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Drilling Strategies to Control Lost Circulation in Basra Oil Fields, Iraq

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Abstract

Lost circulation is a major concern when drilling in the Basra oil fields, Iraq. The best lost circulation strategy involves solutions impacting the total drilling plan including fluid selection, LCM treatment, and overall drilling practices. However, in some cases, due to caverns, large vugs, or other formation anomalies, losses are not totally controllable and additional measures are required to continue drilling safety and efficiently. Blind drilling, casing-while-drilling (CWD), and floating mud cap drilling (a form of managed-pressure drilling) are some of the advanced drilling techniques employed when drilling with significant on-going losses downhole. However, these techniques involve additional risks, rig modifications and a trained crew. Understanding the benefits, risks, and probability of success for each are critical to properly evaluating whether to use these techniques.

This paper is a combination of several case histories and an analysis of the successfulness of the various techniques used to combat continuing lost circulation events in the Basra area. Data was gathered from drilling reports and analyzed to better understand what works for which formations – focusing on mechanical drilling strategies rather than particulate solutions such as pills.

Analysis of the data indicates a probable success rate with the "best" method varying by formation. The data presented is focused on Basra area case histories. However, this work can serve as a practical guide for developing mud loss mitigation strategies for formations with similar geological properties.

Introduction

Lost circulation is a broad subject and several studies and measures have been introduced in the oil industry to combat it. Lost circulation is a common drilling problem especially in highly permeable formations, depleted reservoirs, and fractured or cavernous formations. The range of lost circulation problems begin in the shallow, unconsolidated formations and extend into the well-consolidated formations that are fractured by the hydrostatic head imposed by the drilling mud [1].

Lost circulation can be defined as the reduced or total absence of fluid flow up the formation-casing or casing-tubing annulus when fluid is pumped down the drill pipe or casing. The industry spends millions of dollars every year to combat lost circulation and its associated detrimental effects such as loss of rig time, stuck pipe, blow-outs, and less frequently, the abandonment of expensive wells. Two conditions are both necessary for lost circulation to occur downhole: 1) the pressure in the wellbore must exceed the pore pressure and 2) there must be a flow pathway for the losses to occur [2]. Subsurface pathways that cause, or lead to, lost circulation can be broadly classified as follows:

Induced or created fractures (fast tripping or underground blow-outs).

Cavernous formations (crevices and channels).

Unconsolidated or highly permeable formations.

Natural fractures present in the rock formations (including non-sealing faults).

Circulation may be lost even when fluid densities are within the customary safety-margin; less dense than the fracture density of the formation. Stopping circulation losses before they get out of control is crucial for safe and economically rewarding operations [3]. There is a wide range of lost circulation treatments available applied to control or eliminate lost circulation events. These systems can be divided into conventional systems, which include granular, fibrous and flaky materials that are mixed with the drilling fluids during either the drilling phase or with the cement slurries during the drilling and primary cementing phases. The other approach to control lost circulation is using drilling techniques/procedures, which is the central focus of this work. In addition, this paper will be an extended study of the comprehensive review of conventional lost circulation treatment with an integrated analysis and practical guidelines in Basra's oil fields, Iraq [4].

Using Drilling Techniques/Procedures (Living with Losses)

In some situations, it is very difficult to regulate on mud losses by using conventional lost circulation materials (LCMs). As well as, the cost of these materials is expensive. Thus, it is important to find techniques and mechanism to live with losses. In different words, the driller must "live with the losses". In this section, methods that are used to treat mud losses without utilizing LCMs will be presented. However, it is much recommended to be very cautious when these techniques are applied because utilizing these methods involve risk to the drilling operation. Hence, it must be carefully and thoroughly planned to ensure the safest possible outcome. The drilling techniques/procedures that will describe in the subsequent paragraphs may be used to prevent or remedy lost circulation problems [5] and [6].

Blind Drilling

This method means that drilling operation is continuous but without any returns. In other words, continuing the drilling operation even if there is no mud returned to the surface. This situation is very hazardous because the drilling crew will not know anything about lithology of the formation. In addition, cutting will be accumulated around the bit, which in turn, that lead to the occurrence of stuck pipe problem. In this method, water will be used instead of drilling mud, so it is important to prepare sufficient quantities of clean water before using this technique, and it is necessary to prepare enough amounts of high-viscosity mud and normal drilling fluid. The formation will be drilled by using water, and high-viscosity mud must be pumped after drilling one drill pipe to lift cutting above the bit. The cutting will enter the thief zone. Sometimes, one drill pipe is drilled by using just water, and another drill pipe will be drilled by using drilling mud. But in this case, the cost will be high due to drilling mud losses. Blind drilling will continue with pumping high viscosity after drilling one stand. In this method, it is prudent to monitor surface parameters for the bit, and after completing formation drilling, it is necessary to circulate drilling mud into the hole to clean the well from cutting [5].

