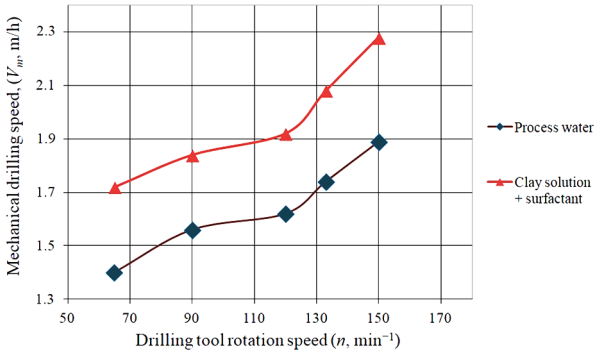

Fig. 1. Indicators of mechanical speed of percussive-rotary drilling when using surfactant-treated drilling fluids

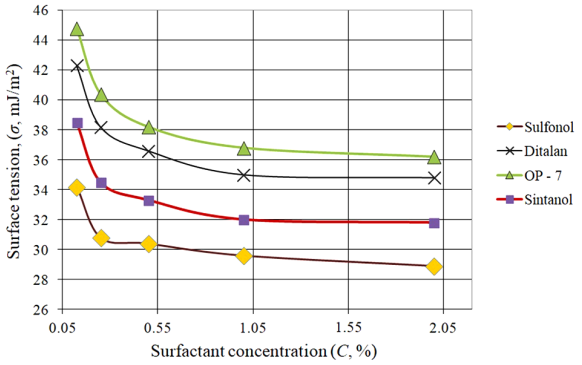

Fig. 3. Surface tension of drilling liquids treated with various surfactants

fluids leads to an increase in mechanical drilling speed by an average of 20–22 %. The positive nature of the use of hydraulic hammers is confirmed by the experimental data shown in Fig. 2. The specified data was obtained based on a study of the rotary drilling method.

Based on the consideration of the data obtained (Fig. 2), we can state the presence of certain phenomena, described below. The presence of a surfactant in the drilling fluid during rotary drilling also makes it possible to increase the mechanical speed by approximately 20 %. However, in comparison with rotary impact drilling, under other equal circumstances (uniformity of rock properties and drilling mode), the indicated mechanical speed indicators are 36–38 % less.

The reason for the increase in mechanical drilling speed when using surfactant-treated drilling fluids is a decrease in the surface tension of the circulating medium (Fig. 3). It should be said that a decrease in surface tension helps to increase the penetrating ability of the drilling liquid. The consequence of the above will be a significant reduction in the strength of the rocks at the bottom of the well and improvement in the conditions for removing slurry from destroyed rock.

The experimental data in Fig. 3 convincingly indicate the influence of the surfactants involved in the study on surface tension indicators. Taking into account the results obtained, we can assume that from the standpoint of maximizing the reduction in surface tension, the most acceptable reagent is OP-7 with its concentration in the clay solution up to 1 %.

It will be appropriate here to provide specific factual data regarding the issues under consideration, taking into account the problem of the need for effective opening of productive horizons [24]. On the basis of the industrial data analysis of the bits operation, in the conditions of the Buhruvativske deposit (associated with a group of structural highs, disturbed by discharges, stratified, vaulted, tectonically shielded and lithologically limited deposits), it was determined that with an increase in mechanical velocity and bit penetration in unstable rocks the cavernousness of the wellbore decreases (Fig. 4), and this prevents the occurrence of various complications: violation of the integrity of the borehole walls, the attachment of the drilling tool and the casing strings, this also helps to reduce the consumption of drilling flushing liquids and tamping solutions [25].

