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Issue **Article**

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SELECTION OF THE THE BOTTOM-HOLE ASSEMBLY FOR DRILLING UNDER THE PRODUCTION COLUMN OF THE DIRECTIONAL WELL

Abstract*: the article considers the design of the bottom-hole assembly (BHA) for the production column of an inclined directional production and evaluation well in order to successfully drill well № 707 at the Western Cheleken field in the coastal zones of the coastal waters of the Caspian Sea.*

Materials of previously drilled wells and standard calculations, as well as safety rules in the oil and gas industry, were used for the design of the BHA for the purpose of drilling the interval for the production column.

This work can be used to perform the tasks set when drilling directional wells, in the fight against possible complications in the open hole in conditions of abnormally high reservoir pressures.

Key words*: overhead centralizer, translator, deflector motor, bit, radius of curvature, angle of skew, bend, section, rigid link, telesystem, extension.*

Language*: English*

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Introduction

Based on the calculated optimal dimensions of the layout of the bottom of the drill strings (BHA), taking into account the size of the bit, the location of the centralizers (calibrators) and other technological elements of the BHA is determined.

When drilling by the rotary method, the length of the extension adapter (drill collar segment) is determined, which must be installed between the centralizer and the bit or calibrator, if the latter is included in the BHA, so that the length of the guide section is equal to the calculated (L_{op}) optimal value [1].

Figure 1 shows the calculation scheme of the BHA.

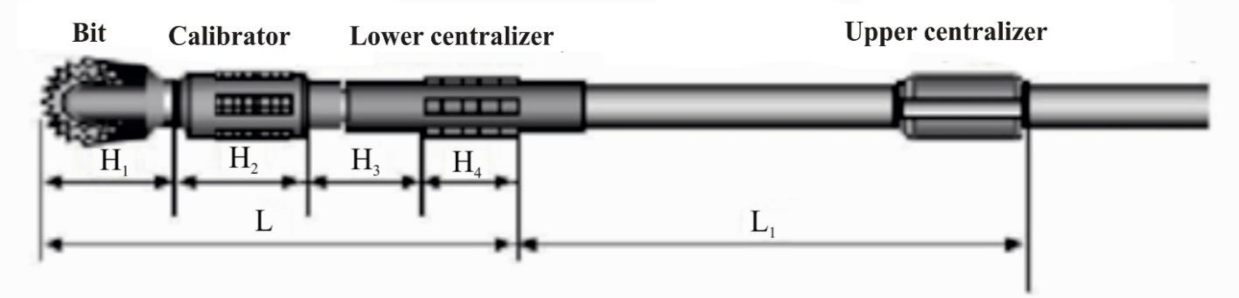


Figure 1 – Calculation scheme of the BSC with centralizers

The length of the extension sub is determined from the expression:

$$H_3 = L - H_1 - H_2 - H_4 \;, \qquad (1)$$

where H_3 is the length of the extension sub, m;

L is the estimated length of the guide section of the BHA, m;

H_1 – bit height, m;

H_2 – length of the over-the-bit calibrator, m;

H_4 is the length of the centralizer, m.

When drilling with a downhole motor and using mobile centralizers, the installation location (the distance from the end of the shaft spindle translator to the centralizer) of the lower centralizer on the body of the downhole motor [2] is determined from the expression:

$$H_3 = L - H_1 - H_2 - H_4 \qquad (2)$$

where H_3 is the distance from the lower end of the over–the-head shaft of the spindle shaft of the downhole motor to the centralizer, m;

L is the estimated length of the guide section, m;

H_1 – bit height, m;

H_2 – length of the over-the-bit calibrator, m;

H_4 is the length of the centralizer, m.

At the bottom-hole deflector motor, a curved translator or a curvature mechanism is located between the spindle section and the working section (Figure 2).

