Bit Performance in Directional Oil Wells

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ABSTRACT

This work aims to analyze and study the bit performance in directional oil wells which leads to get experience about the drilled area by monitoring bit performance and analyzing its work. This study is concerned with Rumaila Oil Field by studying directional hole of one oil well with different angles of inclination. Drilling program was used in order to compare with used parameters (WOB, RPM and FR).in those holes. The effect of the drilling hydraulic system on the bit performance was studied as well as the hydraulic calculation can be done by using Excel program. This study suggests method which is used to predict the value of penetration rate by studying different formation type to choose the best drilling parameters to drill each formation. Finally, the main aim of this research is to have the benefit from the past well drilling data to drill new wells without needing new drilling program for each well, also knowing the problems of each formation to avoid them as soon as possible through drilling the new wells, which will improve the bit performance.

Key words: bit performance, directional well, drilling parameters, formation.

ادائية الحافرة في الابار النفطية الموجهة

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الخلاصة

هذا العمل يهدف الى تحليل ودراسة ادائية الحافرة في الأبار الموجهة وبالتالي اكتساب خبرة عملية عن المنطقة المحفورة وذلك من خلال مراقبة ادائية الحافرة وتحليل عملها ومراقبة الاخفاقات التي ترافق عمل الحافرة وسبب تلك الاخفاقات والعمل على تحسين ادائيه الحافرة .

تم دراسة المنطقة المحفورة (حقل الرميلة) من خلال دراسة بئر موجه واحد. وذلك من خلال مقارنة البرنامج الموضوع لحفر البئر(خطة الحفر)مع ماتم استخدامه من عوامل حفر(الوزن المسلط على الحافره ,عدد دورات عمود الحفر, معدل الجريان) وكيف سيؤثر ذلك على ادائية الحافرة

تم دراسة تأثير منظومة الحفر الهايدروليكية على ادائية الحافرة وهل تم اتباع برنامج الهايدروليك المعد ام لا وذلك من خلال برمجة برنامج" اكسل". تم اقتراح طريقة للتنبؤ بأفضل معدل اختراق عبر دراسة تكوينات مختلفه لبئر موجه وذلك لأختيار احسن مجموعة عوامل حفر ملائمة لحفر ذلك التكوين (الهارثة-السعدي-المشرف) يمكن القول بأن الاستنتاج الرئيسي من هذه الدراسة هو الاستفادة من بيانات حفر الأبار السابقة لحفر الأبار الجديدة وكذلك معرفه المشاكل الخاصة بكل طبقة لتجنبها قدر الامكان عند حفر الابار الجديدة وبذلك نضمن ادائية افضل للحافرة .

الكلمات الرئيسة : ادائية الحافرة,بئر موجه,عوامل حفر,تكوين .

1. INTRODUCTION

Bit is very important tools in drilling operation. Bits have to be suitable with type of formations, rock construction, and in a way that will consistently obtain the best results. During drilling directional wells the directional contractor should be asked to provide an assessment of the required Bottom Hole Assembly (BHA) changes, motor requirements and any limitations on the bit operating parameters which may affected on the selection of the bits and its performance in one way or another. Formation characteristics should be studied in details to assess the type of cutting structure required to successfully drill the formation. Choosing the right bits is easier when drilling additional wells in the field because the crew knows what formations expect and which bit drills them best **Bela, 2012.**

The type of formation, weight, rotary speed of the bit and the hydraulics effect on the bit performance .What the crew gets out of the bit depends on attention to such factors and using good operating procedures. Getting best performance from a bit depends on properly adjusting the weight on the bit and rotary speed and hydraulics. To get the most footage and fastest penetration rate, the crew must select the right bit for the work. The crew has several ways of getting information to make this decision. Dull bit records from bit records from nearby wells show wear to the bits used for drilling them **B.Dow, 2012.** Rumaila Oil Field which is the field under study is one of the largest oil fields in the south of Iraq. It consists from north and south domes. Most beds of this field have a large thickness such as; UmmEr-Radhuma, Tayarat, Sadi, Nahr Umr, and Zubair formations.

