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Geological Considerations Related to Casing setting depth selection and design of Iraqi oil wells (case study)

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Abstract

Well integrity is a vital feature that should be upheld into the lifespan of the well, and one constituent of which casing, necessity to be capable to endure all the interior and outside loads. The casing, through its two basic essentials: casing design and casing depth adjustment, are fundamental to a unique wellbore that plays an important role in well integrity. Casing set depths are determined based on fracturing pressure and pore pressure in the well and can usually be obtained from well-specific information. Based on the analyzes using the improved techniques in this study, the following special proposition can be projected: The selection of the first class and materials must be done correctly and accurately in accordance with the depth of casing preparation and the strategy in the considered field that must be taken into account definitely in the drilling and completion period, nevertheless correspondingly in production and upkeep, conversion to an injection well or the opposite, the plug in addition to the closing stage. Features that control the depth of the casing seat have been studied, which consist of fracture gradient, pore pressure with other issues are the surviving lithology's of rocks. Subsequently defining the casing seat can be sustained with an investigation of the determination of the suitable drilling fluid. According to the consequences of the fracture pressure and pore pressure investigation and the findings of casing setting depth by means of the bottom-up technique, the consequences are gotten to each casing for the 4 studied wells. reference point designed from the rotating table RT. For well A, the conductor casing depth is 47m, the casing surface depth is 533m, the intermediate casing setting depth is 1882 m. Finally, for the production casing depth is 3441 m. Compared to the collapse pressure method, it was found that the bottom-up method gave results that are close and similar to the real results. The results of other wells are included in the search consequences

Keywords: Casing, formation, design oil well, setting depth, formation pressure

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1- Introduction

The first strategic duty in developing a well plan is to choose the depths to which the casing is to be installed and fixed. The drilling engineer must take into account geological conditions for example, fracture gradients, formation pressures, and other well problems, as well as the company's plan [1]. The results of the program should allow the well to be drilled safely without the need to build a "steel monument" to the casing chains. Inappropriately, numerous well strategies provide significant thoughts to the real pipe project, with that, just give a quick attention to the depth of tube adjustment [2]. It cannot be exaggerated if it is said and emphasized the importance of choosing the appropriate depths to adjust the casing.

A basic detailed drilling application with initial information of the geological conditions in a part can help in organizing where to set the casing strings to ensure that drilling can proceed with minimal effort, as will be explained in detail in this research [3].

The choice of casing string depth of adjustment depends on the fracture gradient values of the well as well as pore formation pressure and geological factors [4]. Well integrity is a vital feature that should be upheld into the lifespan of the well, and one constituent of which casing, necessity to be capable to endure all the interior and outside loads. Casing program design includes assembling depth settings, casing ranks, and sizes that allow for secure drilling, and well completion in order to prepare for required production [5].

A variety of casing string and their respective location depths are constructed according to geologic conditions and the fresh aquifers they contain. Casing setting depth means founded from the seat sector casing depending on the fractures gradient and pore pressure information commencing to the offset wells [6]. Assortment of the casing string sizes is usually well-ordered by three main issues which are: (1) production tubing string size, (2) the number of casing strings essential for reaching the ultimate depth, and (3) the other drilling circumstances and geological aspects [7].

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Then the number of casing strings necessary to include the hole is released, their particular setting depths and its outside diameters, steel grade, the nominal weight, and couplings of each of these strings necessity to be designated. The existing casing installed in some wells depends only on the formation of the drill weight statement mainly without reference to fracture pressure and pore pressure. Then, during production, the casing disappointment was revealed. [8]. This research aims to find the fastest and most accurate ways to determine the depth of fixing casings and compare them with what is available through the study of four wells in one of the fields in southern Iraq.

2- Methodology

2.1. Bottom Up Method

Aimed at the casing setting depth purpose, the fracture gradient and pore pressure are typically termed in pound per gallon(ppg) as shown in Fig. **1**. [9]

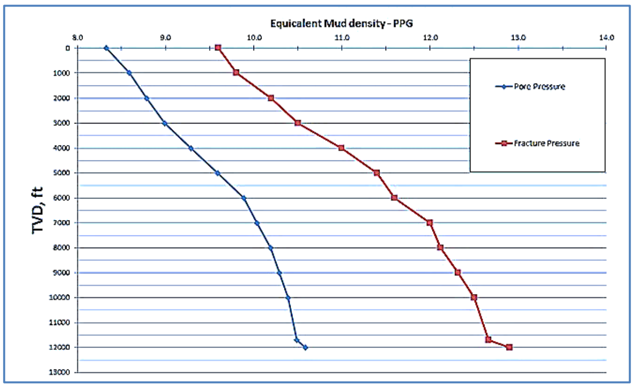

Fig. 1. Fracture Pressure with pore pressure values apposite depth [9]

