DRILLING MUDS
INTEGRATING THEORY IN THE DRILLING PROGRAMME

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1. Generalities

1.1 Introduction

Drilling fluids perform many functions: controlling layer pressures, removing debris from the well, sealing a permeable layer encountered during drilling, cooling and lubricating the bit, transmitting hydraulic energy to the tools in the borehole and to the bit, and perhaps most importantly, maintaining the stability and control of the borehole. Often referred to as mud, drilling fluid was first introduced around 1913 for underground pressure control. In the 1920s and 1930s, the first American companies specializing in the distribution, development and engineering of drilling fluids and components were born. In the decades that followed, drilling fluid companies laid the groundwork for developments in chemistry, measurement, and process engineering that led to significant improvements in drilling efficiency and well productivity.

The compositions of drilling fluids vary depending on the characteristics of the well, the installation and environmental concerns. Engineers design drilling fluids to control groundwater pressures, minimize cross-layer damage, reduce circulation losses, control borehole erosion, and optimize drilling parameters such as the rate of penetration (RoP) and borehole cleaning (removal of debris). In addition, because a large percentage of boreholes are deviated wells, drilling fluid systems must help manage the cleaning and stability specific problems of such boreholes.

1.2 Drilling mud systems

Drilling fluid systems have a continuous phase, which is liquid, and a discontinuous phase comprising solids. Occasionally, they might also have a gaseous phase - either by design or as a result of entrainment of gases in the layer. The continuous phase can be used to classify types of drilling fluids as gas, aqueous fluids or non-aqueous systems. These fluids are a mixture of liquid and solid components, each designed to modify a specific property of the drilling fluid, such as its viscosity and density.

Aqueous drilling fluids, generally called water-based drilling muds (WBM - water based muds), are the most common and varied of the three types of drilling fluids.

Fig. 1 *Drilling mud with added bentonite, stirred and agitated*

They range in composition from simple mixtures of water and clay to complex systems of inhibitory drilling fluids or clay stabilizing ones, which include many components. In recent years, engineers and scientists have focused on improving the inhibitory and thermal performance of water-based systems in their efforts to compete with non-aqueous fluids commonly used in difficult drilling environments.

In non-aqueous drilling fluids, commonly referred to as synthetic-based drilling mud (OBM - oil based muds), the continuous phase may consist of mineral oils, biodegradable esters, olefins or other variants. Although usually more expensive than water-based drilling fluids, these systems tend to provide excellent control of drilling, thermal stability, lubrication and penetration rate, which can help reduce overall operator costs.

In fractured rocks or environments where the borehole will not support a column of water without significant fluid loss in the layer, drilling engineers use drilling fluid systems based on air, fog or foam to help remove debris from wellbore and to maintain its integrity.

1.3 Basic functions

Drilling fluids are formulated to perform a wide range of functions. Although the list is long and varied, the most important features are the following:

Formation Pressure Control - Drilling fluid is vital for keeping a well under control. The drilling mud is pumped down through the drill string and then through the bit, finally rising through the annular space. In the open hole, the hydrostatic pressure exerted by the mud column is used to compensate for the increases in formation pressure

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that would otherwise force fluid from the layer to enter the wellbore, possibly causing loss of well control. However, the pressure exerted by the drilling fluid must not exceed the fracturing pressure of the rock; otherwise the mud will be lost in the formation - a condition known as loss of circulation.

Debris removal - The circulating drilling fluid transports debris - fragments of rock created by the bit in the process of volume dislocation of the rock - to the surface. Maintaining the ability of the fluid to transport these solids to the surface - called carrying capacity - is essential for efficient drilling and minimizing the chance of blocking the drill string. To achieve this, drilling fluid specialists work with drilling engineers to carefully balance the rheology of mud and flow in order to optimize the transport capacity while avoiding an increase in equivalent circulation density (ECD) - the actual density of the mud plus the pressure drop from the annular space at a given point in the borehole. Uncontrolled and elevated EDC can lead to loss of circulation.

Cooling and lubricating the bit - As the drilling fluid passes through and around the rotary drilling assembly, it helps cool and lubricate the bit. Thermal energy is transferred to the drilling fluid, which transports heat to the surface. In extremely hot drilling environments, heat exchangers can be used at the surface to cool the mud.

