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Issue **Article**

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SELECTION OF DRILLING MUD FOR DIRECTIONAL DEVELOPMENT WELL

Abstract: *The article discusses the design for the selection of drilling mud for the directional development well No. 707 of the Western Cheleken field in the coastal zones of the coastal waters of the Caspian Sea, with the aim of successful drilling.*

Materials of previously drilled wells and safety rules in the oil and gas industry were used for the design and development of drilling fluids regulations, as well as the experience of foreign companies in the preparation of a hydrocarbon-based solution was applied.

This work can be used to perform the tasks set when drilling directional wells and to draw up regulations for drilling fluids in extremely difficult mining and geological conditions at abnormally high reservoir pressures.

Key words: *viscosity, statistical shear stress, clay crust, hydraulic fracturing, absorption, tack, pore pressure, rock pressure skeletal stress, hydrogen sulfide, fluid.*

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Introduction

The type and properties of drilling mud in combination with technological measures and technical means should ensure trouble-free drilling conditions with high technical and economic indicators, as well as high-quality opening of productive horizons.

When drilling wells that are supposed to open zones with possible gas and oil occurrences or productive horizons in newly drilled areas, as well as when drilling in gas, gas condensate fields with abnormally high reservoir pressures (AHRP) or with hydrogen sulfide and other aggressive and toxic components in the fluid, it is necessary to have a constant supply of drilling mud in the amount of, equal to the volume of the well [1].

For all other wells, the volume of the reserve solution during drilling under normal conditions is carried out as follows: density and viscosity are checked every hour; twice a shift – statistical shear stress, water output, temperature, pH, solid phase and sand content, filtration crust thickness; twice a week – salt content in the filtrate. When drilling gas horizons and drilling in complicated conditions, control is carried out: every 10-15 minutes – density and viscosity; every hour – statistical shear stress, water output, temperature; once every 10 days – oil content in solution. After the opening of the gas reservoir, in the absence of a gas drilling station, the drilling fluid should be monitored for gas saturation twice a shift [2, 3, 4]. The density of drilling mud during the opening of gas-oil-water-saturated formations should be determined for the horizon with the maximum gradient of reservoir pressure in the range of compatible conditions. Normal reservoir pressure in any geological conditions is equal to the hydrostatic pressure of a column of water with a density of 1 g / cm^3 from the roof of the formation to the surface. Abnormal reservoir pressures are characterized by any deviation from normal.

The maximum permissible repression (taking into account hydrodynamic losses) should exclude the possibility of hydraulic fracturing or intensive absorption of drilling fluid at any depth of the interval of joint drilling conditions. In intervals composed of clays, mudstones, clay shales and layers prone to loss of stability and fluidity during drilling, the density, filtration and chemical composition of the drilling fluid are established based on the need to ensure the stability of the walls of the well.

Depression on the walls of the well is allowed within 1 – 15% of the effective skeletal stresses (the difference between the rock and pore pressure of these rocks), if this does not cause a threat of flow, scree, landslides and does not lead to gas and oil occurrences.

Let's consider an example of calculating the density of drilling mud. In the range of 3500 – 4000 m there are clays with the coefficient of anomaly of pore pressure K_{an} = 1.6. The opening of the clay is planned with depression on the walls of the well, which is 12% of skeletal stresses.

Pore pressure at a depth of 4000 m;

$$P_{por} = 1.6 \times 0.1 \times 4000 = 640 \text{ kgf/cm}^2.$$

Rock pressure at a depth of 4000 m;

$$P_{rock.} = 0.1 \times 2.3 \times 4000 = 920 \text{ kgf/cm}^2.$$

Skeletal tension:

$$P = P_{moun} - P_{por} = 920 - 640 = 280 \text{ kgf/cm}^2.$$

Hence, 12% of P is 34 kgf / cm^2 and then the design density of the drilling mud will be:

$$\rho = (640-34) \times 10/4000 = 1.51 \text{ g/cm}^3.$$

If, at the selected values of the drilling mud density, there is a landing or tightening of the drilling tool, the optimal value of the drilling mud density should be selected by stepwise increasing it [5].

