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Stuck Pipe Management & Analysis Operation In Bahr Essalam field NC41, Offshore Basin, Northwest -Libya

Emad Aljabali[1], Yahya Salem[2]

University of Zawia – Faculty of Oil and Gas Engineering

e.aljbali@zu.edu.ly, y.salim@zu.edu.ly

الملخص

تتناول هذه الورقة أهم العوامل التي يجب التحكم بها لتجنب التصاق الأنابيب التفاضلي في بئر الحفر مثل فقدان الطين أو عمق غلاف المجموعة، وغيرها من المعلمات .يعتبر فقدان سائل الحفر عاملاً مؤثرًا، حيث أن فقدان السوائل يكون كعكة الطين سميكة بشكل غير مرغوب فيه وتزداد فرصة الالتصاق مع مدى فقدان السوائل. نفس النتائج في حالة عدم تنظيف قاع الحفرة بشكل صحيح. وباختصار، أهم العوامل لتجنب الالتصاق التفاضلي: معرفة نوع الصخور والجيولوجيا في المنطقة، تصميم الأنابيب، وبرنامج سائل الحفر المخطط له. وكانت المشكله الرئيسية في منطقة الدراسة NC 41 هي فقدان سائل الحفر الكلي بسبب الكسور. وللتغلب على مشاكل فقدان السوائل والتصاق الانابيب، تم استخدام تدابير مثل إضافة كربونات الكالسيوم والطين عالي اللزوجة لتقليل فقدان السوائل، وتحليل تعديلات وزن الطين، وتقييم معلمات الحفر مثل معدلات التدفق وأقطار الأنابيب. وقد أدت التعديلات إلى عملية حفر أكثر تحكمًا وتقليل مخاطر الالتصاق التفاضلي.

Abstract

This paper study the most important factors control to avoid differential type of sticking pipe in drilling well such as mud loss or depth of set casing, and other parameter. Fluid mud drilling loss is an influencing factor, where fluid loss, the mud cake would be undesirable thick, and the chance of sticking is increasing with the extent of fluid loss. The same results of improper hole cleaning. In summary, the most important factors to avoid differential sticking: Knowing the type of lithology geology of the area, casing design, planned mud program. The area study NC 41, the main problem is total mud loss due to fractures. To overcome the fluid loss and stuck pipe problems, measures such as adding CaCO3 and high-viscosity mud to reduce fluid loss, analyzing mud weight adjustments, and evaluating drilling parameters like flow rates and pipe diameters were employed. Adjustments led to a more controlled drilling process and reduced risks of differential sticking.

Keywords: *Stuck pipe, Bahr Essalam field, drilling, drilling mud, drill pipes*.

1. Introduction

Drilling Well is drilling the process of drilling a hole in the ground for the extraction of a natural resource such as ground water, brine, natural gas, or petroleum, for the injection of a fluid from surface to a subsurface reservoir or for subsurface formations evaluation or monitoring. Drilling of well use drilling rig for the exploration of the nature of the material underground (for instance in search of metallic ore) is best described as borehole drilling. It's one of the oldest technologies in the world. Drilling engineering is a branch of knowledge where the design, analysis and implementation procedure are completed to drill a well as sustainable as possible [1] [6]. In a word, it is the technology used to unlock crude oil and natural gas reserves. The responsibilities of a drilling engineer are to facilitate the efficient penetration of the subsurface with wellbore and cementing operations that range from the surface to an optimum target depth, while minimizing safety and environmental hazards.

1.1 Method of Study

In an attempt to meet the purpose of this study, all the data available were used. These data include; pipe stuck, lost circulation, hole deviations, directional control, pipe failures, borehole instability, mud contamination, formation damage, annular hole cleaning, hazardous gas and shallow gas (i.e., H2S-bearing formation), casing (collapse), mud cake formation, pollution and corrosion in wells, stacked tools, drill string failures, kicks, slow drilling, and equipment, communications and personnel-related problems. There are some specific problems related to directional drilling which cover directional / horizontal well drilling, multilateral well drilling, [2] coiled tubing drilling, under-balanced drilling, slim hole drilling.

1.2 General Information History of the Well CE7-NC41

Well CE07-NC41 is located in block NC41 in 679 ft of water. The location is sited approximately 110 km North West of Tripoli, in the Tripoli-Gabes Basin (Fig 1). Drilling Rig to top reservoir (El Garia Formation at depth of 12,975ft MD, 8,350 ft TVD) The 7” Casing liner was set and cemented at depth 12,958ft MD, 8,343 ft TVD, was then temporary abandoned. The well re-entered with 6’’phase to total depth of 13,115 ft MD, 8,411 ft TVD in El Garia reservoir has been drilled and the 4 ½’’ completion string was set to 12900 ft (El Garia Top at 12,975 ft MD, 8,350 ft TVD). [3]

