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Pre-Planning of Casing Seat Position to Choose Optimum Equivalent Circulation Density to prevent lost circulation

Ayad Abdulhaleem A.Razzaq*, Wasan A. Kzar
Department of Petroleum, College of Engineering, University of Baghdad, Baghdad, Iraq

Abstract

Loss of drilling fluid in the Nasiriyah oil field can be considered as a big, serious, and expensive problem at the same time, therefore accurate and integrated program must be prepared before start drilling in layers that are likely to get loss circulation. From the available data of well Ns-13, the area of loss was detected in five layers, which are Dammam, Um- radoma, Tayarat, Shiranish and Hartha since these layers contain natural cracks and high porosity represented by vugs.

Methods of prevention have been identified by specifying the minimum values of drilling parameters to reduce hydrostatic pressure, thus reducing equivalent density of drilling mud during the circulation, depths of casing shoes is determined (2500 ft, 3550ft, 5300ft and 6894.5ft) to strengthen the wall of the well and prevent losses.

Keywords: Nasiriyah oil field, Casing seat selection, Lost circulation, ECD control.

التخطيط المسبق لموقع تجليس البطانة لاختيار كثافة التدوير المكافئة المثلى لمنع فقدان سوائل الحفر

اياد عبد الحليم*، وسن عبدالله كزار
قسم النفط، كليه الهندسة، جامعه بغداد، بغداد، العراق

الخلاصة

ان مشكله فقدان سائل الحفر في حقل الناصرية النفطي هي مشكلة كبيرة وخطيرة ومكلفة في نفس الوقت لذا لا بد من إعداد برنامج دقيق ومتكامل قبل البدء بعملية الحفر في الطبقات التي يحتمل أن يحصل فيها الفقدان. من خلال البيانات المتوفرة للبئر Ns-13 تم تحديد مناطق الفقدان في خمس طبقات وهي الدمام، وام رضومه، الطيارات، شيرانيش، الهارثه وذلك لاحتوائها على شقوق طبيعية ذات مسامية عالية متمثلة بالتكهفات. لقد تم تحديد طرق الوقاية بتحديد القيم الدنيا لمتغيرات الحفر لتقليل الضغط الهيدروستاتيكي وبالتالي تقليل الكثافة المكافئة لطين الحفر اثناء الدوران، كما وتم تحديد أعماق مناطق حذوه البطانة (2500, 3550, 5300, 6894.5) قدماً لتقوية جدار البئر ومنع فقدان سائل الحفر.

Introduction:

The Effective Circulating Density (ECD) is defined as the effective mud weight at a given depth created by the total hydrostatic (including the cutting pressure) and dynamic pressures [1].Induced fractures result when the ECD of the drilling fluid exceeds the fracture gradient. This causes the formation to part, opening a fracture. Unlike natural losses, which first occur at the bit, induced fractures occur at the weakest exposed formation. Induced fractures happen when the ECD is increased while weighing up, tripping, drilling too fast, or as the result of a mud ring or other situation causing a temporary pressure surge that breaks down a weak formation. [2] Induced fractures may initiate in any formation [3] due to well irregularities, high mud weight, excessive backpressure or choke down, rough handling of drilling tools, or due to a closed hydrostatic system.

A successful drilling requires that the drilling fluid pressure stay within a tight mud-weight window defined by the pressure limits of wellbore stability. The lower pressure limit is either the pore pressure in the formation or the limit for avoiding wellbore collapse [4]. Typically, a margin of 0.3 pound per

*Email: ayadah62@yahoo.com

gallon (ppg) is added to the pore pressure to allow a safety factor when stopping circulation of the fluid, the compensation of 0.3 ppg allows for the dynamic effect while drilling also. The compensation varies from scenario to scenario but typically lies between 0.2 and 0.5 ppg.[5] or using mud weights that yield pressures equal to the pore pressure of the formation of concern plus 200 psi.[1]

The upper pressure limit for the drilling fluid is the minimum that will fracture the formation. If the drilling fluid exceeds this pressure, there is a risk of creating or opening fractures resulting in lost circulation and a damaged formation. In the language of drilling engineers, pressures are often expressed as pressure gradients or equivalent fluid densities [5]. The squeeze pressure must be monitored to avoid fracturing exposed formations.

