Liner Hanger Installation in Challenging Offshore Well Conditions*

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Abstract

ERD wells are commonly associated with major challenges for operations subsequent to drilling such installation of casing and liner strings. These wells typically present high torque and drag parameters that jeopardize getting strings to total depth. In an attempt to optimize production, a major oil Company in Angola decided to re-enter the case of study well in early 2016. A sidetrack was opened in the 9 5/8 in casing, drilling continued in the 8 ½ in hole and penetrated the objective zone in the highest location. Then a 7 in production liner was run. To reach the objective zone, 5,583 ft of 8 ½ in hole was drilled with deviations varying from 45° to 87°. This trajectory was a challenge for subsequent operations of 7 in liner, T&D models showed liner rotation at TD was not possible and a surge model indicated likelihood of mud losses while running the liner. Liner hanger technologies became a very important phase of well construction, and service companies developed advanced liner hangers to overcome hostile well environments. In this case study, the short time available from planning to execution phase and the current oil market conditions, made it imperative that the right equipment, service and technology were available in country. To achieve the ideal working parameters and get the liner to bottom, a thorough assessment needed to be performed to ensure sure this risk would be mitigated. This paper presents a summary of steps considered during planning for the 7 in liner run in BAP6ST1 including a detailed engineering analysis that enabled the operator to make the best decisions based on the available resources. There are also lessons learned and best practices captured during the job that will be used for subsequent liners in similar wells.

LINER HANGER INSTALLATION IN CHALLENGING OFFSHORE WELL CONDITIONS

David Luna, Roberto Elizalde, Wantuadi Diwaku

Weatherford Angola

PRESENTATION AGENDA

1. Well objectives
2. 7 in Liner challenges
3. Selection of 7 in liner equipment
4. Simulations run in planning stage
5. Operations summary
6. Conclusions
7. Q & A

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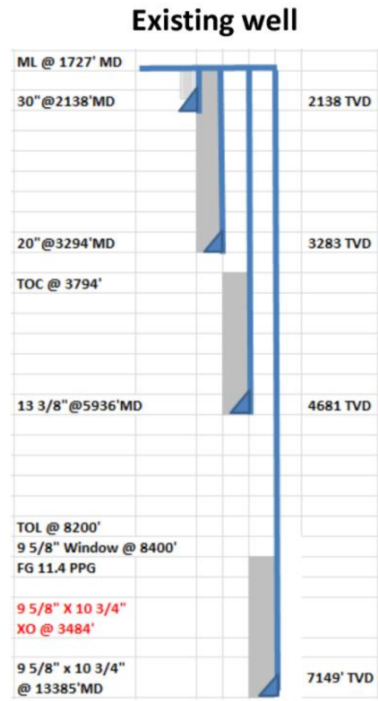
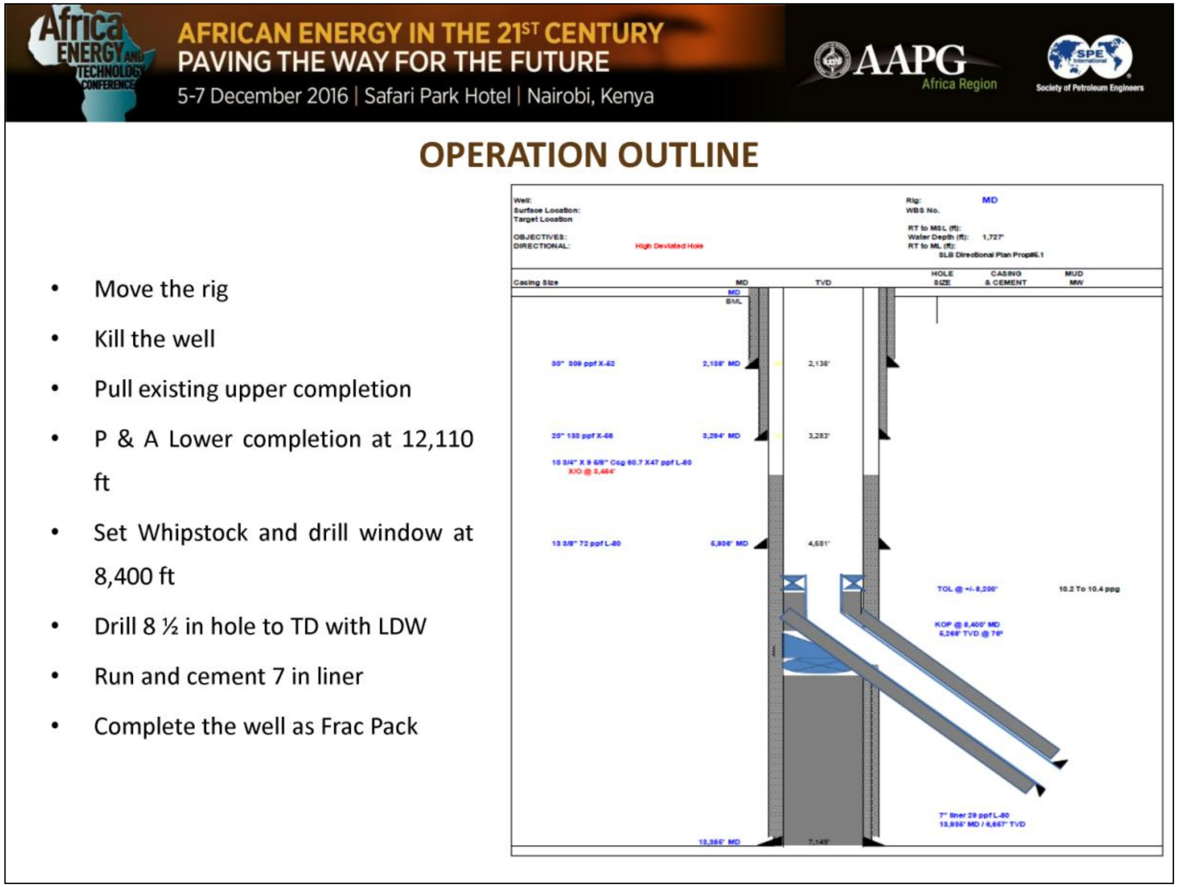
WELL OBJECTIVES

- Sidetrack from existing well - Shut in due to low performance
- Complete and bring the new well in production – Estimated 6,035 BOPD



Presenter's notes: In an attempt to optimize production, a major oil company in Angola decided to re-enter the study well in early 2016. A sidetrack was opened in the 9 5/8 in casing, drilling continued in the 8.5- in. hole and penetrated the target zone in the highest location. Then a 7 in production liner was run. The case study well was planned as a sidetrack from an existing well that had been shut- in because of low performance. The main well had been drilled and completed as a single gravel pack in 2007. The objective of the sidetrack was to penetrate the reservoir organized complex in the structurally highest location to access reserves and optimize production. A constrained initial production was estimated at 6035 BFPD.