It is allowed in case of absorption of drilling fluid during drilling (with or without circulation outlet), opening of collectors at bottom-hole pressure approaching reservoir pressure. The deepening of the well in such conditions should be carried out according to a special plan with a set of measures to prevent gas occurrences, agreed with the anti-spontaneous service. It is not allowed to change the density of the drilling fluid (released from gas) in circulation by more than 0.02 g/cm^3 from the one set by the project. The formulation and methods of preparation, processing, weighting and cleaning of drilling mud are developed by research organizations, and controlled on the basis of regulations. The treatment of drilling mud with chemical reagents and a weighting agent is carried out in accordance with the developed formulation. Before adding oil, lubricating additives and surfactants to the weighted drilling mud, a laboratory assessment of the oil wettability and flocculation of the applied barite should be carried out. When flocculating barite, it is necessary to pretreat the solution with hydrophilizing reagents [6].

During the drilling and flushing of the well, the properties of the drilling fluid should be monitored at intervals established for a given area (field). Indicators of the properties of the drilling mud at least once a week should be monitored by the central laboratory with the issuance of drilling results and recommendations for bringing the parameters of the solution to the indication in the project. Before and after the opening of formations with abnormally high pressure, when resuming well flushing after descent and lifting operations, geophysical surveys, repair work and downtime, it is necessary to start monitoring the density, viscosity and gas content in the drilling fluid immediately after the restoration of circulation.

During the opening of gas-bearing horizons and further deepening of the well (before the descent of the next casing), the drilling fluid should be monitored for gas saturation [7].

If the volume content of gas in the drilling fluid exceeds 5%, then measures should be taken to degass it, identify the causes of saturation of the solution with gas (reservoir operation, gas intake with drilled rock, foaming, etc.) and eliminate them. Increasing the density of the drilling fluid located in the well by pumping individual portions of the weighted solution is prohibited. When using emulsion, inhibited and non-dispersing polymer drilling fluids, oil-based solutions and others, the control of the properties characteristic of each special solution and their regulation are carried out according to the relevant instructions.

Cleaning of drilling mud from drilled rock and gas should be carried out by a set of means provided for by the well construction project in the sequence: well – coarse cleaning unit (vibrating screen) – degasser – fine cleaning unit (sand and silt separator) – solid phase control unit (hydrocyclone clay separators, centrifuge).

When using hydrocarbon–based drilling fluids (lime –bitumen, inert – emulsion, etc.), measures should be taken to prevent workplace pollution and gas contamination - measures should be taken to eliminate it [8].

For drilling directional production and evaluation well No. 707 at the Western Cheleken field, a special drilling mud formulation was developed, which shows the type, parameters, components and composition of drilling fluids at intervals.

When drilling a well from zero to a depth of 800 m, an oil-emulsion humate-lignosulfonate solution was used to drill unstable sand-clay rocks of the quaternary deposit and stabilize the wellbore.

Stabilizers reagents are used as regulators of the properties of the drilling mud: a carbon-alkaline reagent (CAR) and ligno-sulfonates - condensate of sulfate-alcohol bard (KSSB-2). Caustic soda (NaOH) is used to regulate the alkalinity of the calcium solubility solution in seawater. Oil and graphite are used from specialized reagents functionally designed to hydrophobize the solid phase of drilling mud and improve lubricating properties. To prevent foaming of the solution, a surfactant HT-48 is used. The hydrogen pH of the solution is 8.5-9.0.

Preparation of an oil-emulsion humate-lignosulfonate solution [9].

In a clay mixer with a volume of 4 m3, water is poured to half the volume and 60 kg of caustic soda (NaOH) is added - mixing is carried out for 15-20 minutes, after that 600 kg of water is poured with periodic scrolling of the blades of the clay mixer and water is added to the upper level. The mixture is mixed for 1-130 hours, after which the reagent is added to the drilling mud during one circulation cycle. During the first treatment, it is necessary to add the 2nd clay mixer ($8m^3$) of the carbon-alkaline reagent to $100m^3$ of the drilling solution.

