SPE/IADC-221448-MS

Influx Detected and Circulated Out Entirely with MPD on the First Deployment of MPD on Deepwater Rig. A Description of the Well Planning and Execution Process

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This paper was prepared for presentation at the SPE/IADC Managed Pressure Drilling and Underbalanced Operations Conference and Exhibition held in Rio de Janeiro, Brazil, USA, 17 – 18 September, 2024.

Abstract

A well was to be drilled in the Gulf of Mexico that had limited offset data. Several interpretations from geoscience indicated a level of uncertainty that the operator identified as an ideal scenario for the implementation of the Managed Pressure Drilling (MPD) technology in deepwater of Mexico, with the main purpose of enhancing the ability to manage process safety while drilling with great variations of probable geopressures.

A low intensity 5 barrels kick was identified, controlled, and circulated out entirely through the mud gas separator with the MPD system, utilizing the specific procedure, lessons learned, and best practices identified by the operator and contractors previous experience.

The well was concluded successfully, navigating through the narrow operating window without non-productive time, with effective use of early kick and loses detection (EKLD) implemented by the integrated team of service provider and well-trained rig personnel.

This paper will describe all the phases from MPD deployment on the rig, rig crew training, drills for influxes handling, well planning, and execution.

Introduction

The MPD system was installed while the rig was actively drilling. Training of key staff (operator, Rig provider, and MPD provider) was integrated in preparation for the first deep water deployment of MPD in this drillship. MPD operations were carried out successfully with a Below-Tension Ring-Applied Back Pressure (BTR-ABP) MPD system installed on this rig.

This paper will highlight the importance of influx detection when using an MPD, and how well control is enhanced by being able to immediately increase the surface back pressure (SBP) controlling the influx and circulating it out through the MPD system. Two wells were safely drilled using MPD Techniques optimizing the overall drilling operation, including mud weight management, accurate annular pressure control while drilling, on connections, tripping, and mud displacements; the early kick and losses detection capabilities were also a critical component when drilling these two wells, especially during the first well when two kicks were identified, controlled, and circulated out using the MPD system.

This is short description about how the influx detection process works in the MPD System:

- An influx will be detected if flow out is larger than flow in. In addition, the following conditions must also be met within the time frame specified: 1- the rate of change for flow out is larger than rate of change for flow in; 2- flow out increases from the last measured value, and at a rate higher than the flow difference value; 3- stand pipe pressure (SPP) increases more than the minimum limit set.

Drilling Challenges & MPD Drivers

The main driver to use the MPD system to drill this well was to mitigate the risks and potential non-productive time associated with formation pressure uncertainties throughout the well. Additionally, the MPD system was used to add flexibility to the drilling operation by instantly manipulating annular pressures as needed and enhance safety by providing EKLD capabilities while drilling through the target formations.

Planning, Engineering and Design

The Operator contacted the MPD Service Company to provide a proposal to install an MPD System in the drillship while it was actively drilling. This drillship was built in 2015, has a water depth of 12,000ft and a drilling depth of 40,000ft. A Rig Survey was performed at the start of the 4th quarter of 2022. Based on the Rig Survey and experience with a sister ship, it was confirmed that the MPD components were available. A strategy was developed, and a project planner was created to ship the components from worldwide to perform the Factory Acceptance Test (FAT) in the US, and then ship it to Mexico via road / sea.

Equipment

The following are the major components of the MPD System used in this project:

1. Subsea:
    a. MPD Integrated Riser Joint (IRJ): it includes a BTR rotating control device (RCD), a Drillstring Isolation Tool (DSIT) and a flow spool. (including riser crossovers provided by rig contractor).
2. Surface:
    a. Buffer manifold Skid.
    b. Pressure Relief Valve (PRV) system.
    c. Junk Catcher Skid.
    d. MPD Choke Skid.
    e. MPD Detection Skid.
    f. Accumulator skid, 2 × HPUs, surface valves.

Engineering and Design

An MPD Program was designed based on comprehensive hydraulic simulations, including determination of the equivalent mud weight required on static and dynamic conditions, the equivalent circulating density (ECD) / equivalent static density (ESD) management plans and the MPD Operation matrix calculations for the implementation of MPD in this well.