Presenter's notes: Upon completion of objectives, customer agreed the operational sequence having as critical points for the liner the whipstock setting depth and angle and the 8.5 in hole drilling. An operations overview of the complete intervention is as follows:

- Set a 8 ½- in. whipstock in existing 9 5/8-in.casing at 8,400 ft and mill the window.
- Drill an 8 ½- in. hole section to 13,923 ft MD / 6,657 ft TVD.
- Run and cement 7- in. liner.
- Displace the hole with completion fluid.
- Perform cement bond logs and hand the well over to completion

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7 IN LINER CHALLENGES

Measured depth at whipstock point: 8,400 ft

TVD at whipstock point: 5,279 ft

Deviation at whipstock point: 78.25° deg

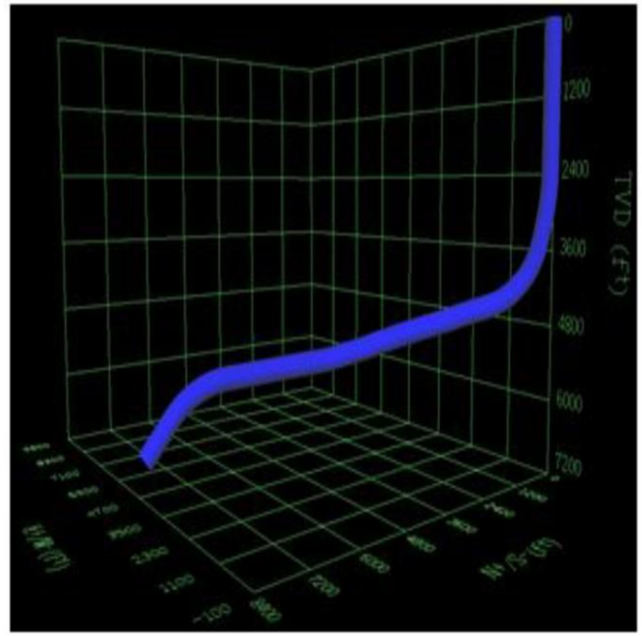
Length of 8 ½- in. hole: 5,583 ft

Measured depth at TD of 8 ½- in: 13,983 ft

TVD at 8 ½- in. hole TD: 6,695 ft

Maximum deviation in 8 ½- in. open hole: 86.9° deg

Maximum dog leg severity in 8 ½- in open hole: 5.21° deg/100 ft at @ 8,933 ft MD



Presenter's notes: The operator and the liner hanger service company used proprietary simulation tools during the planning phase to predict possible issues for running the liner. The simulation considered main aspects such as well trajectory and the influence of the whipstock installed in the 9 5/8- in. casing. All analyses were performed, and maximum working parameters were defined and included in the well program. The operator also considered possible limitations that using standard equipment available in country might impose on well life. The final management decision was to proceed with the plan presented.

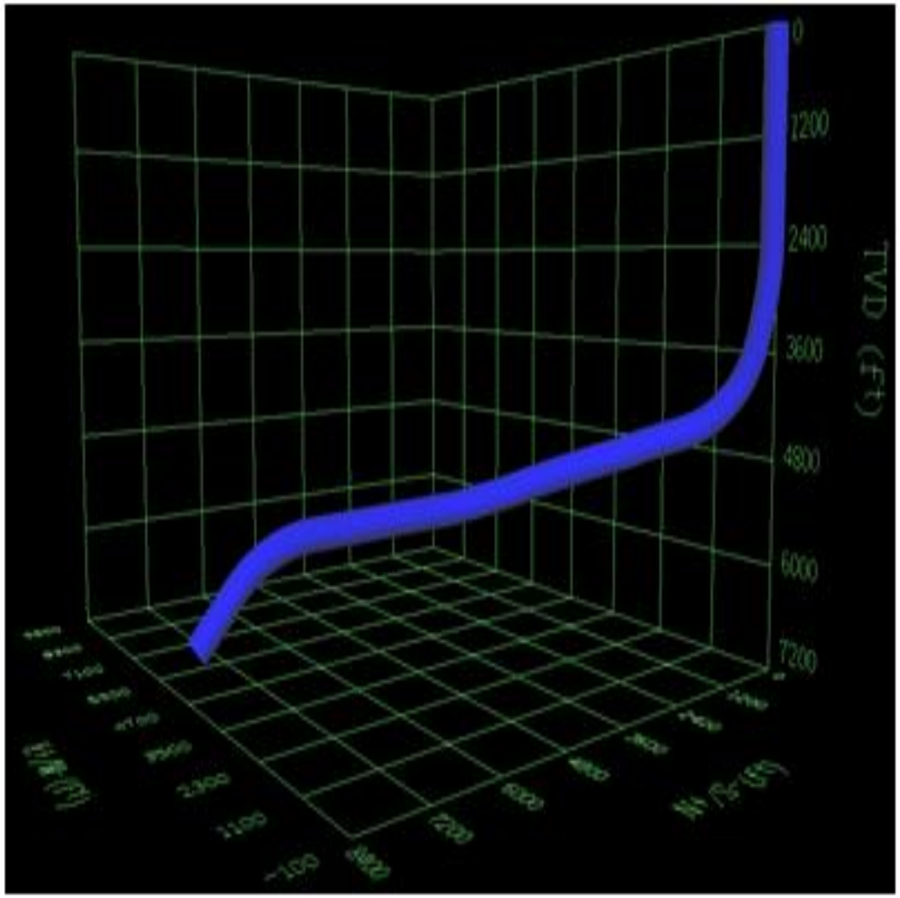
7 IN LINER CHALLENGES

Long Liner string

Tortuous wellbore trajectory

Passing the liner through casing window

Cement quality should not be compromised



7 IN LINER PERFORMANCE REQUIREMENTS

Burst	6,800 psi
Collapse	5,850 psi
Differential pressure at liner top	4,000 psi
Liner hanger capacity	400,000 lbs
Temperature rating	250 F

- Ability to rotate before and after liner hanger has been set
- Running tools able to work the liner to TD without risk of prematurely disconnection
- Liner top packer required to isolate production annulus

Presenter's notes: The demanding nature of this well and the high loads and torques to which the liner equipment would be exposed on a long-term basis made the choice of equipment critical to the success of the project. The liner system used for these types of demanding installations must be able to withstand the same dynamic forces that drilling tools encounter in open holes, while still being able to perform its designated functions at the final installation depth.