The reasons for using the blind drilling technique:

- If loss zone is the last zone of the hole, and there is no ability to plug it. In this case, blind drilling is used to drill all formation and running casing after that.
- To reach competent formations, the blind drilling approach is recommended to use to exactly determine the depth of the thief zone. Hence, after implementing cement plug after blind drilling, the competent zone will be filled with hard cement, so that will give an indication on the bottom of the loss zone.
- Sometimes, thief zone is the first in the hole, so there is usually no complications and implications if blind drilling technique is used.

Not always, blind drilling can be used in the Dammam formation, it is recommended to use this technique because it is a shallow depth and the first formation of the intermediate hole. Therefore, the risk of experiencing a kick or blowout is minimal. Figure 1 illustrates the probability of the success and failure for the Dammam formation in regard blind drilling method.

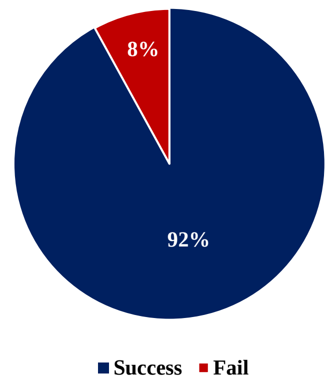

Figure 1. Blind Drilling, Dammam Formation in Basra's Oil Fields

Blind drilling method cannot be readily applied in the Hartha formation. Two zones, Umm ER Radhuma and Tayarat, located above the Hartha, contain H_2S. If mud density is reduced to control loss into the Hartha, then a kick may occur in these shallower zones. Table 1 summarizes the close tolerances of mud density for these formations, and figure 2 illustrates the probability of the success and failure for the Hartha in regard blind drilling method.

Table 1. Various Drilling Densities

Formation	Required Density, gm/cc
UMMER-RADHUMA	1.14 to 1.15
TAYARAT	1.14 to 1.15
HARTHA	1.12 to 1.13

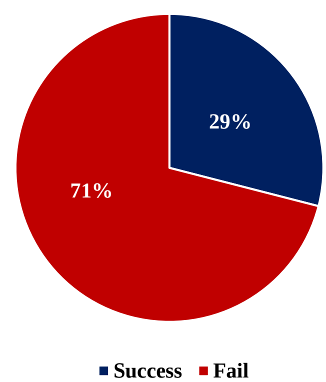

Figure 2. Blind Drilling, Hartha Formation in Basra's Oil Fields

It is crucial to consider that the Shuaiba formation is located below transitional zones such as Mishrif, Mauddud, and Nahr Umr. Using blind drilling will cause collapse issues since these formations have abnormal pressures. Hence, there is a big hazard when blind drilling is utilized in the Shuaiba formation because there are abnormal formations which are located above this formation. Table 2 illustrates various required drilling densities for these formations. These zones will also be susceptible to a kick since the mud level will fall due to lost circulation in the Shuaiba formation. In addition, figure 3 illustrates the probability of the success and failure for Shuaiba formation in regard blind drilling method.

Table 2. Different Drilling Densities

Formation	Required Density, gm/cc
Mishrif	1.17 to 1.18
Nahr Umr	1.17 to 1.18
Shuaiba	1.15 to 1.16

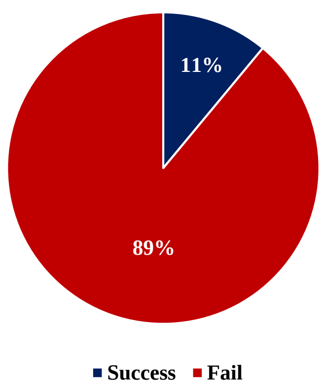

Figure 3. Blind Drilling, Shuaiba Formation in Basra's Oil Fields

Aerated Mud

There is two-phase flow in this kind of method, and two-phase flow is air and mud. The principle of work for aerated mud to decrease equivalent circulation density (ECD) to the 4 to 8 lb/gal range. In subnormally pressured intervals, this method is usually used to reduce massive mud losses that cannot be easily resolved. ECD in this type of mud will slightly be higher than the pore pressure to avoid breakout and tensile failures. In this technique, there is equipment on the surface to separate the air and mud so that the mud can be processed through the surface system and recirculated. It is very important to use air drilling compressor and other equipment with this method like a rotating head and mist and air/mud separator. Some issues are associated with aerated mud such as severe corrosion rates, unsteady flow in large diameter holes, and erosion from turbulent flow.