The Eaton equation, equation 1is used for estimating the fracture gradient:

$$F = S/D * \alpha + (1 - \alpha) * P/D \quad (1)$$

where:
F = fracture gradient, psi/ft.
D = depth, m
S = overburden stress, psi
P = bottom hole static pressure, psi
$\alpha = V / (1-V)$, α that diverges between 0.3 and 0.6.
V = Poisson's ratio, dimensionless .The thick lines in

Fig. **1** are not a safety aspect; Thus, the first stage of casing preparation depth design, the safety factor should be acceptable. 0.3 ppg. is added as a safety factor for fracture gradient and pore pressure as in Fig. **2**.

The safety factor should be complementary to the formation pressure to maintaining the wellbore pressure between the supreme value which does not principal to fracture of the formation and the pressure of the fluid within the formations, since the pressure of the wellbore surpasses the pressure of the fracture, damage to the formation happens, that subsequently leads to the loss of circulation difficulties [9].

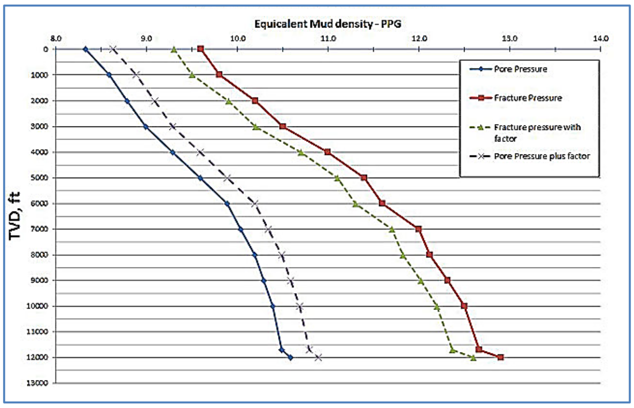

Fig. 2. Safety limits for fracture pressure and pore pressure [9]

Two methods are used for determining the casing setting depths which are: top-down method and bottom-up. In this paper the Bottom Up Casing Design is used.

This strategy will flinch on or after the bottom of the well up to superficial on the other hand, the setting depths are calculated surrounded by the safety feature restrictions (scattered lines).

The techniques are as follow: Preliminary at the bottom or formation pressure intermittent line at Point A), then make a perpendicular line rising to fracture pressure intermittent line at Point B as shown in Fig. **3**.

Thus, the casing must be adjusted from 4,500 ft. Total Vertical Depth (TVD)to 12,000 ft. total vertical depth to cause 12,000 ft. total vertical depth to be reached with a maximum equivalent mud density. in other words, we will not be broken down the formation at shallow depth (4,500 TVD), and the same concept to another string will be applied [9].

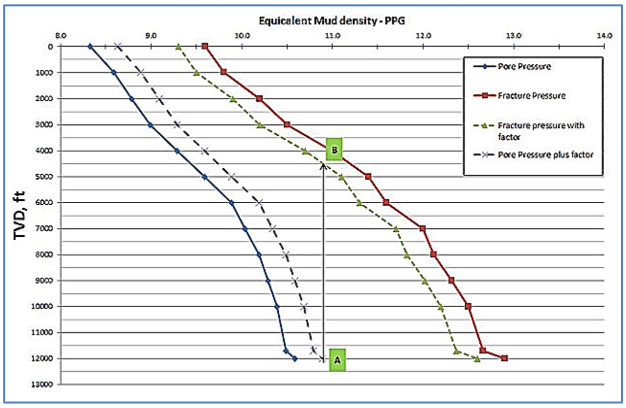

Fig. 3. The first step of the bottom design [9]

The subsequent casing string is founded by sketch a straight line from Point B for intersecting the pore pressure intermittent line through Point C. At that point make a perpendicular line from the Point C until the fracture gradient intermittent line by the side of Point D as shown in Fig. **4**. By conclusion Casing should be established from 1,800 ft. TVD to 4,500 ft. TVD [9].