In a clay mixer with a volume of 4 m^3, water is poured to half the volume and 70-80 kg of caustic soda (NaOH) is filled in - mixing is carried out for 15-20 minutes, after that 700-800 kg of KSSB-2 is filled in with periodic scrolling of the blades of the clay mixer and topping up the water to the upper level. The mixture is mixed for $1\text{-}1^{30}$ hours, after which the reagent is released into the drilling mud during one circulation cycle. During the first treatment, the 2nd clay mixer ($8m^3$) of the KSSB-2 reagent must be added to 100 m^3 of drilling mud.

For 100 m^3 of drilling mud, it is necessary to add 10tn oil and 500 - 700kg graphite. Surfactant HT- 48 is used in drilling mud as a defoamer. Surfactant HT must be added to 100 m^3 of drilling mud- 48 - 200 - 400kg. All these reagents are alternately added to the drilling mud during one circulation cycle, depending on the volume of the drilling mud being processed [10].

In the future, the processing of an oil-emulsion humate-lignosulfonate solution is carried out in order to reduce the viscosity of the solution and water loss to the set values of the parameters. If the pH of the solution falls below the value, the required amount of NaOH should be injected into the solution. Preparation and addition of reagents in the future is carried out as needed.

The parameters of the oil-emulsion humate-lignosulfonate solution used at well 707 on the Western Cheleken area are shown in Table 1.

Table 1.

Name (type) of the solution	Interval, m		Drilling mud parameters					
	From (top)	To (bottom)	Density g/cm^3	Condi-tional visco-sity, sec.	Water output, cm^3/ 30 min	Crust, mm	Statistical shear stress, kgf/cm^2 In , min: 1	10
n/a humate-lignosulfonate	0	200	1,40	40-60	10-12	2-3	20-40	50-70
	200	800	1,47	40-60	10-12	2-3	20-40	50-70

Continuation of table 1.

Interval m		Drilling mud parameters					
		Composition of the solid phase, % vol.					
From (top)	To (bottom)	$V_{Colloid.act.subs.}$	V_{Sand}	V_{amount}	pH	Mineralization, mg/l	Density up to weighting g/cm^3
0	200	14,03	5	19,03	9 – 9,5	13 - 15	1,2
200	800	16,69	5	21,69	9 – 9,5	13 - 15	1,2

In order to completely clean the drilled rock from the barrel of directional wells, it is necessary to select the appropriate ratio of the drilling pump parameters, density and rheological parameters of the drilling fluid. The successful flushing of the well from the rheological properties of the drilling fluid primarily depends on the static shear stress and viscosity.

When drilling a well from a depth of 800 m to a depth of 2764 m in an obliquely directional interval, a hydrocarbon-based solution was used in the zone of elevated temperatures +104 °C, in order to suppress the clays of the lower red-colored thickness and open the productive layers of the well, stabilize the wellbore and excessive saturation of the drilled rock. Provides stability of the solution parameters in the zone of elevated temperatures.

Hydrocarbon-based solutions provide the possibility of drilling unstable, swelling or expanding rocks in the aquatic environment, prevent oil seal formation and tool grabs due to the pressure drop between the well and the formation. They have the best lubricating properties, protect the tool from corrosion [11].

This system is a solution based on diesel fuel with a highly emulsified system that withstands high temperatures and at the same time does not lose the stabilizing properties of the solution. This system is successfully used for drilling deep wells.

The substitution of an oil-emulsion humate-lignosulfonate solution for a solution with a hydrocarbon base was performed without opening the cement cup of the 339.7 mm conductor.

Table 2 shows the required amount of materials and chemical reagents for the interval preparation of a hydrocarbon-based solution in a diesel/water ratio of 80/20.

Table 2.

№/	Name of materials and chemicals	Required quantity		
		800 m (339.7mm) Conductor (162 m^3) ρ =1.47g/cm ^{3}	800 m-2119m (311.15 mm) technical column (348 m^3) ρ =1.68g/cm^3	2119m-2764m (215.9 mm) production column (246 m^3) ρ =1.81g/cm^3
1.	Diesel	102	214	151
2.	Poliogel (organophilic bentonite)	4	7	6
3.	Lime CaO	7	14	10
4.	STAB – DT (emulsifier)	4	8	6
5.	NeoInvert GF brand 1 (hydrophobizer)	3	5	4
6.	Poli STJ (Calcium Chlorine $CaCl_2$)	9	18	13
7.	Polioilchek Filtr-GS (filter step-down)	4	7	6
8.	Polioilchek Wis (viscosity reducing agent)	2	3	2
9.	Poliantifrik (additive against the seizure of drilling tools)	3	5	4
10.	Sawdust	0,162	0,348	0,246
11	Calcium Carbonate $CaCO_3$ (large grains)	0,162	0,348	0,246
12.	Calcium Carbonate $CaCO_3$ (medium grains)	0,162	0,348	0,246
13.	Calcium Carbonate $CaCO_3$ (small grains)	0,162	0,348	0,246
14.	Barite (weighting agent)	146	122	56