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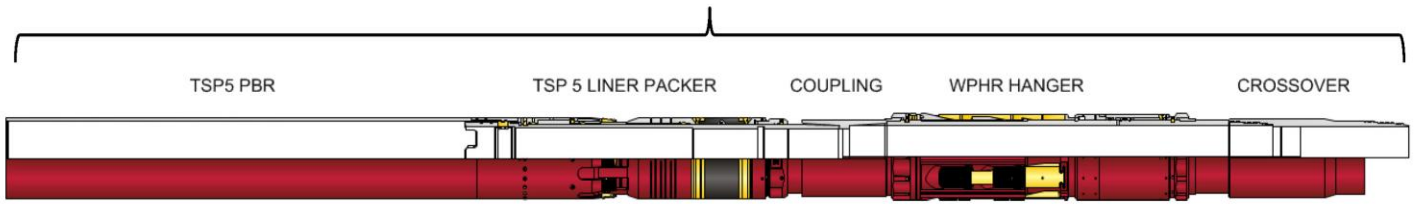
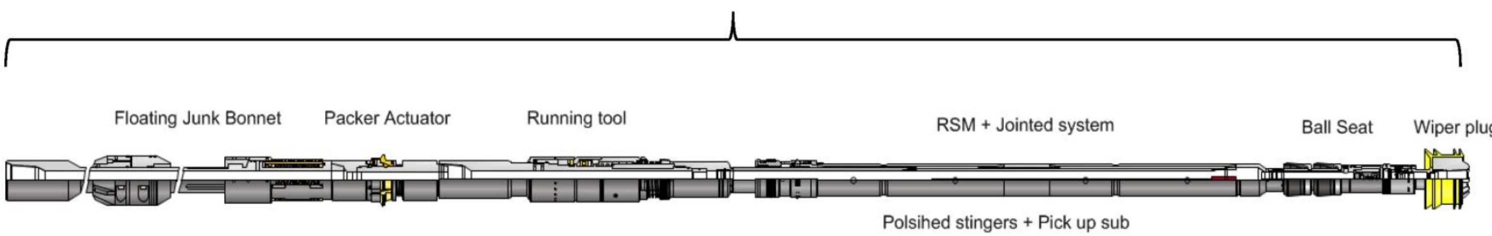
SELECTION OF 7 IN LINER EQUIPMENT

Liner top equipment



Setting tools



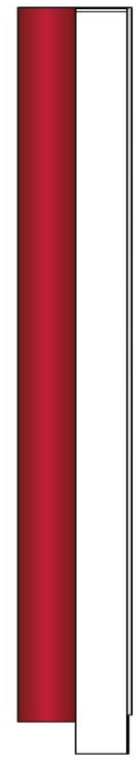
Presenter’s notes: Here is a simple drawing of liner setting tools and liner equipment.

LINER OPERATION OUTLINE

- Run 7 in liner pipe and connect liner hanger assembly
- Continue running liner with DP to desired setting depth
- Release setting ball from surface, once ball lands on ball seat increase pressure against it to set liner hanger and de-activated R Tool hydraulic lock
- Verify liner hanger is set,. With string being compressed, release tools from liner by applying right hand rotation
- Shear out ball seat
- Pump cement program and release dart from surface
- Dart launches on wiper plug and displacement continues until plug bumps on float collar
- Pick Up tools and set liner top packer
- Retrieve setting tools to surface

POLISHED BORE RECEPTACLE (PBR) TSP5

- Honed ID provides a mean to tieback the liner: well design requirement or liner top integrity issue
- Protect the running tools while being run in hole
- Transmit the applied weight to set the mechanical liner top packer when cementing operation is finished
- Wire locking mechanism to prevent the PBR from backing off



Presenter's notes: The premium hydraulic rotating liner system WPHR selected for this job had been used successfully in multiple scenarios including hostile environments where the tool string is hardly worked to get it to bottom, even in drilling with liner applications. The hanger system is hydraulically actuated, meaning differential pressure is placed across a cylinder with a set of calibrated shear pins that determine setting pressure of the slips. (Presenter's notes continued on next slide)

(Presenter's notes continued from previous slide)

This can present a challenge, when this system is run in a wellbore with severe fluid losses because the shear-pin ratings may become down- rated because of the constantly changing fluid levels within the wellbore. This situation, coupled with hole stability issues, can lead to unexpected events when running a hydraulic liner system. The key for success with hydraulic liner systems is safe management of the circulating pressures so as not to exceed the differential limit established with the preset shear pin pressures of the hydraulic components. The liner hanger also includes a special mechanical locking device, which is deactivated when the hydraulic setting pressure is reached; these devices prevent premature setting while running in the hole (RIH) and allow for the highest of flow rates and pressures to be used. Once setting pressure is achieved, the hydraulic cylinder forces the slips to contact the parent casing, and then liner weight is transferred to the slips by lowering the running string.

The selected liner top packer was model TSP5, a mechanically set, premium design that allows for extended rotation periods and maximum workability during deployment. The packing element is designed so that atmospheric pressure is trapped under the element; thus, as the liner system is lowered into the wellbore, the hydrostatic pressure acts to simply vacuum it to the liner-top packer mandrel. This capability prevents swabbing and premature setting while keeping cuttings from under the packing element as they are circulated past, all of which can affect the packer's performance. The packer is set by raising the running string to expose the packer actuator dogs, forming a no-go that is set down on the polished bore receptacle (PBR). The no-go transfers weight through the PBR, shearing the pins in the packer and allowing the element and slips to be set in the host casing and the ratchet rings to lock in the compressive forces. The packer was supplied with a tie-back completion PBR using a patented locking mechanism designed to prevent the PBR from backing off when a liner system encounters tight dogleg sections or a high-debris environment, which could lead to costly fishing operations.

POLISHED BORE RECEPTACLE (PBR) TSP5

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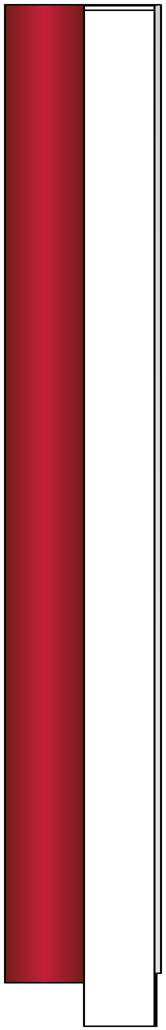
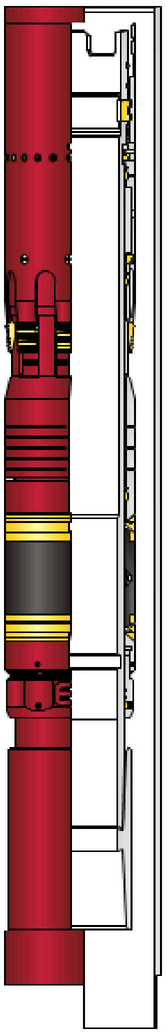


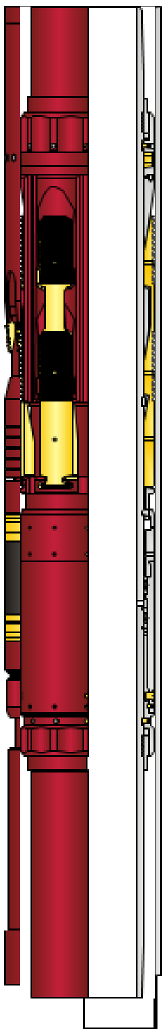
LINER TOP PACKER TSP5

- Mechanically set liner top packer
- Allows for rotation and workability during deployment
- Mechanical locking mechanism prevent premature setting of liner top packer
- Hydrostatic pressure is trapped under the element to prevent swabbing and premature setting
- Equipped with hold down slips to ensure packer remains set
- Incorporates profile and seal bore for RSM
- Differential pressure rating 7500 psi @ 300 F