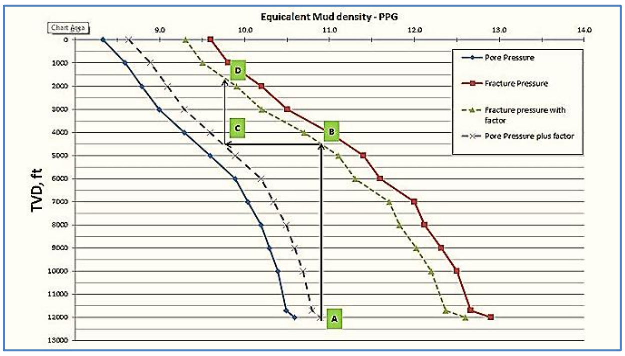

Fig. 4. The second stage of the bottom design [9]

Using the above steps, determine the next casing chain by sketch a straight line from point D to point E and an orthogonal line from point E to point F as shown in Fig. **5**. So the casing should be adjusted from the surface to 1800 TVD[9].

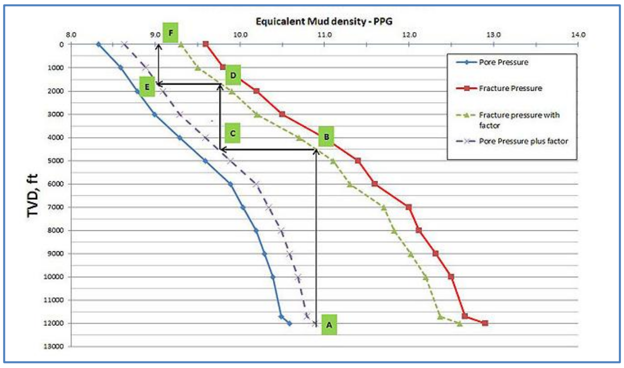

Fig. 5. The third stage of the bottom design [9]

Depending on the aforementioned bottom-up design principles, 3 series of casing will be required at 1800 ft. TVD, 4500 ft. TVD and finally 12000 ft. TVD as shown in Fig. **6** [16].

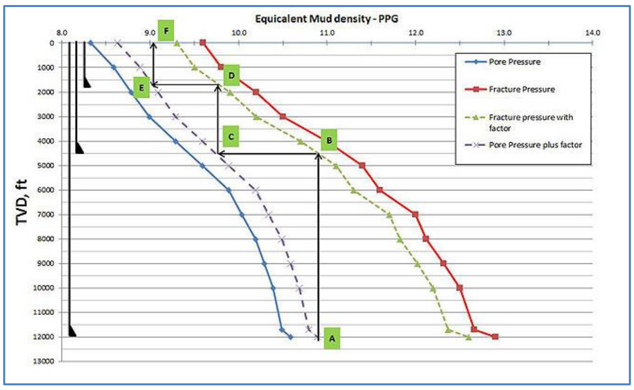

Fig. 6. The final step of the bottom design [9]

2.2. Top Down Method

This method of design starts from the surface of the well downwards, where the depths are designed, including the limits of the safety factor, as shown in Fig. **7**.

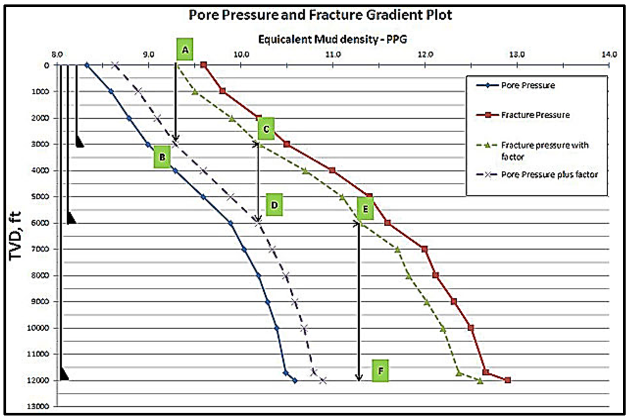

Fig. 7. Top Down Method Final design (all steps) [9]

2.3. Collapse Pressure Method

In order to determine the depth of installation in a section other than the lower section, the effect of axial tension on the buckling pressure must be taken into consideration, and this involves the use of either a trial and error solution or schematic solutions [10]. At some point from the upper end of the well, the buckling resistance control stops as a major and controlling factor in the design from this point to the surface and begins to control the durability of the joint and the longitudinal compliance, [11] as they are the first consideration in the design, so the lining pipes must achieve the equation 2:

$$Ls = \frac{Pc}{0.052 * \rho * Ns} \qquad (2)$$

Where:
Ls= Setting depth (ft.).
ρ=Mud weight (ppg).
Pc= Collapse pressure (psi)
Ns= Design factor (dimension less), From the steps bellow, it can be seen that several stages must be calculated as an iterative process in order to calculate the depth of installation, i.e., trial and error [12].