Transmission of hydraulic energy to the bit or drilling rig equipment - The drilling fluid is discharged through nozzles in front of the bit. The released hydraulic energy dissipates and lifts the debris. This energy also powers drilling motors and other devices that direct the bit and obtain drilling or formation data in real time. Data collected in the borehole is frequently transmitted to the surface using pulse telemetry through the drilling mud, a method that relies on pressure pulses through the mud column to send data to the surface.

Maintaining the stability of the borehole - The basic components of the borehole stability include density adjustment, minimizing hydraulic erosion and controlling the shale. The optimum density is maintained by slightly exceeding the pressure in the rock pores by the pressure of the drilling mud column. Engineers minimize hydraulic erosion by balancing wellbore geometry, cleaning requirements, fluid transport capacity, and annular flow rate. The shale control process is complex. The shales in some formations expand in the presence of water, while others disperse. To some extent, these effects can be controlled by changing the properties of the drilling fluid. Regardless of the approach used, controlling the effect of the fluid on the traversed formations helps control the drilling and the integrity of the debris and ultimately leads to a cleaner, easier-to-maintain drilling fluid.

1.4 Drilling mud's life cycle

The design and maintenance of drilling fluids are iterative processes affected by both surface and borehole conditions. These conditions change as the well is drilled through deeper formations and gradually increases in temperature and pressure, and the mud undergoes chemical changes caused by different types of rocks and fluids in the formations. Fluid specialists and engineers use continuous process design to adjust drilling fluid parameters in response to changing drilling conditions, then evaluate fluid performance and change its properties in a continuous cycle.

Initial design - in the design phase, drilling fluids engineers select the type of mud system and the design for each well. Certain specifications such as density requirements, borehole stability, temperature gradients, logistics and, most importantly, environmental protection requirements must be met. Drilling can be started with a simple fluid system. Water is often the first fluid used to drill the first section. As the borehole deepens, increasing layer pressure, increased temperatures and more complex rock formations require increased levels of mechanical control of the borehole and cleaning capacity. Thus, simple fluid systems can be replaced or converted into heavy and inhibitory WBMs, followed, at great depths, by OBM.

Circulation - the character of the drilling fluid is constantly evolving: In a circulation cycle, the fluid consumed energy, released debris, cooled the bit and the borehole and evacuated the solids to the surface. Engineers and fluid specialists constantly evaluate and recharge the system with fresh mud and additives.

Measurement and redesign - the drilling fluid specialist measures certain properties of the mud that returns from the well. The specific properties measured depend on the type of fluid used, but usually include density, rheology, filtration rate, continuous phase content and ratios, solids content and their classification. The pH, hardness, alkalinity, chlorides and acid gas content are further analysed. Then a treatment plan is determined for the next 12-24 hours.

2. Drilling programme model for various sections within a well in Saudi Arabia

2.1. Surface Section – 28'' Hole – 24'' Casing

Project XYZW – Saudi Arabia
Lithology: limestone / shale

The section is excavated in Aruma limestone, Lower Aruma and Ahmadi clays. The Aruma formation is representative of the Upper Cretaceous, widely distributed in Saudi Arabia and consists of three layers: Khanasir limestone, Hajajah limestone and Lina shale. Nearby wells showed no problems with the shale when using water-based drilling mud (WBM). However, problems with annulus isolation and blocked casing have been reported.

Drilling begins with the remaining fluid from the previous section (if we have remaining volumes). If there are no leaks, the drilling fluid will be supplemented with Polysal fluid loss control additive (starch). Before drilling in Aruma limestones, if unsustainable or even total losses are recorded, drilling will be done with mud permanently mixed with viscous gel until the annular space is filled at a rate of 1 bpm (9.54 m3 / h). No effort will be made to limit losses in this section. Whenever deemed necessary, high viscosity mud control volumes will be pumped with 40 ppb pre-hydrated bentonite, recommended 30 + 30 + 50 barrels (3.6 + 3.6 + 6 m3). If detritus cleaning problems are found, 50 + 50 + 70 barrels (6 + 6 + 8.3 m3) will be used.