There are several different methods used to achieve aerated mud:

- Down the drill pipe" aeration – injecting both air and mud into the standpipe.
- Using a parasite tubing string run outside the last casing string to inject the air and pumping mud as normal. The mud and air mix at the casing shoe and the aerated mud flows up the annulus.
- "Dual casing micro-annulus" aeration – where a temporary casing is hung inside the last cemented casing so that air is injected down the two casings annulus and flows into the mud at the inner casing shoe then back up the drill pipe to inner casing annulus as aerated mud.

The most common method that used to achieve aerated mud is by injection of both air and mud into the standpipe. For parasite aeration, it is easy to regulate on air and mud flows, the air pressure requirement is usually lower. On the other hand, extra cost and more time are required for parasite injection in terms tubing plus extra equipment for pressure control. As well as, in parasite aeration, ECD will not be low as can be obtained with standard aeration due to the restricted air volume capacity of the tubing and the depth of injection being higher. While dual casing micro-annulus aeration, the last cemented casing must be large sufficient to allow the temporary inner casing to be run. This may require a larger casing size and previous hole size [5] and [6].

Foam

In this method, air (or gas) with water and foaming surfactant slurry are used to form foam drilling. This method will reduce equivalent circulation density to the 0.24 to 0.48 gm/cc range that in turn will affect positively on wellbore stability. This method is applied in very low-pressure zones where massive lost circulation occurs and is difficult to cure. When drilling, the air and foamer slurry foam must be metered within a narrow range of ratios and requires a rotating head and extra mechanical equipment. There are two types of this mud. The first one is stable foam drilling, and other is stiff foam drilling. Stable foam uses mainly water and a surfactant (commonly called soap) to form a stable air-in-water foam mixture with the air while stiff foam drilling uses a mud-like formulation as the foamer slurry with bentonite and polymers to form a long-lasting foam. Stiff foam drilling is preferred to drill large holes more than stable foam drilling. Stiff foam drilling has sufficient air volumes to do the proper cleaning for large holes while stable foam drilling does not have enough air volumes to do the good cleaning for large holes. In general, foam has excellent hole cleaning features and uses less air volume as compared to air or mist drilling. On the other hand, high cost is associated with water and foamer chemical because the foamer slurry cannot be recovered and reused [5] and [6].

Air or Mist

ECD in this kind of mud will be the lowest from 0 to 0.24 gm/cc. The most common application for this method is in dry formations where the well produces little liquid and massive lost circulation and networks of vugs or caverns are encountered. The requirements of this method are large capacity high-pressure air compressors, a rotating head, and other mechanical equipment. Air drilling is commonly referred to as "dust" drilling as the discharge from the well is dust. Mist drilling uses water and a small amount of 1% foamer solution injected to help remove small amounts of produced fluids from the well [6].

Case Histories (General Considerations)

Narrow mud weight windows represent a challenging environment to well designers. A narrow mud weight window forms when a high collapse pressure or formation pressure zone exists in the same drilling interval with a weak formation. This is usually seen in drilling depleted formations. The following case histories are from Basra's oil fields, which represent a big challenge due to lost circulation issues. Using drilling techniques/procedures applications are especially suitable for meeting this challenge. However, the application of the techniques technology may be different when the sequence of the high-pressure zone and the weak zone varies.

When the weak zone is at the top, the mud used to drill through it may be particulate free as long as the ECD is maintained below the fracture gradient. After drilling through the weak zone, a method should be used to determine how weak this zone really is. Due to the uncertainty of depletion, some formations may not be as weak as predicted. If this is the case, advanced methods are not needed. When the weak zone is below a high pore/collapse pressure zone, the mud weight should be higher than the low fracture strength when penetrating this weak formation. In this case, the mud must be treated with the designed particulates for strengthening while drilling. If this doesn't work, and lost circulation occurs. In this case, appropriate corrective methods should be used to stop or mitigate this problem. In some situations, it is very difficult to combat mud losses by using conventional remedial treatments. As well as, the cost of these materials is expensive, so it is important to find techniques and mechanism to live with losses. Therefore, in this section, methods that have been used to ameliorate lost circulation without the use of LCMs will be presented. The following case histories are from Basra's oil fields to provide more understanding in regard alternative techniques to regulate or mitigate mud losses.