2. BIT TYPES:

A bit usually is classified according to its design as either fixed cutter bit or rolling cutter bit**.** The fixed cutter bits consist of fixed cutter blades which are integral with the body of bit and rotate as a unit with the drilling string. Roller cutter bit has two or more cones containing the cutting elements, which rotate about the axis of the cone like the bit is rotated at the bottom of the hole**.**

2.1 Bit Drilling Mechanic:

2.1.1 PDC bit:

Principle of work: to shear the formation with blades by (WOB) and Torque.

Suited to the formation: soft to hard formation.

2.1.2 Cone bit:

Principle of work: drill by crushing and /or gouging the rock, rock requires high energy (WOB) to fracture the rock with compressive loading.

Suited to the formation: soft to hard formation.

2.2 Directional Effects of Choosing the Bit Type:

2.2.1 Roller cutter bits (insert bits):

Insert bits sometimes causes right hand walk when the rotary drilling assemblies are used.

Soft drill bits with grater cone offset is created a greater degree of right hand walk than hard drill bits with few or zero offset. Right hand walk generated is due to the gouging and scraping actions produced by using soft tri cone bit **Allen, 1977.** Tri cones bit have been preferred for kicking off a directional well from vertical.

2.2.2 Fixed cutter bits (PDC bits):

There are a little walk has been produced with most PDC bits with using rotary drilling assemblies. PDC bits are used with angle drop assemblies produce a lower rate of drop than when using a rock bit. PDC bits which have a flatter profile were found to work better for dropping angles using rotary assemblies, **Aswad, 1996.**

2.3 BHA Design for Directional Drilling that Effected on Bit Performance:

The BHA refers to the Drill collar (DC), Stabilizers (STB) and other accessories which are used in the drill string. All the wells whether vertical or deviated required careful design of BHA in order to control the direction of the well to achieve the target objectives, **Eisa, 2011**. STB and DC are the main tools used to control hole inclination.

3. BIT HYDRAULIC CALCULATIONS:

In general bit hydraulics is calculated in order to improve rate of penetration. There are many factors that affect rate of penetration:

- Bit type
- Bit features
- Formation type and strength
- Bit hydraulics

The main objective of hydraulics calculation is to obtain a good balance in controlling down hole pressures, flow rate, hole cleaning, pump pressure, ECD(equivalent circulation density), and pressure drop across the bit, **Glowka, 1983.**

3.1 Hydraulic Variables:

- Flow rate (Q).
- Mud weight (Mw).
- Total flow area (TFA).
- Pressure drop (P_d).
- Jet Impact Force (JIF).
- Hydraulic Horsepower per square inch (HSI).

3.2 Hydraulic Horse Power (HHP):

The recommended values of Hydraulic Horse Power (HHP) range for most rock bits are 2.5 to5.0 Horsepower per Square Inch (HSI) of bit area. Low HHP at the bit can result in low ROP and poor bit performance. The Bit hydraulic horsepower should be not exceeding the total system hydraulic horsepower, **Tuna, 2010.**

Hydraulic horsepower per square inch of bit area is called (HSI). There is term used in drilling hydraulics to get a better feeling for the magnitude of the hydraulic horsepower.

This term is called the H.S.I (hydraulic horsepower per square inch of bit face area) and is basically obtained by dividing the hydraulic horsepower by the bit size area. Eq. (1) and Eq. (2) can be used to calculate HHP_{Bit} and HSI respectively.

$HHP_{Bit}=Q*P_{Bit}/1714$ (1)

$HSI=1.27*HHP_{Bit}/ (D_{Bit})^2$ (2)

Where:

D_{Bit}: Bit diameter (inch), Q: Flow Rate (gpm) ,P_{Bit}: Bit Pressure Drop (psi)

H.S.I = HHP available at the bit/ bit face area.

3.3 Jet Impact Force :

The force exerted by the exiting fluid below the bit, it has been gotten by using Eq. (3):

$(IF)=V_n *Q * \rho /1932$ (3)

Where:

IF= Hydraulic Impact Force (lb.)

V_n=nozzle velocity (ft. /sec)

Q=Flow rate (gpm)

ρ =mud density (lb. /gal)

3.4 Nozzle Velocity:

Nozzle velocities of 250 to 450 ft. /sec are recommended for most bits. Nozzle velocities in excess of 450ft/sec may erode the cutting structure of the bit**, Eckel, 1949.**

● It is closely related to the cleaning action taking place at the bit.

