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# Using of surface back pressure with water based mud in managed pressure drilling technique to solve lost circulation problem in Southern Iraqi Oil Fields

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## Abstract

Many drilling problems are encountered continuously while drilling oil wells in the southern Iraqi oil fields. Many of these problems are ineffectively handled resulting in a longer non-productive time. This study aims to identify the formations such as Dammam, and Hartha formations،diagnose potential problems and provide the solution for lost circulation problem. After conducting a comprehensive study on the subject and based on available data, previous studies and some information, the managed pressure drilling (MPD) method was the best technique to solve this problem. This process may use various techniques including control of back pressures .Thus, reducing the risk and control the costs of drilled wells, which have narrow pressure window by managing the wellbore pressure profile. The well plan software program provided by Halliburton Company was used, this software is based on a database and data structure common to many of Landmark's drilling applications. Mud used with various injection rates to choose the rate that provides the conditions to achieve the best drilling process, as it using mud weights of (8.8 - 8.7 ) ppg and applied a surface back pressure (50 psi). Depending on specifications of second hole the optimal injection rate was chosen using the (hydraulics) program. As a results, rate of water injection (850) gpm, is the best which it provides a good efficient cutting transport ratio (CTR), which means high stability and preventing formation damage in addition to controlling in mud losses.

**Keywords:** Managed pressure drilling (MPD), Surface pack pressure, Lost circulation, water based mud, Cutting transport ratio (CTR).

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# استخدام SBP مع الطين المائي في تقنية MPD لحل مشكلة التدوير الضائع في حقول النفط الجنوبية العراقية


## الخلاصة:

تواجه العديد من مشاكل الحفر بشكل مستمر أثناء حفر آبار النفط في حقول النفط جنوب العراق. يتم التعامل مع العديد منها بشكل غير فعال مما يؤدي إلى وقت أطول غير منتج. تهدف هذه الدراسة إلى التعرف على التكوينات مثل تكوينات الدمام والهارثة وتشخيص المشاكل المحتملة وتقديم أفضل حل لمشكلة فقدان الطين. بعد إجراء دراسة شاملة حول الموضوع واستناداً إلى البيانات المتوفرة والدراسات السابقة وبعض المعلومات، كانت طريقة الحفر بالضغط المُدار (MPD) هي أفضل تقنية لحل هذه المشكلة. قد تستخدم هذه العملية تقنيات مختلفة بما في ذلك التحكم في الضغوط الخلفية، وبالتالي، تقليل المخاطر والتحكم في تكاليف الآبار المحفورة، والتي لها حدود ضغط ضيقة من خلال إدارة ملف تعريف ضغط حفرة البئر.

البرنامج المستخدم هو برنامج Wellplan المقدم من شركة Halliburton، ويستند هذا البرنامج إلى قاعدة بيانات وهيكل بيانات مشترك في العديد من تطبيقات الحفر في Landmark يستخدم الطين بمعدلات مختلفة من الحقن لاختيار المعدل الذي يوفر الشرط لتحقيق أفضل عملية حفر وتجنب أي خسائر، عن طريق استخدام وزنين من الطين (8.8 -8.7) ppg وتطبيق الضغط السطحي الخلفي (SBP) لاختيار الأفضل لحفر آبار أخرى. تم اختيار معدل الحقن الأمثل لهذا القسم حسب مواصفاته وباستخدام برنامج (الهيدروليك). ونتيجة لذلك، فإن معدل حقن الماء (850) جالونًا في الدقيقة هو الأفضل لأنه يوفر نسبة نقل جيدة وفعالة (CTR)، مما يعني استقراراً عاليا للحفرة ويمنع تلف التكوين بالإضافة إلى التحكم في فقد الطين.


## 1. Introduction:

Lost circulation is a major problem when drilling in Basra oil fields. Where, some formations may contain caverns, large or some problems, so losses are not totally controllable and additional measures must be taken to maintain the safety and efficiency of the drilling process. Lost circulation can be defined as a decrease or complete absence of the fluid flow to the formation-casing or to casing-tubing section[1]. MPD is a new technology which used to treat mud losses by controlling the annular frictional pressure losses during drilling operation, and this technique uses tools almost similar to the tools used in drilling underbalanced operation. This method is usually used in the fields with narrow mud window between pore pressure and fracture pressure. Depending on this method, the percentage of non-productive time can be reduced which caused by several problems such as stuck pipe, lost circulation, and excessive mud cost[2]. Most calculations are in fluid motion (dynamic state), because most problems occur when the fluid is in a state of movement such as lost circulation influx and other problems. Therefore, the aim of this research is to explain how to control the bottom hole pressure, mud losses and

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fluid flow from formation by using the technique of MPD. This is to improve drilling operation for the hole 17.5 in by utilizing the lowest possible mud weight to reduce the differential pressure between mud pressure and pore pressure, by utilizing single phase drilling fluid with applied surface back pressure.

## 2. Overview

### 2.1 Underbalanced Drilling (UBD) Versus the Conventional Drilling (OBD):

Underbalanced drilling is a process to drill gas and oil wells when the wellbore pressure is kept less than the pore pressure of the formation being drilled. Where, the formation fluid influx into the well and up to the surface.

Overbalanced drilling is a process to drill gas and oil wells when the wellbore pressure is higher than the pore pressure. Therefore, the rock around the wellbore can damaged in high pressure [3]. Based on the foregoing, The prime differences between overbalanced drilling (OBD) and underbalanced drilling (UBD) are which the drilling fluid in UBD does not implement as a barrier against the pore pressure, so which it allow formation fluids influx into wellbore. Figure (1) illustrates the underbalanced drilling operating area, that is above the collapse pressure and below the formation pressure. Also, there are several differences which evolve from previous two main differences. Where, a conventional drilling is carried out with carefully designed drilling fluid programs which use to maintain in most conditions an overbalanced state. Moreover, another option can be use which is managed pressure drilling (MPD) that in several cases can be provided very good results and cheaper [4].