A volume of +/- 1300 barrels (155 m3) of drilling fluid with a density of 80 pcf (1281 kg / m3) must be mixed and prepared for filling the casing before cementing the 24-inch casing to counterbalance the collapse pressure. Normally, if the cement used has the usual parameters, this volume of fluid is not required. That is why it must be confirmed with the Project Engineer. Na2CO3 is added until we obtain a Ca content of less than 400 mg / l.

Mud properties		
28" Hole		
Property	**Unit**	**Value**
Density	pcf	64–65
Gel - 10 min	lb/100ft2	15–20
Gel - 10 sec	lb/100ft3	25–35
pH		9,5–10
Funnel Viscosity	sec	60-80

Composition		
Product	**lbs**	**ppb**
Barite	3307	if needed
Bentonite	2205	25–30
Lime	55	0,25
Xanthan gum	55	0,5
Starch	55	1–2
Na_2CO_3 (soda ash)	55	if needed

Fig. 3 and 4 *Properties and composition of the drilling mud used for the 28'' hole section*

Comments:

- Bentonite is pre-hydrated for 6 hours in reserve tanks before adding lime.
- For an optimal cleaning a minimum flow of 3.8 m^3 / min will be used.
- It is essential to use optimal solid control equipment but also dilution to control density and viscosity. The addition of water will be done at the site to accelerate the retention of fine solids and density control.
- 2-6 kg / m^3 of starch is added to the drilling in the Aruma state to reduce the filtrate and the thickness of the cake.

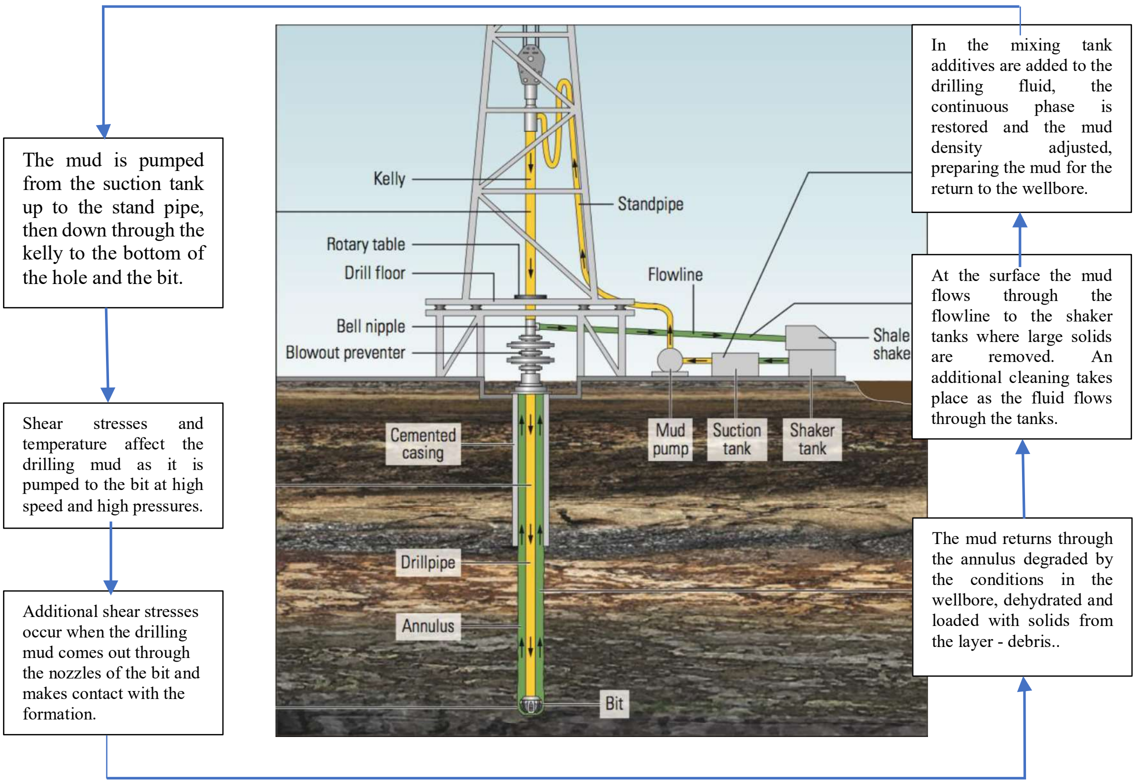

Fig. 2 *Drilling fluid life cycle. During its circulatory cycle it is the subject of processes that change its physical parameters. The drilling fluid maintenance plan must keep up with these changes.*