A list of measures can be considered to control ECD that includes: a) volume of drill cuttings in the annulus b) controlling viscosity and gel strength c) controlling annular pressure d) controlling surge pressure e) Reducing mud weight [6].

The complete prevention of lost circulation is impossible, because some formations, such as inherently fractured, cavernous, or high permeability zones, are not avoidable if the target zone is to be reached. However, limiting circulation loss is possible if certain precautions are taken, especially those related to induce fractures.[7] These precautions include: a) maintaining lowest safe mud weight, b) minimizing annular-friction pressure losses during drilling and tripping in, and c) setting casing to protect upper weaker formations within a transition zone.

Area of Study

Nasiriyah oil field is one of the important southern oil fields in Iraq. It was located in the province of Thi-Qar 38 km almost away northwest of Nasiriyah, as shown in Figure-1[8]. The field was discovered by seismic surveys carried out from 1973 up to 1988. The actual lithological column that had formations names and their mineral description provided by Iraqi National Oil Company (INOC). Figure 2 shows the lithology of well Ns-13for the first and second holes. [9]

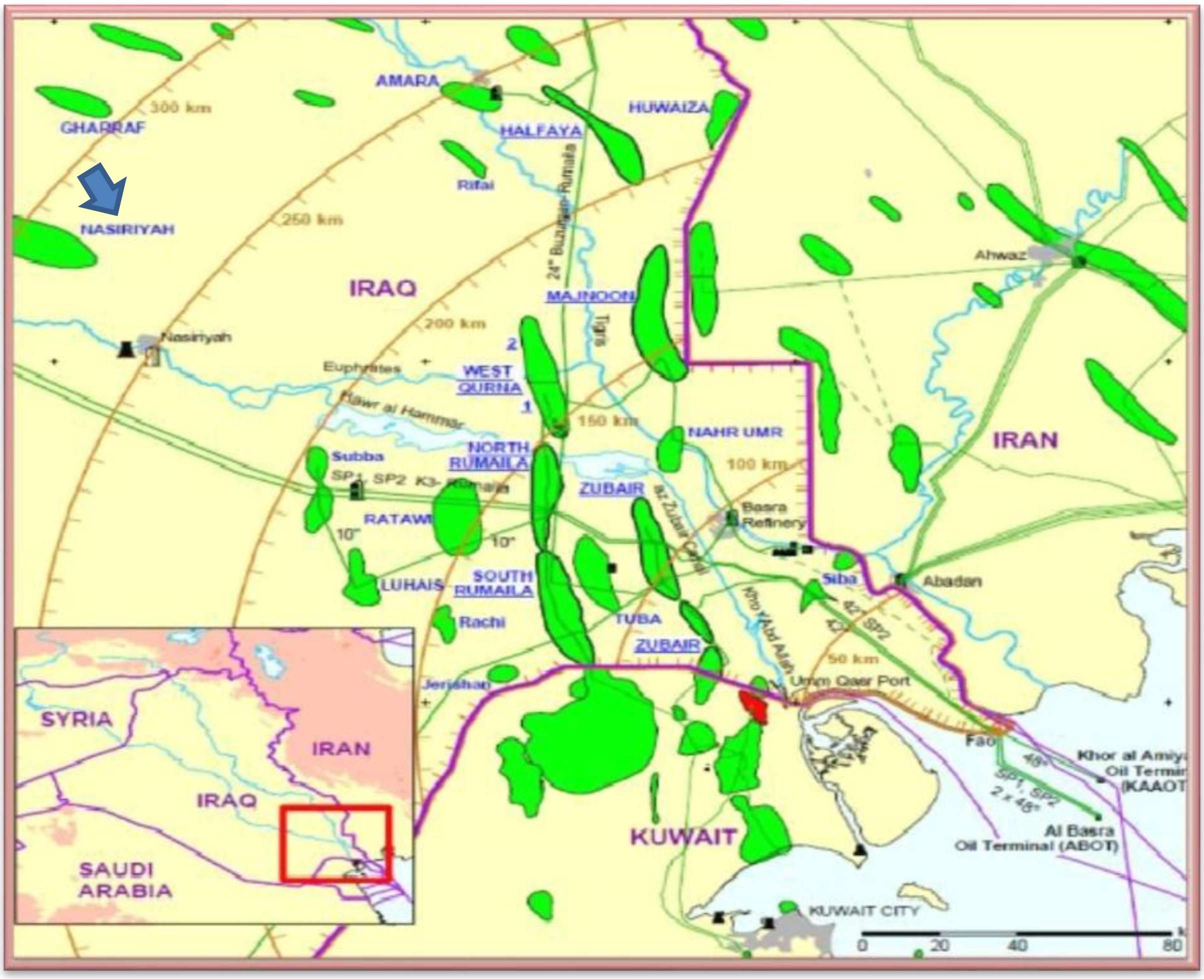

Figure 1- Geographical location map for Nasiriyah oil field [8]

Depth from R.T.K.	Age	Formation	Lithology	Description
296	L-MIO-PLIO	U. Fars		clay
385	E-M MIOCENE	L. Fars		Marl, gray, plastic locally sandy. Anhydrite Limestone shally.
430		Garibe		Dolomite, bf-light grey, Anhydritic.
633	ML EOCENE	Dammam		Limestone Dolomite, bf-light grey at the top, bf, beige porous vuggy.
714	PALEOUSNE-EARLY EOCENE	Rus		Anhydrite, white, massive intercal, w/ dolomite buff, porous, vuggy.
1154		Um-Radoma		Dolomite buff. brown some grey to word bottom porous and vuggy saccharolodol impart anhydratic
1231	LATE CRETACOUS	Tayarat		Bituminous shale Dolomite, grey, buff, saccharolodol porous and vuggy anhydrite locally
1455		Shiranish		Marl ash grey plastic.
1568		Hartha		Limestone, grey Dolomite buff. Fine porous , locally vuggy
1803		Sadi		limestone while chalky, fine, compact

Figure 2- Lithological column of Ns-13 well [9]

Casing Seat Selection