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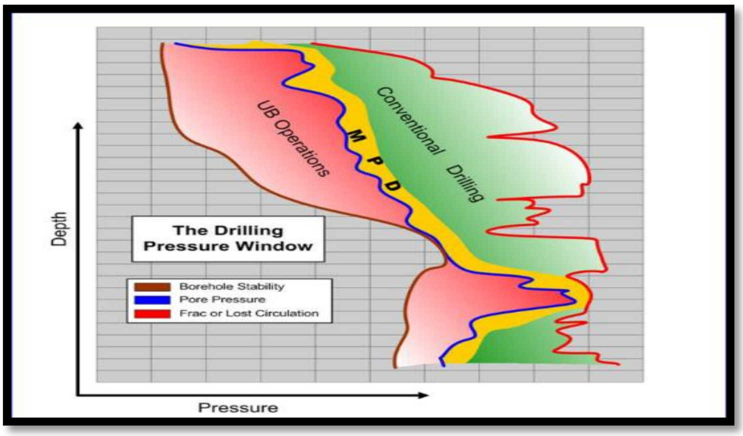


**Fig. (1) The drilling pressure window for the OBD operations, MPD operations and UBD operations[5]**

### 2.2 The Difference among Managed Pressure Drilling (MPD), Underbalanced Drilling (UBD), and Performance Drilling (PD):

Today's drilling is more challenging and complex than the wells that were drilled earlier, therefore conventional drilling may be unable to drill some wells because of geological complexity, unexpected problems and narrow operational window. The industry needed to develop and explore alternative methods for further development of complex reservoirs and depleted [6]. Where, these three techniques (MPD, UBD, PD) contain common equipment but all applied in different condition [7]. Ostroot et al. stated that although UBD and MPD offer management of pressures in the wellbore via drilling operation, the methods differ in how to achieve this technically. While the MPD is designed to keep the wellbore pressure equal or slightly above to the formation pore pressure, the UBD is designed for maintaining that pressure continuously less than the pore pressure of formation, and thus, it causes fluid of formation influx into wellbore, and then, to the surface [8]. On the other hand in performance drilling, the wellbore pressure is as low as possible. Also, the aim of performance drilling (PD) is to increase rate of penetration and to reduce cost of the drilling by faster drilling [7]. Additionally there are similarities between UBD and MPD operations, for example both methods tend to use similar governing pressure tools, like choke manifold and rotating control device (RCD). Nevertheless, the main difference between these approaches being that the MPD purpose is to

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solve and avoid problems of drilling .UBD is used to prevent reservoir damage because of the fluid invasion to formation Figure (2) illustrates the difference among PD and MPD as well as UBD.

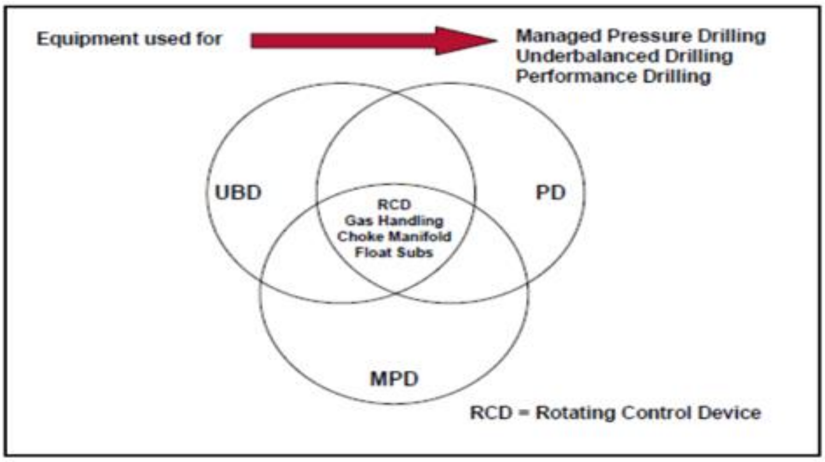


**Fig. (2) The shared equipment for the technology of MPD, UBD and PD** [7]

## 3. Methodology

Constant bottom hole pressure (CBHP) was known as a proper technique of MPD to reduce the weight of overbalanced mud while applied a surface back pressure to avoid the low-pressure formations problems. Well plan software program provided by Halliburton Company for water base mud were used, using the appropriate data provided by Al Basra Oil Company for the intermediate section which includes six formations (Dammam, Rus, Umm-Er-Radhuma, Tayarat, Shiranish and Hartha) to build the appropriate model. WellPlan™ software is founded upon a database and data structure familiar to numerous of the drilling uses of Landmark. Such database is named the Engineer’s Drilling Data Model™ (EDM™) and is supporting the data various levels that are needed for using the software of drilling.

### 3.1 Flow rate

The injection rate of liquid calculated using a hydraulics software program from Schlumberger to choose the optimal flow rate for the purpose of drilling this hole. The range of the flow rate (800-850) gpm was found to be the best for drilling this well.

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### 3.2 Pore and fracture pressure:

The pore pressure and fracture pressure at each formation required to drilling should be recognized. Their values are obtained from digitizing Figure (4.1) from the final well report of the Zubair field by utilizing the Didger program.

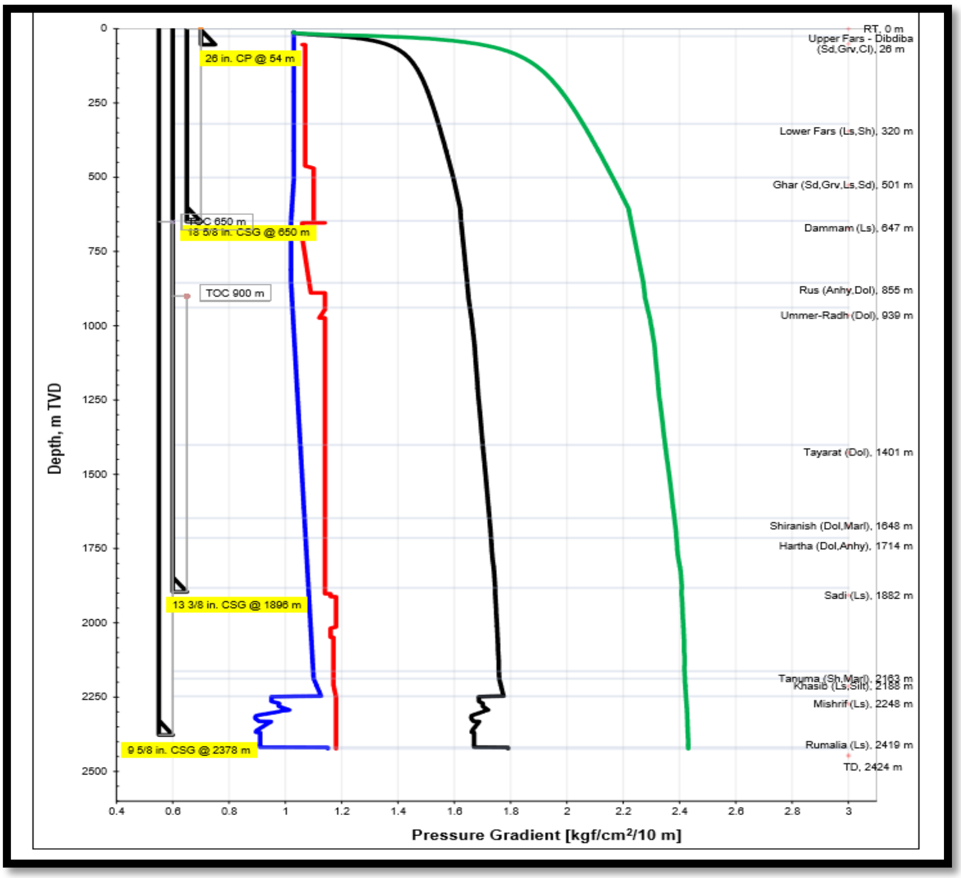


**Fig. (3) Pressure gradient versus depth [9]**

## 4. <u>Result and Discussion</u>

The main reason for using MPD in this well is to reduce overbalance against these formations to avoid lost returns, increase penetration rate, reduce formation damage, stuck pipe events which requires control of bottom hole and surface back pressure. This task was performed in a manner that allows comparison with conventional drilling and the results are clarified as two scenarios[10]:

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1- drilling without SBP (Open hole condition)
2- drilling with SBP (Close hole condition)

In this section, water base mud is used as drilling mud, so two weights of mud (8.8-8.7) ppg were used and SBP of (50-100-150) psi was applied to choose the best. The optimal injection rate was chosen 12211for intermediate section was (850 gpm). When using an injection rate (800 gpm) for comparison purposes, the well cleaning rate was less compared to (850 gpm) with a rate of (0.05%). As well, the application of SBP (100-150) psi gave a high ECD might cause the formation fracture and mud losses, so they were excluded from the comparison.