1- data collection, drilling lithology, pressure and geologic
2- data identification and verification
3- evaluation based on practices and standard
4- analysis: actual casing setting depth and design, and casing failure
5- recalculation casing setting depth and design by using equation 1

Tension load is created from the load of casing and power that formed axially. Established on the maximum force idea, the supreme tension force happens in order to its individual load minus the buoyancy next to casing running then in advance the cementing process [13] and as in equation 3

$$BF = 1 - (MW / 7848.6) \quad (3)$$

where: BF=buoyancy feature, MW=mud density (kg/m3)

The extreme burst weight happens as soon as the cement is pushed through the well. The interior pressure is designed by using equation 4 bearing in mind the hydrostatic pressure related to the cement slurry [14]:

$$P_i = P_{sur} + G_{ce} \times D \quad (4)$$

where: Pi = the internal pressure (MPa), Psur = pumping surface pressure (MPa) Gce = pressure gradient of cement slurry (MPa/m) D= casing shoe depth (m)

3- Data Collection

Getting data is one of the basics and implementing to get the necessary data is from the South Oil Company SOC / Rumelia Oil Field, where it helped to prepare this research.

The basic data consists of:4 wells in Rumelia oil field, depth (vertical and measured) lithology, casing program, Leak of test LOF, pore pressure and fracture pressure, mud density, formation tops, Fig. **8** shows the lithological columns for well 4 for Rumelia oil field, table 1 represent casing information. Table **1** signify Top, bottom of formation with pore and fracture pressure.

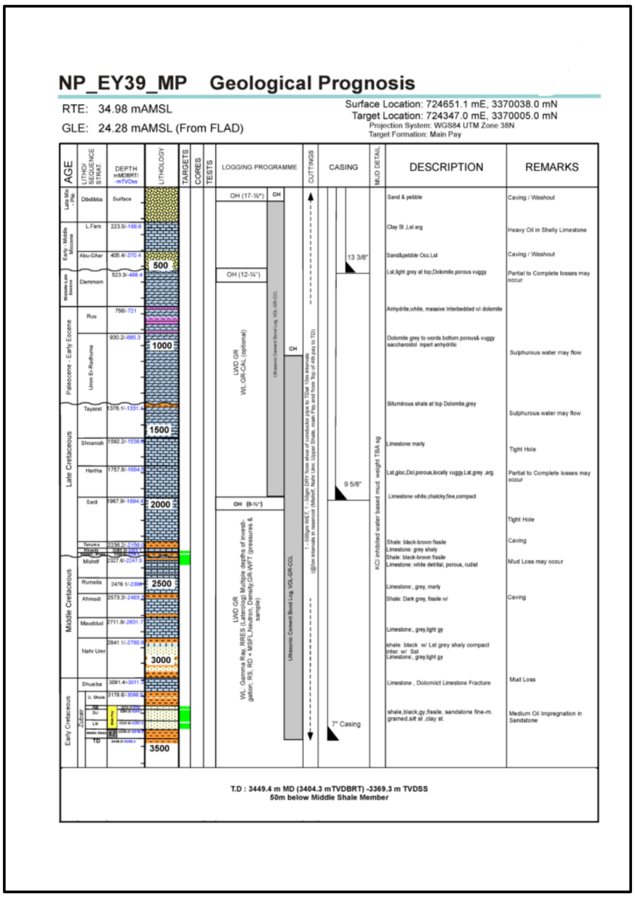

Fig. 8. lithological columns for well 4 for Rumelia oil field [15]