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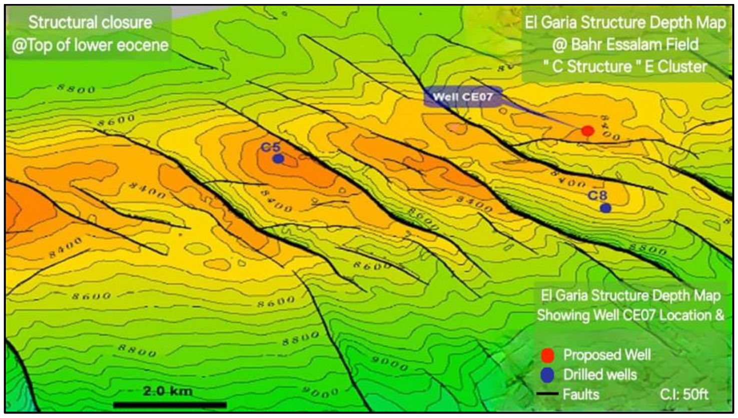

Figure 1. location of well CE7 –NC41

1.3 Drilling Problems

1.3.1 Stuck pipe Problems

The stuck pipe can lead to major nonproduction incidents [1]. Because the possibility of losing the drill string, a pipe of then increase of as much as 30%, during offshore operations [2]. A pipe is stuck if it cannot be freed from the hole without damaging the pipe, and without exceeding the drilling rig's maximum allowed hook load. Pipe sticking can be classified under two categories: differential pressure pipe sticking and mechanical pipe sticking [3]. Often stuck pipe problems arise from non-optimal operation of the hydraulic system. Some of the indicators of differential pressure stuck pipe while drilling permeable zones or known depleted-pressure zones are an increase in torque and drag (Fig 2).

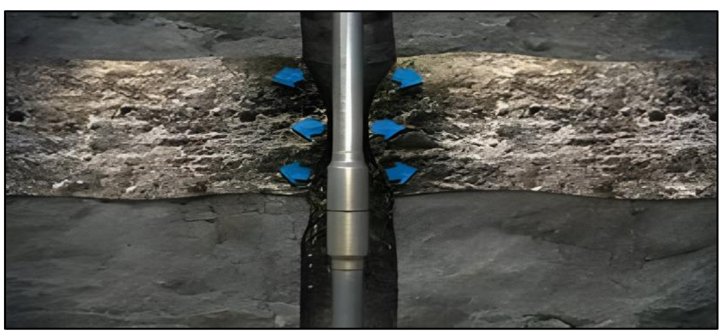

Figure 2. Depleted-pressure zones

1.3.2 Stuck pipe Problem prevent

The problem can be prevented by the following precautions: Maintain the lowest continuous fluid loss adhering to the project economic objectives. Maintain the lowest level of drilled solids in the mud system, or, if economical, remove all drilled solids. [4] Use the lowest differential pressure with allowance for swab and surge pressures during tripping operations.

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Select a mud system that will yield smooth mud cake (low coefficient of friction). Maintain drill string rotation at all times, if possible. The above guideline is applicable from the hydraulic considerations alone. Other factors might play a role, thus altering the optimal operating conditions described above.

1.4 Drilling phase

In ½” 17 phase no significant drilling the well with no major problems were recorded during drilling of this phase. In ¼” 12 phase throughout drilling this section the hole was major problem showing a tendency to back off (Fig 3). The lithology in this well is (Shale and Limestone) (Table 1).

A new 12 ¼” PDC and stearable bottom hole assembly were made up and run-in hole on joints of 5 ½” drill pipes. The string was RIH then reamed all the way to bottom. Reaming purpose was to re-log the reamed section with the MWD tools. [13].

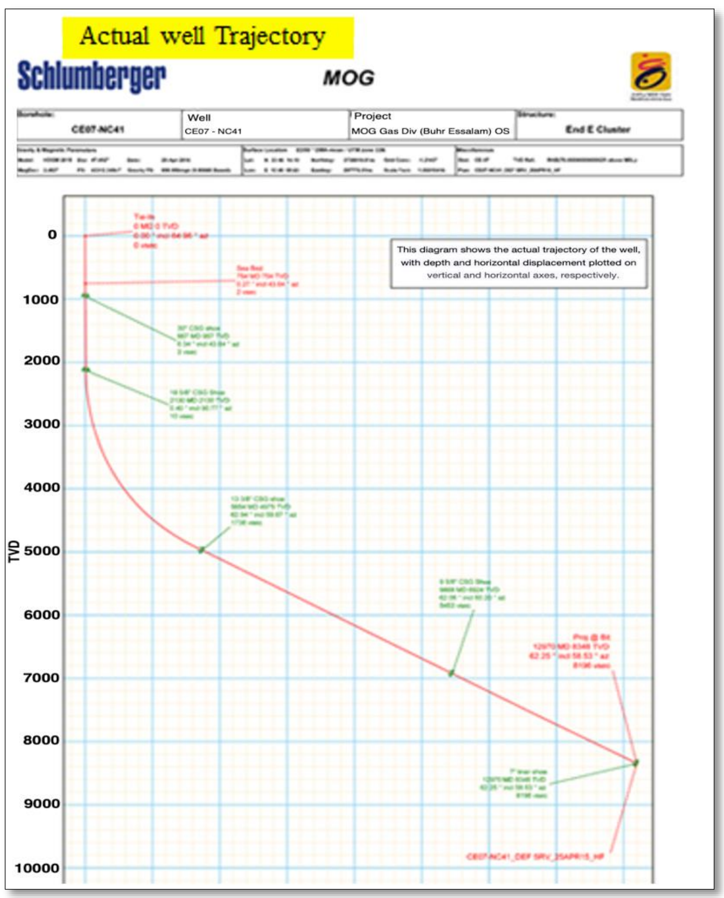

Figure 3. Original Well Path & Redesign Path for Gas Well

Table 1: Comparison of Original & Redesigned well path from the problematic formation