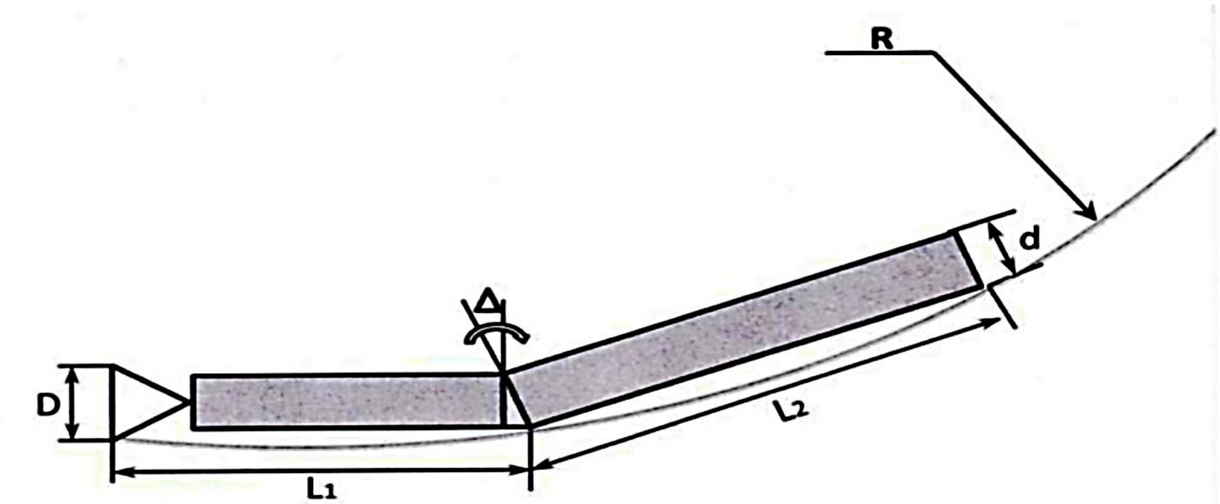


Figure 2 – Design scheme of the downhole diverter motor

In accordance with the specified radius (R) of the curvature of the borehole, the required angle (Δ) of bending of the curved translator or the curvature mechanism is calculated according to the formula:

$$\Delta = \arcsin\left[\frac{L_1 + L_2}{2R}\right] + \beta, \qquad (3)$$

where R is the radius of curvature of the borehole, m;

L_1, L_2 - the length of the lower and upper sections of the downhole diverter motor, respectively, m;

$$\beta = \operatorname{arctg}\left[\frac{D - d}{2L_1}\right] + \beta,$$

D is the skew angle of the curved translator, deg;
where D, d is the diameter of the borehole and the body of the downhole diverter motor, respectively, m.

In this case, the following conditions must be met.

The length of each section must be less than the length (L_1) of the rigid link of the BHA, which is determined from the expression:

$$L_1 = \frac{4}{3} \cdot \sqrt[4]{\frac{(D - d) \cdot EJ}{g}}, \qquad (4)$$

where D, d is the diameter of the bit and the section of the downhole motor, respectively, m;

EJ is the bending stiffness of the downhole motor section, kN*m^2;

g is the transverse component of the weight of the unit length of the downhole motor section, kN/m.

Geometric and stiffness characteristics of downhole motors are given in Table 1.

Table 1.

Type of downhole motor	Diameter, mm	Length, m	Weight, kN/m	Weight 1 m, kN/m	Bending stiffness, kN* m^2	$m=\sqrt[3]{\frac{EJ}{q}}$, m
Turbo drills						
ZTSSH-240	240	23,2	59,80	2,58	24000	21,0
A9GTSH	240	23,3	61,30	2,63	24000	20,9
ZTSSH -195	195	25,7	47,90	1,86	9000	17,5
A7 GTSH	195	25,0	44,30	1,77	9000	17,8
ZTSSH -172	172	26,3	35,30	1,36	6400	16,6
Screw downhole motors						
D-195	195	7,7	13,30	1,73	9000	17,7
D-172	172	7,0	10,00	1,26	5000	15,2

The maximum length (L_{Sp}) of a spindle with a bit, at which its insertion into a curved borehole with a radius of curvature R is ensured, is determined by the formula:

$$L_{sp.} = 2{,}4 \cdot \sqrt{R(D-d)}. \qquad (5)$$

The working section of the downhole diverter motor must also fit into the curved borehole without deformation, and its length (L_s) must satisfy the ratio:

$$L_s \le 2{,}828 \cdot \sqrt{R \cdot (D-d)}. \qquad (6)$$

Drilling of the directional operational evaluation well No. 707 on the Western Cheleken field from a depth of 2119 m was drilled with a set of a zenith angle of 38 degrees to a depth of 2389 m. From a depth of 2389 m to a design depth of 2765 m (along the hole), the well was deepened with a stable maintenance of the zenith angle of 38 degrees [3].