XYZW-1234-A1			
Interval	**Drilling 28" Hole**		
Average (ROP) - ft/h	50		
Expected Drilling hours	35		
Interval Size - inch	28		
Previous Casing Size - inch	30		
Casing - ID	29		
Liner OD			
Liner ID			
Liner Position ft			
From - ft	763		
To - ft	2.491		
Interval Legth - ft	1.728		
Expected downhole losses depth - ft	800		
Blind drilling interval - ft	1.691		
Blind drilling interval - h	34		
Mud type	WBM		
Mud Weight - lb/ft3 (pcf)	64-66		
Casing volume - bbs	623		
Liner volume - bbs			
Open Hole Volume - bbs till loss circulation depth	1.540		
Dilution factors SCE/LGS/HE	0,95	0,07	1,10
Open Hole Volume Enlarged - bbs	1.694		
Dilution Volume - bbs	1.125		
Surface Volume - bbs	900		
LCM Pill Volume - bbs	1.300		
Sweep Pills - vol bph - interval h - total vol	50	45	1.920
Mud Cap - bph - h - total vol	60	50	3.000
Blind Drilling gpm - h - total vol	900	34	43.483
Spot Pill / Kill Mud	500		
Surface losses + evaporaration - bbs	500		
Provision for Down Hole Losses			
Volume transferred from previous interval - bbs	500		
Total volume - bbs	4.343		
Combined sheet volume	6.263		

Fig. 5 *mud volumes for the 28'' hole section*

If stability problems are found in the borehole stability, a plug of loss control materials (LCM) will be circulated according to the above instructions, with the following composition.

Weight	pcf	75–80
Product	**Unit**	**Doses ppb**
Na_2CO_3	55	la nevoie
NaCl	1mt bb	30
Bentonite	1mt bb	10
Caustic soda	55	0,25
Starch	25	4
Xanthan Gum	25	0,5
Barite	1mt bb	40

1 mt bb = metric ton per bag (big bag)

Fig. 6 *LCM composition for the 28'' Hole section*

2.2. 22'' Hole section with 18-$^5/_8$ inch casing

Lithology: shale/sandstone/limestone

Drilling is made in the following formations after Ahmadi (see previous section): Wara, Wasia and Shuaiba, belonging to the Middle Cretaceous. The associated risks are fluid loss or water contamination. In this sense, a drilling fluid with a high concentration of bentonite (denoted HB - hoigh bentonite or HBM – high bentonite mud) will be used to counteract both risks.

Mud Properties		
22" Hole		
Property	**Unit**	**Value**
Density	pcf	64--65
Gel - 10 min	lb/100ft2	20--35
Gel - 10 sec	lb/100ft3	10--15
pH		9–10
Funnel Viscosity	seconds	75-120

Fig. 7 *Drilling mud properties for the 22'' hole section*

The HB drilling mud will be mixed on the surface with a bentonite concentration of 100kg / m^3 ab initio. This is done to ensure optimal cleaning of detritus but also to avoid excessive mud flow at vibrating screens. After the start of the drilling, after the first 30 m, the concentration of bentonite increases to 115-140 kg / m^3 to convert the mud into HB according to the following technique:

- There is a prepared amount of Spersene CF at the surface (150 barrels or about 23m^3). [1]
- Start adding bentonite to the active system, during drilling, at a rate of 3-4 bb / h (bb = big bag, about 1 ton).
- During the mixing of bentonite, it is drained from the amount of Spersene CF from the first point, in order to preserve the viscosity and the rheological parameters.
- Greater care is required during drilling in Wasia clays as a sudden increase in viscosity is expected. The funnel viscosity is checked at values less than 70-80 seconds before drilling in Wasia and then checked so as not to exceed 100 seconds. Add 3-5 bags of Mica F per hour. Similar Mica M.[2]
- If no losses are observed, as soon as the roof of the Biyadh layer is reached, the rheology of the drilling mud will be diminished by an aggressive dilution and the addition of Spersene.