Table 1. casing information for surface, intermediate and production [15]

property	MD m	OD in	Joint m	Weight lb./ft.	ID in	Grade	Collapse psi	Burst psi	Thread
Tubulars and Casing Hardware surface casing									
Prev .Casing	42	20	12.5	94	19.124	K-55	520	2110	BTC
Casing	583	13 3/8	12.2	54.5	12.688	J-55	1130	2730	BTC
Tubulars and Casing Hardware intermediate casing									
property	MD m	OD in	Joint m	Weight lb./ft.	ID in	Grade	Collapse psi	Burst psi	Thread
Prev. Casing	583	13 3/8	12.2	54.5	12.688	J-55	1130	2730	BTC
Tubulars and Casing Hardware surface casing									
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Casing	583	13 3/8	12.2	54.5	12.688	J-55	1130	2730	BTC
Tubulars and Casing Hardware intermediate casing									
property	MD m	OD in	Joint m	Weight lb./ft.	ID in	Grade	Collapse psi	Burst psi	Thread
Prev. Casing	583	13 3/8	12.2	54.5	12.688	J-55	1130	2730	BTC
Casing	2036	9 5/8	12.2	47	8 37/50	L-80	4750	6870	Vam Top
Tubulars and Casing Hardware production casing									
property	MD m	OD in	Joint m	Weight lb./ft.	ID in	Grade	Collapse psi	Burst psi	Thread
Prev. Casing	2036	9 5/8	12.2	47	8 37/50	L-80	4750	6870	VAM TOP
Casing	2557	7	12.2	29	6.185	0	7030	8160	VAM TOP

Table 2. Top, bottom of formation with pore and fracture pressure.

Formation							
Top Md m	Bottom Md m	Bottom TVD m	Top ED SG Frac	Bottom ED Frac SG	Top ED Pore SG	Bottom ED SG Pore	Formation
0.0	412.0	412.0	1.34	1.34	1.11	1.11	Sandstone
412.0	694.0	694.0	1.26	1.72	1.11	1.08	Limestone
694.0	794.0	794.0	1.72	1.71	1.08	1.08	Sandstone
794.0	1050.0	1050.0	1.70	1.63	1.08	1.06	Sandstone
1050.0	1088.0	1088.0	1.58	1.73	1.06	1.06	Dolostone
1088.0	1530.0	1530.0	1.73	1.72	1.06	1.06	Dolostone
1530.0	1690.0	1690.0	1.72	1.70	1.06	1.07	Dolostone
1690.0	1840.0	1840.0	1.70	1.70	1.07	1.08	Shale
1840.0	2034.0	2034.0	1.71	1.72	1.08	1.11	Dolostone
2034.0	2182.0	2182.0	1.72	1.70	1.11	1.13	Limestone
2182.0	2227.0	2227.0	1.70	1.76	1.13	1.12	Shale
2227.0	2557.0	25570	1.80	1.80	1.12	1.11	Limestone
2557	3440	3440	1.81	1.8	1.13	1.12	Limestone

Table 3. Formations with facture, pore pressures and lithology for the studied wells

Well	Casing Setting Depth (m) from Down up	Casing Type	Hole Size in	casing Size in	Casing Setting Depth (m) from collapse pressure	Actual Casing Setting Depth (m)
A-1	47	Conductor	26	20	44	46.5
	583(10m in Top of Dammam)	Surface	17.5	13 3/8	530	582
	1882 (15m into Top of Sadi)	Intermediate	12.25	9 5/8	1881	1882
	3441 (50m above Upper Shale)	Production	8.5	7	3440	3442
A-2	53	Conductor	26	20	51	52
	544(12m in Top of Dammam)	Surface	17.5	13 3/8	542	543
	1892 (10m into Top of Sadi)	Intermediate	12.25	9 5/8	1891	1892
	3431 (40m above Upper Shale)	Production	8.5	7	3430	3431
A-3	45	Conductor	26	20	44	44
	533(11m in Top of Dammam)	Surface	17.5	13 3/8	532	532.5
	1882 (20m into Top of Sadi)	Intermediate	12.25	9 5/8	1882	1881
	3440(33m above Upper Shale)	Production	8.5	7	3439	3440
A-4	56	Conductor	26	20	555	55
	543(9m in Top of Dammam)	Surface	17.5	13 3/8	541	542
	1889 (2m into Top of Sadi)	Intermediate	12.25	9 5/8	1887	1888
	3441 (40m above Upper Shale)	Production	8.5	7	3449	3440

4- Results and Discussion

Many methods are used for determining the casing setting depth for instant the bottom-up technique and the collapse pressure method, which were used in this study.

In general, the bottom-up technique used in development wells. in some circumstances, the exploration wells also use the down top method when facing complex lithology circumstances and nonstandard pressure.