Formation	Actual well path	Redesigned well path
Shale laying	1800-2050	1780
Limestone	2050	2040
Length of shale layer	250	
Averger Inclination	49	

2. Results and Interpretation

2.1 Drilling Mud problems

A new 12 ¼" Smith with a junk basket and BHA were RIH to fish the lost parts and cutters from the previous PDC bit. The string RIH then drilling commenced with loss mud problems (Table 2). The hole then swept with 100 hi viscous pill and circulated until the stop loss, [12] the shakers cleaned. A flow check for 15 minutes was implemented and indicated for a static hole. The bit and its adjoined BHA then POOH to surface and the junk basket was cleaned and checked.

Table 2: Loss mud problem in well CE 7-NC41

Interval	Losses	During
9868 ft	45m^3	Working on stuck pipe

The drilling of the section, (Fig 4) & (Table 3) total fluid loss to the formation was observed. The differential pressure at 9868 ft was 20 bar. For decrease the fluid loss effect, CaCO3 and hi-vis mud was added to the mud. In the formation, the fluid loss could have stopped, but it started again in the shale rock. The differential pressure was between 20 bar and 24 bar when the last formation was drilled. Having examined the mud window, using the pore pressure- and the fracture gradients, that they are used a conservative 3% safety margin when planned the mud weights. Therefore, the differential pressure could be lowered if we use a smaller safety margin, as 1%, for the problematic casing section. The problematic shale formation could be found in the other wells. The target layer is below this formation, a Limestone rock from Eocene the shale layer located above the main target with 49.56° average inclination and 1.25 °/30m dogleg. [5] The kick off point is at 9869 feet in a clay marl layer. This shale. marl layer continued from 90=120 feet, so the kick off point could be 9868 ft for safely. If the kick off point is higher, the average inclination angle could be lower. The length of the well in this formation could be lower. Therefore, the fracture zone in side limestone formation creates total loss in the well.

Table 3: Comparison of the Original and the Redesigned Mud Weight values

Casing shooe TVD (ft)	**Original mud weight (kg/m^3)**	**Redesigned mud weights(kg/m^3)**
18 5/8" @ 2130 ft	13	12,4(kg/m^3)
13 3/8 @ 4974 ft	9.8	9 (kg/m^3)
9 5/8 @ 6925 ft	12.5	13 (kg/m^3)
7" @ 12676 ft	9.9	9.1 (kg/m^3)

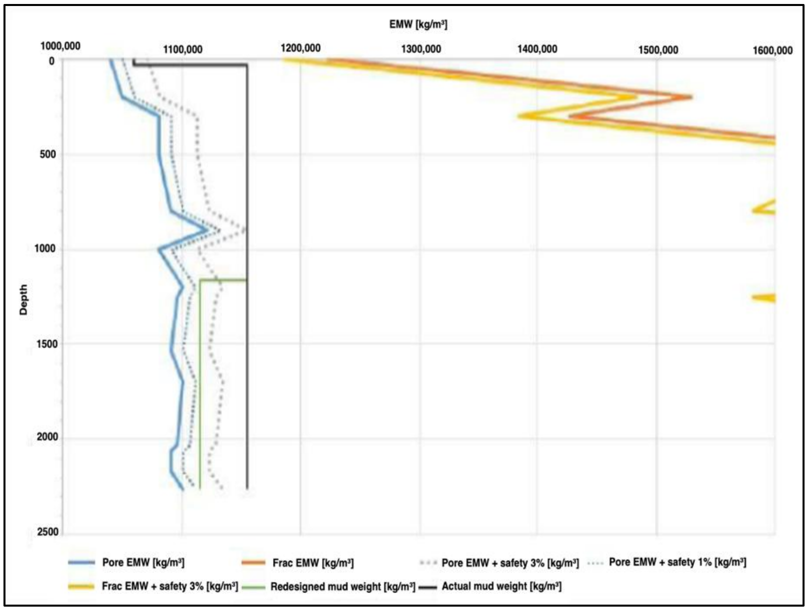

Figure 4. Original and Redesigned Mud Weight

Although fluid loss occurred, there were only laminar flow during the drilling. When the fluid started to migrate into the formation, CaCO3 was added to the mud. This was not a perfect solution, because the fluid loss started again few times. The problem maybe come from the fact that the small size of fractures in the limestone bed was not proper to the pore size. If the fluid loss could be stopped, it should be considered to change the flow pattern form laminar to turbulent. It would help to keep the mud cake thin enough to avoid sticking. The effect of changes of every parameter on flow pattern were investigated (Fig 5).