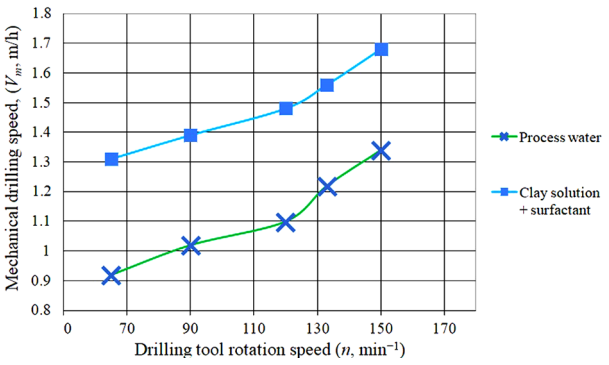

Fig. 2. Mechanical speed of rotary drilling when using surfactant-treated drilling fluids

It should be noted that the Buhruvativske oil deposit is located on the territory of the Okhtyr district of the Sumy region and was discovered in 1974 by borehole No. 1. The Buhruvativske deposit is characterized by the high complexity of the geological structure and conditions of oil saturation of the productive layers. The deposit is multi-layered, contains 11 oil horizons: V-14, V-15, V-16, V-17, V-18, V-20, V-21, V-22, T-1, Fm-5-6, Fm-11-12. As of 2023, about 250 boreholes have been drilled at the Buhruvativske deposit. The operating fund includes more than 158 boreholes. Oil boreholes are mainly operated by a mechanized method [26].

The pressure on the productive layers during deepening was up to 26 MPa, and during cementing – from 25 to 33 MPa during boreholes drilling at the Buhruvativske deposit. The excess pressure of process liquids above reservoir pressures ranged from 97 to 140 %.

Based on the geomorphological conditions of the area and the difficulties in allocating land for the construction of boreholes (croplands), the vast majority of the boreholes of the Buhruvativske deposit were drilled as inclined–directed (Fig. 5) with a deviation from 300 m (borehole No. 312) up to 760 m (borehole No. 348). The average depth of the boreholes is 4,000 m.

The complexity indicated in Fig. 2 of the trajectory is due to the loss of part of the wellbore as a result of a complication and the necessity to perform a geological task.

During the construction of boreholes, according to the project documentation, there may be complications in the geological section of the deposit [27], namely: absorption of drilling liquid in the Bashkir stage, caving and collapse of borehole walls in the Serpukhov, Moscow, and Visei stages, showings of oil-and- gas water in the Visei and Famen stages.

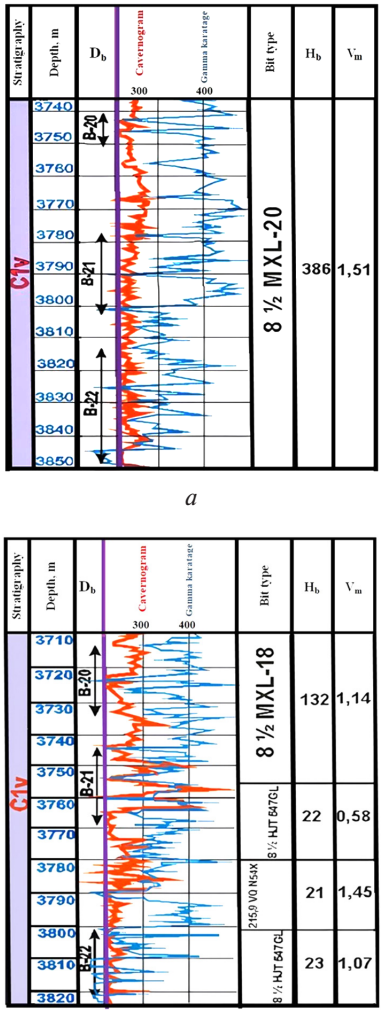

Fig. 4. The state of the wellbore and the characteristics of working out the drill bits for the conditions of the Buhruvativske oil deposit:

D_b – bit diameter (215.9 mm); H_b – advance per bit, m; V_m – mechanical drilling speed, m/h

The type of drilling liquid during the opening of productive deposits, its parameters, as well as the sequence and treatment scheme, were designed taking into account the existing mining-and-geological conditions of borehole drilling, regulatory documents, in addition, the best experience of borehole construction has been applied in given oil production area.