The plan for this well considered three MPD sections; the RCD was going to be installed and MPD available for use on all sections after latching the riser including contingencies. The use of MPD provided the ability to address potential drilling hazards while facilitating the ability remain statically and dynamically overbalanced relative to the pore pressure and the wellbore stability gradient, as well as maintain the bottom hole ECD and ESD below the estimated fracture gradient at all times utilizing a Constant Bottom Hole Pressure (CBHP) MPD technique. Once drilling operations start, and if any of the limits was changed during the implementation phase, the MPD plan was updated based on the simulation results using the latest available data. Also, the plan stated that upon reaching total depth (TD) of each hole section, the well was going to be displaced to statically overbalanced mud density, and the MPD system could be used for stripping operations to offset swab when pulling the bottom hole assembly (BHA) out of the hole. The MPD Program also included an MPD Operations Matrix for each hole section, and it was updated at the start of the section considering the results of the formation integrity test (FIT) / leak off test (LOT) and any changes in mud weight, rheology, drilling parameters, trajectory, among others. Multiple influx simulations were run to demonstrate that while circulating out an influx the following parameters were not exceeded: fracture pressure at the shoe, maximum casing, riser, and surface equipment pressures, and the MGS rated capacity for fluids and gas.

Operations Preparation

The rig was actively drilling while the MPD system was being installed. To ensure proper use of equipment and execution integrated training was done for key personnel. The key personnel were the MPD operators, drillers, Assistant drillers, tool pushers, and operator supervisors. The training took place over 3 days allowing for personnel to interact and understand work practices.

The training sessions covered the MPD principles that were then practiced in simulators. A key focus area was process safety and ensuring well control was well understood. The MPD Operations Matrix and decision tree were reviewed and drilled in the simulators. In addition to standard procedures, problems were also introduced in the simulators to force personnel to identify and work through the contingencies.

Standard and contingency procedures were developed by the MPD contractor with integrated reviews and approvals by the Rig contractor and Operator. These reviews were done with the workers to ensure accurate procedures and understanding.

During the installation and commissioning of the equipment, the rig provider leveraged the experience of their sister rig by deploying competent staff for assistance and transfer best practices. This with all parties collaborating built confidence and comfort with the system quickly.

Overview of the Influx Detection and Control with the MPD System

This section will focus on the influx detected while drilling describing the event including operations, MPD Operations Matrix and the influx detection and control procedure implemented.

After drilling about 200 m at the start of the section with a, a drilling break was observed, noticing a change in torque and weight on bit (WOB); almost immediately, the MPD system detected an influx, which was confirmed by the driller as a 5bbl gain. SBP was increased from 300 psi to 360 psi approx. to control the influx and making sure the parameters were within the limits of the MPD Operations Matrix. When flow out and flow in were balanced out, picked up off bottom and circulated the well until the influx was about 1,000 m from surface. Flow rate was reduced, lined up through MPD to rig MGS and close DSIT to continue circulating influx to surface. Once the influx was out, DSIT was open and lined up ack to the shakers. The surface mud weight (MW) was increased, and drilling was resumed maintaining constant bottom hole pressure. The influx event is shown in Fig. 1 The benefit of circulating out the influx through the MPD system is that it avoids having to transition to the BOPs simplifying and speeding up the well control response.