LINER HANGER WPHR

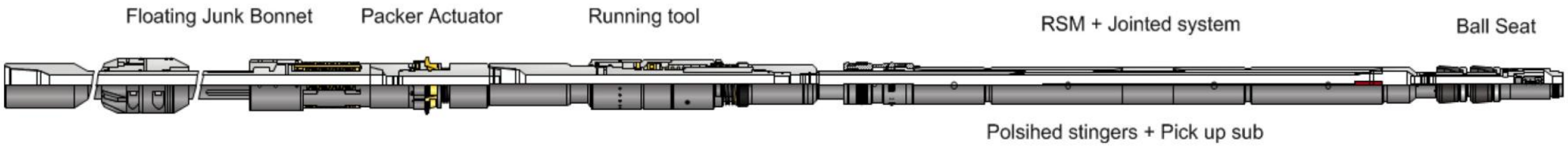
- Hydraulically activated – No string manipulation required
- Mechanical Locking device that prevents premature setting while running in hole
- Bearing allows rotation of the liner after the hanger has been set and during cementing operations
- Hydraulic cylinder rotationally locked to prevent seal damage during rotation
- Bypass channels allow circulation after the hanger has been set



SUB SURFACE RELEASE (SSR) TOP PLUG

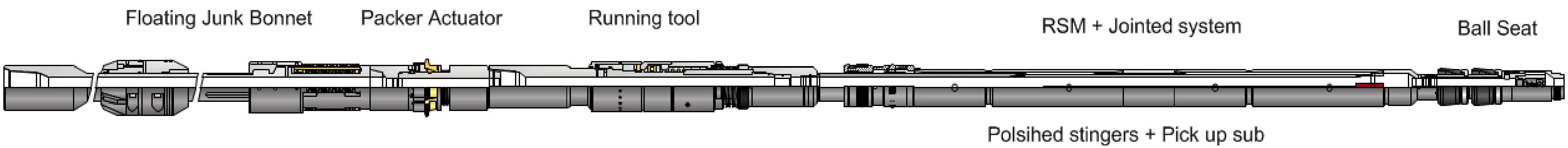
- Designed for use with sub-sea casing hanger or liner hanger
- Integral Pressure Equalizer system prevents pressure building up above plugs
- Polyurethane plug fins offer superior abrasion resistance and wiping action
- PDC Drillable with WiperLok non-rotating system

SETTING TOOLS



Presenter's notes: The setting tool model R that was used allows the liner to be rotated as required while running in. Hydraulic pressure, coupled with a ball-dropping event, is used to shear the sleeve of the hydraulic cylinder on the setting tool so that it can be mechanically released; this hydraulic event is generally simultaneous to activation of the liner hanger slips. Drill pipe weight is slacked off to de-clutch the tool (10,000 to – 20,000 lbs approximately), which is then turned to the right to release the thread that connects to the liner equipment (float nut). At that point, hydraulic pressure is re-applied to shear the ball from its seat in the liner wiper plug tool, thereby restoring circulation. The running string is then picked up to check that the setting tool is free, which is confirmed by the loss of the liner weight.

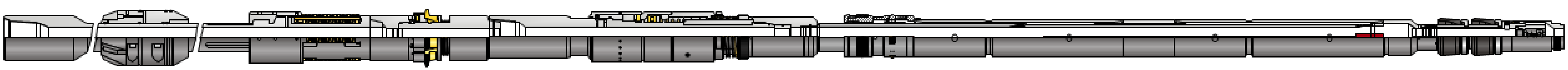
SETTING TOOLS



Floating Junk Bonnet

- Debris Barrier to protect running tools
- Bonnet remains stationary when checking that running tools are released
- Back reaming blades allow retrievable though debris
- Bypass slots allows pressure to equalize fro retrieval
- Spring sleeve facilitates removal of running tools by opening circulation path if required

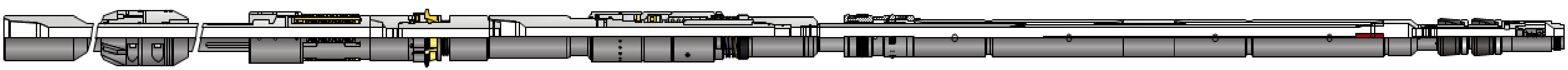
SETTING TOOLS



Packer Actuator

- Engaged top of PBR to set the liner top packer
- Maximize set down weight applied when drill string is rotated

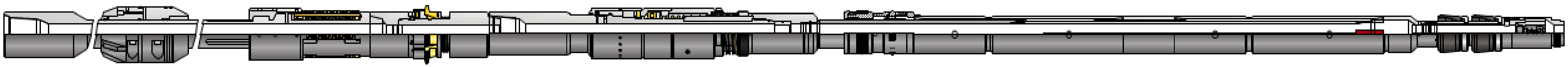
SETTING TOOLS



Running Tool

- Mechanically connected to the liner assembly with the float nut
- Hydraulic lock feature prevents premature liner release
- Float nut is made up to the R profile in packer and releases mechanical after hydraulic lock is de activated
- Hydraulic pressure and right hand rotation required for release
- Landing profile for standing valve for backup release

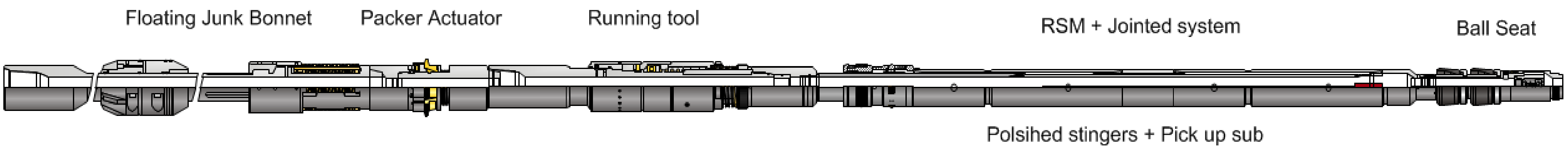
SETTING TOOLS



Polished stingers

- Polished OD seals against RSM ID
- Provides conduit for ball to reach the ball set and dart to reach the wiper plug
- Moves independently from outer joint movement

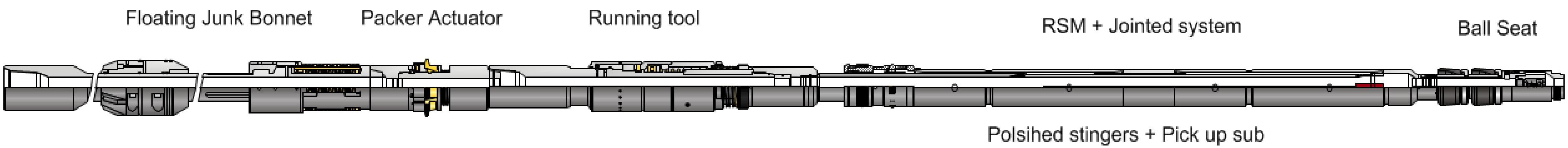
SETTING TOOLS



Retrievable seal mandrel RSM

- Provide seal between running tools and liner
- Retrieve with running tools
- Provides connection to joined system below