Preparation of a hydrocarbon-based solution formulation in field conditions for 1 m^3 of solution: The required amount of diesel fuel (0.5 m) is poured into one of the tanks, then, with intensive stirring, surfactant emulsifiers-Versamul and Versacodt are introduced through the funnel using a jet of centrifugal pumps and agitators, achieving their complete dissolution. In another container, mineralized water (containing CaC_{12}) of the required activity is prepared. Mineralized water is slowly added to the container with the treated reagent with diesel fuel through the mixer funnel, mixing thoroughly (in addition, you can add dry powder CaC_{12}). Then quicklime (CaO) is introduced, thoroughly mixed for 30-60 minutes and a filtration reducing reagent, Versatrol, is introduced, mixed for 30-60 minutes. Barite is added to the resulting initial solution to the required density and mixed for an hour. Technological parameters of the finished solution are determined [12].

The necessity is the sequence of reagent input and mechanical mixing of the system. In this regard, constant speed mixers (n = 2000 rpm and more), and hydraulic and mechanical agitators should be used on the drilling rig.

The parameters of a hydrocarbon-based solution for drilling for a technical column and for an operational column are given in Table 3.

Table 3.

Name (type) of the solution	Interval, m		Drilling mud parameters					
	From (top)	To (bottom)	Density g/cm^3	Condi-tional viscosi-ty, sec.	Water output, cm^3/ 30 min	Crust, mm	shear stress, kgf/cm^2 In , min	
							1	10
n/a humate-lignosulfonate	800	2119	1,68	50-70	3-4	0,5-1	5-15	5-20
	2119	2764	1,81	50-70	2-3	0,5	5-15	5-20

Continuation of table 3.

Interval, m		Drilling mud parameters					
		Composition of the solid phase, % vol.			pH	Mineralization, mg/l	Density up to weighting g/cm^3
From (top)	To (bottom)	V_{oil}	$V_{s.f}$	$V_{liq.}$			
800	2119	65,09	18,64	16,27	9 – 9,5	15-17	1,47
2119	2764	66,01	17,2	16,79	9 – 9,5	15-17	1,68

Due to the lack of new hydrodynamic research data, when designing the drilling mud formulation, all the data for drawing up the regulations were taken from previously drilled wells. When drilling the inclined part of the well with a drilling mud density of 1.74g / cm^3, at a depth of 2120 m, due to the pressure drop, the drilling tool was seized. After the release of the drilling tool, drilling continued by reducing the specific gravity of the drilling mud to 1.62 g/cm^3, which was successfully brought by drilling to the design depth.

There are also some disadvantages in the hydrocarbon-based solution when drilling wells, which requires compliance with the rules of technical and fire safety [13].

Hydrocarbon-based solution has an increased fire hazard, and requires additional environmental protection measures (disposal, closed circulation cycle, storage of materials and substituted solution, etc.).

If the concentration of hydrocarbon vapors exceeds 300 mg/cm^3, work should be suspended and people removed from the danger zone. The self-ignition temperature of the hydrocarbon-based solution should be 50 °C higher than the maximum expected temperature of the solution at the wellhead.

Conclusions

1. The developed drilling mud formulation has successfully fulfilled its purpose and objective.
2. The lack of fresh (updated) data from hydrodynamic studies of previously drilled wells can lead to complications and further emergency situations.
3. When cleaning the bottom of an inclined-directional well, it is necessary to observe the parameters of the solution according to the project
4. When drilling on a hydrocarbon-based solution, it is necessary to observe the rules of technical and fire safety.

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