### 4.1 Drilling with 850 gpm and 8.8 ppg:

This section includes the results and analysis of the second hole of the well from (679m to 1887m) without SBP and with SBP ( 50 psi) at 850 gpm and 8.8 ppg .

#### 4.1.1 Drilling without SBP:

The results and analysis of the second hole of the well from (679m to 1887m) without SBP at 850 gpm and 8.8 ppg are illustrated in Table (1) and Figure (4)

**Table (1) Results of second hole of utilizing water based mud without SBP**

| Case | MD | BHP | ECD | CTR | P gradient |
|---|---|---|---|---|---|
| | (m) | (psi) | (ppg) | % | psi/ft |
| 1 | 679 | 1,027.40 | 8.87 | 0.55 | 0.46124 |
| 2 | 701.04 | 1,060.75 | 8.87 | 0.55 | 0.46124 |
| 3 | 731.52 | 1,106.87 | 8.87 | 0.55 | 0.46124 |
| 4 | 762 | 1,153.00 | 8.87 | 0.55 | 0.46124 |
| 5 | 792.48 | 1,199.12 | 8.87 | 0.55 | 0.46124 |
| 6 | 822.96 | 1,245.24 | 8.87 | 0.55 | 0.46124 |
| 7 | 853.44 | 1,291.36 | 8.87 | 0.55 | 0.46124 |
| 8 | 883.92 | 1,337.48 | 8.87 | 0.55 | 0.46124 |
| 9 | 914.4 | 1,383.60 | 8.87 | 0.55 | 0.46124 |
| 10 | 944.88 | 1,429.72 | 8.87 | 0.55 | 0.46124 |
| 11 | 975.36 | 1,475.84 | 8.87 | 0.55 | 0.46124 |
| 12 | 1,005.84 | 1,521.96 | 8.87 | 0.55 | 0.46124 |
| 13 | 1,036.32 | 1,568.08 | 8.87 | 0.55 | 0.46124 |
| 14 | 1,066.80 | 1,614.21 | 8.87 | 0.55 | 0.46124 |
| 15 | 1,097.28 | 1,660.33 | 8.87 | 0.55 | 0.46124 |
| 16 | 1,127.76 | 1,706.45 | 8.87 | 0.55 | 0.46124 |

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| | | | | | |
|---|---|---|---|---|---|
| 17 | 1,158.24 | 1,752.57 | 8.87 | 0.55 | 0.46124 |
| 18 | 1,188.72 | 1,798.69 | 8.87 | 0.55 | 0.46124 |
| 19 | 1,219.20 | 1,844.81 | 8.87 | 0.55 | 0.46124 |
| 20 | 1,249.68 | 1,890.93 | 8.87 | 0.55 | 0.46124 |
| 21 | 1,280.16 | 1,937.05 | 8.87 | 0.55 | 0.46124 |
| 22 | 1,310.64 | 1,983.17 | 8.87 | 0.55 | 0.46124 |
| 23 | 1,341.12 | 2,029.29 | 8.87 | 0.55 | 0.46124 |
| 24 | 1,371.60 | 2,075.41 | 8.87 | 0.55 | 0.46124 |
| 25 | 1,402.08 | 2,121.54 | 8.87 | 0.55 | 0.46124 |
| 26 | 1,432.56 | 2,167.66 | 8.87 | 0.55 | 0.46124 |
| 27 | 1,463.04 | 2,213.78 | 8.87 | 0.55 | 0.46124 |
| 28 | 1,493.52 | 2,259.90 | 8.87 | 0.55 | 0.46124 |
| 29 | 1,524.00 | 2,306.02 | 8.87 | 0.55 | 0.46124 |
| 30 | 1,554.48 | 2,352.14 | 8.87 | 0.55 | 0.46124 |
| 31 | 1,584.96 | 2,398.26 | 8.87 | 0.55 | 0.46124 |
| 32 | 1,586.11 | 2,400.00 | 8.87 | 0.55 | 0.46124 |
| 33 | 1,615.44 | 2,444.38 | 8.87 | 0.55 | 0.46124 |
| 34 | 1,645.92 | 2,490.50 | 8.87 | 0.55 | 0.46124 |
| 35 | 1,676.40 | 2,536.63 | 8.87 | 0.55 | 0.46124 |
| 36 | 1,698.73 | 2,570.42 | 8.87 | 0.55 | 0.46124 |
| 37 | 1,699.75 | 2,571.96 | 8.87 | 0.55 | 0.46124 |
| 38 | 1,706.88 | 2,582.75 | 8.87 | 0.55 | 0.46124 |
| 39 | 1,727.77 | 2,614.37 | 8.87 | 0.6 | 0.46124 |
| 40 | 1,728.77 | 2,615.89 | 8.87 | 0.6 | 0.46124 |
| 41 | 1,737.36 | 2,628.90 | 8.87 | 0.6 | 0.46124 |
| 42 | 1,755.90 | 2,656.98 | 8.87 | 0.59 | 0.46124 |
| 43 | 1,765.06 | 2,670.85 | 8.87 | 0.6 | 0.46124 |
| 44 | 1,767.84 | 2,675.06 | 8.87 | 0.6 | 0.46124 |
| 45 | 1,798.32 | 2,721.23 | 8.87 | 0.6 | 0.46124 |
| 46 | 1,820.39 | 2,754.66 | 8.87 | 0.63 | 0.46124 |
| 47 | 1,821.41 | 2,756.21 | 8.87 | 0.63 | 0.46124 |
| 48 | 1,828.80 | 2,767.41 | 8.87 | 0.63 | 0.46124 |
| 49 | 1,849.15 | 2,798.25 | 8.87 | 0.63 | 0.46124 |
| 50 | 1,851.36 | 2,801.60 | 8.87 | 0.63 | 0.46124 |
| 51 | 1,859.28 | 2,813.61 | 8.87 | 0.63 | 0.46124 |
| 52 | 1,860.54 | 2,815.52 | 8.87 | 0.63 | 0.46124 |
| 53 | 1,864.56 | 2,821.61 | 8.87 | 0.63 | 0.46124 |
| 54 | 1,866.68 | 2,824.83 | 8.87 | 0.63 | 0.46124 |
| 55 | 1,885.33 | 2,853.09 | 8.87 | 0.63 | 0.46124 |
| 56 | 1,886.56 | 2,854.96 | 8.87 | 0.63 | 0.46124 |
| 57 | 1,887.00 | 2,855.63 | 8.87 | 0.63 | 0.46124 |