The first design task in preparing the well plan is selecting the depths to which the casing will be run and cemented. The drilling engineer must consider geological conditions such as formation pressures and fracture gradients, hole problems, internal company policies, and, in many cases, a variety of government regulations. A primary purpose of this string of pipe is to provide a fluid conduit from the bit to the surface. Very shallow formations tend to wash out severely and must be protected with pipes. In addition, most shallow formations exhibit some type of lost circulation problem that must be minimized. An additional function of the pipe is to minimize hole-caving problems. Gravel beds and unconsolidated rock will continue to fall into the well if not stabilized with casing. Typically, the operator is required to drill through these zones by pumping viscous muds at high rates [10].

After the depths have been chosen, it is necessary to determine what type of formation/rock type occurs at that depth. Generally, rocks that are relatively competent, resistant to washout, have low permeability and high fracture pressures are chosen as the place to set the casing seat [11].

The IP program (Interactive physics Petro 3.5) prepared by the Schlumberger company was used to calculate pore pressure and fracture pressure by using sonic log readings as a LAS file format and compared the results with the Drilling Parameter method [12].The mud density, pore pressure and fracture pressure are plotted against depth. Once plotted, the selection of casing seats begins at the bottom of the borehole and moves towards the surface. During drilling, the mud density (hydrostatic pressure) and ECD must not exceed the formation fracture gradient. As shown in Figure-3, starting at (point 1), a vertical line is drawn upwards until it intersects the fracture gradient curve (point 2). It will be necessary to set casing or a liner at this depth (5300ft). Depending on the safety factor or kick tolerance, the casing may be set higher or lower than this depth. Casing seat selection continues by moving horizontally to a new mud density (point 3), then vertically to the next casing seat (point 4). Again, move horizontally to the mud density curve (point 5) and finally vertically to the fracture gradient curve at (point 6). The new densities, which suggested to be used in the selected well were calculated according to the obtained pressures from Figure-3. Table-1 demonstrate the depths of casing shoes, pressure and new densities that suggested to be used in well Ns-13 for different holes.