● It can lead to hole erosion at high velocities in fragile formation.

In IADC Drilling Manual, the (Vn) is calculated by using Eq. (4):

$$V_{Bit\ Nozzles}(ft/Sec) = \frac{0.32086\ Q}{TFA} \quad (4)$$

Where:

TFA: Total Flow Area (inch square)

3.5 Pressure Drop at Bit:

The pressure losses through the nozzles of a drill bit may be calculated from Eq. (5).

$\Delta p_{bit} = (\rho)* (Q)/10858* (TFA)^2$ (5)

Where:

$\Delta P_{bit:}$ Bit Pressure Drop

Total flow area (TFA) = $(D_{bit}/64)^2*3.14286$ (6)

4. IADC BIT DULLGRADING SYSTEM:

Although there are small differences between the fixed cutter and roller cone systems, the same eight categories has been used for both.

The first four points is related to cutting structure only. The first two points have been used to grade cutting structure wear: firstly the wear of the Inner teeth (or inserts, or cutters, or cutting elements) then the outer teeth (or inserts, or cutters, or cutting elements).

The major dull is indicated by a two-letter code, followed by its location. For roller cone bits, the condition of the seals or bearings is noted. Whether the bit is in gauge, or if not, by how much it is under gauge is shown in the next category, **Robison, 1988.**

The other dull characteristics are described, using the two letter code system, as shown in **Table 1.**

5. Hydraulic EFFECT ON THE BIT PERFORMANCE:

Excel program was prepared by using Eq.(1) through Eq.(6) which is used to get the value of bit pressure drop, nozzle velocity, impact force and hydraulic horsepower for the selected wells, and as follows:

The input data are: (bit size, mud weight, flow rate, nozzles size and total flow area) should be entered, in order to get these output data which they are: (bit pressure drop, jet velocity, impact force, hydraulic horse power, and Hydraulic horsepower per square inch).

Hydraulic program will be compared with the used hydraulic parameters in this well.

5.1 Well RU-417: The general information of well RU-41 which was drilled to Mishrif reservoir is shown in **Table 2**.

The Excel sheet program as in the **Table 3** has been used to find the planned bit hydraulics parameters and as follows: FR=3000 lpm (from bit manufacture).

-bit pressure drop = 670 psi
-jet impact force= 496kg
-H.S.I. =2.63

From daily mud logger report (DMLR), the used hydraulic parameters as follow:

1- FR=2750 lpm, MW=1.13sp.gr.
 -bit pressure drop = 590 psi
 -jet impact force= 437kg
 -H.S.I. =2.2

2- FR=2815 lpm, MW=1.13sp.gr.
 -bit pressure drop = 603 psi
 -jet impact force= 441kg
 -H.S.I. =2.3

3- FR=2620 lpm, MW=1.13sp.gr.
 -bit pressure drop = 630 psi
 -jet impact force= 442kg
 -H.S.I. =2.4

From the above calculations, the crew has used hydraulic parameters nearly to the planned parameters which led to good bottom hole cleaning and good bit dullness: (Bit Dull Grading: 1-1-No-A-X-I-No-BHA).

It is important to mention that the crew was used different values of flow rate due to drill more than one formations type which gave three sets of hydraulic parameters as shown above.

5.2. Case Study:

It should be known what happen to the bit that has drilled those depths, which will be the first step to assess the bit performance. Since the bit that drilled those depths don't enter to the well and get out from it without any damaging, bit dull grading is the key that from it, it can be noticed easily what happen to the bit after POOH (Pull Out of Hole).For this well, one hole section will be chosen for study and the choosing hole section should contain both vertical and directional sections.

5.2.1 Well RU-417:

The 12.25 " hole section will be drilled down by using the following drilling parameters, see **Fig.1**

-WOB of 10 -40 klbs.

- Flow rate of 2500-3000 lpm.

-Rotation of 70 – 120 RPM.