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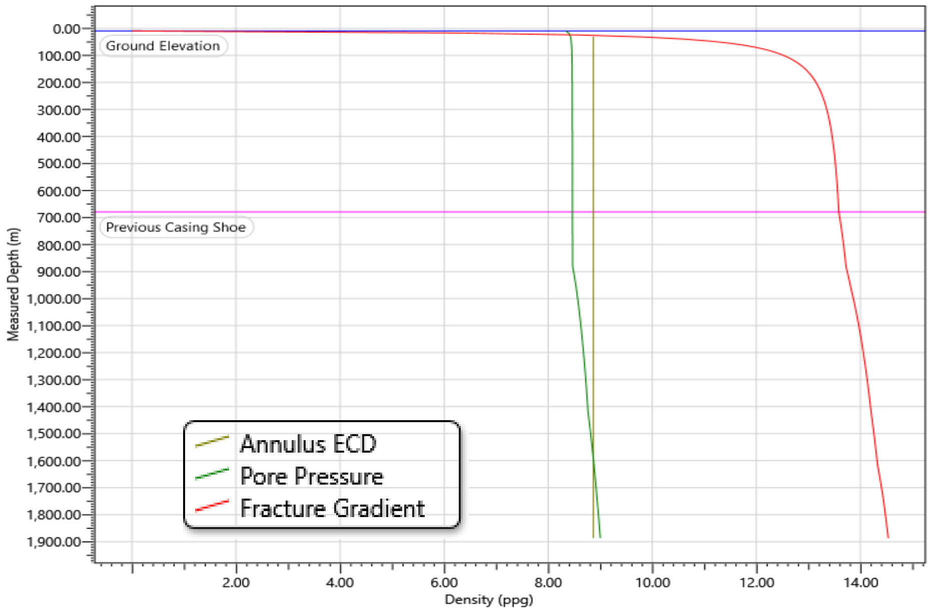


**Fig. (4) Density vs depth at the second hole utilizing water based mud without SBP**

In this scenario, drilling was done using a mud weight (8.8 ppg) with an injection rate of (850 gpm) without applying any surface back pressure to the second hole that begins with the formation of Dammam and ends with Hartha. Where, it is observed from Table (1) that the pressure gradient is (0.461 psi/ft), noting that the highest pressure gradient for this section is (0.465 psi/ft) and the rate of cleaning for the well (CTR) is greater than (0.5), ranging between (0.55-0.63). In case 39, CTR begins to increase from (0.55) to reach (0.63) at the total depth in the Hartha formation, and this is due to the fact that ECD has become less than the pore pressure at this point, which is the beginning of Hartha formation. Therefore the pressure difference becomes negative, that meaning the pore pressure it becomes greater than the mud pressure (drilling under-balanced) and as a result of less ECD, it increases CTR and ROP accordingly, but the wellbore instability problem is present, which leads to many problems. As for above formations, the pressure difference is small compared to drilling with a mud weight (9.1 to 9.4) ppg, as is practically used in this well, thus reducing the cost of high mud weights and increasing CTR and ROP as a result of reducing the differential pressure. The most important thing is to avoid the occurrence of mud losses in the formation of Dammam and Hartha. The ECD is

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approximately equal to the pore pressure at the beginning of Shiranish formation at a depth of (1615 m) and are less than the pore pressure at the beginning of Hartha formation at a depth of (1736 m), where the pore pressure becomes greater than the pressure of mud, and upon it the chock can be used for additional SBP upon reaching the formation of the Hartha to increase ECD to become balanced or near-balanced with the pore pressure and control of the well and avoid the problems of wellbore instability.

### 4.1.2 Drilling with SBP:

The results and analysis of the second hole of the well from (679m to 1887m) with SBP (50 psi) at 850 gpm and 8.8 ppg are illustrated in Table (2) and Figure (5).

**Table (2) Results of second hole of utilizing water based mud with SBP (50 psi)**

| Case | MD | BHP | ECD | CTR | P gradient |
|---|---|---|---|---|---|
| | (m) | (psi) | (ppg) | % | psi /ft |
| 1 | 679 | 1,077.48 | 9.3 | 0.55 | 0.4836 |
| 2 | 701.04 | 1,110.83 | 9.29 | 0.55 | 0.48308 |
| 3 | 731.52 | 1,156.95 | 9.27 | 0.55 | 0.48204 |
| 4 | 762 | 1,203.07 | 9.25 | 0.55 | 0.481 |
| 5 | 792.48 | 1,249.19 | 9.24 | 0.55 | 0.48048 |
| 6 | 822.96 | 1,295.31 | 9.23 | 0.55 | 0.47996 |
| 7 | 853.44 | 1,341.43 | 9.21 | 0.55 | 0.47892 |
| 8 | 883.92 | 1,387.56 | 9.2 | 0.55 | 0.4784 |
| 9 | 914.4 | 1,433.68 | 9.19 | 0.55 | 0.47788 |
| 10 | 944.88 | 1,479.80 | 9.18 | 0.55 | 0.47736 |
| 11 | 975.36 | 1,525.92 | 9.17 | 0.55 | 0.47684 |
| 12 | 1005.84 | 1,572.04 | 9.16 | 0.55 | 0.47632 |
| 13 | 1036.32 | 1,618.16 | 9.15 | 0.55 | 0.4758 |
| 14 | 1066.8 | 1,664.28 | 9.14 | 0.55 | 0.47528 |
| 15 | 1097.28 | 1,710.40 | 9.14 | 0.55 | 0.47528 |
| 16 | 1127.76 | 1,756.52 | 9.13 | 0.55 | 0.47476 |
| 17 | 1158.24 | 1,802.64 | 9.12 | 0.55 | 0.47424 |
| 18 | 1188.72 | 1,848.77 | 9.12 | 0.55 | 0.47424 |
| 19 | 1219.2 | 1,894.89 | 9.11 | 0.55 | 0.47372 |
| 20 | 1249.68 | 1,941.01 | 9.1 | 0.55 | 0.4732 |
| 21 | 1280.16 | 1,987.13 | 9.1 | 0.55 | 0.4732 |
| 22 | 1310.64 | 2,033.25 | 9.09 | 0.55 | 0.47268 |
| 23 | 1341.12 | 2,079.37 | 9.09 | 0.55 | 0.47268 |
| 24 | 1371.6 | 2,125.49 | 9.08 | 0.55 | 0.47216 |