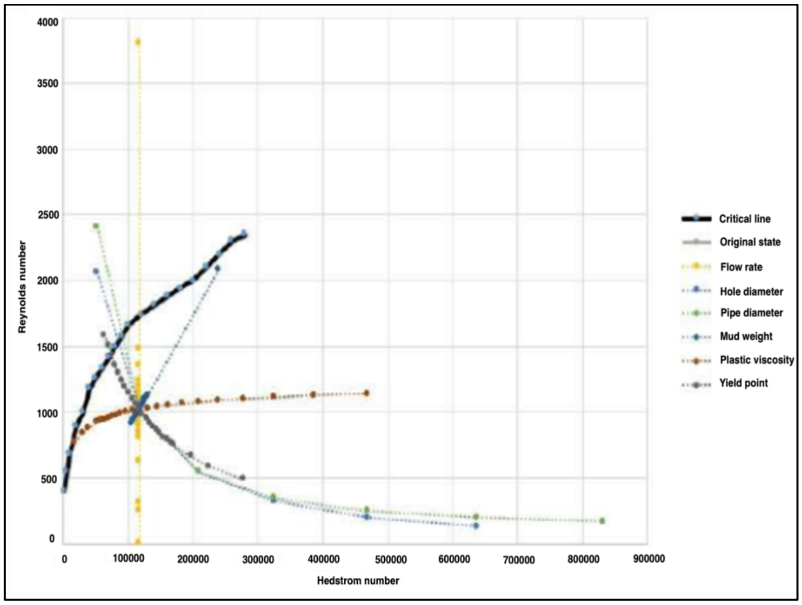

Figure 5. How the different parameters affect flow pattern

In the (Fig 6) can be seen the critical Reynolds number line. If the actual Reynolds number is below this line, the flow is laminar, if it is above the flow is turbulent. From the plotted parameters, consider the hole diameter and the mud weight (because it was calculated earlier) fix. Also, mud weight does not really effect the flow pattern by itself, the Reynolds number changes in nearly a parallel with the critical line. Then, we could change the drill pipe diameter, the Flow rate, plastic viscosity and yield point. The drill pipe diameter and the flow rate also have effect on differential pressure, so it should be considered prior changing them. In the following (Fig 7) could be seen the effect of the Flow rate and the pipe diameter on differential pressure at 8760 ft MD.