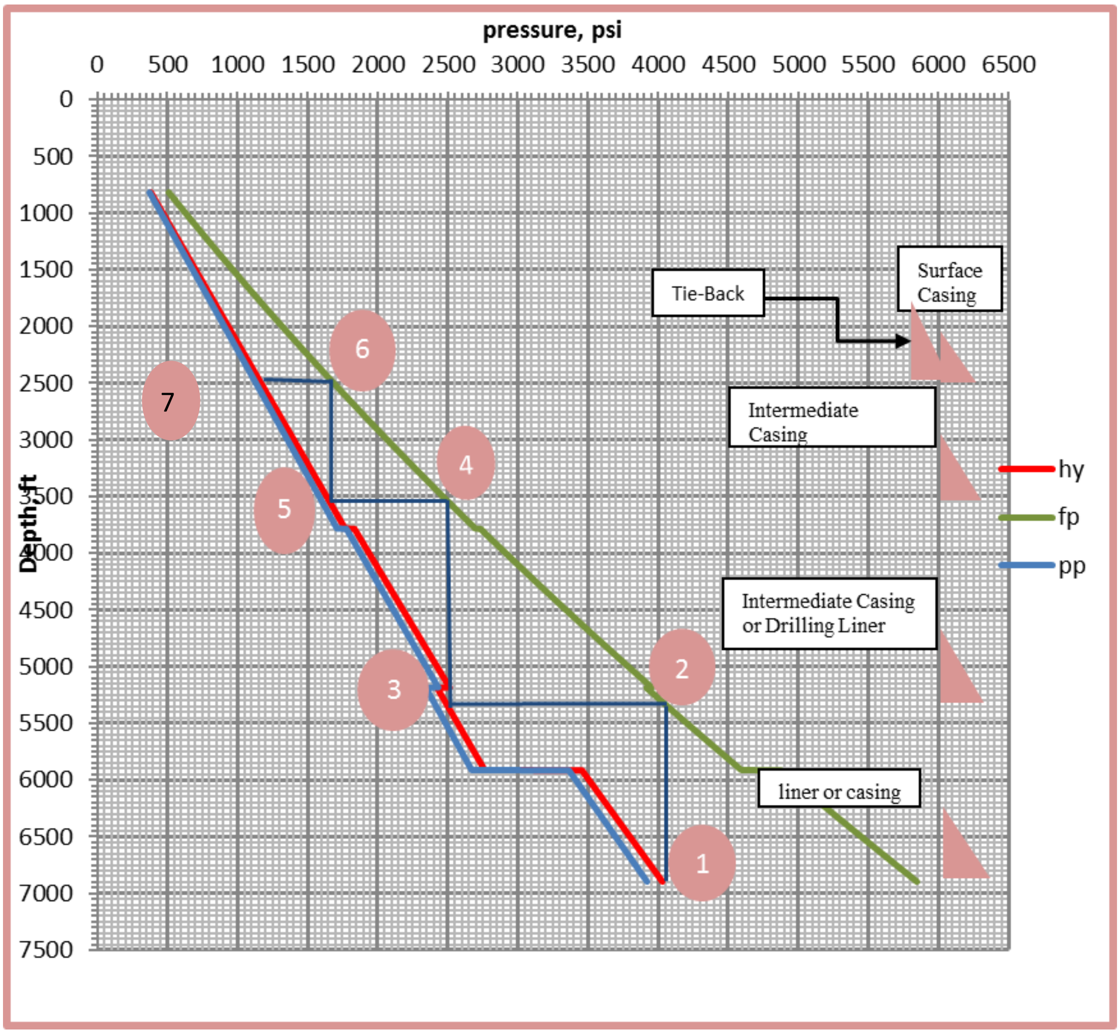

Figure 3- Pre-planning casing seat selection

According to the obtained pressure values, point (2), (4) and (6) were chosen to be the places to set the casing seat. It is important to note that any pressure values higher than the selected pressures may cause induced fracture. Obviously, to minimize or avoid lost circulation problem and to the proper selection of casing seat depths, the fracture gradient points (point 2, 4 and 6) were chosed.