The drilling data of the section for the production column of 139.7 mm along the barrel interval are shown in Table 2.

Table 2.

The interval of the barrel diameter	2119 – 2765 (by hole)
215.9 mm	2100m – 2620m (vertical) 501 m
Interval length:	
Drilling barrel interval with a screw downhole motor :	2119 – 2765m (along the hole)
The length of the drilling interval with a screw downhole motor:	2100 m – 2620 m (vertical)

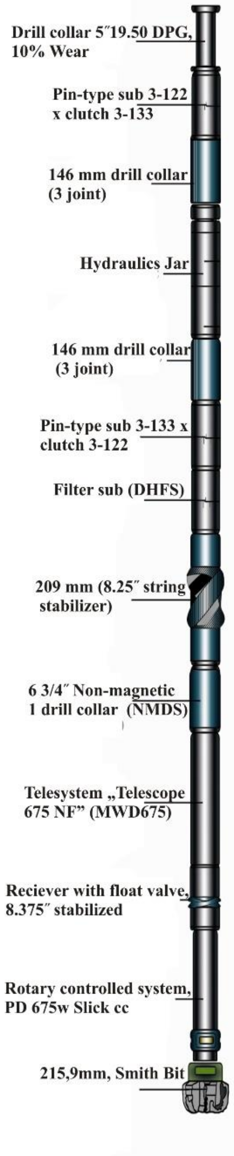
For drilling all intervals, the following layout of the bottom of the drill strings (BHA) is selected. The zenith angle was set by a rotary controlled system.

The actual position of the borehole in space during drilling and downhole in the productive horizon should be determined in accordance with the requirements of the project by inclinometric measurements during drilling, including using downhole telemetry systems [4].

Rotary arrangements are usually designed for drilling areas of set, drop, or stabilization of the zenith angle of the well. The behavior of any rotary arrangement is regulated by changing the diameter and position of the centralizers within the first 36 m from the face. Additional centralizers installed above will have little effect on the characteristics of the borehole. These layouts require deflection of the weighted drill pipe between the first and second centralizers. The deflection leads to the inclination of the bit, drill pipes and the creation of a lateral force on the bit directed towards the upper wall of the borehole. The intensity of the zenith angle set for this arrangement increases with increasing [5].

BHA for drilling with a diameter of 139.7 mm under the production column.

For drilling an interval of 2100-2620 m (vertically) 2119-2765 m (along the hole) of the zenith angle set, the following BSC was designed.



Field Name	Turkmennebit/Turkmen	Borehole Name	707	Hole Size (in)	8.500
Structure Name	West Cheleken# 707	BHA Name	КНБК2	Depth in (m)	2118.49
Well Name	Gunbatar Cheleken# 707		PowerDrive+MWD	Depth Out (m)	2764.37