LCM (Loss Control Materials):

- Prepare 36m^3 with LCM 228 kg / m^3 (80 ppb) in advance which will be used diluted or not as needed. [3]

Inhibited Casing Go Pill		
Weight	pcf	78
Product	**Unit**	**Doses ppb**
Na_2CO_3	55	if needed
NaCl	1mt bb	30
Bentonite	1mt bb	10
Caustic soda	55	0,25
Starch	25	2--4
Xanthan Gum	25	0,5
Barite	1mt bb	if needed

Fig. 8 *LCM composition for the 22'' hole section*

- Very viscous mud plugs (sweep pills) are not necessary because the HB drilling fluid will clean the well hole very well given its aggressive rheological parameters.
- After reaching the target of the section, clean the borehole and circulate an inhibiting "pill" (pill - a volume of fluid) before inserting the 18-$^5/_8$ inch casing.

In case of total fluid loss in Wasia or Shu'aiba:

- During drilling:
  - Pumping of 12m^3 with LCM 228 kg/m^3.
  - If unsuccessful, the drilling is restarted adding 7-9 kg of bentonite pe m^3.
  - 8 m^3 of highly viscous mu dis circulated for each drill pipe step.
  - Inhibited drilling mud is pumped at 1120-1200 kg/m^3 at a rate of 1 barrel per minute (1bpm=0,16 m^3/60s) according to the table below.
- After reaching the target:
  - 24 m^3 of high viscous mud is circulated.
  - A 60 m^3 inhibited mud pill is circulated before introducing the casing.

Consideration should be given to loading the system with materials capable of sealing or closing the porous formations during drilling to minimize the tendency of differential sticking.

1. With MWD equipment:
   LCM Pill 114 kg/m^3
   57 kg/m^3 LCM Fine Grade
   28,5 kg/m^3 LCM Medium
   28,5 kg/m^3 $CaCO_3$ Medium
2. Without MWD equipment:
   LCM Pill 228 kg/m^3
   85,5 kg/m^3 LCM Fine Grade
   86,5 kg/m^3 LCM Medium
   57 kg/m^3 LCM Coarse
3. With Well Commander[4]:
   LCM Pill 456 kg/m^3
   114 kg/m^3 LCM Fine Grade
   171 kg/m^3 LCM Medium
   171 kg/m^3 LCM Coarse
   LCM Pill 570 kg/m^3
   171 kg/m^3 LCM Fine Grade
   199,5 kg/m^3 LCM Medium
   199,5 kg/m^3 LCM Coarse

[1] Spersene is a lignosulfonate manufactured by MI-Swaco, effective for controlling viscosity and reducing fluid losses in the layer for all water-based drilling fluids, even in the presence of contaminants or very high temperatures. Because it has a low pH, Spersene treatments should be supplemented with caustic soda or another alkaline alternative. A normal ration would be 1 bag of caustic soda to 4 bags of Spersene. Spersene CF is the chrome-free version of the product, for environmental reasons.

[2] Mica C (coarse) Mica M (medium) and Mica F (fine) are small white granules - a phyto-silicate called muscovite, which does not affect the pH and are well tolerated by all types of drilling mud. It acts as a seal for pores and microcracks, which makes it effective in preparing the drilling fluid with Loss Control Materials (LCM).

[3] The presence of a bottom hole engine restricts the use of LCM to 80ppb or 228 kg / m^3. To the extent that there is equipment for MWD (Measurement While Drilling) this limitation is reduced by half.

[4] Well Commander is a Schlumberger system consisting of a directional valve operated by inserting a ball from the surface. It allows the circulation of a certain volume of fluid that contains materials for hardening the wellbore, avoiding the bottom hole assembly and the bit.