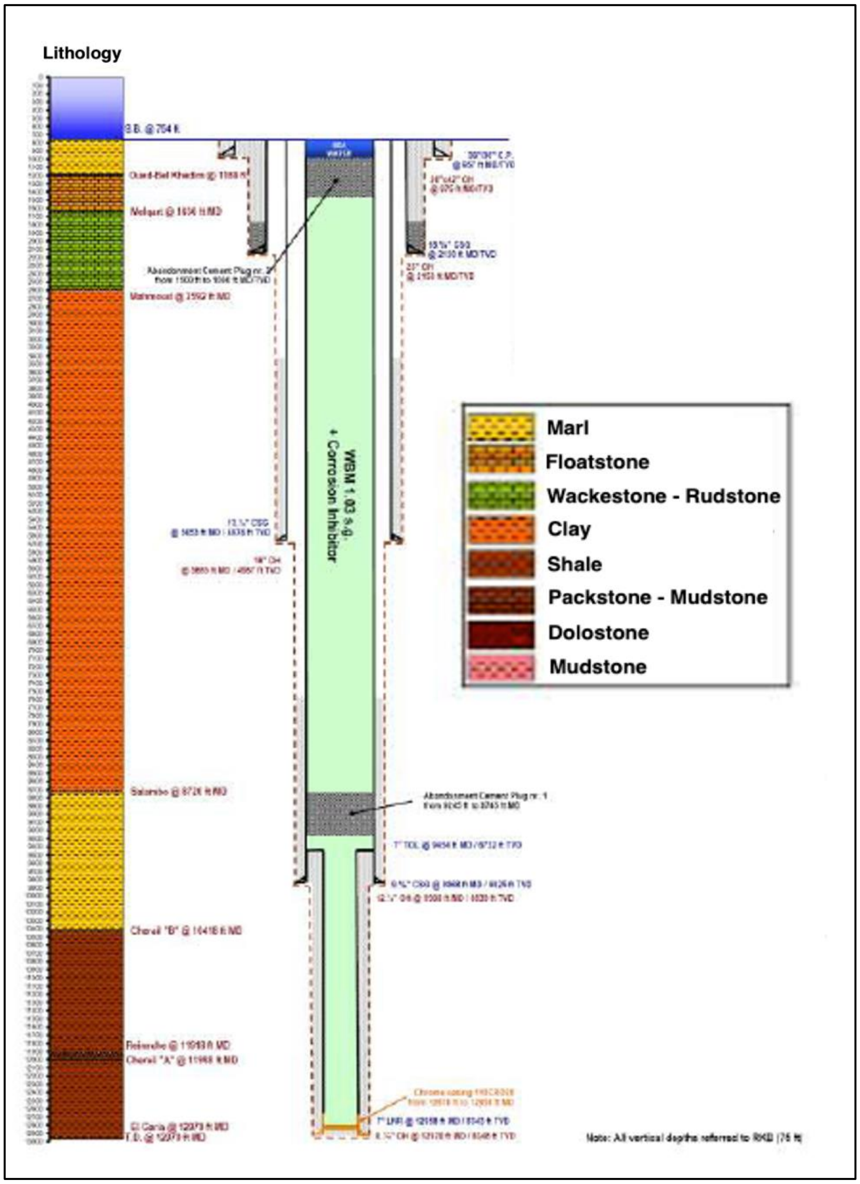

Figure 6. Well plan with lithology

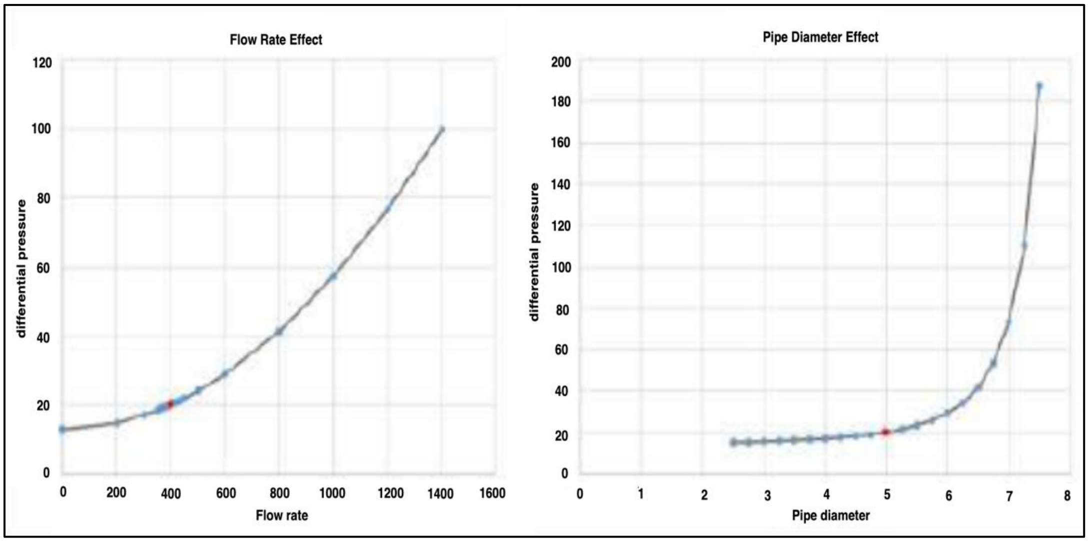

Figure 7. Effect of Flow Rate and Pipe Diameter changes on Differential Pressure

As could be seen, the pipe diameter has a huge effect on differential pressure, especially at small clearance, nearly the same as on the flow pattern. So, it does not worth to increase the pipe diameter. Flow rate is increase much more profitable, but only minor or moderate extent. With the new mud weight, the fixed hole and pipe diameter, and the changeable flow rate, plastic viscosity and yield point, the new mud regime were determinate to achieve turbulent flow in the well. Considered to keep the differential pressure lower than the original value. The Figure 8 shows that the new mud states in the turbulent flow pattern zone, instead of the original mud's laminar flow state.

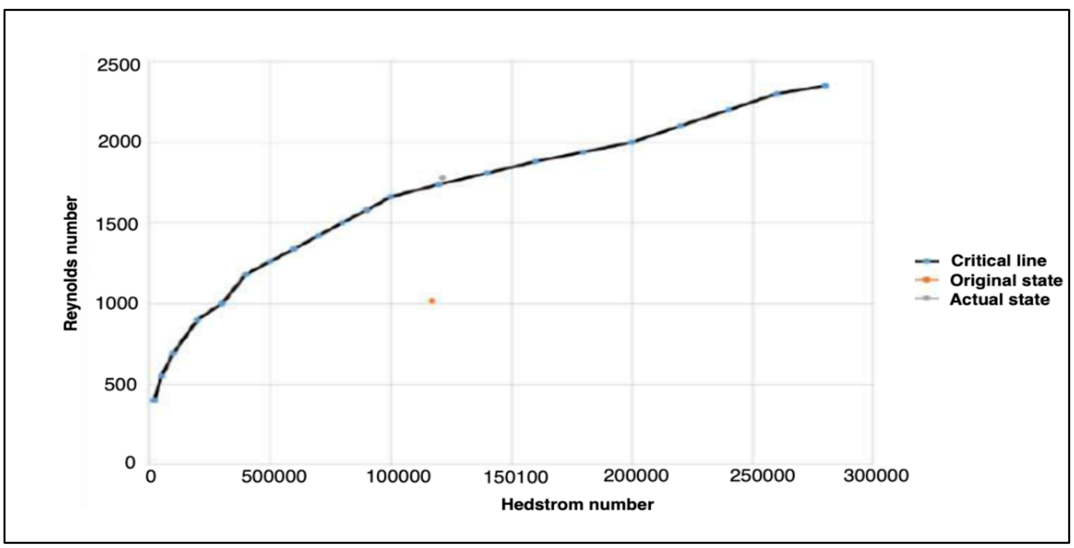

Figure 8. Flow Pattern state for the new mud

The yield point value could be seemed slightly low to carry the cuttings, but it is associated with a great flow velocity, so it would not cause problem. If the fluid loss could not be prevented, with these parameters easily could change the flow pattern back to laminar, with decreasing the flow rate and even increasing the yield point. This operation would decrease the differential pressure at the same time. Another parameter to investigate is the BHA. When the sticking occurred, the planned operation was RIH for wiper trip. The table (4) below contains the detailed BHA.