	Desc.	Manu.	OD (in) / ID (in)	Max OD (in)	Bot Type / Top Type	Bot Gender / Top Gender	FN OD (in) / FN Length (m)	Length (m)	Cum. Length (m)	Cum. Weight (t)
1	215,9mm, Smith Bit	Smith/ Schlumberger	6.772 / 2.250		4-1/2 REG	Pin		0.23	0.23	0.0
2	Rotary controlled system, PD 675w Slick cc	Schlumberger	6.750 / 4.200		4-1/2 REG / 5-1/2 FH	Box / Box	0.000 / 0.00	4.11	4.34	0.7
3	Reciever with float valve, 8.375″ stabilized	Schlumberger	6.750 / 2.250		5-1/2 FH / 5-1/2 FH	Pin / Box		1.52	5.86	0.9
4	Telesystem „Telescope 675 NF" (MWD675)	Schlumberger	6.772 / 5.118		5-1/2 FH / 4-1/2 IF	Pin / Box	0.000 / 0.00	7.53	13.39	1.8
5	6 3/4″ Non-magnetic 1 drill collar (NMDS)	Schlumberger	6.772 / 2.835	6.772	4-1/2 IF / 4-1/2 IF	Pin / Box	6.772 / 1.00	9.42	22.81	3.3
6	209 mm (8.25″ string stabilizer)	Schlumberger	6.750 / 2.813		4-1/2 IF / 4-1/2 IF	Pin / Box		1.52	24.33	3.5
7	Filter sub (DHFS)	Schlumberger	6.772 / 2.835	6.772	4-1/2 IF / 4-1/2 IF	Pin / Box	0.000 / 0.00	1.00	25.33	3.6
8	Pin-type sub 3-133 x clutch 3-122	TN	6.772 / 2.835	6.772	4-1/2 IF / 4 IF	Pin / Box	0.000 / 0.00	1.00	26.33	3.8
9	146 mm drill collar (3 joint)	TN	5.748 / 2.441	5.748	4 IF / 4 IF	Pin / Box	0.000 / 0.00	27.43	53.76	6.7
10	Hydraulics Jar	Smith/ Schlumberger	6.496 / 2.756	6.496	4 IF / 4 IF	Pin / Box	6.496 / 0.50	4.87	58.63	7.4
11	146 mm drill collar (3 joint)	TN	5.748 / 2.441	5.748	4 IF / 4 IF	Pin / Box	0.000 / 0.00	27.43	86.06	10.3
12	Pin-type sub 3-122 x clutch 3-133	TN	6.457 / 2.835	6.457	4 IF / 4-1/2 IF	Pin / Box	0.000 / 0.00	1.00	87.06	10.5
13	Drill collar 5″19.50 DPG, 10% Wear	TN	4.928 / 4.276	6.625	NC50 (4-1/2 IF) / NC50 (4-1/2 IF)	Pin / Box		9.45	96.51	10.8

BHA Comments

Total Length (m)	96.51
Total Weight in Air (t)	10.8
Total Buoyant Weight (t)	8.4
Buoyant Weight Below Jar (t)	5.3
Weight in Air Below Jar (t)	6.7

Mud Properties	
Mud Weight (g/cm3)	1.85
Mud Type	OBM
PV (cP)	42.00
YP (0.01 lbf/ft2)	32.00

Sensor Offset from Bit (m)		Stabilizer Summary	
		Blade Mid-Pt to Bit (m)	Blade Length (m)
Gamma Ray	8.88	5.036	0.300
D+I	9.52	23.262	0.610
		Bend Summary	
		Bend Angle (deg)	

BHA Nozzle Summary		
Component	Count x ID (1/32 in)	TFA (in2)
Bit	6 x 12	0.663
PD Flow Restrictor (1/32 in)		0.00
Rotor Bypass Nozzle (1/32 in)		

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Figure 3. BHA for drilling the interval 2119-2389 m (along the hole) in order to stabilize and set the zenith angle for the production column before the drilling tool is seized.

Diamond bit with a diameter of 215.9 mm; 212.7 mm Rotary controlled system PD675; calibrator with check valve 212.7 mm; 175 mm Telescope 675 NF; drill collar 172 mm non–magnetic - 9.42 m; calibrator with check valve 209 mm; translator with filter 172 mm; pin-type sub Z-133x clutch Z-122; drill collar 146 mm -27.43 m; hydraulic jar 165 mm; drill collar 146 mm -27.43 m; pin-type sub Z-122x clutch Z-133; BT 139.7 mm-9.45 m (thickened drill pipe).

The designed BHA for drilling this section includes two important elements:

- The PowerDrive X6 rotary controlled system (RCS) is a new generation of drilling equipment with increased reliability and productivity, which allows achieving greater penetration per chiseling, accurately following the planned trajectory of the hole while reducing drilling time. All external elements of the system rotate, which ensures high uniformity and stability of the borehole, the transfer of the necessary load to the bit and, ultimately, minimizing the probability of snapping the arrangement at the bottom [6, 7].

- The Telescope system for measuring and transmitting data during drilling, which is used for measuring the zenith angle and azimuth and transmitting data to the surface in real time by creating pressure pulses decoded by sensors installed on the drilling line.

Drilling procedure in the range 2119-2764m along the hole (angle set interval + stabilization)

1. Before lowering the BHA for deflection, drill the cementing valve check throttle (CVCT), cement cup and shoe and at least 5 meters of rock to ensure the purity of the face from foreign objects.