XYZW-1234-A1			
Interval	**Drilling 22" Hole**		
Average (ROP) - ft/h	40		
Expected Drilling hours	59		
Interval Size - inch	22		
Previous Casing Size - inch	24		
Casing - ID	22,67		
Liner OD			
Liner ID			
Liner Position ft			
From - ft	2.491		
To - ft	4.862		
Interval Legth - ft	2.371		
Expected downhole losses depth - ft	3.200		
Blind drilling interval - ft	1.662		
Blind drilling interval - h	42		
Mud type	WBM (High Bentonite)		
Mud Weight - lb/ft3 (pcf)	64-65		
Casing volume - bbs	1.244		
Liner volume - bbs			
Open Hole Volume - bbs till loss circulation depth	849		
Dilution factors SCE/LGS/HE	0,85	0,07	1,10
Open Hole Volume Enlarged - bbs	934		
Dilution Volume - bbs	1.861		
Surface Volume - bbs	900		
LCM Pill Volume - bbs	300		
Sweep Pills - vol bph - interval h - total vol	30	45	1.581
Mud Cap - bph - h - total vol	60	50	3.000
Blind Drilling gpm - h - total vol	1.000	42	59.357
Spot Pill / Kill Mud	600		
Surface losses + evaporaration - bbs	300		
Provision for Down Hole Losses			
Volume transferred from previous interval - bbs	600		
Total volume - bbs	5.139		
Combined sheet volume	6.720		

Fig. 9 *Drilling mud volumes for the 22'' hole section*

If the losses are severe or complete, it is recommended to channel the LCM pill in the area with leaks and leave it to act for at least 1 hour. If LCMs are circulated, they are only effective in case of partial losses. [5]

2.3. 16'' Hole section with cu 13-$^{3}/_{8}$ inch casing

Lithology: sandstone/limestone
Drilling mud KCl – polymer
Mud weight 1280-1440 kg/m^3
Maximum bottom hole temperature 119 °C

It is desired to drill this section with a 1280 kg / m^3 initial weight KCl polymer type drilling fluid and gradually increase to 1440 kg / m^3 60 m before the meeting of the Arab C layer. Drilling begins in limestone, continues through sandstones and shale Murrat and Minjur. Murat sandstones and Minjur shales are formed in the late Triassic, representative of the Middle East (especially Saudi Arabia, Iraq and Kuwait), are considered an important aquifer but also hydrocarbon deposits. Murrat sandstones and Mijur shales require shale inhibitors and stabilizers. KCl will be used as inhibitor and Asphosol supreme and Black Fury [6] will be used for stabilization.

[5] LCM composition example at 80 ppb (228 kg/m^3): $CaCO_3$ fine 10 ppb, $CaCO_3$ medium 10 ppb, $CaCO_3$ coarse 20 ppb, Mica fine 10 ppb, Mica medium 20 ppb, other materials 10 ppb.

[6] Asphasol Supreme is a product of MI-Swaco company. It is an inhibitor of hydration of shale based on asphaltenes, which stabilizes the section drilled through the shales by controlling the dispersion of solids and improving the properties of the filtrate cake. It is also used as an additive to prevent fluid loss in WBM fluid systems in high temperature conditions. Normally 9-17 kg / m^3 will be used to control the clays and 17 kg / m^3 to control the losses in high temperature conditions. Black Fury is a Schlumberger company stabilization product that consists of a liquid and easily dispersible asphalt suspension.

Mud properties		
16" Hole		
Property	Unit	Value
Densitaty	pcf	80
Densitaty max	pcf	90
Gel - 10 secunde	lb/100ft2	8--12
Gel - 10 secunde	lb/100ft3	13--16
pH		9--10
Solids LGS	%	<6
API Filtrate	cc/30 min	<7
HPHT Fluid Loss	cc/30 min	16--18

Fig. 10 *Average drilling mud properties for the 16'' hole section*

Concentration		
Product	lbs	ppb
Barite	3300	130
Bentonite	2200	10
Black Fury	480	3
Lime	4404	10
Citric Acid	55	1
NaCl	2200	70
KCl	2200	15
Xanthan Gum	55	0,5
Asphasol	50	3--4
Starch	55	1--2
Na_2CO_3	55	0,5