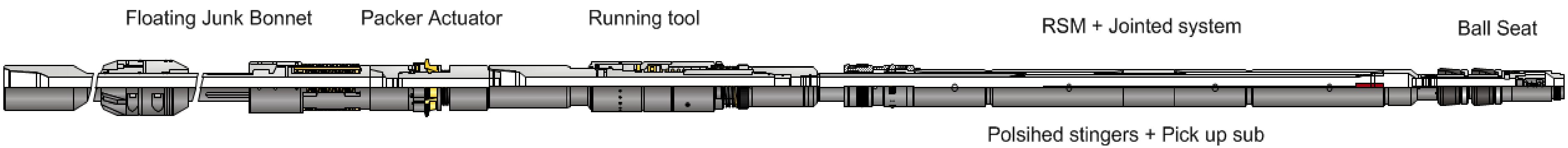
SETTING TOOLS



Jointed system

- Connect to RSM and Ball seat mechanical
- Remain stationary until RSM is released

SETTING TOOLS



Mechanical Ball Seat

- Temporarily plugs the string to provide the pressure chamber to hydraulically activate the liner hanger or release the running tools.
- Location mitigates surge pressure on the formation when the seat is sheared.
- The lower packoff provides a positive seal between the running-string OD and the liner ID to facilitate setting the hanger.
- Compatible with all Weatherford wiper plugs for added operational flexibility.

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TORQUE AND DRAG MODEL

Four critical events were selected to model in the engineering software:

- Liner located at top of Whipstock
- Liner at TD
- Running string disconnected from liner after R Ttool has been disengaged
- Setting the liner top packer by applying 60,000-lb klbs weight on liner top.

Presenter's notes: TORQUE AND DRAG MODEL. Simulations were run and calibrated against drilling torque readings, and the following critical operational events were selected to predict possible issues:

- Liner located at top of whipstock
- Liner at TD

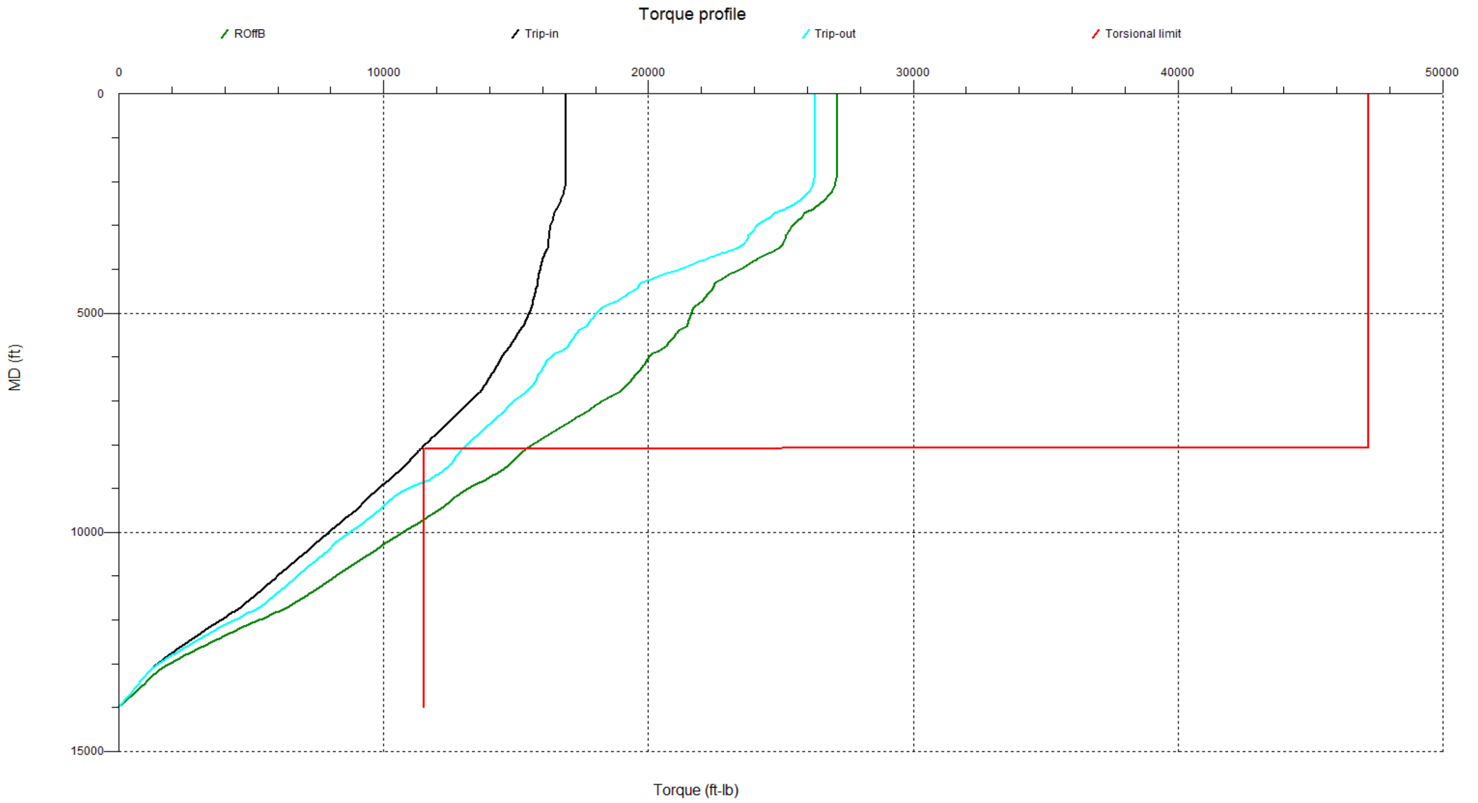
(Presenter's notes continued on next slide)

(Presenter’s notes continued from previous slide)

- Running string disconnected from liner after R tool has been disengaged
- Setting the liner top packer by applying 60,000-lb weight on liner top

Each event was input with different parameters and evaluated separately in the T & D software. Initial simulations showed the torque value at liner top would exceed the liner connection rating, even when attempting to rotate at low rpm. A series of subsequent models was run to evaluate the effect of placing different centralizer placements ion reducing of torque but also its negative effect on increasing required push down force to move the liner in the open hole.