5.2.2 Section objective:

The objective of the first BHA is to drill cement after well was cemented due to severe losses in Dammam formation and keep the trajectory vertical. The second BHA is to kick off the well toward 50 deg. azimuth to reach 12 deg. inclinations in order to set the 9 5/8 casing; **Table 4** contains drilling data of well RU-417.

5.2.3 The first BHA from 426m to 1673m:

A 9 5/8" GT motor combined with the MSi616 Smith bit were used to drill this section. Cement was tagged at 470 m and start drilling with low parameters (WOB, RPM, and FR) to avoid any risk of sidetracking the well. Formation was tagged at 662m, continued drilling using minimum motor flow rate to reduce losses risk in Umm Er Radhuma formation 4 m. sliding were needed to correct the well trajectory and bring it to vertical. KOP point reached and decided to POOH to change the bent housing from 1.15deg to 1.5 deg. And after bit POOH,the **bit dull grade** is as bellow :

Bit Dull Grade: 2-3-BT-A-X-I-No-BHA.

Where:

BT: it means bit broken teeth.

5.2.4 The second BHA from 1673m to 1795m:

12.25" Smith Bit (MDi616) dressed with 6* 14/32" nozzles-962XP Motor"-Telescope 81/4"-NMDC-Stabilizer 12"-1x8"DC- JAR-8"- 1x8"DC 24- X/O- 12x5" HWDP -5" DP to Surface.The BHA was tested successfully and RIH. Tagged bottom and circulate two bottoms up and start drilling in Umm Er Radhuma formation.

KOP was performed in Hartha formation with an average ROP of 5 m/hr. Formation was sticky and argillaceous, inter-bedded with limestone and shale. The 3 deg dogleg achieved with 60 % sliding.

They faced some BHA hanging once when reached 5 deg. inclinations. Tool face was unstable in Hartha formation and more stable once entered Sadi formation. Sliding was performed on single basis to be able to take a survey every 10 m as per client requirement to obtain smoother doglegs. After ending drill this section the bit dull grading is: 1-1-No-A-X-I-No-BHA**.**

6. FACTORS EFFECTING ON THE VALUE OF PENETRATION RATE:

Rate of penetration is a function of large numbers of controllable and uncontrollable variables. The alterable variables which they are :WOB,RPM, Hydraulics, drilling fluid type and properties and bit type and size. The unalterable variables are ; rock properties, formation or pore pressure , bottom hole temperature, round trip time, depth , weather, rig conditions and flexibility, location, hole problems, and crew efficiency, **Lisa B. Brown and Harold J. Flanagan,2010.**

6.1 The Studied Formations and Well:

This section shows how it can be predicting the values of ROP by using data of one directional oil wells. This will done by using field data to determine the relationship between several parameters like bit type, WOP, RPM, FR , MW and ROP, in the other words, drawing the relationship between drilling parameters which they have been reprehensive as a" group "on X-axis and ROP which is resulted from the selected group on Y-axis.

It is similar to the bit formation test which is used to get the value of recommended drilling group that has gave good value of ROP with taking the formation type and bit manufacturing into the consideration. The present value of recommended group can be used in the drilling the next wells.

The Rumaila Oil Field consists of many heterogeneous formation types. Each rock type will give a special color, the reason behind that is to know the effect of formation type on the drilling parameters, as shown in **Table 5.**

6.2 Well RU-417: The directional section in this well passed the following formations:

1-Hartha formation: The top of Hartha is limestone, then dolomite and finally, fracture limestone. From **Table 6 and Fig.2**, the recommended group is group 1. In this formation there is build section which is between (0-11) deg.to create angle of inclination.

2-Sadi formation: This formation consists of limestone and low percentage of vuggy limestone. From **Table 7 and Fig.3**, the recommended group is group 5. In this formation there is a build section to create an angle of inclination between (12-50) deg. Therefore; there is increasing in value of WOB and decreasing in value of FR.

3-Mishrif formation: This formation consists of limestone (homogeneous lithology). From **Table 8 and Fig.4,** the recommended drilling groups are: group 8,9and10. In this formation there is build section to create an angle of inclination which is between (50-70) deg. So, there is increasing in the values of WOB and RPM and decreasing in value of FR.

CONCLUSIONS:

1- There are more than one factor effects on the bit performance but WOB, FR and RPM have the major effect especially in directional sections.