Table 1- Casing shoe selections

Seat depths no.	Casing shoe (ft)	Pressure, psi	Density (ppg)
7	2500	1200	9.230769
5	3550	1700	9.209101
3	5300	2500	9.071118
1	6894.5	4033.3	11.25

Annular Pressures and Surge pressures

When circulating, the pressure exerted by the mud column increases due to frictional pressure losses within the borehole annulus. Those pressures loses can be calculated using annular pressure loss in a laminar flow (Bingham plastic model) that can be calculated as following procedure [13]

► Calculate the annular velocity (Va) for each annular geometry.

$$\mathbf{Va}= \frac{24.5*Q}{(Dh^2-Dp^2)} \qquad \mathbf{(1)}$$

Where:
Va = Annular flow rate (ft/min)
Dh = Well bore diameter (inches)
Dp = Collar or drill pipe or diameter (inches)

►Calculate the critical velocity (Vc) for each annular geometry.

$$\mathbf{Vc}= \frac{97\mu p+97\sqrt{\mu_p{}^2+6.2\rho*Y_p*D_e{}^2}}{\rho*D_e} \qquad \mathbf{(2)}$$

$$D_e\mathbf{=(Dh\text{-}Dp)} \qquad \mathbf{(3)}$$

Where:
Vc = critical velocity (ft/min)
Y_P= Yield point (lbs/100ft^2)
μ_P= Plastic velocity (cps)

► Compare each critical velocity to its annular velocity.

If Va > Vc the flow is turbulent; use

$$\mathbf{P}= \frac{8.91*10^{-5}*\rho^{0.8}*Q^{1.8}*\mu_p{}^{0.2}*L}{D_e{}^3(Dh+Dp)^{1.8}}$$

(4)

Where:
P = Annular pressure (psi)
L = Length of the annular section (ft)
If Va< Vc the flow is laminar; use

$$\mathbf{p}= \frac{L\,x\,\mu_p\,x\,V}{60000D_e{}^2}+\frac{L\,x\,Y_p}{200D_e} \qquad \mathbf{(5)}$$

Surge pressure result due to pipe running in the hole, when adding surge pressures to the hydrostatic pressure of drilling mud, it may be caused fracturing the uncovered formations. Especially, the unconsolidated formations and these able to fracture when the pipe down speed is high resulting in loss. Surge pressure. In zones of probable lost circulation, the calculations of surge pressure must be achieved and the drill engineer consideration as to the maximal speed which permissible to down pipes. Down speeds could be observed on drilling mud logging for helping the drill engineer in choose safe down speed [6] Pressure can be calculated using a Bingham method or a same method that used to calculate annular pressure losses.[14].

Fluid velocity of the displaced mud caused by the pipe movement has to be calculated. [15]

For Closed Ended Pipe:

$$\mathbf{Va}= Vp[0.5 + \frac{Dp2}{Dh^2-Dp^2}] \qquad \mathbf{(6)}$$

Where:
Vp = Pipe speed (ft/min)
Dh= Hole diameter (in)
Dp= Pipe outer diameter (in)
For Opened Ended Pipe:

$$Va = Vp[0.5 + \frac{Dp^2-Di^2}{Dh^2-Dp^2+Di^2}] \qquad \mathbf{(7)}$$

Where: Di= Pipe inner diameter (in)

Minimum values of drilling parameters including values of plastic viscosity and yield point were selected from Table-2 according to density value to calculate minimum annular pressure, minimum surge pressure loss by Bingham equations. This annular pressure loss and surge pressure are calculated for each individual annular section. The ECD is then calculated by adding those pressure losses to the mud density [6].

Table 2 - Gel/Water-Base Properties [11]

Mud weight, ppg	Funnel Viscosity, sec/ qt	Plastic viscosity, cp	Yield Point, lb/100 ft^2	Solid, %
8.5	32-40	5-8	5-18	1-3
9.0	32-40	5-8	5-18	3-6
10.0	33-38	10-15	5-15	9-12
11.0	34-40	16-20	5-14	13-17
12.0	38-42	19-23	5-13	17-20

Figure-4 and Table -3 showed the comparison of ECDs (used, calculated and suggested). It is noted that the difference between the ECD of used density and ECD of pore pressure is greater than the value of the safety factor and this difference may be one of the factors causing the loss of drilling fluids.