The density of the drilling liquid is selected based on the necessity to ensure the stability of the borehole walls, as well as the creation of the minimum permissible pressure on the formation during opening the productive horizons. However, it should be noted here that the world experience in the construction of boreholes points to the priority direction of preserving the primary properties of reservoir rocks, namely the opening of productive horizons in depressions, that is, at pressures below the formation pressure. The wide implementation of this technology in foreign countries with a developed oil and gas industry showed its promise and a number of significant advantages over classical technology (drilling with repression):

- a significant increase in the productivity of oil reservoirs;
- reduction of costs and time for development of boreholes;
- increasing the extraction rate of hydrocarbons from formations;
- increasing the penetration velocity and stability of the rock-destructive tool;
- prevention of drilling mud absorption;
- reducing the probability of the drill tool sticking.

At the same time, the transition to the boreholes construction according to the considered scheme requires the application of highly efficient and reliable blowout prevention equipment.

An idea about some characteristic features of the process of opening productive horizons can be given by the relevant data presented in Tables 1–3, distributed by periods of operation of a number of boreholes.

Production experience indicates that the intensity of filtration and the formation of BHZ depends not only on the filtration performance of the drilling liquid, but also on the excessive differential pressure of the drilling mud on the walls of the borehole in the interval of the productive horizon. The research has proven that even a slight increasing in pressure on the productive layer causes a drop in production from the boreholes in several times.

Complex mining-geological and technical-technological conditions of boreholes drilling and fixing in the deposits of PJSC "Ukrnafta" require the application of various types of tamponage cements, chemical reagents and special additives. A variety of factors of a geological, physical-and-chemical and technical-technological nature causes the necessity to improve the properties of tamponage systems in order to increase the quality of layers demarcation.

The basic and currently applied technology for cementing production columns, despite the existing com-

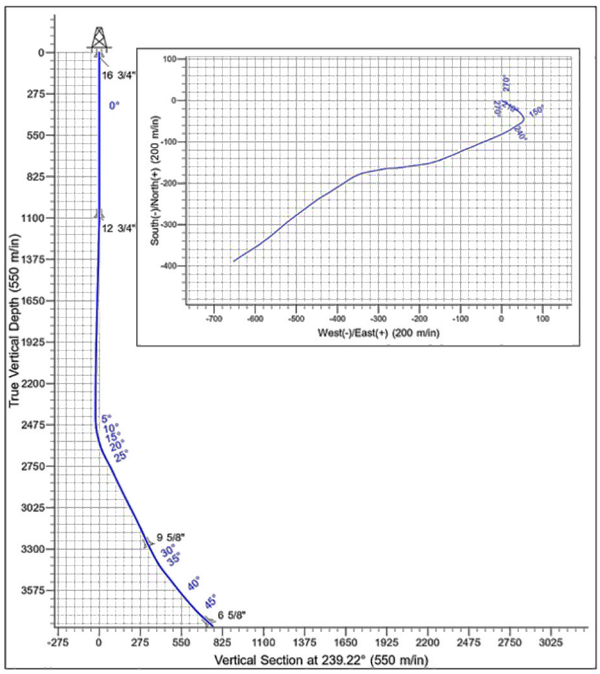

Fig. 5. Spatial position of the trajectory of borehole No. 348 Buhruvativska

(∅ 426 mm × 29 m; ∅ 324 mm × 1,095 m; ∅ 245 mm × × 3,364 m; ∅ 168/146 mm × 4,030 m)

Table 1

Flow rate of boreholes and conditions for opening productive horizons (I period of operation)

Borehole	512	334	320	174
Horizon (block)	V-14-21 (block 4-5)	Fm-5-6 (block 4)	Fm-5-6 (block 6)	V-22-T-1 (block 6)
Production output for one borehole per days: oil/ water/gas, t/t/thousand m^3	8.21/7.78/0.41	131.61/3.06/26.33	4.4/0.36/0.88	35.11/1.2/7.38
Time of the borehole operation, boreholes/days	175.5	173	97.5	232.9
Bits imported/domestic (crowns), pcs.	–/14(2)	1/20(6)	2/10	2/10(5)
Time from the moment of discovery of the productive horizons to the fastening of production column, days	55	79	70	58
Return permeability coefficient B, %	44.6	90	37.4	8.6
Colloid/solid phase content, %	5.8/34.3	–/23	1.98/20	2.14/16
The content of oil in the washing liquid, %	16.7	7.5	16	10