Fig. 11 *16'' hole section drilling mud composition*

XYZW-1234-A1			
Interval	Drilling 16" Hole		
Average (ROP) - ft/h	40		
Expected Drilling hours	151		
Interval Size - inch	16		
Previous Casing Size - inch	18--5/8		
Casing - ID	17,75		
Liner OD			
Liner ID			
Liner Position ft			
From - ft	4.862		
To - ft	10.654		
Interval Legth - ft	5.792		
Expected downhole losses depth - ft	7.000		
Blind drilling interval - ft	3.886		
Blind drilling interval - h	97		
Mud type	KCl / polimer		
Mud Weight - lb/ft3 (pcf)	80-90		
Casing volume - bbs	1.488		
Liner volume - bbs			
Open Hole Volume - bbs till loss circulation depth	1.498		
Dilution factors SCE/LGS/HE	0,95	0,07	1,10
Open Hole Volume Enlarged - bbs	1.648		
Dilution Volume - bbs	1.095		
Surface Volume - bbs	900		
LCM Pill Volume - bbs	300		
Sweep Pills - vol bph - interval h - total vol	40	90	2.677
Mud Cap - bph - h - total vol	60	97	5.820
Blind Drilling gpm - h - total vol		42	
Spot Pill / Kill Mud			
Surface losses + evapoararation - bbs	300		
Provision for Down Hole Losses	500		
Volume transferred from previous interval - bbs	0		
Total volume - bbs	5.931		
Combined sheet volume	7.400		

Fig. 12 *16'' hole drilling mud volumes*

- It is necessary for the fluid engineer to ensure that there is at least 500 bb (tons) of barite in place before drilling this section.
- The increase in density from 1280 to 1441 kg / m^3 must be considered for the most unfavourable scenario.
- The addition of KCl for mixing and storage at the expected concentration is done 100 m before drilling in Marrat and Minjur to improve the plastic characteristics of the drilling cake and reduce the amount of filtrate. 100 m before drilling in Marrat add 1% Black Fury and 3-4 ppb Asphosol.
- Strictly monitor the KCl concentration so as not to decrease below 5% weight concentration.
- For the solid control, vibrating screens with a size of 120-170 mesh and drilling mud cleaners with a screen of 200 mesh will be used.
- Water is treated with Na_2CO_3 if the Ca concentration exceeds 400 mg / l.

- The pH is controlled by adding of caustic soda NaOH. It should be kept at a value of 9-10 to counteract CO_2 contamination.
- The density of the mud is controlled by the addition of barite.
- Bentonite is kept at about 15kg / m^3 to improve the properties of the mud. It is necessary to reuse the remaining fluid for the next section and the addition of bentonite above the indicated value will compromise it for this purpose.
- Prepare LCM (loss control materials) 300 barrels (35m^3) 228 kg / m^3 to be handy if leaks occur

2.4. 12'' hole section with 9-$^5/_8$ inch liner

Lithology: limestone/shale
KCl – polymer (Resinex) Drilling Mud
Weight 1666 kg/m^3
Maximum bottom hole temperature 140 °C

Drilling in the Khuff layer, characteristic of the Upper Permian (Permo-Triassic layer), a specific gas reservoir in Saudi Arabia and other neighbouring states, and Sudair and Jilh, related to the Triassic[7]. For this section the drilling mud remaining from the previous section treated for solids removal is used and diluted so that the solids and bentonite are below 5 ppb. The amount of prepared mud will be 120 m^3 at a density of 1666 kg / m^3 and half of the remaining mud from the excavation of the previous section will be used. The other half will be used for drilling in cement. From the information from vicinity dug wells, it is unlikely to encounter blow-out manifestations in the Jilh layer, but, nevertheless, there must be enough barite in place to increase the density of drilling mud, if necessary, up to 2323 kg / m^3.

A 25 m^3 volume of drilling fluid with lubrication properties will be pumped at the end of the drilling, before the casing introduction.

Mud Properties		
12" Hole		
Property	**Unit**	**Value**
Densitaty	pcf	104
Densitaty max	pcf	145
Gel - 10 secunde	lb/100ft2	10--12
Gel - 10 secunde	lb/100ft3	12--16
pH		9--9,5
Solids LGS	%	<6
API Filtrate	cc/30 min	<5
HPHT Fluid Loss	cc/30 min	14--16

Composition		
Product	**lbs**	**ppb**
Barite	3307	320
Caustic soda	55	0,5
Black Fury	465	3
Lime	4210	10
Resinex	50	4--5
Drill Zone	465	3
KCl	2205	18
Xanthan Gum	55	0,5
Asphasol	50	4
Starch	55	1
Na_2CO_3	55	0,5
$Na_2S_2O_5$	55	0,4
Spersene	55	1
Lube	460	2,5

Fig. 13 *12'' Hole drilling mud properties and composition* [8]

[7] The Khuff permo-Triassic layer is one of the extremes, dimensionally, depositionally and architecturally. It is formed with the splitting of the unique continent Pangea and the related opening of the Neo-Thetys Ocean. The ratio of thickness to surface area reaches 1 in 200,000. It is estimated that 25% of the world's conventional gas reserves are in the Khuff formations.