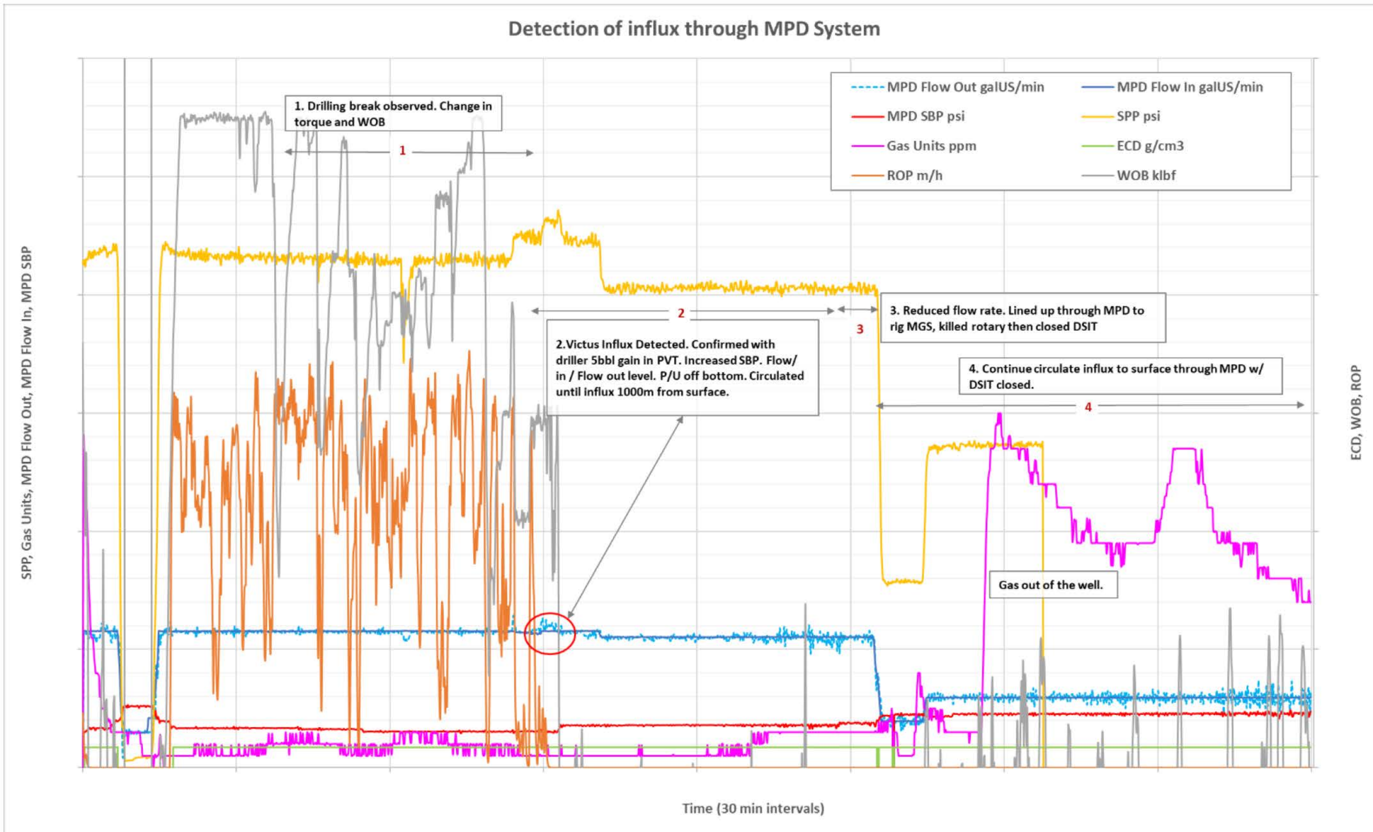

Figure. 1—Influx Event: Detection, Control and Circulation through MPD System.

MPD Operations Matrix

The MPD Operations Matrix establishes the pressure and flow control actions as functions of influx volume and applied SBP per API 92S. The colored areas are determined to allow a safe reaction time to return operations to a green light condition. The red shaded areas indicate well control events. The MPD Operations Matrix is designed using hydraulic simulations such that the pumps can be shut down at any time during the circulation of the influx and constant bottom hole pressure (BHP) can be maintained while not exceeding the surface equipment or downhole pressure limitations (whichever represents the most critical scenario). The effect of cuttings load, thermal profile, and fluid compressibility are considered in the dynamic influx management simulations.

It is very important to ensure that the MPD Operations Matrix is updated and available when drilling with MPD, making sure it is understood by all parties MPD personnel, rig contractor, and operator. It is posted in the drillers cabin. The MPD Operations Matrix is based on the Influx Management Envelope, and it defines the limits at which an influx can be safely circulated out through the MPD system as well as defines when an influx will be handed over to the rig to proceed with conventional well control procedures.

During the influx event that occurred while drilling described in the previous section, the SBPs required to control and circulate out the detected influx were within the limits of the MPD Operations Matrix (Fig. 2); this was confirmed during the operation and facilitated the full influx circulation through the MPD system.