2- The studied cases proved that there are different between the planed drilling program and the followed drilling parameters according to the special conditions related to the drilling process and formation type.

3- Using the available bit that has been suitable to drill all type of formations in this field ,it is very important because the wrong bit selection cause more problem that will be effected on the bit and drilling performance

4- It is important to recognize that the overall success of any drilling performance is a combination of good planning and good execution.it is recommended that asset of appropriate drilling practices is developed to assist with execution and implementation.

5- It was found that in directional section, it is important to treat with a combination of some drilling parameters also; it's clear that for each formation there is a special combination of drilling parameters which depends on lithology of formation.

REFRENCES:

- Allen, J.H., *1977, Determining Parameters that Affect Rate of Penetration,* Oil and Gas J., *94.*

- -Aswad, Z. A. R., 1996, *Advanced Drilling Engineering,* M. Sc. Course at University of Baghdad, Petroleum Engineering Dept.

- -Bela Liptak, *April 2012, Control for Drilling Oil and Gas Wells.*

- -B. Dow and R., Harmer June 2012, *Improving Drilling Results with A real-time Performance Advisory System,* Schlumberger, World Oil.

- -Eckel , J.R. and Nollely, J.P. 1949, *An Analysis of Hydrualic Factors Affecting the Rate of Penetration of Drag- Type Rotary Bits* , Drill and Prod Prac., API , Dallas 23.

- -Eisa Noveiri, September 2011 , *Directional Drilling Optimization by Non-Rotating Stabilizer,* World Academy of Science, Engineering and Technology.

- Glowka, D., Febuary.1983, *Optimization of Bit Configurations,* Soc. Pet. Eng. J. pp.21-32.

- Lisa B. Brown and Harold J. Flanagan, 2010, *The Effect of Weight on Bit on Rate of Penetration.*

- -Robinson, L. H. Dec. 1988, *On-site Nozzle Selection Increases Drilling Performance,* Petroleum Engineering International, Soc. Pet. Eng. J. pp.7-82

- -Tuna Eren, February 2010, *Real-Time-Optimization of Drilling Parameters During drilling Operations,* Soc. Pet. Eng. J.

NOMENCLATURES:

Pbit= bit pressure Drop, psi.
Vn= nozzle velocity, ft. /sec.
HSI= HHP available at the bit/ bit face area.
$\dot{\rho}$ = drilling fluid's density, lb. /ft^3.
Q= volumetric flow rate, $ft^{3/}$/sec.
D_{Bit}= diameter of the bit, inch.
BHA= bottom hole assembly.
IADC= International Association of Drilling Contractors.
MLU= Mud Logging Unit.
MW= mud weight, lb. /ft^3.
ROP= rate of penetration, ft. /sec.
RPM= revolution per minute, Rev. /min.
WOB= weight on bit, lb.
TFA= Total flow area, in^2.
ECD= equivalent circulating density, lb. /ft^3.
DMLR= Daily Mud Logger Report.