Table 2

Flow rate of boreholes and conditions for opening productive horizons (II period of operation)

Borehole	512	334	320	174
Horizon (block)	V-14-21 (block 4-5)	Fm-5-6 (block 4)	Fm-5-6 (block 6)	V-22-T-1 (block 6)
Production output for one borehole per days: oil/ water/gas, t/t/thousand m^3	2.97/14.11/0,2	141.3/0.77/23.18	14.56/0.16/4.54	18.98/1.88/3.44
Time of the borehole operation, boreholes/days	239	363.6	346.6	349.7
Bits imported/domestic (crowns), pcs.	–/14(2)	1/20(6)	2/10	2/10(5)
Time from the moment of discovery of the productive horizons to the fastening of production column, days	55	79	70	58
Return permeability coefficient B, %	44.6	90	37.4	85.6
Colloid/solid phase content, %	5.8/34.3	–/23	1.98/20	2.14/16
The content of oil in the washing liquid, %	16.7	7.5	16	10

Table 3

Flow rate of boreholes and conditions for opening productive horizons (III period of operation)

Borehole	512	334	320	174
Horizon (block)	V-14-21 (block 4-5)	Fm-5-6 (block 4)	Fm-5-6 (block 6)	V-22-T-1 (block 6)
Production output for one borehole per day: oil/ water/gas, t/t/thousand m^3	8.75/30.38/0.67	141.79/1.16/23.82	47.57/0.54/15.24	7.36/2.77/1.27
Time of the borehole operation, boreholes/days	342.8	364.8	171.9	358.4
Bits imported/domestic (crowns), pcs.	–/14(2)	1/20(6)	2/10	2/10(5)
Time from the moment of discovery of the productive horizons to the fastening of production column, days	55	79	70	58
Return permeability coefficient B, %	44.6	90	37.4	85.6
Colloid/solid phase content, %	5.8/34.3	–/23	1.98/20	2.14/16
The content of oil in the washing liquid, %	16.7	7.5	16	10

plex mining-and-geological conditions, is the application of PCT I-100 with additives in the mixing liquid of the nitrilotrimethylphosphonic acid (NTPA) retarder and the KMC stabilizer. An aqueous solution of KMC is used as a buffer liquid. Unfortunately, the application of such buffer liquids leads to intense interpenetration of special technological liquids, which can provoke the formation of a mixing zone of up to 75 % of the volume of the cementing slurry, and also does not ensure effective removal of the filter crust and removal of a sludge material. The above-mentioned technological solutions are not able to fully ensure reliable horizons demarcation [28].

According to the results of the research into the features of fastening of production columns at the Burhu-

vativske deposit, the quality of their cementation was estimated (Table 4). An example is the coefficient of cementation quality K of operational columns, determined based on the results of geophysical studies

$$K = \frac{100\sum_{i=1}^{n}\lambda_1 + 200\sum_{i=1}^{n}\lambda_2 + 300\sum_{i=1}^{n}\lambda_3 + 400\sum_{i=1}^{n}\lambda_4}{L_c},$$

where L_c is the length of the cemented area, m; λ_1, λ_2, λ_3, λ_4 – the length of the cemented areas, respectively, in the absence of contact, with poor, partial and dense contact, m. For value $K > 300$ – good quality; $K = 200–300$ – satisfactory quality; $K < 200$ – quality is unsatisfactory.

As we can see on the example of typical boreholes (Table 4), the cementing quality coefficient varies widely from 183 ("unsatisfactory" quality) to 361 ("good" quality). For the given examples, the water for mixing the tamponage solution with KMC finishing was applied as a buffer liquid. However, as is known, such buffer systems are not capable of providing high-quality separation of process liquids. As a result, the cement stone formed in such conditions is not able to ensure the proper quality of delineation of horizons and create the necessary operational level of reliability of the borehole fixing as an engineering structure. It is recommended to apply structured buffer liquids, as an example, based on BS to improve the quality of fastening (Table 5).