This effort included two methods for choosing the depth of installation, as it was found that both methods gave results that are close to the truth, but the bottom-up method was more accurate and closer to reality than the design factors method as in Table **3**.

In hydrocarbon wells it collapses, bursts, in addition to the axial tension demands that must be taken into account when choosing a casing adjusting depth. Geological interpretation during the design of the casings is a very important factor, especially knowing the location of the top layer, while sitting the casing and this was proven by Boniface and Marcus,2015.

For Table **4**, it represents the frac. and pore pressures for the studied formations, where the highest value for frac. was. 1.8 for limestone formation at a depth of 2256 m, the lowest value for frac. It was 1.26 for limestone formation at a depth of 694 meters. As for the pore pressure, the lowest value was 1.06 for the formation of dolomite at a depth of 1088 meters and the highest value for clay at a depth of 2227 by 1.13.

This indicates that the density of the mud used should be less than 1.26 and higher than 1.06 to ensure a safe drilling process without losses or kick. Well security is responsible for indicating casing design principles and superior practices to ensure good casings, and as in Table **3** and Table **5** which represent well security for well A-1 as a sample by using CemCADE software. (Certainly, CemCADE is specific to cement, but in this research, it was used to find the security of the well, which is one of the results given by the aforementioned program

Table 4. Well Security for well A-1 for production section

Security of well				
Station	Explanation	Minimum Differential Pressure	Depth m	Time hr:mn
Accomplishment	Fracture	657	2036	06:00
Accomplishment	Production	352	2182	06:50
Accomplishment	Burst	7247	zero	08:00
Accomplishment	Collapse	6505	2557	08:40

Table 5. The designing of casings for well A-1

Casing type	MD m	OD in	Joint m	Weight lb./ft.	ID in	Grade	Collapse psi	Burst psi	Thread
conductor	42.0	20	12.5	94.0	19.124	K-55	520	2110	BTC
surface	583.0	13 3/8	12.2	54.5	12.688	J-55	1130	2730	BTC
intermediate	2036.0	9 5/8	12.2	47.0	8 37/50	L-80	4750	6870	Vamp
production	3440	7	12.2	29.0	6.185	L-80	7030	8160	BTC

Fracture pressure is a serious factor for drilling fluid weight designing in the oil wells manufacturing. Leak-off test information for the used drilling fluid for well A-1 are investigated, and fracture pressure expectation technique for the studied well (drilling can continue drilling under protective casing towards the ahead next casing point, in other words just double checking for the mud density for the next hole). If the drilling fluid pressure surpasses the native tensile failure pressure for the studied formation, in other words, fracture pressure times versus vertical depth, a fracture is founded.

For such these cases, the pore pressures frequently are uncharacteristically high and may be surpass what otherwise are innocuous drilling fluids pressures. For the well-studied, the drilling fluid used is considered safe as in Fig. **9** and Fig. **10**. The red line in Fig. **9** is designed for safety issue; Thus, the first stage of casing design is the safety factor, considering the test limits of borehole drilling.

The goal is to avoid drilling difficulties anytime drilling fluid is circulated and this has been proven by Syazwan et.al.2016 [16]. As for the blue line, it was designed without relying on safe limits, and thus leads to damage to the casings during the rotation of the drilling mud and during later production processes, and this was confirmed by Zhang and Yin,2017 [17] about the importance of taking into consideration the impact of fracturing pressure and fluid pressure in the formation.