Case 1. Using Liner Hanger to Stop Mud Losses in Shuaib Formation, Well-306, South Rumaila Field

Sometimes, lost circulation mud will not be cured by using remedial and preventive methods. Therefore, it is important to find techniques or mechanisms to ceases mud losses. There is specific advanced technology that used for this purpose such as expandable tubulars and casing-while-drilling (CWD), and these methods can serve as long-term methods that will reduce the costly effects of lost circulation while drilling [7]. There is a positive advantage for expandable tubulars which contribute to use a number of mud weights for different sections without losing hole size due to the telescoping effect of the casing. CWD employs downhole and surface components to provide the ability to use normal oilfield casing as the drill string so that the well is simultaneously drilled and cased [8]. The casing is rotated from the surface with a top drive. Drilling fluid is circulated down the casing internal diameter (ID) and up the annulus between the casing the wellbore. The main target of this method is to reduce the non-productive time (NPT), cost, and the casing running times when severe and total fluid losses make conventional drilling practices difficult and expensive. CWD technology has already been used for well-306 in South Rumaila field [5]. Lost circulation mud stopped after using this technique in this field. CWD technology demonstrated to be an effective technical-economical solution to drill and cement production casing string (7 in, 8 1/2 in) in South Rumaila field. There are two kinds of CWD technology: retrievable and non-retrievable systems. The non-retrievable system has been used to isolate the Shuaiba formation, this kind of casing is designed to leave the casing drill shoe (CDS) on the bottom if the last section of the well is being drilled to total depth (TD) or is to be drilled afterward to continue with the following hole sections. Figures 4 and 5 are pictures of part of the CWD assembly. There are some visions and ideas that have already deduced after applying CWD technology in well-306 in South Rumaila field, Shuaiba formation [5]:

- Unwanted consequences of the lost circulation mud such as drilling and operation cost, tripping time to land conventional casing to bottom, and rig floor safety in comparison with traditional mechanisms will be reduced by using CWD technology.
- High-efficiency cleaning due to high annular velocity which in turn lead to avoid bit balling issue, drag problem, and stick pipe dilemma.
- Lost circulation zones have been clearly identified, even drilling without returns.
- CWD technology helps to restore mud circulation to the surface.

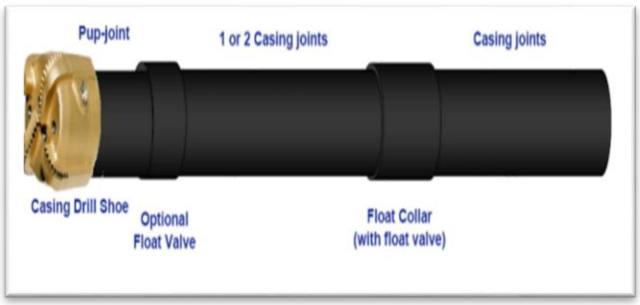

Figure 4. BHA of CWD Assembly (Gallardo et al., 2010 [9])

Figure 5. Top Drive and Casing Drive (Tessari et al., 2006 [10])

The Shuaiba formation occurs at approximately 2900 m and is a limestone with little to no visible porosity. However, the zone is highly susceptible to fracturing and lost circulation, which is more troublesome and even more complicated than lost circulation in the Dammam or the Hartha formations. Sometimes, mud losses in the Shuaiba formation lead to the abandonment of the drilling operation due to unsustainable NPT and drilling cost. Mud losses in the Shuaiba also cause severe wellbore stability problems. Figure 6 shows the borehole and well construction typical of a well drilled in the South Rumaila field at the time the well passes through the Shuaiba formation. Both the 13-3/8" and 9-5/8" casing strings have been set. Commonly an 8 1/2" bit is used to drill through the formation.