It was established that the received buffer liquid based on the BS buffer mixture is characterized by satisfactory technological properties and has a high washing ability and is superior to the stabilized buffer mixture of the SBS-2 type in terms of consumer indices.

The data on the compatibility of special buffering and backfilling liquids, based on the example of their mutual penetration, are quite interesting in terms of ensuring the manufacturability of borehole cementing operations (Tables 6 and 7).

The obtained data of testing the compatibility of technological liquids "drilling liquid – buffer liquid" (Table 6) and "cementing slurry – buffer liquid" (Table 7) in the established ratios show the identity of BS in relation to the typical researched drilling flushing liquids and cementing slurries. Therefore, the application of modern composite plugging materials in combination with highly efficient buffer systems can improve the quality of cementation and the reliability of fixing constructed by boreholes drilling.

When analyzing the specified circumstances in a complex, it can be stated that the solution to the problem of qualitative and rapid opening of productive horizons is restrained by the following factors:

1. Absence of methods of evaluation and management of the quality of reservoir rocks discovery. Indeed, none of the known methods meet the criterion of reasonableness, the existence of a mutually unambiguous correspondence between the results of the assessment of the quality of the disclosure process and, ultimately, the obtaining of an economic effect. Because of the absence of substantiated methods for assessing the quality of the pri-

Table 4

Geophysical CBD (Cement Bond Tool) of operational columns of the Buhruvativske deposit

Borehole number	174	174	320	320	512	512
Section length, m	1,790	2,180	2,243	1,837	1,752	1,935
Buffer liquid volume, m^3	5.5	5.0	5.5	5.5	5.0	4.0
The height of the buffer liquid level in the annular space, m	183	289	167	318	189	232
Contact time of the buffer liquid with the walls of the borehole, min-s	7–00	6–00	5–00	4–00	4–54	3–10
Type of cement	SSCM-120 (Slag-Sand-Cement Mixture)	OWPC III-Pol 5-100 (OWPC I-100) (Oil-Well Portland Cement)	SSCM-120	OWPC III-Pol 5-100 (OWPC I-100)	OWPC I-100	OWPC III-Pol 5-100 (OWPC I-100)
The velocity of the upward flow of cement mixture, m/s	0.43	1.62	0.55	1.33	0.64	1.22
The number of stabilizers, pcs	23	3	47	3	8	3
Thickness of the cement column, mm	65.2	28.0	73.8	28.0	54.4	28.0
Adhesion of the stone to the column: good/partial/absent, %	49.4/32.1/18.5	86.2/8.3/5.5	62.3/12.1/25.6	44.1/28.7/27.2	33.7/35.0/31.3	54.8/30.8/14.4
Coefficient of cementation quality	296	371	305	275	253	310

Table 5

Technological properties of existing and proposed buffer liquid

Indices	SBS-2 buffer liquid	BS buffer liquid
Density, kg/m^3	1,580	1,400
Fluidity, mm	210	220
Water trapping, ml	0	0
Filtering index, cm^3 for 30 min	6	7
Plastic viscosity, mPa·s	68	45
Dynamic shear stress, dPa	301	284
Detergent capacity, %	65	72

mary disclosure, it is not advisable to ask questions about the quality management of the performed operations.

2. Regulations and projects for the boreholes construction are drawn up without taking into account the requirements for high-quality boreholes construction, without substantiating the conditions under which they will fulfill their purpose. For example, there is no quality assessment of the technology for opening productive deposits and development of the borehole, substantiation of permissible loads on the state of fastening and productive horizons depending on the mode of hydrocarbon production.

3. In the relationship between the customer and the contractor, in the economic aspect, there is no interest of drilling companies in increasing the quality and speed of opening productive horizons and in implementing new technical and technological means to achieve this purpose. The main factor taken as a basis by drilling enterprises is the reduction of the borehole construction period and the reduction of the actual cost of drilling operations in comparison with the design tasks. Obtaining this result is accompanied by a sharp decrease in the quality of the performed operations, both during deepening the productive section and during completing and developing the borehole to maintain the minimum required level for handing over the borehole to the customer.