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|---|---|---|---|---|---|
| 25 | 1402.08 | 2,171.61 | 9.08 | 0.55 | 0.47216 |
| 26 | 1432.56 | 2,217.73 | 9.07 | 0.55 | 0.47164 |
| 27 | 1463.04 | 2,263.85 | 9.07 | 0.55 | 0.47164 |
| 28 | 1493.52 | 2,309.97 | 9.07 | 0.55 | 0.47164 |
| 29 | 1524 | 2,356.10 | 9.06 | 0.55 | 0.47112 |
| 30 | 1554.48 | 2,402.22 | 9.06 | 0.55 | 0.47112 |
| 31 | 1584.96 | 2,448.34 | 9.05 | 0.55 | 0.4706 |
| 32 | 1586.11 | 2,450.08 | 9.05 | 0.55 | 0.4706 |
| 33 | 1615.44 | 2,494.46 | 9.05 | 0.55 | 0.4706 |
| 34 | 1645.92 | 2,540.58 | 9.05 | 0.55 | 0.4706 |
| 35 | 1676.4 | 2,586.70 | 9.04 | 0.55 | 0.47008 |
| 36 | 1698.73 | 2,620.49 | 9.04 | 0.55 | 0.47008 |
| 37 | 1699.75 | 2,622.04 | 9.04 | 0.55 | 0.47008 |
| 38 | 1706.88 | 2,632.83 | 9.04 | 0.55 | 0.47008 |
| 39 | 1727.77 | 2,664.45 | 9.04 | 0.6 | 0.47008 |
| 40 | 1728.77 | 2,665.96 | 9.04 | 0.6 | 0.47008 |
| 41 | 1737.36 | 2,678.97 | 9.04 | 0.6 | 0.47008 |
| 42 | 1755.9 | 2,707.06 | 9.04 | 0.59 | 0.47008 |
| 43 | 1765.06 | 2,720.93 | 9.04 | 0.6 | 0.47008 |
| 44 | 1767.84 | 2,725.14 | 9.04 | 0.6 | 0.47008 |
| 45 | 1798.32 | 2,771.31 | 9.03 | 0.6 | 0.46956 |
| 46 | 1820.39 | 2,804.74 | 9.03 | 0.63 | 0.46956 |
| 47 | 1821.41 | 2,806.28 | 9.03 | 0.63 | 0.46956 |
| 48 | 1828.8 | 2,817.49 | 9.03 | 0.63 | 0.46956 |
| 49 | 1849.15 | 2,848.33 | 9.03 | 0.63 | 0.46956 |
| 50 | 1851.36 | 2,851.68 | 9.03 | 0.63 | 0.46956 |
| 51 | 1859.28 | 2,863.69 | 9.03 | 0.63 | 0.46956 |
| 52 | 1860.54 | 2,865.60 | 9.03 | 0.63 | 0.46956 |
| 53 | 1864.56 | 2,871.69 | 9.03 | 0.63 | 0.46956 |
| 54 | 1866.68 | 2,874.90 | 9.03 | 0.63 | 0.46956 |
| 55 | 1885.33 | 2,903.17 | 9.03 | 0.63 | 0.46956 |
| 56 | 1886.56 | 2,905.04 | 9.03 | 0.63 | 0.46956 |
| 57 | 1887 | 2,905.70 | 9.03 | 0.63 | 0.46956 |

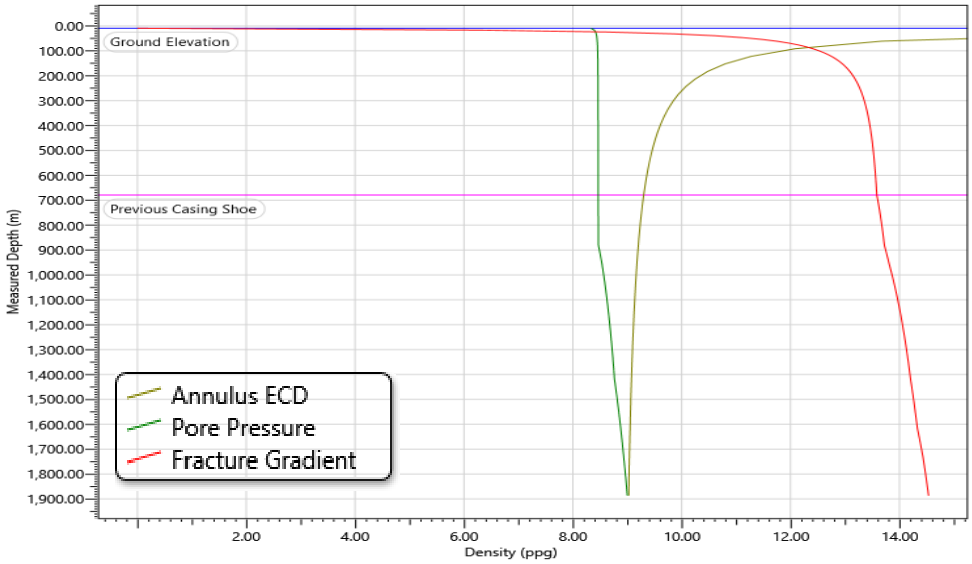


**Fig. (5) Density vs depth at the second hole of utilizing water-based mud with SBP (50psi)**

This section is drilled with implementation SBP (50 psi), as can be shown from Table (2). That CTR is greater than (0.5), ranging between (0.55-0.63) as in the first case without SBP, but this additional pressure resulted in increasing in ECD and BHP, thus increase the pressure gradient to reach its highest (0.484 psi/ft) compared to the formation of Dammam at a depth of (679 m) . Therefore, this value exceeds the amount of pore pressure of Dammam, and the probability of the occurrence of mud losses is very high. As for Hartha formation, ECD decreases as a result of increasing the depth, reaching (9.03 ppg) compared to the formation of Hartha with the pore pressure (8.95 ppg). Thus, the pressure difference is small, allowing the possibility of drilling the formation without any losses and without the need to reduce the weight of the mud to drill this formation which may lead to an influx from Tayarat and Umm-Er-Raduma formations. Despite overcoming the mud loss problem in Hartha, increasing the value of ECD for Dammam formation leads to the occurrence of problems and, accordingly, the first formations can be drilled, such as Dammam, Rus, Tayarat, and Umm-Er-Raduma without implementing SBP. And when reach Hartha formatin, SBP (50 psi) is applied to bypass the formation and put a cement plug to avoid the problems of Dammam's formation, as the losses in Hartha are more dangerous than the losses in the Dammam formation. Where, the

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formation of Tayarat and Umm-Er-Raduma contains $H_2S$ gas, therefore, mud loss problem lead to an inflow from these formations as a result of the decrease in mud pressure. It is also be noted that reducing ECD and the amount of pressure difference leads to increase in ROP as well as increasing CTR in addition to reducing non-productive time, thus reducing the cost compared to conventional drilling. It is also noted from Figure (5) the difference between the ECD and pore pressure are greater than in the first case (without SBP) as a result of the additional pressure exerted from applied SBP (50 psi). While at a depth of (1736 m), the beginning of Hartha formation, it becomes balanced or near-balanced with the pore pressure.

