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Issue Article

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

Abstract*: the article considers the design of the bottom-hole assembly (BHA) of the technical column of intervals (a set of zenith, rectilinear) of an obliquely directed operational evaluation well for the purpose of successful drilling of 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 to design the BHA of the intermediate technical column of the well. The application of new downhole equipment for the selection of the zenith angle and logging operations during drilling in real time is described.

This work can be used to perform the tasks set when drilling directional wells in fields with difficult mining and geological conditions and abnormally high reservoir pressure.

Key words*: technical column, design, flushing fluid, drill string, bending, calibrator, compression, curvature, check valve, rotary controlled system, translator, nipple, clutch.*

Language*: English*

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Introduction

An important technological factor determining the curvature of the vertical borehole is the longitudinal stability of the drill string located above the bit. When the stability of the drill string is lost, a deflecting force appears on the bit, under the action of which the bit will destroy the face at a certain angle to the axis of the well and mill the barrel wall in the transverse direction, which will lead to a curvature of the well.

The correct selection (design) of technological and technical means, namely the bottom-hole assembly (BHA) (bits, drill string, rotating downhole motor, telesystems and deflectors), as well as drilling mud, are the fundamental factors ensuring successful (controlled) well wiring [1, 2].

When drilling wells, the following main methods are used to ensure the verticality of the hole:

- using the "pendulum" effect by creating the maximum possible deflecting force on the bit, directed in the direction opposite to the direction of curvature of the barrel, and increasing the intensity of milling the barrel wall with the side surface of the bit;
- maintaining the existing insignificant zenith angle of the borehole by centering the lower part of the BHA by placing the centering elements at the optimal distance from the bit;
- active reduction of the curvature of the barrel due to the deflecting force or a change in the direction of the axis of the bit.

These methods of wiring a vertical borehole are implemented by appropriate technical means:

- pendulum BHA;
- hard BHA;
- stepped BHA;
- RCS -s.

Therefore, the main task in calculating the BHA for drilling a vertical well is to find such a length of its guide section at which the total angle of rotation of the bit axis would be minimal with any combination of

technological factors [3]. The calculation scheme of such a rigid BHA is shown in Figure 1.

The minimum of the total angle ($\varphi_{tot.} = \varphi_{pr} + \varphi_{init}$) of rotation of the bit axis (Figure 1.) is the criterion for finding the optimal length of its guide section for vertical well conditions.

The length of the guide section of the BHA to prevent the curvature of the vertical well is determined by the formula (1), and the geometric and stiffness characteristics of the drill collar are given in Table 1.

$$l_{max} = 0{,}5 \cdot \sqrt[3]{\frac{EJ}{q}}. \quad (1)$$

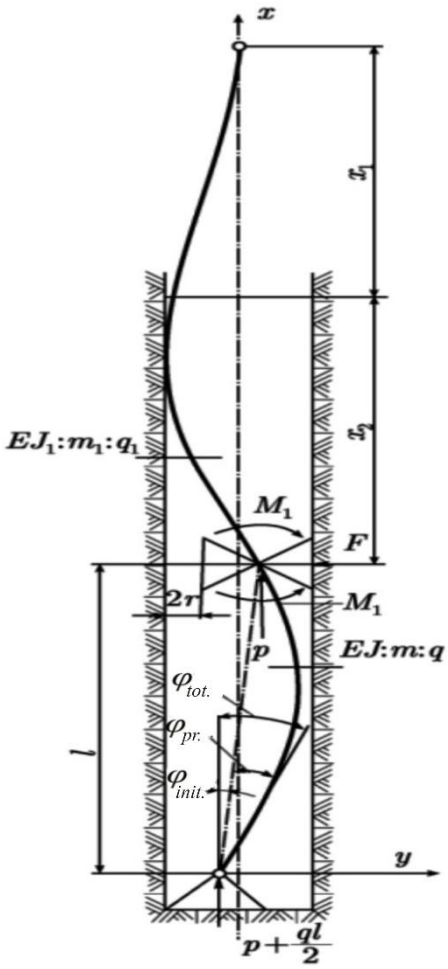


Figure 1. Calculation scheme of rigid BHA:

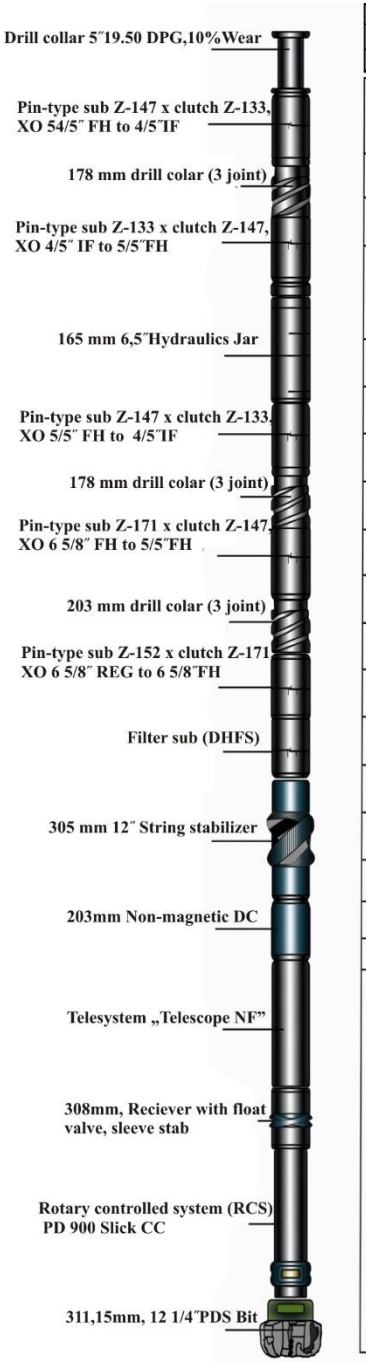
X_1 – length of the stretched part of the drill string;
X_2 - length of the compressed part of the drill string;
P is the axial reaction applied to the lower end of the drill string and equal in magnitude to the weight of the compressed part of the string;
M_1 – reactive bending moment;
F - lateral reaction on the support (centering element located at the upper end of the BHA);
EJ_1 - bending stiffness of the drill string;
q_1 is the weight of the unit length of the drill string in the flushing fluid;
l is the length of the rigid BHA;
EJ - bending stiffness (drill collar, downhole motor) of the BHA;
q is the weight of the unit length of the base of the BHA in the washing liquid.

Pendulum BHA are used to bring the hole of a curved well to the vertical. A typical pendulum BHA does not include support-centering elements [4].

Drilling of the directional operational evaluation well № 707 on the West Cheleken field with a depth of 1650 meters was planned to be drilled vertically and

a set of zenith angle to deepen obliquely correcting the azimuth angle with a trajectory towards the sea area.

The drilling data of the section for a technical column of 244.5 mm along the barrel interval are shown in Table 1.