INITIAL TORQUE PROFILE WITH LINER AT TD



- No centralization used. CH FF 0.2, OH FF 0.25
- Unable to rotate Liner at TD

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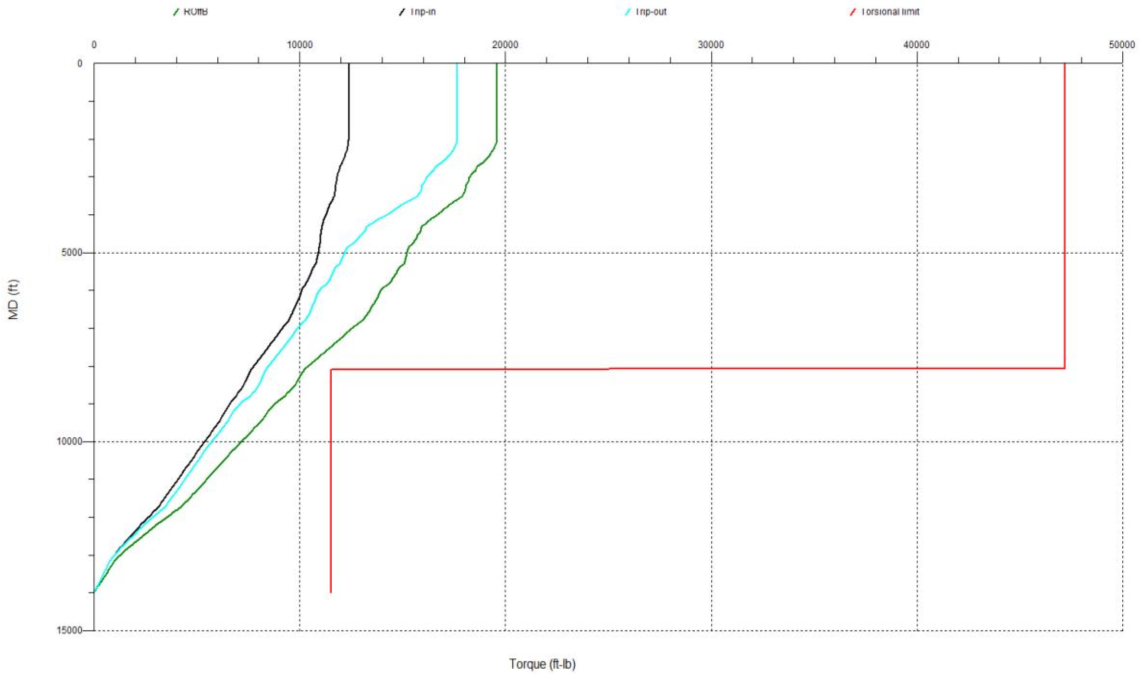
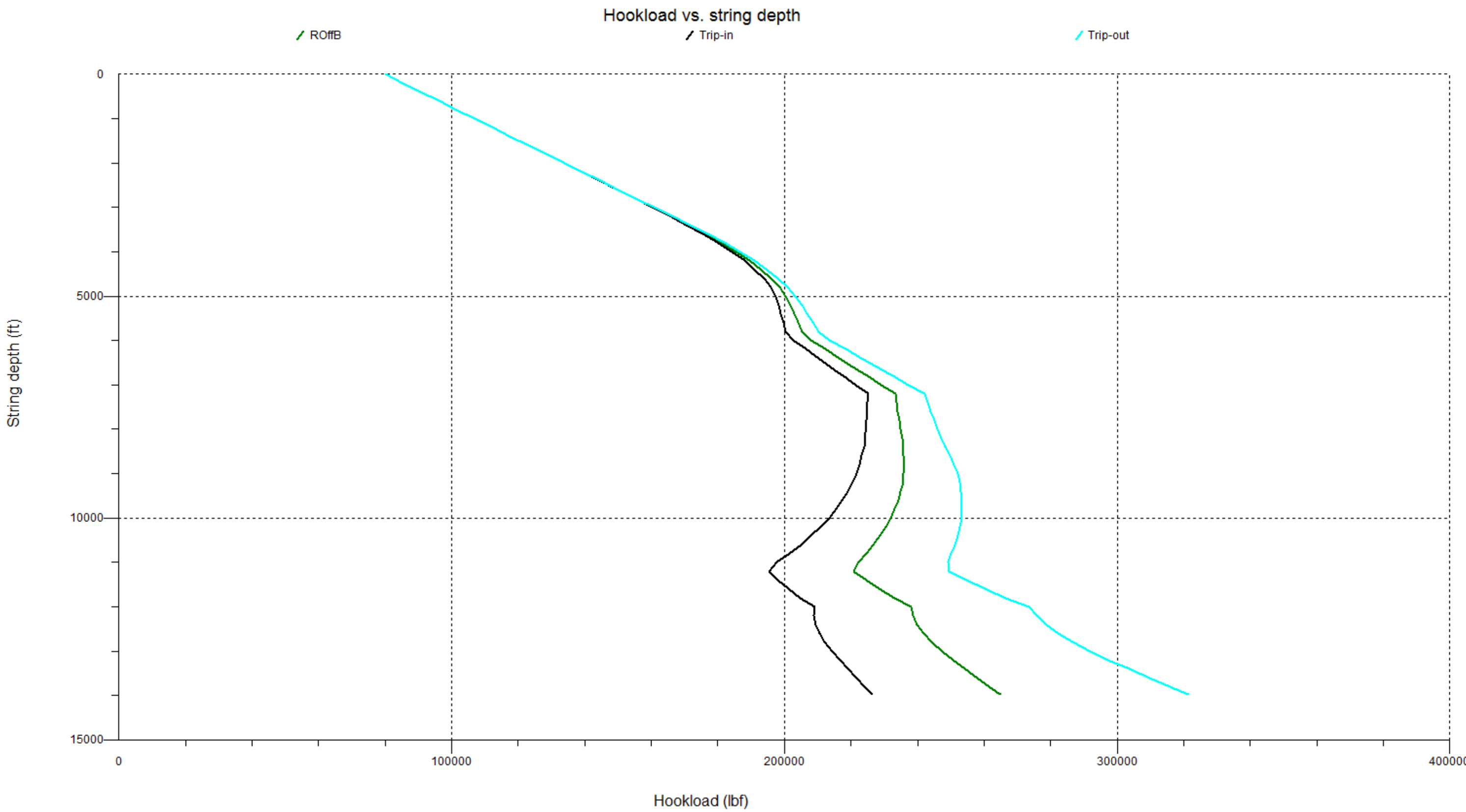
TORQUE PROFILE WITH LINER AT TD WITH CENTRALIZATION



- One bow spring single piece centralizer per joint
- Able to rotate Liner at TD

Presenter's notes: The best scenario obtained was to place one centralizer per joint across all liner sections; that gave enough standoff for cementing (more than 75%) and torque reduction effect. Hook loads still looked reasonable with this number of centralizers on the string.