[8] Resinex is a product of MI-Swaco company based on lignite resin designed to control filtration over a wide range of temperatures and in the presence of contaminants. DrillZone is a product of the Schlumberger company, a drilling fluid additive with the role of bit RoP increase in WBM, cleaning the bottom of the hole.

Criteria for the use of drilling mud from the 16-inch section within the 12-inch section: the concentration of solids and bentonite is checked. As long as they are between 5% and 6%, 50% of the remaining fluid volume will be used. For bentonite> 6% and solids <7% 40% will be used, for> 7% respectively <8% 30% will be used and for> 8% bentonite and <9% solids 20%. Above 9% of any of the criteria, the drilling fluid is not compatible with drilling the 12-inch section and a new one will be prepared.

XYZW-1234-A1			
Interval	**Drilling 12" Hole**		
Average (ROP) - ft/h	24		
Expected Drilling hours	99		
Interval Size - inch	12		
Previous Casing Size - inch	13–3/8		
Casing - ID	12,125		
Liner OD			
Liner ID			
Liner Position ft			
From - ft	10.654		
To - ft	13.071		
Interval Legth - ft	2.417		
Expected downhole losses depth - ft	13.258		
Blind drilling interval - ft	0		
Blind drilling interval - h	0		
Mud type	KCl / polimer		
Mud Weight - lb/ft3 (pcf)	104		
Casing volume - bbs	1.555		
Liner volume - bbs			
Open Hole Volume - bbs till loss circulation depth	332		
Dilution factors SCE/LGS/HE	0,85	0,05	1,10
Open Hole Volume Enlarged - bbs	365		
Dilution Volume - bbs	1.040		
Surface Volume - bbs	800		
LCM Pill Volume - bbs	0		
Sweep Pills - vol bph - interval h - total vol	30	90	791
Mud Cap - bph - h - total vol	0	0	0
Blind Drilling gpm - h - total vol		0	
Spot Pill / Kill Mud			
Surface losses + evaporaration - bbs	300		
Provision for Down Hole Losses	0		
Volume transferred from previous interval - bbs	600		
Total volume - bbs	3.460		
Combined sheet volume	3.460		

Fig. 14 *12'' hole drilling mud volumes*

- Due to anticipated high temperatures, drilling fluid losses will be controlled with Resinex and Pac-UL[9].
- 100 m before drilling in Sudair addition of 1% by volumes of DrillZone is required to minimize shale bonding trends and increase the RoP. It should be also treated with 1% BlackFury and 5-6% by mass KCl. Reduced RoP is estimated during drilling in the Sudair because there are intercalations of Radish shale. The latter have a rubbery nature, which prevents the drill bit from dislocating properly.
- pH 9-9.5 is maintained during drilling in Sudair to prevent solids from dispersing.
- Never add chemical additives without pre-mixing, except for the LCM.
- High evaporation rates are estimated, both due to the ambient temperature and the temperature in the wellbore. In this respect, a minimum evaporation compensation of 1-1.5 m^3 per hour will be required. To maintain the density of the drilling mud, the hose with the addition of water will flow into the intermediate tanks.

[9] MI Swaco's additive - PAC UL is designed for situations where it is necessary to control the filtration with minimal increases in rheology. It performs well in all applications with salty mud (brine), especially salt water fluids.

- If drilling with very high-density drilling mud, over 2200 kg / m^3, water must be added at a rate of 1.5-2.5 m^3 / hour just to compensate for dilution and make sure we have a sufficient water quantity in the system for the additives to work.
- **The most important aspect of high-density mud drilling is the control of water in the system. The rheological parameters are constantly measured and the addition of water is made as necessary to keep them under control. The above indications only consider the situation in which the rheological parameters are not affected.**
- To ensure that the drilling fluid is not contaminated during drilling in Jilh, its salinity is constantly monitored. Any deviation is an indicator of contamination

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