2. Assemble and descend the BHA to a depth of 2119 m along the hole for drilling in the range 2119 – 2764 m along the hole.

3. Drilling in this interval will be carried out by the BHA with RCS. Set from 27 to 39 of the zenith angle and maintaining the zenith angle of 39 degrees, together turning the direction from 250 degrees to 260 degrees, to the design depth of 2764 m along the hole (2620 m vertically). The planned drilling interval can be increased or reduced by the customer's decision.

4. When drilling with RCS, the minimum required rotation speed of the drilling column is 120-130 revolutions per minute. (Optimal rotation speed 140 revolutions per minute)

5. RCS commands are given by varying the supply of drilling mud by pumps.(min-max-min-max allowed for the device, etc.)

6. To assess the degree of cleaning and the condition of the borehole, the volume of drilled sludge, as well as the torque value must be constantly monitored [8].

7. If there are landings or delays during drilling, work out the borehole of the drilling well. In case of critical landings and tightening, in order to avoid wear of the elements or loss of the BHA, make a descent and lifting operations to change the BHA to a rotary one, and further study of the borehole. In the absence of problems along the hole, lift the BHA for the subsequent implementation of the planned GSW (geophysical studies of wells) complex.

8. At the design depth of the hole of 215.9 mm (8.5”), flush the borehole until the sludge is completely washed out, and carry out a control descent into the shoe of the previous column. Flush the well, align the parameters of the drilling mud at the maximum possible feed rate and the corresponding rotor rotation speed (recommended at least 80 rpm), with simultaneous monitoring of the presence of sludge on the vibrating screens [9].

From a depth of 2119 m to 2150 m, the interval is drilled stably with maintaining a zenith angle of 27 degrees and an azimuth angle of 250 degrees. Drilling from a depth of 2150 m to a depth of 2388 m was carried out with a set of zenith angle of 39 degrees with an azimuth angle correction from 250 to 260 degrees. After opening the shoe of the intermediate technical column at a depth of 2120 m, the specific gravity of the drilling mud was raised from 1.70 g/cm^3 to 1.74 g/cm^3. When reaching a depth of 2227 m at a zenith angle of 31.5 degrees and an azimuth angle of 254 degrees at a drilling mud density of 1.78 g/cm^3, the drilling tool was seized [10].

If the hydrostatic pressure in the borehole exceeds the reservoir pressure in the reservoir opened during drilling, the absorption of drilling fluid may occur. If the hydrostatic pressure in the borehole exceeds the reservoir pressure in the reservoir opened during drilling, the absorption of drilling fluid may occur. Violation of the borehole zone of the well during drilling is very dangerous, and often leads to accidents and costs a lot of money and time to eliminate it. Most of these complications occur when drilling clay rocks.

A timely increase in the density of the drilling mud and a decrease in the filtration rate to the required size contribute to the prevention of this complication.

To eliminate the seizure, it is necessary first of all to pace the column with cranking. If at the same time it is not possible to eliminate the tack, more complex methods of elimination are used: the installation of water, acid or oil baths, depending on the nature of the tack. At well № 707 on the Western Cheleken field, an oil and acid bath was installed twice to free the drilling tool from being seized, but the attempts were unsuccessful. When installing the third oil bath while pacing the drilling tool 160 ts, the tool was released. The reason for the seizure is a very large discrepancy in the density of the drilling fluid, which led to a pressure drop and, with partial absorption, sticking of the drilling tool to the wall of the well. After that, the density of the drilling mud was reduced to 1.62 g/cm^3. When drilling from a depth of 2227 m to a design depth of 2764 m, the BHA was changed with a decrease in stiffness (Fig. 4).