Table 4: BHA at sticking situation

Size (in)	Item	Length (m)
8 1/2"	PDC Bit	0.26
8 1/8"	Stabilizer	1.78
6 1/2"	DC	18.46
8 1/4"	Stabilizer	2.39
6 1/2"	DC	54.85
6 1/2"	Jar	5.2
6 1/2"	DC	18.62
5"	HWDP	111.4
5"	DP	1969.32

The proper action would be to use the centrifuge further and solve the fluid loss problem other way, what was described earlier. In term of generic mud type, of course they could not use oil-based mud, but they used gypsum-poly mud.

2.2. Drilling Steps

2.2.1 Drilling hole phase

Phase 6'' hole drilled the well to total depth of 13,115 ft MD, 8,411 ft TVD in El Garia reservoir has been drilled and the 4 ½'' completion string was set to 12900 ft (El Garia Top at 12,975 ft MD, 8,350 ft TVD).

2.2.2 Re - enter well

The objective is to re-enter the well temporary suspended and run the completion string as per below operations:

- Re-entry the well and drill the temporary cement plugs using betonies mud
- Drill 6'' open hole section through reservoir
- Secure the well
- Run 4 ´" CRA completion string with DHPTT
- Sub-sea Tubing Hanger installation
- Packer setting
- Acidize with 28% HCL acid.
- Clean up using CT lift with N2 if required.
- Test well with multi choke sizes
- Close the well at sub-sea Horizontal X-Tree level
- Install TPS canopy
- Move to the next well

2.2.3 Re - enter well operation

The Gas Well CE7 operation was started with pump HCl acid job was performed in open hole to a maximum depth 12,993 ft MD Coiled Tubing (CT counter), (fig 9 & 10), because it was not possible to go deeper with the Coiled Tubing string. The well was then open but no flow observed. Decision was made to lift the well with nitrogen: not possible due to the nitrogen pump broken immediately after the cool down operation. While waiting on a new nitrogen pump, a clean out run with CT jet blaster 2 1/8'' gauge ring BHA with 2.75'' centralizer was performed but it was not possible to go deeper than 12,988 ft. A new attempt was done by running a 2 1/8'' slick CT BHA composed as follow: 2 1/8" CT dimple connector, 2 1/8" dual flapper valve, 2 1/8" disconnect sub, 2 1/8" circulating sub, 2 1/8 jetting nozzle, (total BHA length 4.1 ft) but still was not possible to go deeper. While POOH the Coiled Tubing slick BHA got stuck at 12,690 ft MD (CT counter): pack off. Several attempts to free the string were performed by pumping pills of soda ash, 28% HCl acid and Nitrogen without success. It was decided to proceed with cut and retrieve the CT string., successfully cut at 10,636 ft, LIH 2,054 ft of coil size 1.5" OD.