HOOK LOAD WITH LINER AT TD WITH CENTRALIZATION



- One bow spring single piece centralizer per joint

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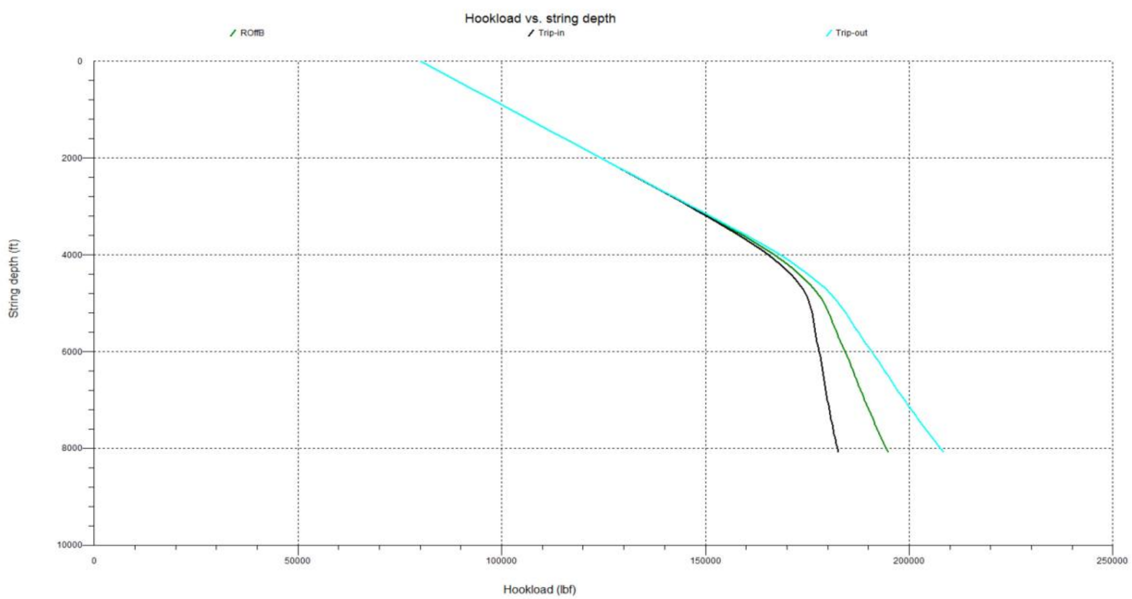
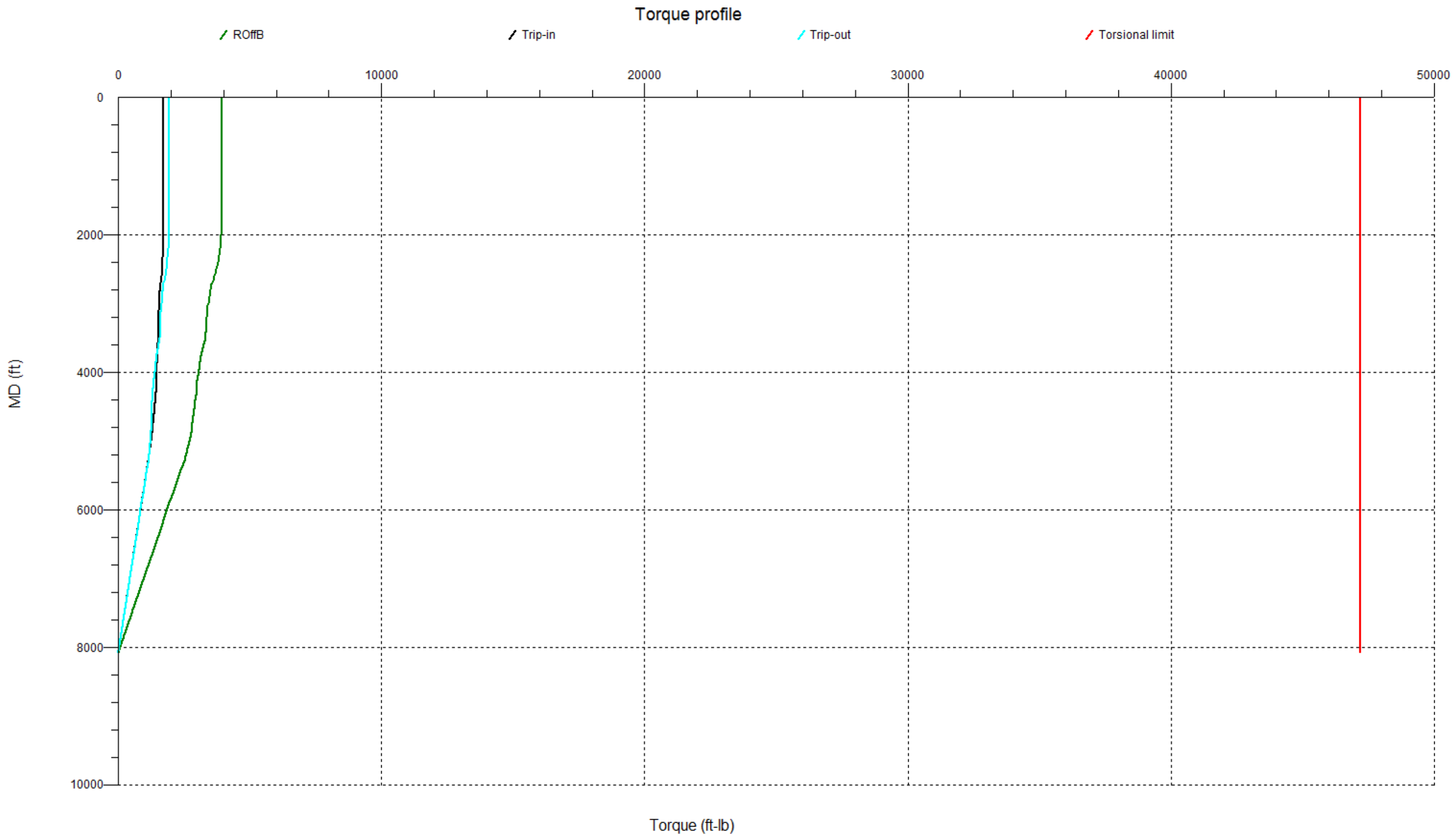
HOOK LOAD WITH RUNNING TOOLS FREE FROM LINER



- Weight loss once running tools is released 100 Klbs approx.

Presenter’s notes: T & D modeling also showed that there would be clear confirmation of liner weight loss and surface torque indicating that the tools have been disconnected from the liner after pressure is built up against the ball seat

TORQUE PROFILE WITH RUNNING TOOLS FREE FROM LINER



- Surface torque reduction in 15Klbs approx.