### 4.2 Drilling with 850 gpm and 8.7 ppg:

The results and analysis of the intermediate section of the well from (679m to 1887m) without SBP and with SBP (50 psi) at 850 gpm and 8.7 ppg.

#### 4.2.1 Drilling without SBP:

The result and analysis of the of intermediate section the well from (679m to 1887m) without SBP at 850 gpm and 8.7 ppg, are illustrated in Table (3) and Figure (6).

**Table (3) Results of second hole of utilizing water based mud without SBP**

| Case | MD | BHP | ECD | CTR | P gradient |
|---|---|---|---|---|---|
| | (m) | (psi) | (ppg) | % | psi /ft |
| 1 | 679 | 1,015.91 | 8.77 | 0.55 | 0.45604 |
| 2 | 701.04 | 1,048.89 | 8.77 | 0.55 | 0.45604 |
| 3 | 731.52 | 1,094.49 | 8.77 | 0.55 | 0.45604 |
| 4 | 762 | 1,140.10 | 8.77 | 0.55 | 0.45604 |
| 5 | 792.48 | 1,185.70 | 8.77 | 0.55 | 0.45604 |
| 6 | 822.96 | 1,231.31 | 8.77 | 0.55 | 0.45604 |
| 7 | 853.44 | 1,276.91 | 8.77 | 0.55 | 0.45604 |
| 8 | 883.92 | 1,322.52 | 8.77 | 0.55 | 0.45604 |
| 9 | 914.4 | 1,368.12 | 8.77 | 0.55 | 0.45604 |
| 10 | 944.88 | 1,413.73 | 8.77 | 0.55 | 0.45604 |
| 11 | 975.36 | 1,459.33 | 8.77 | 0.55 | 0.45604 |
| 12 | 1,005.84 | 1,504.94 | 8.77 | 0.55 | 0.45604 |
| 13 | 1,036.32 | 1,550.54 | 8.77 | 0.55 | 0.45604 |
| 14 | 1,066.80 | 1,596.15 | 8.77 | 0.55 | 0.45604 |

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| | | | | | |
|---|---|---|---|---|---|
| 15 | 1,097.28 | 1,641.75 | 8.77 | 0.55 | 0.45604 |
| 16 | 1,127.76 | 1,687.36 | 8.77 | 0.55 | 0.45604 |
| 17 | 1,158.24 | 1,732.96 | 8.77 | 0.55 | 0.45604 |
| 18 | 1,188.72 | 1,778.57 | 8.77 | 0.55 | 0.45604 |
| 19 | 1,219.20 | 1,824.17 | 8.77 | 0.55 | 0.45604 |
| 20 | 1,249.68 | 1,869.78 | 8.77 | 0.55 | 0.45604 |
| 21 | 1,280.16 | 1,915.38 | 8.77 | 0.55 | 0.45604 |
| 22 | 1,310.64 | 1,960.99 | 8.77 | 0.55 | 0.45604 |
| 23 | 1,341.12 | 2,006.59 | 8.77 | 0.55 | 0.45604 |
| 24 | 1,371.60 | 2,052.20 | 8.77 | 0.55 | 0.45604 |
| 25 | 1,402.08 | 2,097.80 | 8.77 | 0.55 | 0.45604 |
| 26 | 1,432.56 | 2,143.41 | 8.77 | 0.55 | 0.45604 |
| 27 | 1,463.04 | 2,189.01 | 8.77 | 0.55 | 0.45604 |
| 28 | 1,493.52 | 2,234.62 | 8.77 | 0.55 | 0.45604 |
| 29 | 1,524.00 | 2,280.22 | 8.77 | 0.55 | 0.45604 |
| 30 | 1,554.48 | 2,325.83 | 8.77 | 0.55 | 0.45604 |
| 31 | 1,584.96 | 2,371.43 | 8.77 | 0.55 | 0.45604 |
| 32 | 1,586.11 | 2,373.15 | 8.77 | 0.55 | 0.45604 |
| 33 | 1,615.44 | 2,417.04 | 8.77 | 0.55 | 0.45604 |
| 34 | 1,645.92 | 2,462.64 | 8.77 | 0.55 | 0.45604 |
| 35 | 1,676.40 | 2,508.25 | 8.77 | 0.55 | 0.45604 |
| 36 | 1,698.73 | 2,541.66 | 8.77 | 0.55 | 0.45604 |
| 37 | 1,699.75 | 2,543.19 | 8.77 | 0.55 | 0.45604 |
| 38 | 1,706.88 | 2,553.86 | 8.77 | 0.55 | 0.45604 |
| 39 | 1,727.77 | 2,585.12 | 8.77 | 0.6 | 0.45604 |
| 40 | 1,728.77 | 2,586.62 | 8.77 | 0.6 | 0.45604 |
| 41 | 1,737.36 | 2,599.49 | 8.77 | 0.6 | 0.45604 |
| 42 | 1,755.90 | 2,627.26 | 8.77 | 0.59 | 0.45604 |
| 43 | 1,765.06 | 2,640.97 | 8.77 | 0.6 | 0.45604 |
| 44 | 1,767.84 | 2,645.14 | 8.77 | 0.6 | 0.45604 |
| 45 | 1,798.32 | 2,690.79 | 8.77 | 0.6 | 0.45604 |
| 46 | 1,820.39 | 2,723.85 | 8.77 | 0.63 | 0.45604 |
| 47 | 1,821.41 | 2,725.37 | 8.77 | 0.63 | 0.45604 |
| 48 | 1,828.80 | 2,736.45 | 8.77 | 0.63 | 0.45604 |
| 49 | 1,849.15 | 2,766.95 | 8.77 | 0.63 | 0.45604 |
| 50 | 1,851.36 | 2,770.26 | 8.77 | 0.63 | 0.45604 |
| 51 | 1,859.28 | 2,782.13 | 8.77 | 0.63 | 0.45604 |
| 52 | 1,860.54 | 2,784.02 | 8.77 | 0.63 | 0.45604 |
| 53 | 1,864.56 | 2,790.05 | 8.77 | 0.63 | 0.45604 |
| 54 | 1,866.68 | 2,793.23 | 8.77 | 0.63 | 0.45604 |
| 55 | 1,885.33 | 2,821.18 | 8.77 | 0.63 | 0.45604 |
| 56 | 1,886.56 | 2,823.02 | 8.77 | 0.63 | 0.45604 |
| 57 | 1,887.00 | 2,823.68 | 8.77 | 0.63 | 0.45604 |