Field Name		Turkmennebit/Turkmen		Borehole Name		707		Hole Size (in)			12.250
Structure Name		West Cheleken# 707		BHA Name		BHA 1 PowerDrive+MWD		Depth in (m)			1650.00
Well Name		Zapadny Cheleken# 707				311.15mm-6in Jar		Depth Out (m)			2114.00
	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	311,15mm, 12 1/4″PDS Bit	Smith	8.000 / 3.250	12.250	6-5/8 REG	Pin		0.44	0.44	0.2	
2	Rotary controlled system (RCS), PD 900 Slick CC	Schlumberger	9.000 / 5.125	12.125	6-5/8 REG / 6-5/8 FH	Box / Box		4.21	4.65	1.3	
3	308mm, Reciever with float valve, sleeve stab	Schlumberger	8.000 / 2.500	12.125	6-5/8 FH / 6-5/8 FH	Pin / Box		1.52	6.17	1.7	
4	Telesystem „Telescope NF”	Schlumberger	8.250 / 5.109	8.410	6-5/8 FH / 6-5/8 REG	Pin / Box		7.53	13.69	3.3	
5	203mm Non-magnetic DC	Schlumberger	8.228 / 2.835	8.228	6-5/8 REG / 6-5/8 REG	Pin / Box	7.992 / 9.42	9.40	23.09	5.5	
6	305 mm 12″ String stabilizer	Schlumberger	8.250 / 3.000	11.500	6-5/8 REG / 6-5/8 REG	Pin / Box	0.000 / 0.00	2.30	25.39	6.0	
7	Filter sub (DHFS)	Schlumberger	8.000 / 2.500	8.000	6-5/8 REG / 6-5/8 REG	Pin / Box		1.52	26.92	6.4	
8	Pin-type sub Z-152 x clutch Z-171, XO 6 5/8″ REG to 6 5/8″FH	Schlumberger	8.228 / 2.835	8.228	6-5/8 REG / 6-5/8 FH	Pin / Box	0.000 / 0.00	1.00	27.92	6.6	
9	203 mm drill colar (3 joint)	TN	7.992 / 2.835	7.992	6-5/8 FH / 6-5/8 FH	Pin / Box	0.000 / 0.00	28.20	56.12	12.9	
10	Pin-type sub Z-171 x clutch Z-147, XO 6 5/8″ FH to /5″FH	TN	7.992 / 2.835	7.992	6-5/8 FH / 5-1/2 FH	Pin / Box	0.000 / 0.00	1.00	57.12	13.1	
11	178 mm drill colar (3 joint)	TN	7.008 / 2.835	7.008	5-1/2 FH / 5-1/2 FH	Pin / Box	0.000 / 0.00	28.50	85.62	17.7	
12	Pin-type sub Z-147 x clutch Z-133, XO 6 5/5″ FH to 6 4/5″IF	TN	6.750 / 2.250	6.750	5-1/2 FH / NC50 (4-1/2 IF)	Pin / Box		1.52	87.14	18.0	
13	165 mm 6,5″Hydraulics Jar	Schlumberger	6.500 / 2.750	6.500	4-1/2 IF / 4-1/2 IF	Pin / Box		9.50	96.64	18.8	
14	Pin-type sub Z-133 x clutch Z-147, XO 4/5″ IF to 5/5″FH	TN	6.750 / 2.250	6.750	4-1/2 IF / 5-1/2 FH	Pin / Box		1.52	98.17	19.0	
15	178 mm drill colar (3 joint)	TN	7.008 / 2.835	7.008	5-1/2 FH / 5-1/2 FH	Pin / Box	0.000 / 0.00	28.50	126.67	23.7	
16	Pin-type sub Z-147 x clutch Z-133, XO 54/5″ FH to 4/5″IF	TN	6.750 / 2.250	6.750	5-1/2 FH / NC50 (4-1/2 IF)	Pin / Box		1.52	128.19	23.9	
17	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	137.64	24.2	

BHA Comments

Sensor Offset from Bit (m)		Stabilizer Summary		
		Blade Mid-Pt to Bit (m)	Bl a	Blade Length (m)
MWD Gamma Ray	9.19	5.345	#	0.300
D+I	9.83	24.475	#	0.610

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

Total Length (m)	137.64
Total Weight in Air (t)	24.2
Total Buoyant Weight (t)	19.1
Buoyant Weight Below Jar (t)	14.3
Weight in Air Below Jar (t)	18.0

Mud Properties	
Mud Weight (g/cm3)	1.66
Mud Type	OBM
PV (cP)	40.00
YP (0.01 lbf/ft2)	30.00

BHA Nozzle Summary		
Component	Count x ID (1/32 in)	TFA (in2)
Bit	6 x 14	0.902
PD Flow Restrictor (1/32 in)		0.00
Rotor Bypass Nozzle (1/32 in)		

Date	14Jun2021
Designed By	DIRVPBabanyazov
Approved By	

Figure 2. BHA for drilling the interval of 1650-2100 m (vertically) 1650-2119 m (along the hole) of a set of zenith angle for a technical column

Table 1.

The interval of the barrel diameter 295.3 mm	800m – 2119m (along the hole) 800m – 2100m (vertical)
Interval length:	1319 m
Drilling barrel interval with a screw downhole motor:	800м – 2119m (along the hole) 800м – 2100 m vertical)

The length of the drilling interval with a screw downhole motor:	1319 m
Hole configuration:	Directional (vertical, angle set, straight-line stabilization)

For drilling all intervals, the following BHA is selected. The zenith angle was set by a rotary controlled system.