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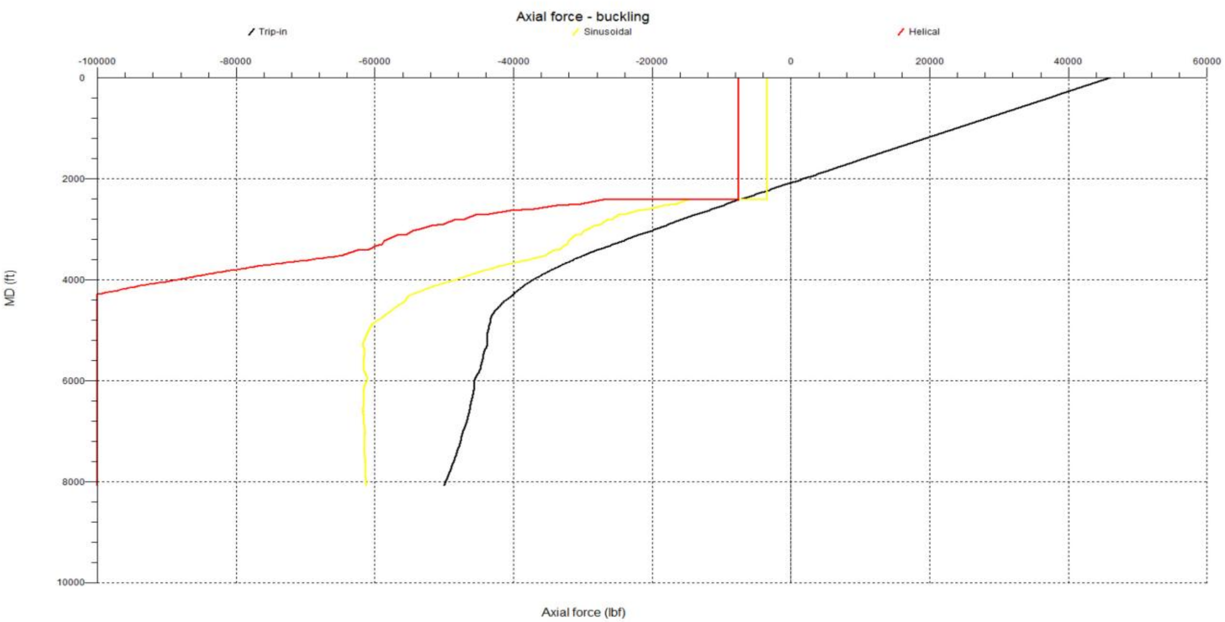
BUCKLING PROFILE SETTING THE LINER TOP PACKER



- Applied weight to set packer 60 Klbs.

Presenter's notes: The running string was evaluated using a combination of available drill pipe (DP) and heavy weight drill pipe (HWDP) to allow transfer of sufficient weight at the moment of setting the liner top packer. In the final string configuration, helical buckling was avoided along all DP to optimize the likelihood of achieving packer integrity in the first attempt.

OPERATIONS SUMMARY

- Whipstock was set and 152 ft rat hole opened with milling assembly.
- 8 ½ in hole was drilled (LWD tools included in BHA) to 13,983 ft MD
- PU 7 in float equipment and run 7 in liner joints as per tally. (Centralizers were previously installed onshore)
- Hanger system was PU and made up to last liner joint
- Pumped 332 Bbls of mud and convert autofill float collar at surface
- Liner was run to Whipstock top and parameters were taken
- System was RIH and reached TD without issues
- Tagged TD with 15 Klbs and PU 5 ft, circulate 953 Bbls prior to setting the liner

Presenter's notes: The first stage of re-entry operation was to set the 8 ½- in. whipstock and open the casing window at a depth of 8,400 ft MD. The operator was able to drilled a 152- ft rat hole using same milling assembly. Stable torque parameters at different rpm suggested optimum condition of casing window, and checks performed at surface indicated the mill was in gauge. Based on this evidence operator decided to continue with the subsequent 8 ½- in. (Presenter's notes continued on next slide)

(Presenter's notes continued from previous slide)

directional drilling operation. The 8 ½ -in. hole was TD at a depth of 13,983 ft MD, and 7- in. liner components were inspected at the rig following Weatherford quality standards. The guide shoe and autofill float collar were picked up and liner was run. One centralizer per joint had were previously been installed onshore to reduce torque and drag issues and maximize the chances of rotating the liner while cementing as suggested by the engineering software. The hanger system was picked up, and the sub surface release top plug SSR was connected to the liner hanger tailpipe. Then the complete system was made up to the last joint of liner and run in the hole. The autofill float collar was converted and the liner was circulated with 332-bbls to confirm there were no obstructions in the string. It was decided decision to convert the autofill at surface was based on the last available formation pore pressure and fracture gradient. The liner was run to whipstock top, where the string weights were then recorded and 859- bbls were circulated prior to entering the open hole section. The system reached TD without any issues. When total depth was tagged with 15,000 lbs, the liner was picked up 5- ft to setting depth and circulated 953 bbls prior to setting the hanger. The 1.5- in. setting ball was released from the top drive cement head at surface and circulated down to the ball seat. When the ball landed in the seat, pressure was increased to 2300 -psi to initiate the setting of the hanger and the release of the running tool. The string was slacked off and the loss of weight confirmed the liner hanger activation. 40-kips of liner weight was transferred to the hanger slips. The running tool was placed in compression with 20,000 lbs of drill pipe weight and released with 10 right-hand rotations. A torque increase from 6000- ft/lbs to 12,700 -ft/lbs confirmed release, with a second indication being a new up weight. 40,000 lbs of weight was slacked off, and the ball seat was sheared at 3850 -psi, and circulation was re-established. String rotation was commenced and maintained during the cement job. Torque parameters observed were similar to the ones predicted using the T& D software, 10 rpm – 18,000 ft-lb. The cement job was pumped according to per the program, and the drill pipe dart was released and observed to launch on the SSR top plug after 158 bbls were pumped. The, pressure required to release the plug from the liner running tools was 2,240 psi. Displacement was continued until the plug bumped on float collar. The pressure was bled off and checked to confirm shoe track integrity. The string was then picked up 13 ft and the liner top packer was activated. 70,000 lbs of rotating weight was set down on the packer, and a shear was observed at 30-kips. The packer was then tested to 1500 -psi for 5 minutes. The RSM pack-off was retrieved, allowing the drill pipe to be circulated in reverse with the RSM still inside the PBR. After the tools were retrieved, the cement/packer integrity was successfully tested for 4,000 psi for 30 minutes.

OPERATIONS SUMMARY

- 1.5 in setting ball was released from cementing head at surface
- When ball landed at ballseat, increased pressure to 2,300 psi
- Slacked off string and loss of 90 Klbs weight confirmed liner hanger was set
- Placed string in compression with 20 Klbs weight and applied right hand rotation to release R Tool
- Torque indication and loss of up weight confirmed tool was released
- Ball seat was sheared with 3,800 psi
- Performed cementing operation as per program, observed plug bumped on float collar
- PU string and applied 70 Klbs weight to set the liner top packer
- Pressure test packer with 1,500 psi to confirm integrity
- POOH Tools to surface

CONCLUSIONS

Collaboration between Operator and Service Company and their combined resources are key for the installation of liners in ERD wells. The case-study of study well became a reference for future such difficult operations that are currently scheduled to be executed in 2017. Application of the engineering process followed in this well proved to be a useful tool that contributes to the success of the liner run and cementing operations.

The Operator was able to saved 0.5 million USD using the proposed equipment, and the liner operation occurred with no nonproduction time (NPT)., The well was completed as a Frack Pack and currently produces 7,194 BOPD.

THANK YOU!

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