Updated: May 2023		First Exploration Well, XY" Hole Section ***This Matrix Uses the Z" Shoe FIT at X.YZ SG, ECD W.XZ SG, Surface Equipment Pressure Limit 1,200 psi (Matrix Limiting Factor: Weak Point Limit - V.XY SG at DEPTH m TVD)			
MPD Operations Matrix (Surface MW X.YZ SG) (DH MW W.XY SG) (Safety Factor 50 psi)		Surface Pressure Indicator			
		At Planned Drilling Back-pressure (< XXX psi)	At Planned Connection Back-pressure (< YYY psi)	< Back-pressure Limit Circ (XXX psi <SBP < WWW psi) Conn (YYY psi < SBP < ZZZ psi)	≥ Back-pressure Limit*** Circ (SBP > WWW psi) Conn (SBP > ZZZ psi)
Influx Indicator (Pit Gain)	No Influx	1. Continue Drilling 2. Monitor trends and drilling parameters 3. Adjust MW to keep SBP within dynamic limit	1. Continue Connection 2. Monitor trends and drilling parameters 3. Adjust MW to keep SBP within static limit	1. Stop Drilling / Connection 2. Consider increasing MW to reduce surface pressure. 3. Review plan forward.	1. Stop Drilling/Connection 2. Pick up and space out in, prepare to shut in. 3. Evaluate if applicable to perform Assisted Shut-In with MPD to limit additional influx volume. 4. Shut in SSBOP. 5. Evaluate and review next action.
	No Influx - Gas Cut Mud (No Flow Out Reading on Coriolis Meter)	Stop Drilling. Increase back pressure, pump rate, mud weight or a combination of all 3 - Reduce gas cut until recovering Flow out reading prior to resuming operations	Stop Connection / Circulate well. Increase back pressure, pump rate, mud weight or a combination of all 3. Reduce gas cut until recovering Flow out reading prior to resuming operations	1. Stop Drilling / Connection 2. Consider increasing MW to reduce surface pressure. 3. Review plan forward to recover Coriolis reading.	1. Stop Drilling/Connection 2. Pick up and space out in, prepare to shut in. 3. Evaluate if applicable to perform Assisted Shut-In with MPD to limit additional influx volume. 4. Shut in SSBOP. 5. Evaluate and review next action.
	< Planned Limit (Verified Influx < 10 bbl)	1. Apply break and stop drilling. Do not pick off bottom, maintain pump rate and rotary. 2. Increase SBP within operational limits. 3. With influx controlled, driller to pick up off bottom, reduce RPM and space out. MPD to compensate with SBP. 4. Maintain BHP constant while circulating influx out (maintain SPP constant and monitor PWD). 5. When influx at 3,000' from surface, adjust pump rate, stop rotation and compensate with SBP as needed. Close DSIT and Line up returns to MGS. Circulate influx out of wellbore. 6. Review plan forward.	1. Stop Connection. 2. Increase SBP within operational limits. 3. When influx controlled, stab FSOV, M/U Top Drive and space out. Bump floats and check SPP. 4. Start string pumps to circulating rate. Adjust SBP accordingly to maintain BHP constant and Flow in = Flow out. 5. Maintain BHP constant while circulating influx out (maintain SPP constant and monitor PWD). 6. When influx at 3,000' from surface, adjust pump rate, stop rotation and compensate with SBP as needed. Close DSIT and Line up returns to MGS. Circulate influx out of wellbore. 7. Review plan forward.	1. Apply break and stop drilling. Do not pick off bottom, maintain pump rate and rotary. 2. Increase SBP within operational limits. 3. With influx controlled, driller to pick up off bottom, reduce RPM and space out. MPD to compensate with SBP. 4. Maintain BHP constant while circulating influx out (maintain SPP constant and monitor PWD). 5. When influx at 3,000' from surface, adjust pump rate, stop rotation and compensate with SBP as needed. Close DSIT and Line up returns to MGS. Circulate influx out of wellbore. 6. Review plan forward.	1. Stop Drilling/Connection 2. Pick up and space out in, prepare to shut in. 3. Evaluate if applicable to perform Assisted Shut-In with MPD to limit additional influx volume. 4. Shut in SSBOP. 5. Evaluate and review next action.
	≥ Planned Limit (Verified Influx ≥ 10 bbl)	1. Stop Drilling/Connection 2. Pick up and space out in, prepare to shut in. 3. Evaluate if applicable to perform Assisted Shut-In with MPD. 4. Shut in SSBOP. 5. Evaluate and review next action.	1. Stop Connection 2. Pick up and space out in, prepare to shut in. 3. Evaluate if applicable to perform Assisted Shut-In with MPD. 4. Shut in SSBOP. 5. Evaluate and review next action.	1. Stop Drilling/Connection 2. Pick up and space out in, prepare to shut in. 3. Evaluate if applicable to perform Assisted Shut-In with MPD to limit additional influx volume. 4. Shut in SSBOP. 5. Evaluate and review next action.	1. Stop Drilling/Connection 2. Pick up and space out in, prepare to shut in. 3. Evaluate if applicable to perform Assisted Shut-In with MPD to limit additional influx volume. 4. Shut in SSBOP. 5. Evaluate and review next action.