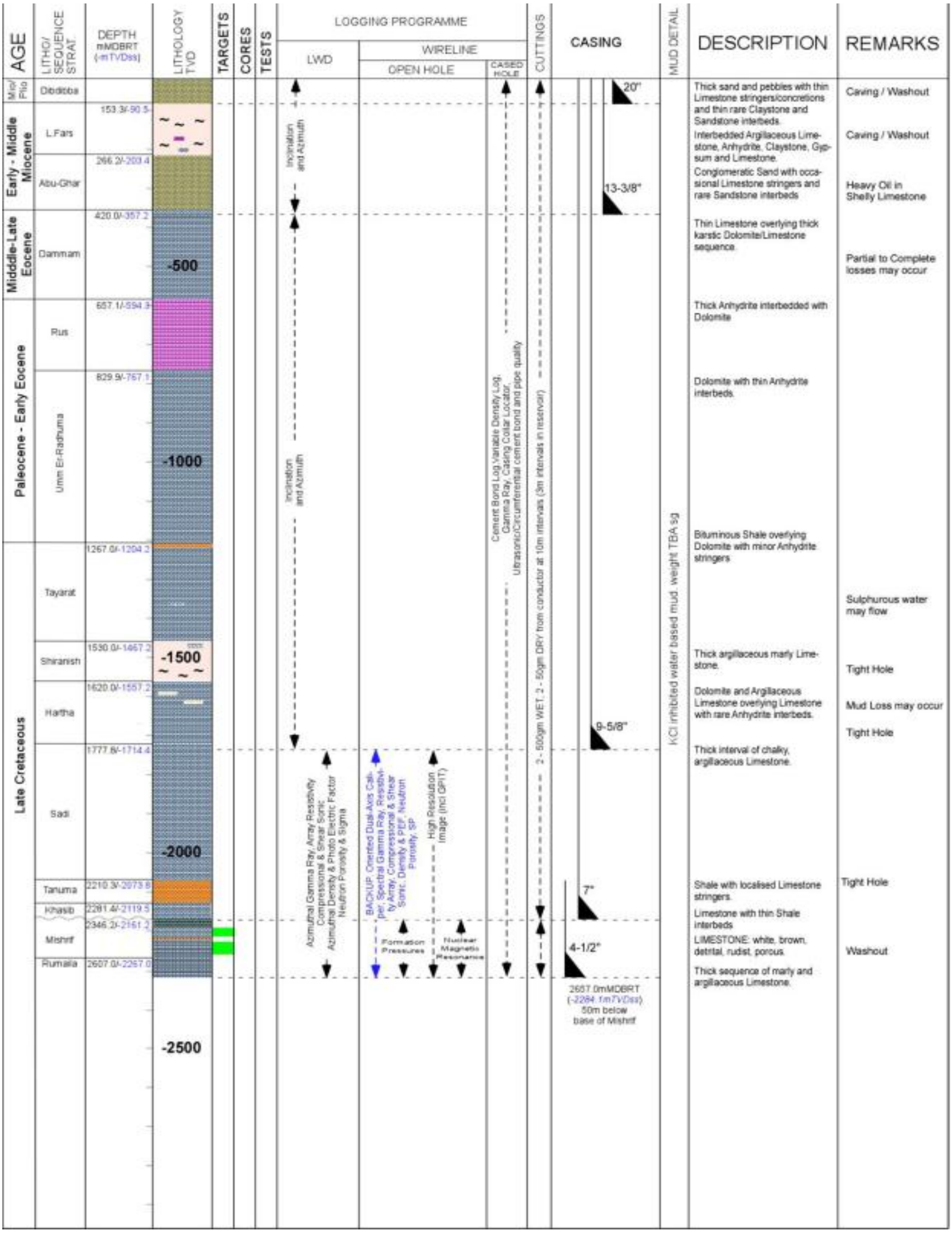
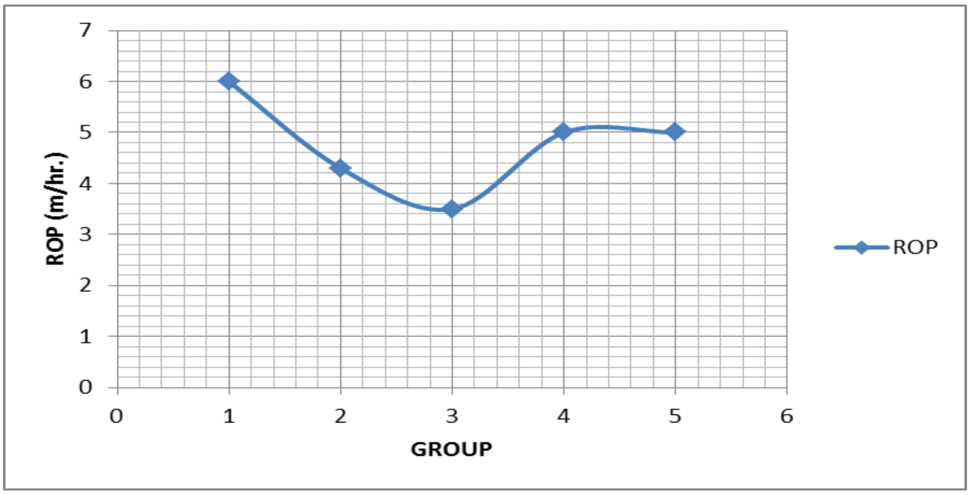


Figure 1. Stratigraphic section of Rumaila oil field of RU-417.