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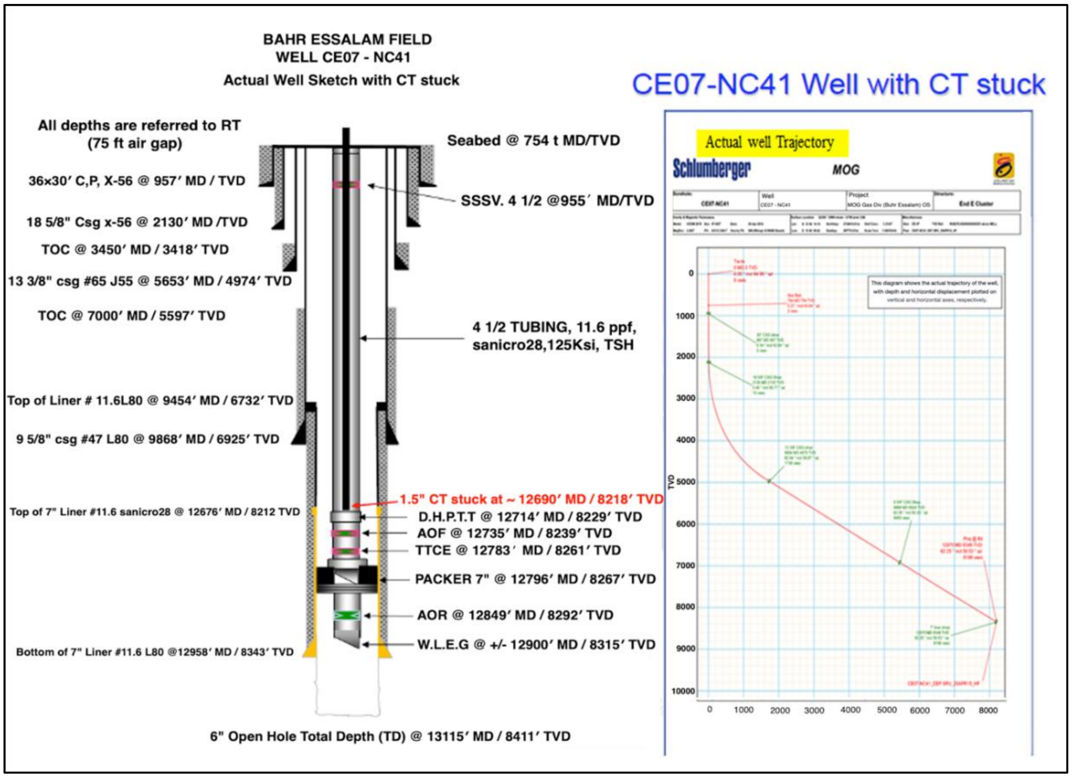
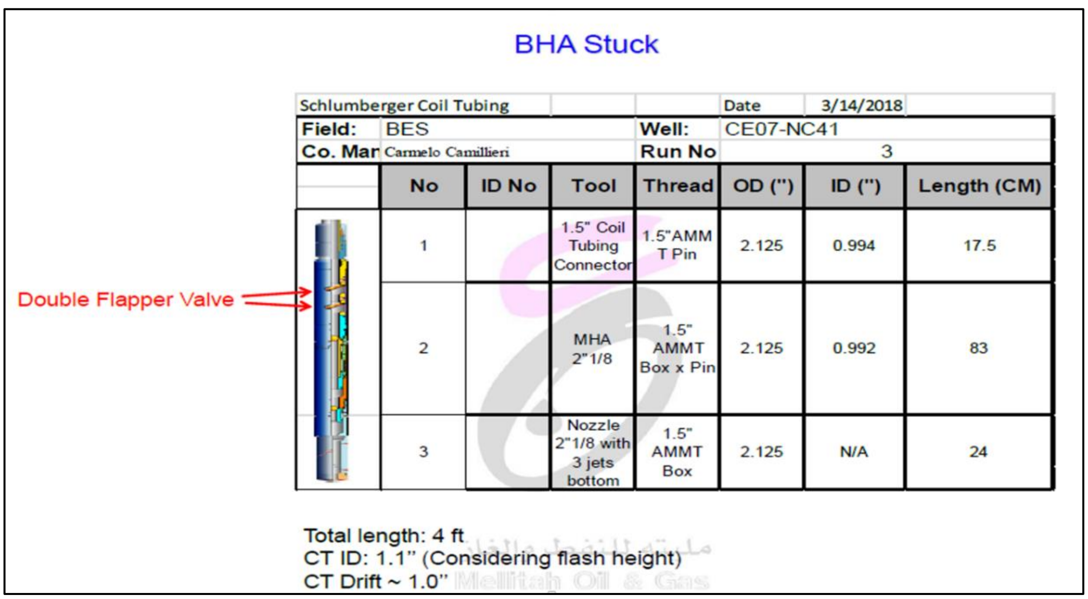


Figure 9. well sketch design for re-enter



Schlumberger Coil Tubing				Date	3/14/2018	
Field:	BES		Well:	CE07-NC41		
Co. Mar	Carmelo Camillieri		Run No		3	
No	ID No	Tool	Thread	OD (")	ID (")	Length (CM)
1		1.5" Coil Tubing Connector	1.5"AMM T Pin	2.125	0.994	17.5
2		MHA 2"1/8	1.5" AMMT Box x Pin	2.125	0.992	83
3		Nozzle 2"1/8 with 3 jets bottom	1.5" AMMT Box	2.125	N/A	24

Total length: 4 ft
CT ID: 1.1" (Considering flash height)
CT Drift ~ 1.0"

Figure 10. BHA Stuck

2.2.4 plan of a well re-enter

Option 1: Cut 4 1/2" tbg at 10,610 ft depth suitable for fishing attempt and for Whipstock side track. Attempt to fish the 4 1/2" tbg above the packer by 5 7/8" overshot and mechanical back-off. If by luck the mechanical back off will occur below DHPTT, the packer can be cut and retrieved, the open hole can be cleaned and the well re-completed.

Option 2: spot a cement plug across the 7" liner head. Sidetrack well by Whipstock installation into 9 5/8" casing above the 7" liner hanger. Drill new 8 1/2" hole section to a new target depth at top of Metlaoui formation. Set a 7" liner and cement it. Drill a new 6" hole into Metlaoui as per Reservoir Department plan.