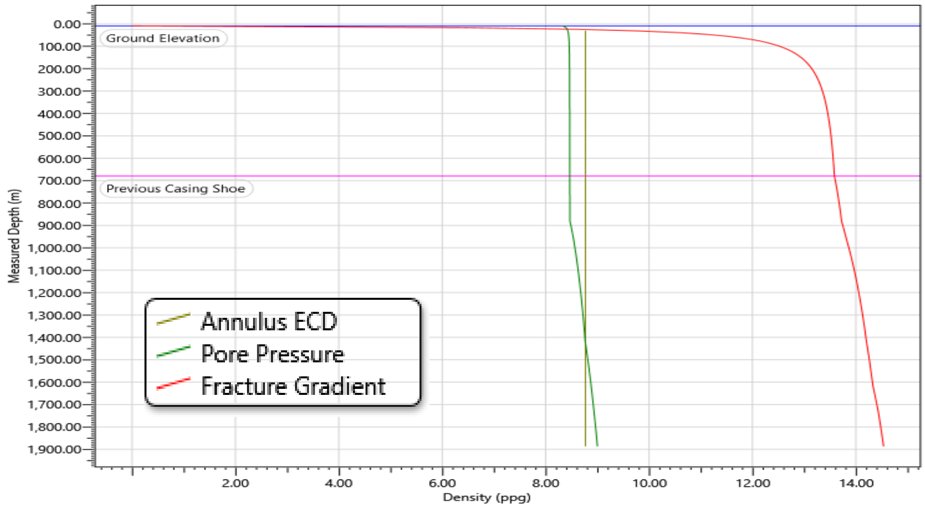


**Fig. (6) Density vs depth at the second hole of utilizing water-based mud without SBP**

From the comparison of Tables (1) and (3), it is noticed that the decrease in the bottom hole pressure by up to (165 psi) at the total depth is a result of the decrease in the mud weight, where, (8.7 ppg) is used in this section . Therefore, the pressure gradient calculated for ECD (8.77 ppg) is (0.456 psi/ft) the first formations of this hole can be drilled, such as Dammam, Rus, and Umm-Er-Raduma, where the differential pressure is low, which leads to an increase ROP as it is noted that CTR is greater than (0.5). In the Hartha formation, the ECD (8.77 ppg) is less than the pore pressure of this formation of (8.95 ppg), meaning that the drilling is under-balanced. Thus, the problem of mud losses in Hartha can be avoided, but this leads to a high probability of an influx from Tayarat formation where the estimated pore pressure is (8.83 ppg) greater than ECD which used to drill this hole, therefore there is a risk of exposure to the flow. Because the formation of Tayarat has $H_2S$ gas, the mud weight can be increased when drilling Tayarat, Shiranish, and Hartha to (8.8 ppg) or using (8.7 ppg) with SBP to allow drilling of these formations and avoiding problems, thus reducing NPT and reducing the cost. As it appears clearly in Figure (6) the annular density and annular pressure exceed the pore pressure above the depth of (1401 m) that meaning, when the beginning of Tayarat formation. Therefore, the use of chock to control the well is of great benefit when drilling this section.

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### 4.2.2 Drilling with SBP:

The results and analysis of the intermediate section of the well from (679m to 1887m) with SBP (50 psi) at 850 gpm and 8.7 ppg are indicated in Table (4) and Figure (7).

**Table (4) Results of second hole of utilizing water based mud with SBP (50 psi)**

| Case | MD | BHP | ECD | CTR | P gradient |
|---|---|---|---|---|---|
| | (m) | (psi) | (ppg) | % | psi /ft |
| 1 | 679 | 1,053.36 | 9.21 | 0.55 | 0.47892 |
| 2 | 701.04 | 1,065.99 | 9.2 | 0.55 | 0.4784 |
| 3 | 731.52 | 1,098.96 | 9.19 | 0.55 | 0.47788 |
| 4 | 762 | 1,144.57 | 9.17 | 0.55 | 0.47684 |
| 5 | 792.48 | 1,190.17 | 9.16 | 0.55 | 0.47632 |
| 6 | 822.96 | 1,235.78 | 9.14 | 0.55 | 0.47528 |
| 7 | 853.44 | 1,281.38 | 9.13 | 0.55 | 0.47476 |
| 8 | 883.92 | 1,326.99 | 9.11 | 0.55 | 0.47372 |
| 9 | 914.4 | 1,372.59 | 9.1 | 0.55 | 0.4732 |
| 10 | 944.88 | 1,418.20 | 9.09 | 0.55 | 0.47268 |
| 11 | 975.36 | 1,463.80 | 9.08 | 0.55 | 0.47216 |
| 12 | 1,005.84 | 1,509.41 | 9.07 | 0.55 | 0.47164 |
| 13 | 1,036.32 | 1,555.01 | 9.06 | 0.55 | 0.47112 |
| 14 | 1,066.80 | 1,600.62 | 9.05 | 0.55 | 0.4706 |
| 15 | 1,097.28 | 1,646.22 | 9.05 | 0.55 | 0.4706 |
| 16 | 1,127.76 | 1,691.83 | 9.04 | 0.55 | 0.47008 |
| 17 | 1,158.24 | 1,737.43 | 9.03 | 0.55 | 0.46956 |
| 18 | 1,188.72 | 1,783.04 | 9.02 | 0.55 | 0.46904 |
| 19 | 1,219.20 | 1,828.64 | 9.02 | 0.55 | 0.46904 |
| 20 | 1,249.68 | 1,874.25 | 9.01 | 0.55 | 0.46852 |
| 21 | 1,280.16 | 1,919.85 | 9 | 0.55 | 0.468 |
| 22 | 1,310.64 | 1,965.46 | 9 | 0.55 | 0.468 |
| 23 | 1,341.12 | 2,011.06 | 8.99 | 0.55 | 0.46748 |
| 24 | 1,371.60 | 2,056.67 | 8.99 | 0.55 | 0.46748 |
| 25 | 1,402.08 | 2,102.27 | 8.98 | 0.55 | 0.46696 |
| 26 | 1,432.56 | 2,147.88 | 8.98 | 0.55 | 0.46696 |
| 27 | 1,463.04 | 2,193.48 | 8.97 | 0.55 | 0.46644 |
| 28 | 1,493.52 | 2,239.09 | 8.97 | 0.55 | 0.46644 |
| 29 | 1,524.00 | 2,284.69 | 8.97 | 0.55 | 0.46644 |
| 30 | 1,554.48 | 2,330.30 | 8.96 | 0.55 | 0.46592 |
| 31 | 1,584.96 | 2,375.90 | 8.96 | 0.55 | 0.46592 |
| 32 | 1,586.11 | 2,421.51 | 8.96 | 0.55 | 0.46592 |
| 33 | 1,615.44 | 2,423.23 | 8.96 | 0.55 | 0.46592 |
| 34 | 1,645.92 | 2,467.11 | 8.95 | 0.55 | 0.4654 |
| 35 | 1,676.40 | 2,512.72 | 8.95 | 0.55 | 0.4654 |