*SBP higher than maximum allowable may result in fracturing the weekest formation and/or exceeding surface equipment pressure rating including maximun pump pressure.
**if during MPD Operations, Surface Pressures approach and/or exceed this limit, proceed as instructed by Matrix and contact Supt./Ops Engineer for plan forward.

Figure. 2—MPD Operations Matrix.

Although not discussed in detail in this paper, the first influx was detected in the previous hole section, and once it was controlled and circulated out through the MPD System, a decision was made to run the contingency liner; one factors accounted for in this decision was that the operating window was very tight if drilling was resumed, and if another influx was encountered, an MPD assisted shut in was required, and most likely, the influx could not be circulated put through the MPD system because the limits of the MPD Operations Matrix would be exceeded.

Influx Detection & Control Procedure in MPD

The influx detection and control procedure when using MPD techniques describes the steps to be taken when an influx is detected by the MPD system in three different scenarios: while drilling, during a connection and swabbing. The procedure while drilling will be briefly discussed here since the influx was detected while drilling in this case.

Based on the influx detection and control procedure, and as illustrated in Fig. 1, these steps were implemented when the influx was detected while drilling:

1. Driller and DSV were informed, and they also confirmed a 5bblg gain in PVT.
2. SBP was increased to control and stop influx, notifying driller of the adjustments. SBP was always within the limits of the MPD Operations Matrix.
3. Once Flow In and Flow Out were balanced out, this confirmed the influx was controlled. Main parameters were recorded including initial SPP, initial SBP to control influx, influx volume and pressure while drilling (PWD) bottom hole (BH) ECD.
4. Picked up off bottom, reducing rotation and spacing out. MPD control system was activated to make sure SBP was going to be adjusted to prevent a drop in BH ECD due to loss of friction when reducing rotation.
5. Since the initial SBP and Influx volume were within the orange zone of the MPD Operations Matrix, the influx was circulated out maintaining BH ECD constant by keeping SPP constant using the MPD system.

6. Once the top of the influx was about 1,000 m from surface, returns were lined up through mud gas separator (MGS), stopping rotation and the DSIT was closed. The influx was then circulated out of the well.
7. Returns were lined up back to the rig's flowline once it was confirmed the influx was completely out of the well. The DSIT was open.
8. Operations continued weighting up the drilling fluid density, to resume drilling with a new target BH ECD.

It is also important to note that the rig contractor and operator have the right to shut the well in and circulate the influx out using conventional well control procedures at any point when detecting and/or controlling an influx.

This is the decision tree approved by the rig contractor (Fig. 3), and the flow paths to circulate the influx out are shown in the figures below; Fig. 4 shows when circulating the influx out and the top of influx is below 1000m (~3000ft) from surface, and Fig. 5, shows when influx is within 1000 m (3000ft) from surface and returns are diverted to MGS. Refer to IADC/SPE -208717-MS for additional details on Influx management decision tree.