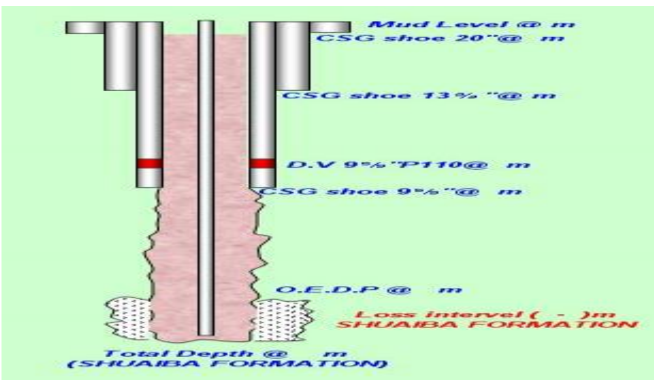

Figure 6. Lost Circulation Mud in the Shuaiba Formation

It is also very crucial to consider that the Shuaiba formation is located below transitional zones like Mishrif, Mauddud, and Nahr Umr zones. These formations have abnormal pressures, so it is very prudent to consider this case to avoid collapse issues in formations like the Mishrif, Mauddud, and Nahr Umr. As it summarized in this work (Table 2), which illustrates various required drilling densities for these formations. These zones will also be susceptible to a kick since the mud level will fall due to lost circulation in the Shuaiba formation.

This case history occurred in well-306, Shuaiba formation, South Rumaila field. It had complete losses for three months, and various plugs treatment were used to stop or mitigate mud losses (e.g. High Viscosity Drilling Mud (Low Density) + Blend of the LCMs, Super Stop Material, Cement Plug, High Filtration Spot Pills, High Filtration Mixtures (200-400 cc API), very high filtration mixtures (>600cc API), High Viscosity Mud (Low Density) + Cement Plug, DOB Squeeze (Diesel Oil Bentonite), DOBC Squeeze (Diesel Oil Bentonite Cement), Gilsonite cement, Fibers in cement, and InstandSeal). At that time, more than 60 conventional treatments and plugs have been used. However, lost circulation didn't remedy, and it was so hazardous on drilling operations. Several unwanted consequences were associated due to complete mud losses such collapse issues, very high cost, and NPT. For this reason, there were orientations to abandon this well. Then, a drilling expert named Kazem Awash suggested drilling the remaining of the Shuaib formation by using blind drilling till the bottom of the zone. Then, run casing string to isolate the Shuaiba formation, and resume drilling till productive zone, which is Zubair formation. 7 inches liner hanger has been run to stop lost circulation in Shuaiba formation. After isolating Shuaiba zone by using 7 inches liner hanger string successfully, productive zone (Zubair Formation) was drilled by using 5 7/8" without any problems. Finally, casing string 4.5" has been run to Zubair zone at depth 3326 m. The major objective of liner hanger is to minimize the cost of the casing drilling [5].

Case 2. Using Floating Mud Cap Drilling to Stop Mud Losses in the Dammam Formation, 176 Well, Zubair Field

Usually, this technique is used during total mud loss and the intrusion of reservoir fluids into the wellbore. By using weighted drilling mud that is continuously pumped into the annulus, the well will be under control. Water is used instead of drilling fluid, and the water and drill cuttings are lost to the zone. Mud column pressure in the annulus will regulate on formation fluids. It is necessary to design appropriate mud weight which is preferred to be (~250 psi) higher than the formation pressure. In addition, it is important to maintain drilling density from time to time by using the addition of fresh mud to the annulus to avoid mud losses. Theoretically, in some levels, mud pressure will be equivalent to the formation pressure that in turn, cause the mud to "float" against the formation pressure, just above the lost circulation zone. It is much recommended to maintain hydrostatic pressure to slightly be higher than the formation pressure to preclude unwanted consequences due to shear failure or tensile failure, Figure 7 will show floating mud cap drilling method [5] and [6].
Mud cap drilling cannot take place without a large dedicated water supply. It is essential to maintain the pump rates that will clean the bit and annular velocities that will convey the cuttings into the loss zone. Slip velocity calculations for the cuttings can be performed. Generally, annular velocities above 120 ft/min will be required. The drilling circumstances have a large role in the procedures for executing the floating mud cap [5] and [6].