Figur 2. The relationship between "GROUP" and ROP for Hartha formation in well RU-417.

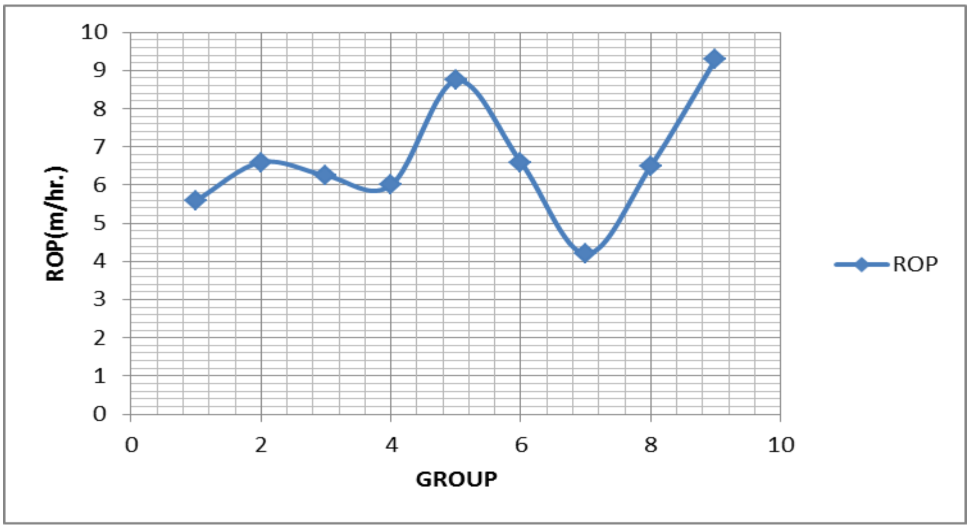


Figure 3. The relationship between "GROUP" and ROP of Sadi formation RU-417.

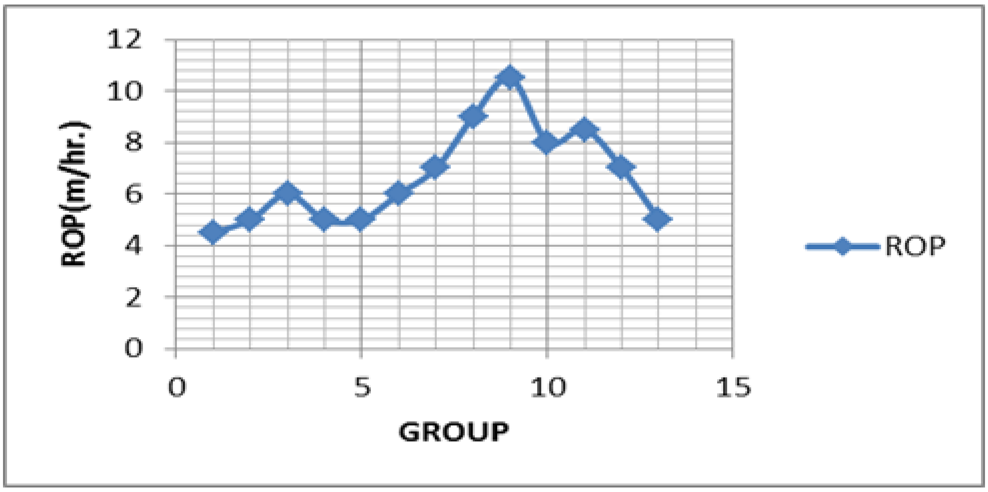


Figure 4. The relationship between "GROUP" and ROP of Mishrif formation RU-417.

Table 1. Bit dull grading characteristic.

T				B	G	REMARKS	
1	2	3	4	5	6	7	8
CUTTING STRUCTURE				B	G	REMARKS	
Inner Rows (I)	Outer Rows (O)	Dull Char. (D)	Loca-tion (L)	Brng. Seal (B)	Gage 1/16 (G)	Other Dull (O)	Reason Pulled (R)

Table 2. General well information of RU-417 Well.