	Desc.	Manu.	Serial Number	OD (in) / ID (in)	Max OD (in)	Bot Type / Top Type	Bot Gender / Top Gender	FN OD (in) / FN Length (m)	Length (m)	Cum. Length (m)	Cum. Weight (t)
1	215,9mm, Smith Bit	Smith/ Schlumberger	Jv5734	6.772 / 2.250	8.500	4-1/2 REG	Pin		0.23	0.23	0.0
2	Rotary controlled system, PD 675w Slick cc	Schlumberger	51023	6.750 / 4.200	8.375	4-1/2 REG / 5-1/2 FH	Box / Box	7.750 / 0.95	4.10	4.33	0.7
3	Reciever with float valve, 8.375″ stabilized	Schlumberger		6.750 / 2.250	8.375	5-1/2 FH / 5-1/2 FH	Pin / Box	6.750 / 0.77	1.75	6.08	0.9
4	Telesystem „Telescope 675 NF" (MWD675)	Schlumberger	H1977	6.750 / 3.875	6.750	5-1/2 FH / 4-1/2 IF	Pin / Box	6.750 / 0.47	8.50	14.58	2.0
5	6 3/4″ Non-magnetic 1 drill collar (NMDS)	Schlumberger	32155-1	6.750 / 2.750	6.772	4-1/2 IF / 4-1/2 IF	Pin / Box	6.750 / 8.99	8.99	23.57	3.4
6	209 mm (8.25″ string stabilizer)	Schlumberger	7082-AK-2	6.750 / 3.125	8.250	4-1/2 IF / 4-1/2 IF	Pin / Box	6.750 / 0.85	2.14	25.71	3.7
7	Filter sub (DHFS)	Schlumberger	154PC	6.750 / 2.875	6.750	4-1/2 IF / 4-1/2 IF	Pin / Box	6.750 / 0.42	1.76	27.47	3.9
8	127 mm drill collar (5″ HWDP 9 joints)			5.000 / 3.000	6.535	4-1/2 IF / 4-1/2 IF	Pin / Box	6.535 / 0.55	84.05	111.52	10.2
9	Pin-type sub 3-133 x clutch 3-122	Schlumberger	26283	6.375 / 2.875	6.375	4-1/2 IF / 4 IF	Pin / Box	6.375 / 0.50	0.50	112.02	10.3
10	127 mm, 5″ Hydraulics Jar		QY159III-Y	6.250 / 2.250	6.250	4 IF / 4 IF	Pin / Box	6.250 / 0.43	5.52	117.54	11.0
11	Pin-type sub 3-122 x clutch 3-133	Schlumberger	SLW3-4877	6.375 / 2.875	6.375	4 IF / 4-1/2 IF	Pin / Box	6.375 / 0.48	0.48	118.02	11.1
12	127 mm drill collar (6 joints)			5.000 / 3.000	6.535	4-1/2 IF / 4-1/2 IF	Pin / Box	6.535 / 0.55	56.34	174.36	15.3
13	Drill collar 5″19.50 DPG, 10% Wear										

BHA Comments

Total Length (m)	183.8
Total Weight Air (t)	15.6
Total Buoyant Weight (t)	12.4
Buoyant Weight Below Jar (t)	8.
Weight in Air Below Jar (t)	10.

Mud Properties	
Mud Weight (g/cm3)	1.6
Mud Type	OB
PV (cP)	42.0
YP (Pa)	15.3

Sensor Offset from Bit (m)	
Gamma Ray	2.18
D+I	2.45
Gamma Ray	9.59
D+I	10.24

Stabilizer Summary		
Blade Mid-Pt to Bit (m)	Blade OD (in)	Blade Length (m)
5.030	8.375	0.300
24.600	8.250	0.510

Bend Summary	
Bend Angle (deg)	Bend to Bit (m)

BHA Nozzle Summary		
Component	Count x ID (1/32 in)	TFA (in2)
Bit	6 x 12	0.663
PD Flow Restrictor (1/32 in)		0.0
Rotor Bypass Nozzle (1/32 in)		

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Figure 4. BHA for drilling the interval 2389-2765 m (along the hole) of the set and stabilization of the zenith angle for the production column after taking the drill tool.

Drilling to a depth of 2350 m was continued with a drilling mud of 1.62 g/cm^3 and a depth of 2350 m to a design depth of 2764 m on a drilling mud of 1.62 g/cm^3.

From a depth of 2388 m, the zenith angle reached 39 degrees and the azimuth angle 260 degrees. From a depth of 2388 m to a design depth of 2764 m, drilling was carried out by stabilizing the zenith angle of 39 degrees and the azimuth angle of 260.

Drilling of the interval under the production column was carried out with a diamond drill bit with a diameter of 215.9 mm of the MDI616 brand manufactured by SmithBits, shown in Fig. 5.