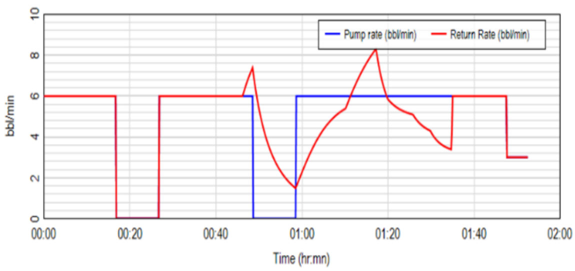

Fig. 9. Fracture and pore pressure limits by leak-off tests

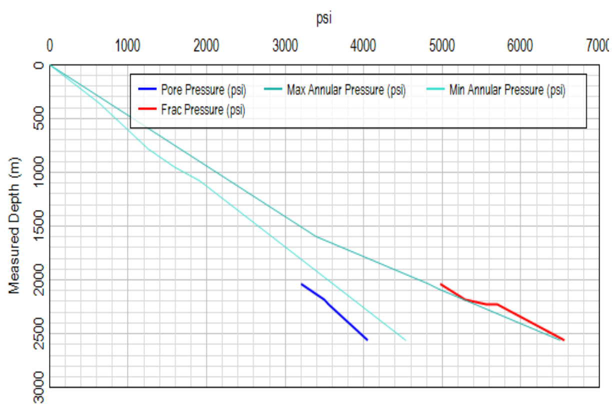

Fig. 10. Fracture and pore pressure values with depth for well A-1

5- Conclusions

1- This effort presents bottom down method to select casing setting depth for 4 wells. The bottom-up technique is in general used for conventional drilling, nevertheless, not wholly development wells depends on the bottom-up technique.
2- Casing evaluation and substantial collection should be directed correctly and exactly as stated by the formation type of the studied Field because of their important at choosing setting depth processes.
3- Depending on casing set depth investigation by using the bottom down method. the subsequent specific suggestion may be projected: the mud density should be selected 0.41 to 0.25 pounds/gallon above the value needed to create a hydrostatic pressure that balances the pressure of the fluids in the penetrating layers.
4- Decision-creation process and is predominantly beneficial for which method is give the exact setting depth is important issues. It was found that the down-up method is possible and successful to be used and applied in the fields of southern Iraq, such as the Rumaila field in southern Iraq, which was studied in this research.

Recommendations

For future works, the use of the bottom-up technique for directional and horizontal drilling can be tried as it was used for vertical drilling and proved successful. It is also possible to recommend the use of the top-down method and compare its results with the results of the top-down method.

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الاعتبارات الجيولوجية المتعلقة بتحديد عمق الغلاف واختيار عمق آبار النفط العراقية (دراسة حالة)

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قسم هندسة النفط ,جامعة بغداد,بغداد ,العراق

الخلاصة

سلامة البئر هي ميزة حيوية يجب الحفاظ عليها في العمر الافتراضي للبئر ، ومن أحد مكونات الغلاف ، يجب أن يكون قادرًا على تحمل جميع الأحمال الداخلية والخارجية. يعتبر الغلاف ، من خلال أساسيتين: تصميم الغلاف وتعديل عمق الغلاف ، وهو أساسيًا اثناء ثقب البئر حيث يلعب دورًا مهمًا في سلامة البئر. يتم تحديد أعماق مجموعة الغلاف بناءً على ضغط التكسير وضغط المسام في البئر ويمكن الحصول عليها عادةً من معلومات محددة جيدًا. بناءً على التحليلات باستخدام التقنيات المحسّنة في هذه الدراسة ، يمكن توقع الاقتراح الخاص التالي: يجب أن يتم اختيار الدرجة الأولى والمواد بشكل صحيح ودقيق وفقًا لعمق إعداد الغلاف والاستراتيجية في المجال المدروس الذي يجب أن يؤخذ في الاعتبار بشكل قاطع في فترة الحفر و بعد الانتهاء منها ، مع ذلك في المقابل في الإنتاج والصيانة ، والتحويل إلى بئر الحقن أو العكس ، بالإضافة إلى مرحلة الإغلاق. تمت دراسة الميزات التي تتحكم في عمق مقعد الغلاف ، والتي تتكون من تدرج الكسر ، وضغط المسام مع مشكلات أخرى هي القطع المتبقية من الصخور. يمكن الحفاظ على تحديد مقعد الغلاف من خلال التحقيق في تحديد سائل الحفر المناسب. وفقًا لنتائج فحص ضغط الكسر وضغط المسام ونتائج عمق ضبط الغلاف عن طريق تقنية من أسفل إلى أعلى ، تم الحصول على النتائج على كل غلاف للآبار الأربعة المدروسة. من النقطة المرجعية المصممة من المنضدة الدوارة .بالنسبة للبئر A ، يبلغ عمق غلاف الاعلى 47 مترًا ، وعمق الغلاف السطحي 533 مترًا ، وعمق إعداد الغلاف المتوسط 1882 مترًا. أخيرًا ، لعمق غلاف الإنتاج هو 3441 متر. بالمقارنة مع طريقة ضغط الانهيار ، فقد وجد أن الطريقة التصاعدية اسفل اعلى أعطت نتائج قريبة ومماثلة للنتائج الحقيقية. تم تضمين نتائج الآبار الأخرى في نتائج البحث

الكلمات الدالة: الغلاف ، التكوين ، تصميم بئرالنفط ، ضبط العمق ، ضغط التكوين