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| | | | | | |
|---|---|---|---|---|---|
| 36 | 1,698.73 | 2,558.33 | 8.95 | 0.55 | 0.4654 |
| 37 | 1,699.75 | 2,591.74 | 8.94 | 0.55 | 0.46488 |
| 38 | 1,706.88 | 2,593.26 | 8.94 | 0.55 | 0.46488 |
| 39 | 1,727.77 | 2,603.93 | 8.94 | 0.6 | 0.46488 |
| 40 | 1,728.77 | 2,635.20 | 8.94 | 0.6 | 0.46488 |
| 41 | 1,737.36 | 2,636.70 | 8.94 | 0.6 | 0.46488 |
| 42 | 1,755.90 | 2,649.56 | 8.94 | 0.59 | 0.46488 |
| 43 | 1,765.06 | 2,677.33 | 8.94 | 0.6 | 0.46488 |
| 44 | 1,767.84 | 2,691.05 | 8.94 | 0.6 | 0.46488 |
| 45 | 1,798.32 | 2,695.21 | 8.94 | 0.6 | 0.46488 |
| 46 | 1,820.39 | 2,740.86 | 8.93 | 0.63 | 0.46436 |
| 47 | 1,821.41 | 2,773.92 | 8.93 | 0.63 | 0.46436 |
| 48 | 1,828.80 | 2,775.45 | 8.93 | 0.63 | 0.46436 |
| 49 | 1,849.15 | 2,786.53 | 8.93 | 0.63 | 0.46436 |
| 50 | 1,851.36 | 2,817.03 | 8.93 | 0.63 | 0.46436 |
| 51 | 1,859.28 | 2,820.34 | 8.93 | 0.63 | 0.46436 |
| 52 | 1,860.54 | 2,832.21 | 8.93 | 0.63 | 0.46436 |
| 53 | 1,864.56 | 2,834.10 | 8.93 | 0.63 | 0.46436 |
| 54 | 1,866.68 | 2,840.12 | 8.93 | 0.63 | 0.46436 |
| 55 | 1,885.33 | 2,843.30 | 8.93 | 0.63 | 0.46436 |
| 56 | 1,886.56 | 2,871.25 | 8.93 | 0.63 | 0.46436 |
| 57 | 1,887.00 | 2,873.10 | 8.93 | 0.63 | 0.46436 |

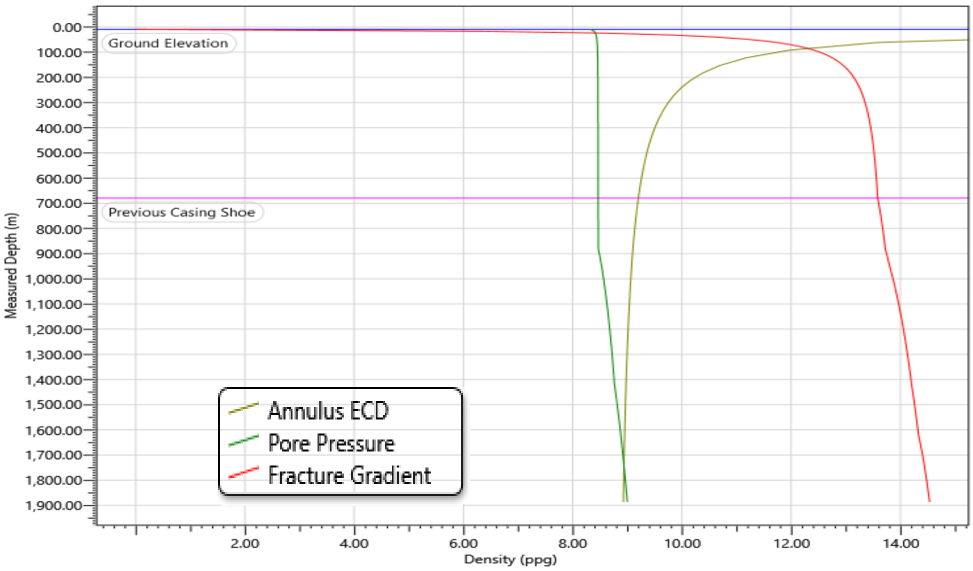


**Fig. (7) Density vs depth at the second hole of utilizing water based mud with SBP(50 psi)**

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Despite the fact that Table (4) gives high values of ECD in front of the formation of Dammam, Rus and Umm-Er-Raduma, which may cause losses in Dammam formation, but it is gave ECD acceptable in front of the formations of Tayarat, Shiranish and Hartha. Where, ECD is in the front of Hartha formation ranges from (8.93) ppg to (8.94) ppg noted that the estimated pore pressure of this formation is (8.95 ppg) which, it is slightly below balanced. And, this is good in terms of avoiding any losses of the mud in Hartha formation and the consequent reduction in the mud weight which leads to the occurrence of the flow from the two formations Tayarat and Umm-Er-Radhuma. It should be noted by reducing the differential pressure of the two formations of Hartha and Shiranish, and the rate of CTR in this case is (0.55-0.63), greater than (0.5), which leads to an increase ROP. Consequently, Dammam, Rus, and Umm-Er- Raduma can be drilled without implementing SBP and then applied SBP by (50 psi/ft) to become ECD balanced or near-balanced, to continue drilling of Tayarat, Shiranish and Hartha formations. And as mentioned previously, the high pressure value of the first formations can be addressed when adding SBP by placing a cement plug and continuing with the drilling process, thus avoiding the problems of mud losses in Hartha and the consequent flow in the formations of Tayarat and Umm-Er-Raduma. This is illustrated in Figure (7) where ECD is greater than the estimated pore pressure of the first formations, then the value begins to approach the value of the pore pressure until it becomes balanced with it and after that become slightly under-balanced at Hartha formation. As it is noticed from the comparison between drilling using (8.8 ppg) and (8.7 ppg), the drilling using (8.7 ppg) tended to be better, because the rate of increase ECD when applied SBP is ideal for formations more than drilling using (8.8 ppg) and applied SBP (50 psi) consequently the problems are reduced and drilling cost is also reduced in terms of reducing the cost of the mud weights.

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## 5. Conclusions:

1- The additional safety provided by the closed system gives MPD technique preference over the conventional technique for this well.

2- Drilling with implemented SBP utilized water based mud provide more control by controlling bottom hole pressure and equivalent circulating density in a safe and efficient manner.

3- Drilling without applying SPB and using water-based mud while reducing the mud weight reduces the problem of lost circulation with the ability to control the well compared to conventional drilling.

4- Drilling in underbalanced method was suitable in terms of reducing lost circulation of drilling fluids, increasing ROP and annular velocity compared with the overbalanced, balanced and near-balanced cases but it's not suitable in terms of allowing the inflow of formation fluids. While, the balanced or near-balanced cases were better compared to the overbalanced cases.

5- ECD and BHP increase as the depth and SBP increases.

6- Drilling with MPD reduces the cost of drilling operation as a result of avoiding drilling risks and reducing NPT in addition to providing additional control to maintain CBHP due to the use of chock, compensating for the low weight of mud an applied SPB.

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