4. Inadequate equipment of the necessary technical means, materials, equipment, control devices and software of drilling enterprises create prerequisites for ignoring the issues of qualitative disclosure of productive deposits.

An integrated approach is necessary to successfully solve the issue of qualitative opening of productive horizons, that is, the implementation of a wide range of interrelated organizational, economic and technical measures developed on a single methodological basis.

Returning to the necessity to ensure the exclusion of the phenomena of deterioration of the collector properties of the deterioration of the collector properties of rocks [29] and based on the condition of successful borehole drilling without accidents, at the Buhruvativske deposit, the primary opening of productive deposits in boreholes 139, 312, 314, 326 was designed on a potassium/polymer liquid. According to the project, the mixture parameters were regulated as follows: density – 1,160–1,180 kg/m^3, conditional viscosity – 40–60 s, water less – 6 cm^3 in 30 min, $SSS_{1/10}$ – 25–30/50–60 dPa. It was planned to treat the solution with the following reagents and materi-

Table 6

Results of compatibility testing of buffer liquid and potassium/polymer and biopolymer drilling liquid

Type of drilling liquid	BS	Potassium/polymer ρ = 1,200 kg/m^3, T = 60 s B = 4 cm^3 for 30 min SSS (static shear stress)$_{1/10}$ = 40/60 dPa			Biopolymer ρ = 1,120 kg/m^3, T = 35 s B = 3.5 cm^3 for 30 min $SSS_{1/10}$ = 15/28 dPa		
Fluidity of suspensions according to the AzRI cone (T = 22 °C), mm	–	250	250	250	250	250	250
The ratio of washing liquid and stabilized buffer mixture	–	1:9	1:1	9:1	1:9	1:1	9:1
Fluidity on temperature T = 22 °C, mm	230	235	240	245	240	245	235
Fluidity on temperature T = 75 °C, mm	245	240	250	250	250	250	245

Table 7

Research of the compatibility of some tamponage systems

Cementing slurry (component composition, density)	Cem-C100 – 100 % NTPA – 0.035 % * W/C – 0.5 ρ = 1,820 kg/m^3				DR-CT100 – 100 % NTPA – 0.035 % * W/C – 0.5 ρ = 1,820 kg/m^3				TS-150PV – 100 % NTPA – 0.08 % * W/C – 0.47 ρ = 1,800 kg/m^3			
The ratio of cementing slurry and liquid based on the buffer mixture	–	1:9	1:1	9:1	–	1:9	1:1	9:1	–	1:9	1:1	9:1
Temperature, °C	75	75	75	75	75	75	75	75	90	90	90	90
Pressure, MPa	45	45	45	45	45	45	45	45	82	82	82	82
Thickening time of the mixture (cementing slurry + buffer liquid), h-min	2–55	4–05	3–30	3–10	3–05	4–20	3–40	3–15	5–30	6–55	6–15	5–45

* W/C – water to cement ratio

Table 8

Conditions and results of research on the behavior of drilling liquids on core material

Borehole	139	312	314	326	348	511	544
Core diameter/length, cm	2.77/4.03	2.66/4.37	2.74/4.18	2.63/4.23	2.62/4.49	2.62/3.66	2.72/5.11
Porosity, %	15.5	18.5	19.1	18.5	20.0	14.0	16.7
Permeability, $\mu m^2 \cdot 10^{-3}$	66.3	61.2	51.7	79.6	91.1	49.5	31.8
$P_{op.}$, MPa	0.5	0.5	0.5	0.3	0.2	0.5	0.5
Volume of pumped filtrate/volume of washed filtrate, cm^3	5.2/1.0	2.0/0.7	0.75/0.7	3.8/0.8	2.1/0.7	2.3/0.4	5.3/–
Recovery time, hours	0.5	0.5	0.5	0.7	0.9	1	3
The number of pore volumes	27	15	20	32,5	20	33	14
Return permeability coefficient *B, %	76.9	79.6	90.7	84.7	74.5	78.1	30.9

* B – return permeability coefficient

als: bentonite clay powder (PBMG), KMC, KSl, oil, graphite, sodium carbonate, PP-2C, VLR, sulfonol [30].