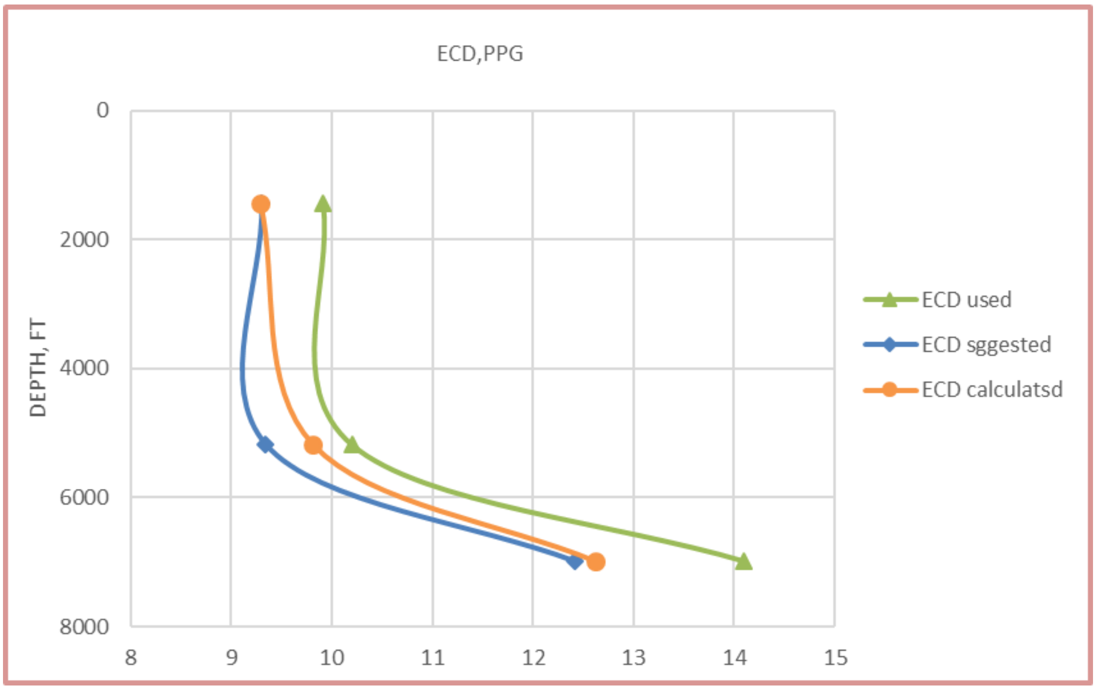

Figure 4- Comparison between used ECD, calculated ECD and suggested ECD

Table 3- Values of different ECDs for the three holes

Depth	Hole no.	ECD $_{used}$*	ECD $_{cal.}$**	difference	ECD $_{suggested.}$***
1436.64	1	9.915932	9.286029	1.67218	9.300087
5182.4	2	10.20261	9.812818	0.857451	9.345159
6986	3	14.09246	12.62028	0.615845	12.42028

*** calculated from actual data**
****calculated from pore pressure density+0.5**
***** calculated by casing seat**

Again the difference between the ECD used and ECD calculated may be attributed to the drilling mud properties and pipes down speed. As an example and for the second hole (which is the section of interest), the used ECD was 10.20261 ppg whereas the calculated ECD was 9.812818 ppg and the safety issue assumed that the two values should be equal.

Conclusions:

1. Pre-drilling pore-fracture pressure prediction is essential in any drilling prognoses. During drilling, it is important to administer the MW program, especially the ECD to keep the borehole stable in the weak zones.

2. ECD management is the key to get effective drilling, i.e., optimization of the drill pipe size, pump rate, fluid rheology ensures a clean hole while minimizing ECD.

Nomenclatures:

ECD=equivalent circulation density
FP=Fracture pressure
Hyp=Hydrostatic pressure
INOC =Iraqi national oil company
MW= Mud weight
Ns-13= Nasiriyah Well-13
pp=Pore pressure
ppg=Pound per Gallon

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