Well Type	Mishrif Producer
Field	Rumaila
Reservoir	Mishrif
Inclination	70 Degree

Table 3. Hydraulic program of well RU-417.

Hydraulic Calculations

Data Input		
Bit Size	inches	12.25
Mud Wt	g/cc	1.13
Flow	lpm	3000

Data Output		Standard Units		Metric Units	
Bit Pressure drop	=	670	psi	46.183833	bar
Jet Velocity	=	282	ft/sec	85.942293	m/sec
Impact Force	=	1090	lbs	495.51345	kg
Hydraulic Horsepower	=	310		310	
H.S.I.	=	2.63		2.63	

Nozzle	Size	TFA	Flow
Nozzle 1	14	0.150	16.7%
Nozzle 2	14	0.150	16.7%
Nozzle 3	14	0.150	16.7%
Nozzle 4	14	0.150	16.7%
Nozzle 5	14	0.150	16.7%
Nozzle 6	14	0.150	16.7%
Nozzle 7			
Nozzle 8			
Nozzle 9			
Nozzle 10			
TFA =		0.902	

Table 4. Drilling data of well RU-417.

Hole Section	12 1/4 in	TVD In	545 m
Casing Size	9 5/8 in	TVD Out	1795 m
Inclination In	00.26 deg.	TVD	1250 m
Inclination Out	10.39 deg.	Bit Manufacturer	Smith

Table 5. Rock type and their colors.

ROCK TYPE	COLOR
V.LIMESTONE	
DOLOMITE	
LIMESTONE	
Pours. LIMESTONE	

Table 6. Drilling parameters used to drill Hartha formation RU-417.

GROUP	FORMATION	BIT SIZE	Section type	WOB klb	RPM	FR(l/min)	ROP (m/hr.)	Mud sp.gr.
1	Hartha	12.25"	build	5	102	2700	6	1.13
2	Hartha	12.25"	build	4.5	94	2825	4.3	1.13
3	Hartha	12.25"	build	5	103	2835	3.5	1.13
4	Hartha	12.25"	build	5	103	2835	5	1.13
5	Hartha	12.25"	build	5	103	2835	5	1.13

Table 7. Drilling parameters used to drill Sadi formation RU-417.

GROUP	FORMATION	BIT SIZE(in)	Section Type	WOB(klb)	RPM(Rev./min)	FR(lpm)	ROP(m/hr,)	Sp.gr.
1	Sadi	8.5	Build	4	110	1920	5.6	1.24
2	Sadi	8.5	Build	6.5	120	1890	6.6	1.24
3	Sadi	8.5	Build	7	115	1960	6.25	1.24
4	Sadi	8.5	Build	6.5	120	1960	6	1.24
5	Sadi	8.5	Build	6	120	1970	8.74	1.24
6	Sadi	8.5	Build	3.5	120	1970	6.6	1.24
7	Sadi	8.5	Build	5.5	120	1960	4.2	1.24
8	Sadi	8.5	Build	6.5	125	1905	6.5	1.24
9	Sadi	8.5	Build	5.5	125	1960	9.3	1.24

Table 8. Drilling parameters used to drill Mishrif formation RU-417.

GROUP	FORMATION	BIT SIZE(in)	Section Type	WOB(klb)	RPM(Rev./min)	FR(lpm)	ROP(m/hr.)	Sp.gr.
1	Mishrif	6	Build	5	80	990	4.5	1.22
2	Mishrif	6	Build	6	80	1000	5	1.22
3	Mishrif	6	Build	6	110	1015	6	1.22
4	Mishrif	6	Build	5.5	100	1050	5	1.22
5	Mishrif	6	Build	5	100	1050	5	1.22
6	Mishrif	6	Build	6	110	1050	6	1.22
7	Mishrif	6	Build	6	121	1033	7	1.22
8	Mishrif	6	Build	7	121	1050	9	1.22
9	Mishrif	6	Build	6.5	121	1025	10.5	1.22
10	Mishrif	6	Build	6.5	121	1020	8	1.22
11	Mishrif	6	Build	6	120	1020	8.5	1.22
12	Mishrif	6	Build	7.25	120	1020	7	1.22
13	Mishrif	6	Build	8	120	1027	5	1.22