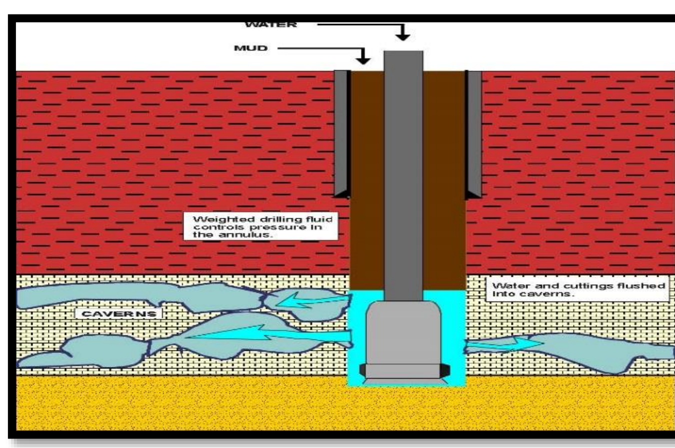

Figure 7. Floating Mud Cap Drilling Method (Baker Hughes, 1999 [6])

The Dammam formation is the first formation in Basra's oil fields that is prone to mud losses. The top of this zone is found between 435 to 490 m, and all of the wells in the field must be drilled through this zone. The interval is composed of interbedded limestone and dolomite, which is generally 200 to 260 m thick. The top of the Dammam was eroded after burial and is karstified at depth. The karst features are believed to lead to the mud losses seen while drilling through this interval [11]. Figure 8 Shows borehole and well construction typical of a well drilled in Zubair field at the time the well passes through the Dammam formation. 13-3/8" casing has been set, and most commonly a 12 ¼" bit is used to drill through the formation. A lost circulation event is shown near the bottom of the openhole in Figure 8, but may occur anywhere in the openhole section through the Dammam [5].

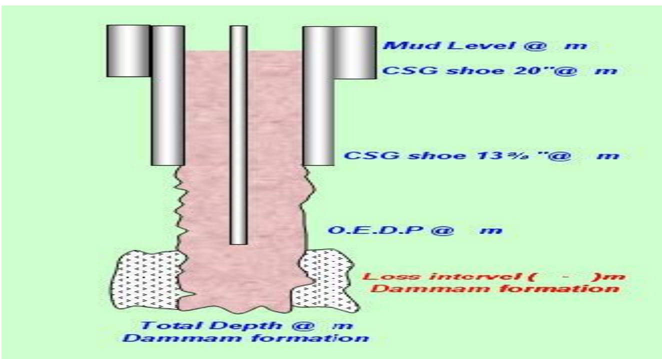

Figure 8. Lost Circulation Mud in the Dammam Formation

Mud cap drilling has been used in the Dammam formation, well-176, Zubair field to stop lost circulation problem, which is a significant problem in this formation. It had complete losses, and various plugs treatment were used to regulate or mitigate mud losses (e.g. High Viscosity Drilling Mud (Low Density) + Blend of the LCMs, Super Stop Material, Cement Plug, High Viscosity Mud (Low Density) + Cement Plug, DOB Squeeze (Diesel Oil Bentonite), DOBC Squeeze (Diesel Oil Bentonite Cement), and Gilsonite cement). However, lost circulation didn't stop, and it caused many issues in the drilling operation. Several unwanted consequences were associated due to complete mud losses such as high cost and NPT. Then, floating mud cap drilling has been implemented, and it provided the best control to mud losses in the Dammam formation. After that, drilling operation has been resumed without problems.

Conclusions

This problem is very common, and most fields in the world suffer from mud losses during drilling operations. Hence, lost circulation is a challenging problem to be prevented or mitigated during drilling. Lost circulation treatments are widely applied to mitigate losses using a corrective approach or to prevent losses using preventive approaches, also known as "wellbore strengthening". Therefore, it is essential to research and find alternative techniques to avoid or mitigate this troublesome problem because that will reflect positively on the oil industry especially the drilling operations in terms time and cost.

This paper summarizes the experience of drilling wells using CWD technology in production section and floating mud cap drilling in the intermediate hole. Total or severe fluid losses in intermediate and production sections turn conventional drilling into a non-cost-effective way to drill these sections in Basra's oil fields. Additionally, the shear failure and associated logistic problems were mitigated through CWD technology in production hole. The experience gained while drilling these wells has led to a better understanding of the advantages of the process. It's the most effective application has been utilized to reduce the cost and risks associated with wells which routinely experience lost circulation when drilled conventionally.
Based on this study, the following conclusions were made:

- Blind drilling can be used to combat mud losses in the Dammam formation; however, this method should be avoided in deeper formations such as the Hartha and Shuaiba formations because it will have a very low probability of success in the deeper formations.
- There are no guaranteed methods for solving lost circulation problems entirely but many approaches can be used to prevent its occurrence, especially those that occur via induced fractures when drilling formations that are prone to losses.
- It is crucial to find alternative approaches if conventional treatments don't remedy lost circulation. In addition, a quick economic evaluation is desirable before doing any action.

Acknowledgments

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