2.3 Additional Equipment mobilized

- RCT Equipment for CT down hole cut mobilized from Malaysia
- CT surface equipment for CT cut mobilized from Denmark/Germany
- Fishing equipment from Denmark/Norway
- New CT reel mobilized from Tunisia

2.3.1 Failure Analysis:

1) Coiled Tubing string never reached the bottom of the hole:

Most likely the Coiled Tubing (CT) stopped on the edge between rat hole 8 ½” bottom and 6” open hole, 12 ft below the 7’’ casing shoeliner shoe was drilled with the drill ahead BHA with 6’’ PDC bit. Drilling the liner shoe and cleaning the rat hole with a dedicated BHA with rock bit might have done a smoother hole reducing the potential edges between the 8 ½’’ rat hole and the 6’’ new hole. Furthermore, the CT bottom part should be cut off, removing the old CT end part (~50 ft), and straightened in order to facilitate the BHA to enter in the new 6’’ hole. CT first run for acid job was done with Jet Blaster 2”1/8 gage ring and centralizer 2.75”, with negative results to access the reservoir TD. All future jobs shall be done by Jet Nozzle 2”1/8.

2) Coiled Tubing CT supervisor communicated the wrong depth to company Representatives:

Coiled Tubing team had some doubts about the Coiled Tubing counter accuracy and assumed that the Coiled Tubing stopped at well TD (34 ft off bottom). [12] Only after the acid job the real coiled Tubing depth (134 ft off bottom) was communicated to MOG representatives. Coiled tubing depth shall always be carefully evaluated before starting the acid job. In case of any doubt the operations shall stop and the situation carefully evaluated.

In this specific case the acid job (150 bbls 28% HCl) shall has not been performed before assuring that the well TD was reached. Furthermore, pumping acid only few feet below the

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7’’ liner shoe could have contributed in destabilizing the marl/limestone transition zone [10] that usually characterize the top of Metlaoui reservoir.

2.3.2 Well Prediction & Time Drillingst

Table 5: BHA at sticking situation

DATASET	DESIRED RESULT	ACTUAL RESULT	PREDICTION%
Original	**Sticking**	**Sticking**	**99.86**
Redesigned	**Non-Sticking**	**Non-Sticking**	**88.48**

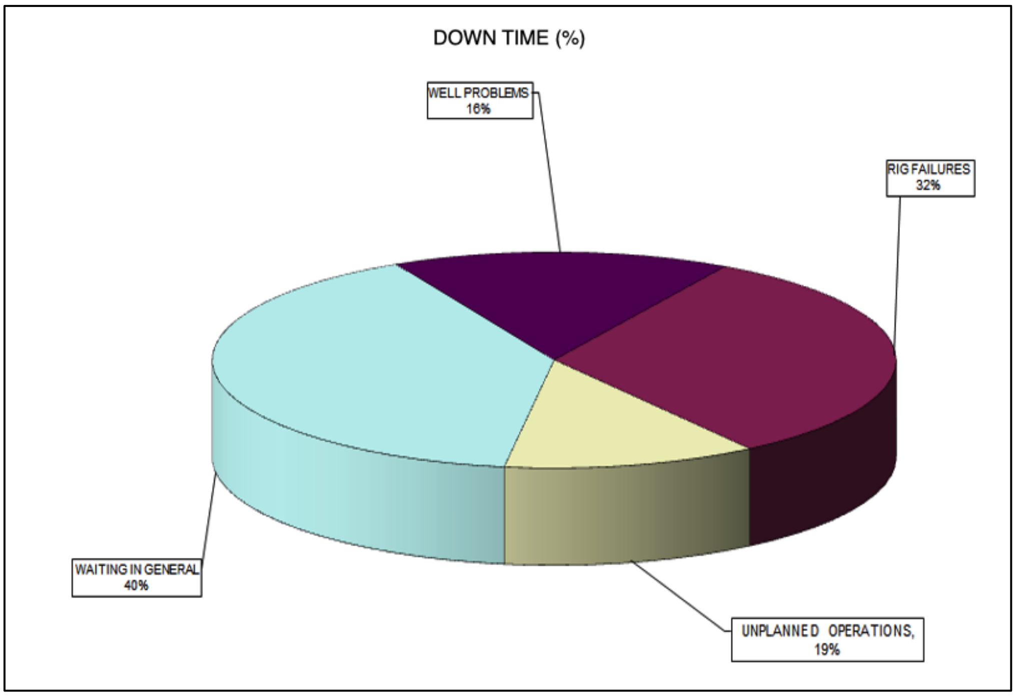

Figure 11. Well Time Drilling

Conclusion

From the results that have been obtained after this study, we can conclude the following:

1. 7’’ liner shoe could set at the top of Metlaoui reservoir due to have contributed in destabilizing the marl/limestone transition zone that usually characterize.
2. CT depth shall always be carefully evaluated before starting the acid job.
3. The common procedure to clean completed wells by CT is by nitrified viscous pills.
4. This study is also a proof of the importance of knowing the exact pore pressures, the sticking could have been avoided, using the proper mud weight help to avoid sticking.

5. Fluid loss is an influencing factor. If there is fluid loss, the mud cake would be undesirable thick, and the chance of sticking is increasing with the extent of fluid loss. There are the same results of improper hole cleaning. If the drilled cuttings stay in the bottom of the hole, later they would build-in the mud cake, and it would be thicker.
6. The most important factors to avoid differential sticking:
   i. Knowing the pore pressures, thus applying enough casing string
   ii. Carefully planned mud program
   iii. Avoiding fluid loss
   iv. Adequate hole cleaning

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