BHA for drilling with a diameter of 244.5 mm for a technical column.

Interval 800-1650 m (vertical part of the directional shaft):

For drilling under a technical column of 244.5 mm in the interval 800-1650 m.

Bit 311.15 mm; calibrator 311.1 mm – 1 piece; drill collar 245 mm – 5 m; calibrator 311.1 mm – 1 piece; drill collar 229 mm – 13 m; calibrator 311.1 mm – 1 piece; drill collar 203 mm – 80 m; BT.

For drilling the interval of 1650-2100 m (vertically) 1650-2119 m (along the hole) of the zenith angle set, the following BHA was designed.

311,15mm, 12 1/4 ´´ PDS Bit″

A bit with a diameter of 311.15 mm diamond; 308 mm. Rotary controlled system PD 900; calibrator with check valve 308 mm; drill collar 203 mm– 9.42 m; ARC LWD logging device during drilling; 214 mm Telescope 675 NF; drill collar 203 mm non–magnetic - 9.42 m; calibrator with check valve 305 mm; translator with filter 203 mm; pin-type sub Z-152 x clutch Z-171; drill collar 203 mm -28.2 m; pin-type sub Z-171x clutch Z-147; drill collar 178 mm -28.5 m; pin-type sub Z-147x clutch Z-133; hydraulic jar 165 mm; pin-type Z-133 x clutch Z-147; drill collar 178 mm -28.5 m; pin-type sub Z-147x clutch Z-133; drill collar 139.7 mm-9.5 m (thickened drill pipe).

The BHA for the interval of 1650-2100 m (vertically) 1650-2119 m (along the hole) of the set of the zenith angle for the technical column is shown in Fig. 2.

Drilling from a depth of 1650 m to 2100 m along the hole reached a zenith angle of 27 degrees with an azimuth of 250 degrees. From a depth of 2100 m to 2119 m, the interval is drilled stably with maintaining a zenith angle of 27 degrees and an azimuth angle of 250 degrees.

Drilling of the interval was carried out with a diamond drill bit with a diameter of 311.15 of the SDI519 brand manufactured by SmithBits, shown in Figure 3.

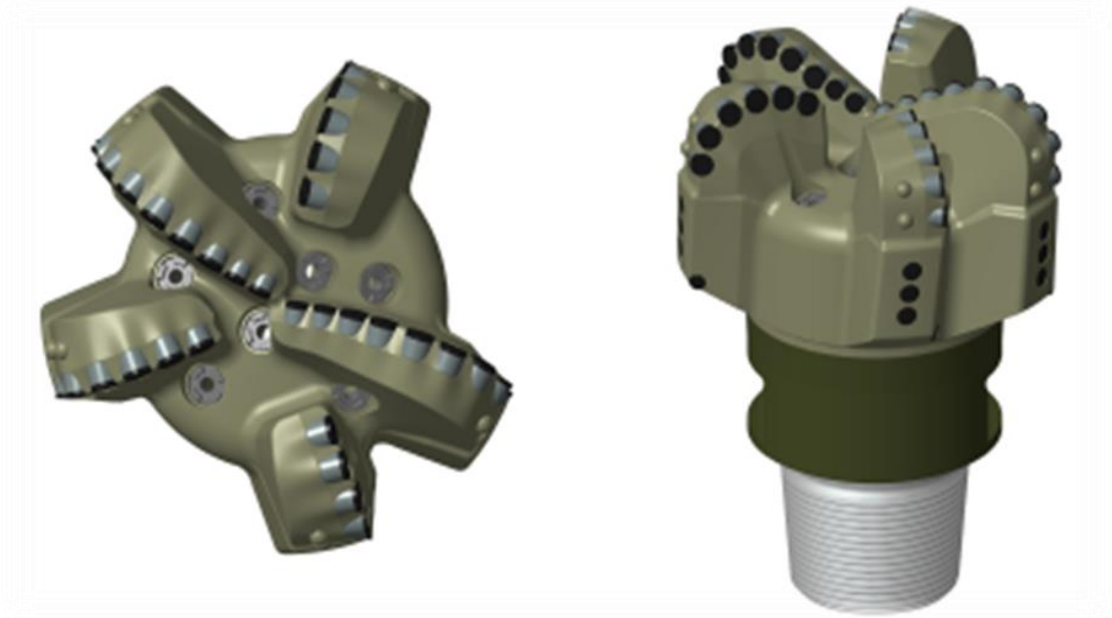


Figure 3. Diamond drill bit with a diameter of 311.15 of the SDI519 brand.