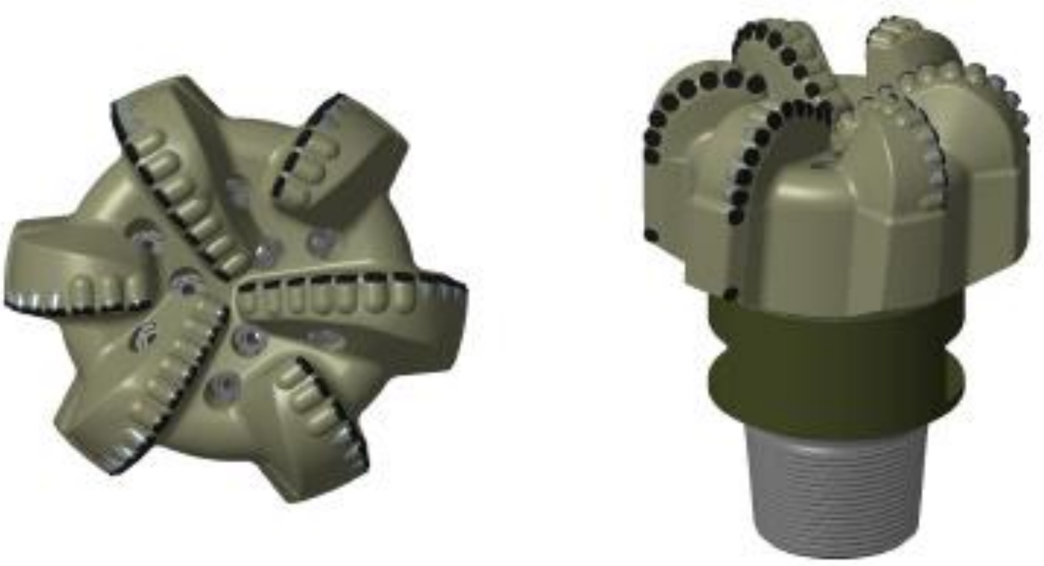

Figure 5. Diamond drill bit, diameter 215.9 mm of the MDI616 brand.

With a diamond drill bit with a diameter of 215.9 mm of the MDI616 brand, a six-bladed PDC bit with a matrix body (M) and a 16 mm cutter, specially designed for directional (D) drilling using a rotary controlled system (RCS) and a rotating downhole motor, which consistently provides excellent performance in directional positions under load, has an increased cleaning of the drilled rock, as well as with the help of permissible hydraulic flows, produces the necessary cooling of the bit and the complete lifting of the drilled rock to the surface. With minimal pressure supply by the pump, there is no risk of lumps forming at the bottom of the well [11].

Drilling of the well was carried out on a hydrocarbon-based drilling mud with a specific gravity of 1.66 g/cm^3; the flow rate of drilling mud is 28 l/sec; the area of the bit nozzles is 427.74 mm^2; the pressure drop on the bit was 40 kg/cm^2; and the total pressure in the riser was 180 kg/cm^2. Drilling was carried out in the following mode:

The load on the bit is 5-10 tons.

Rotation speed 120-130 rpm.

The pump capacity is 25-30 l/sec.

All procedures for setting the drilling mode and drilling mud were followed according to the developed program. The interval of the well (stabilization and a set of zenith angle) with a zenith angle of 39 degrees and an azimuth angle of 260 degrees and an offset towards the sea area of 491 meters with the selected BHA was successfully drilled to the design depth [12].

After fastening, perforation was made at depths of 2568 – 2572m; 2564 – 2568 m; 2549 – 2551m; 2552 – 2554m. During development, there was no inflow in the well. The intervals 2610 – 2612 m 2512 – 2518 m were re–fired and the interval 2564 - 2668 m was re-fired, an influx of oil into the waters with a flow rate of 30 tons /day was obtained.

Conclusions

1. When drilling wells with abnormally high reservoir pressures, in order to avoid complications, all the necessary parameters of the drilling fluid should be adjusted.

2. For the earliest possible release of the grip of the drilling tool, it is necessary to have oil on the drilling rig to install an oil bath.

3. It is necessary to select the right BHA for directional wells in order to avoid complications and accelerate the mechanical drilling speed.

4. When drilling wells with diamond drill bits, it is necessary to adhere to the design parameters of the hydraulic program and drilling mode.

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