The opening of productive deposits by drilling at boreholes 336, 348 Buhruvativski was conducted on biopolymer systems. The parameters of the solution were regulated by the following values: density – 1,160–1,340 kg/m^3, conditional viscosity – 30–90 s, water less – 3–4 cm^3 per 30 min, $S_{1/10}$ – 20–30/25–45 dPa; for these factors, research of the influence of drilling flushing liquids on the filtration-capacitive properties of the core material was conducted (Table 8). The conditions of the research were as follows: the pressure of the hydro-squeezing was $P_{hydro\text{-}squeezing}$ = 10 MPa, the temperature of the working environment T = 70 °C, the pumping time was 3 hours.

The provided results allow us to state that the return permeability coefficient for researched boreholes is in the range of 74–90 %, and for borehole No. 544 is equal to 30.9 %. However, the simulation of the cut end of the core material for borehole No. 544 caused the destruction of the blocking screen, as a result of which it was possible to increase the return permeability coefficient up to 85 %.

Conclusions. In order to obtain a quick and high-quality opening of productive horizons, it is recommended to apply a highly effective rock-destructive tool that will ensure both the achievement of the maximum advance per bit and high stability of the bit with an increase in mechanical drilling velocity, as well as the application of flushing liquids with parameters that have a negative impact on reservoir rocks will be minimal. If proper conditions for opening productive horizons are provided, the coefficient of recovery of the permeability of productive horizons can range from about 40 to 90 %. The use of special methods for preparing the wellbore for cementing and corresponding cementing systems ensures obtaining a cementing quality factor ranging from 183 to 361, in other words, from unsatisfactory to good quality. The buffer fluids proposed for use provide an increase in the quality of wellbore cleaning up to 72 %. To effectively open productive horizons, it is proposed to use flushing fluids with a conditional viscosity of up to the maximum 90 s. A complex combination of factors to preserve the primary properties of the reservoir rocks and the quick, high-quality opening of the productive horizons during the deepening process will ensure a reduction in the cost of borehole construction and create favorable conditions for the implementation of ways to obtain the maximum possible of the borehole flow rate.

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Особливості технологічних факторів спорудження свердловин на прикладі нафтогазових родовищ

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Мета. Комплексне вивчення геологічних і технологічних факторів буріння, промивання у процесі буріння, стабілізації стінок стовбура свердловини, а також розкриття продуктивних горизонтів у складних гірничо-технічних умовах розробки на різних стадіях родовищ вуглеводнів.

Методика. При виконанні досліджень застосовувалися базові методики математичного й фізичного моделювання, стендового експериментування, а також прийоми обробки результатів лабораторних і промислових досліджень у середовищі EXCEL та MATHCAD. Проведення вимірювань параметрів композицій спеціальних технологічних рідин проводилося за допомогою відповідного контрольно-вимірювального обладнання й матеріалів.

Результати. Запропоновані до розгляду лабораторно-виробничі дані щодо аналізу показників поглиблення вибою свердловини та застосування у свердловинах спеціальних агентів – промивальних рідин, тампонажних систем у тандемі з буферними рідинами. Зазначені агенти дозволяють раціоналізувати процес буріння, а також запобігти активному розвитку явищ погіршення фільтраційних властивостей гірських порід-колекторів і створити надійний транспортний канал для вуглеводнів.

Наукова новизна. На підставі вивчення результатів досліджень процесів спорудження свердловин доведено, що вирішення проблеми підвищення якості розробки родовищ, у даному випадку вуглеводневих, полягає в застосуванні комплексних підходів до організації внутрішньо-свердловинних циркуляційних процесів спеціальних технологічних рідин.

Практична значимість. Отримані комплексні результати лабораторно-промислових досліджень можуть бути взяті за основу при створенні сучасних методик проєктування процесів поглиблення вибою, а також промивання під час буріння та кріплення свердловин, спорудження яких ведеться в осадових гірських породах.

Ключові слова: *свердловина, буріння, промивальна рідина, порода-колектор, цементування, фільтраційні властивості*

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