The diamond drill bit with a diameter of 311.15 of the SDI519 brand invariably provides excellent performance in directional positions, with the help of rotations by a rotary controlled system, when loaded on the bit with a turn in the required trajectory. Removable inserts of the Lo – Vibe type are mounted. It has an increased cleaning of the drilled rock, and also, 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 pump pressure, there is no risk of lumps forming at the bottom of the well. Side holes of the PX type, for the circulation of drilling mud, extend the service life of the bit by strengthening its calibration sections with diamond inserts of the DEI type made of wear-resistant tungsten carbide.

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 [5,6].

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 likelihood of the layout being seized at the bottom.

A system for measuring and transmitting data during drilling "Telescope", 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.

The drilling procedure in the range of 1650-2119 m along the hole (angle set interval and stabilization) is as follows:

1. Before lowering the BHA for deflection, it is necessary to make sure that the face is clean of foreign objects.

2. Assemble and descend the BHA to a depth of 1650m along the hole for drilling in the range of 1650 – 2119m along the hole.

3. MWD measurements will be made during the descent of the BHA at an interval of 0-1650m to measure the zenith angle of the already drilled barrel, in the absence of measurements. To do this, you will need to increase the pump supply to 30-38 liters per second (500-600 gallons per minute).

4. Drilling in this interval will be carried out by the BHA with RCS. By setting and maintaining the zenith angle of 27 degrees to a depth of 2100 m along the hole (2083.53 m vertically). The planned drilling interval can be increased or reduced by the customer's decision.

5. When drilling with RCS, the minimum required rotation speed of the drilling column is 120-130 revolutions per minute. (The optimal rotation speed is 140 revolutions per minute) [7, 8, 9].

6. The commands of the RCS-s are given by varying the supply of drilling mud by pumps (allowed for the device minimum - maximum, maximum - minimum, etc.)

7. To assess the degree of cleaning and the condition of the wellbore, the volume of drilled sludge, as well as the torque value must be constantly monitored.

8. 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, perform a descent -lifting operation to change the BHA to a rotary one, and further study of the borehole. In the absence of problems along the hole, to lift the BHA for the subsequent implementation of the planned complex of geophysical exploration of the well [10].

9. At a depth of 2119 m of the hole of 311.15 mm (12.25”), flush the borehole until the sludge is completely washed out, and carry out a control descent-ascent 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.

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 41 l/sec; the area of the bit nozzles is 582 mm^2; the pressure drop on the bit was 40 kg/cm^2; and the total pressure in the riser was 193 kg/cm^2 [11, 12].

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 40-45 l/sec.

All procedures for setting the drilling mode and drilling mud were followed according to the developed program. The interval of the well (the set of the zenith angle and the stabilization of the zenith angle) with a zenith angle of 27 degrees and an azimuth angle of 250 degrees and an offset towards the sea area of 112 meters with the selected BHA was successfully drilled.

Conclusions

1. In order to ensure the provided design trajectory of the borehole, it is necessary to make the correct selection of the most effective bottom-hole assembly (BHA) for these drilling conditions.

2. Strict compliance with the hydraulic drilling program, in order to increase the mechanical drilling speed and complete cleaning of the drilled rock from the face.

3. The use of advanced technologies for the transmission of information in real time to determine the direction of the trajectory of the hole and the data of geophysical studies of the layers of the well from the bottom of the well to the surface of the well.

4. The correct selection of the BHA for the site of selection and stabilization of the zenith angle indicates the successful achievement of the well to the design depth in a given direction.

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