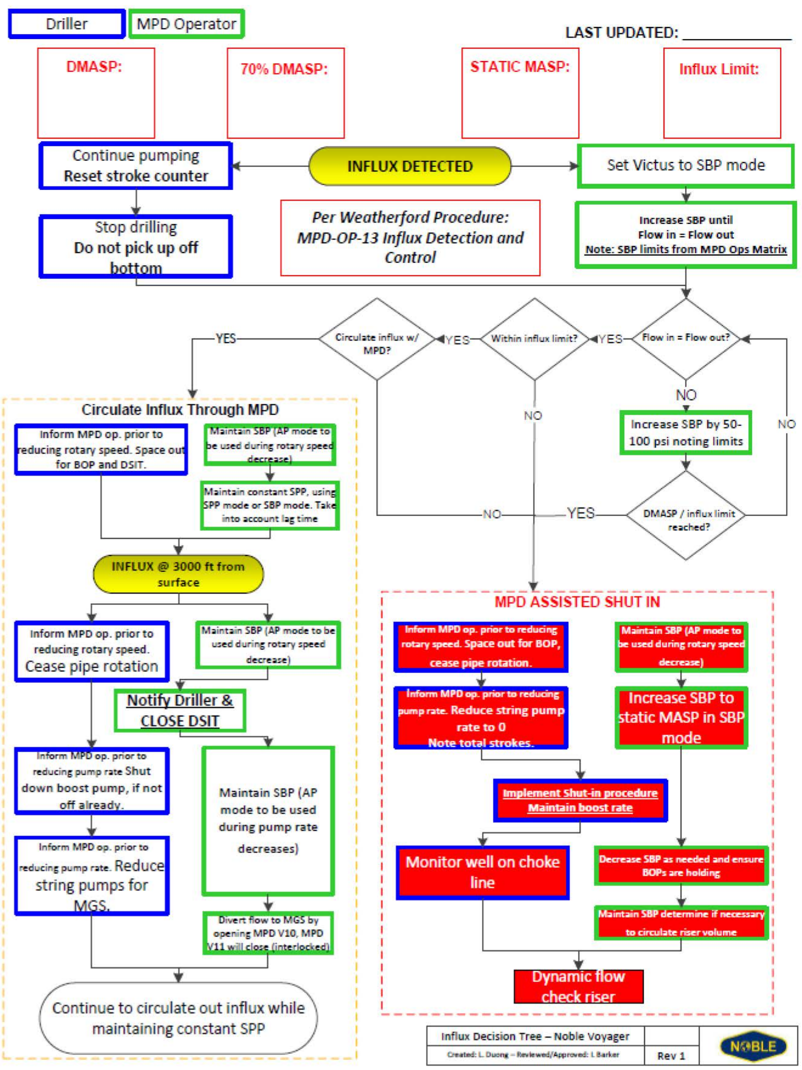

Figure. 3—Influx Detection Decision Tree.

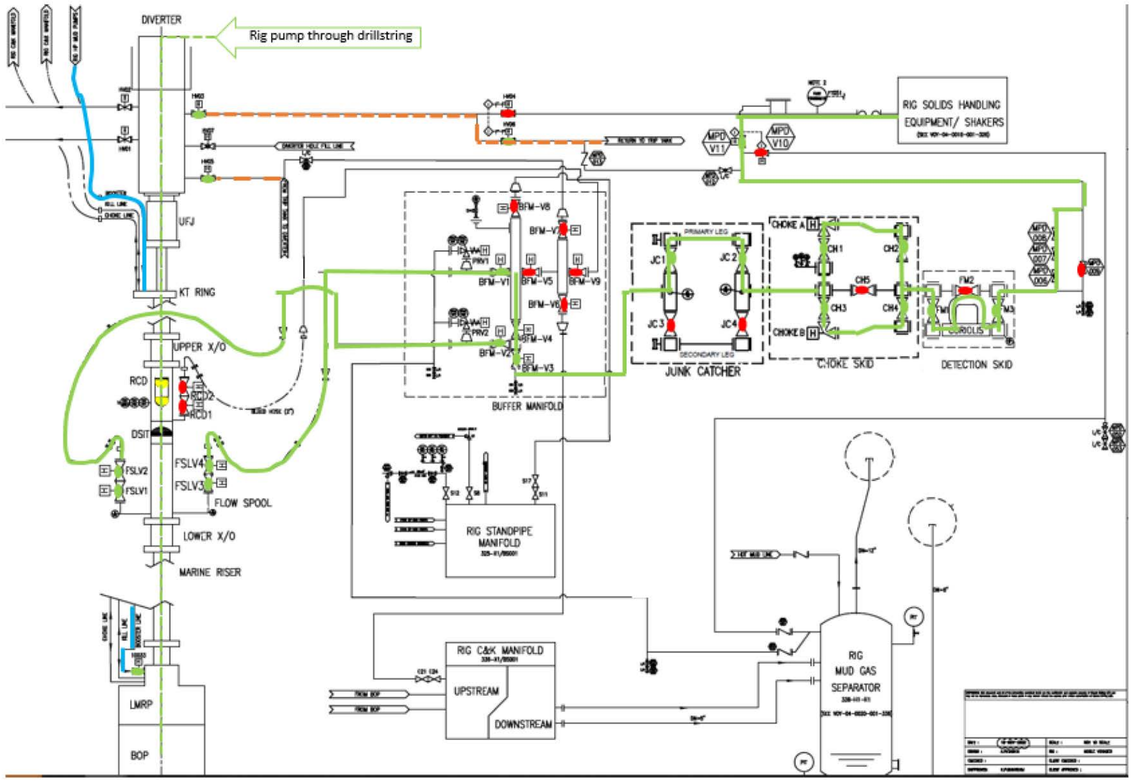

Figure. 4—Flow Path when circulating the influx out and the top of influx is below 1000m (~3000ft) from surface.

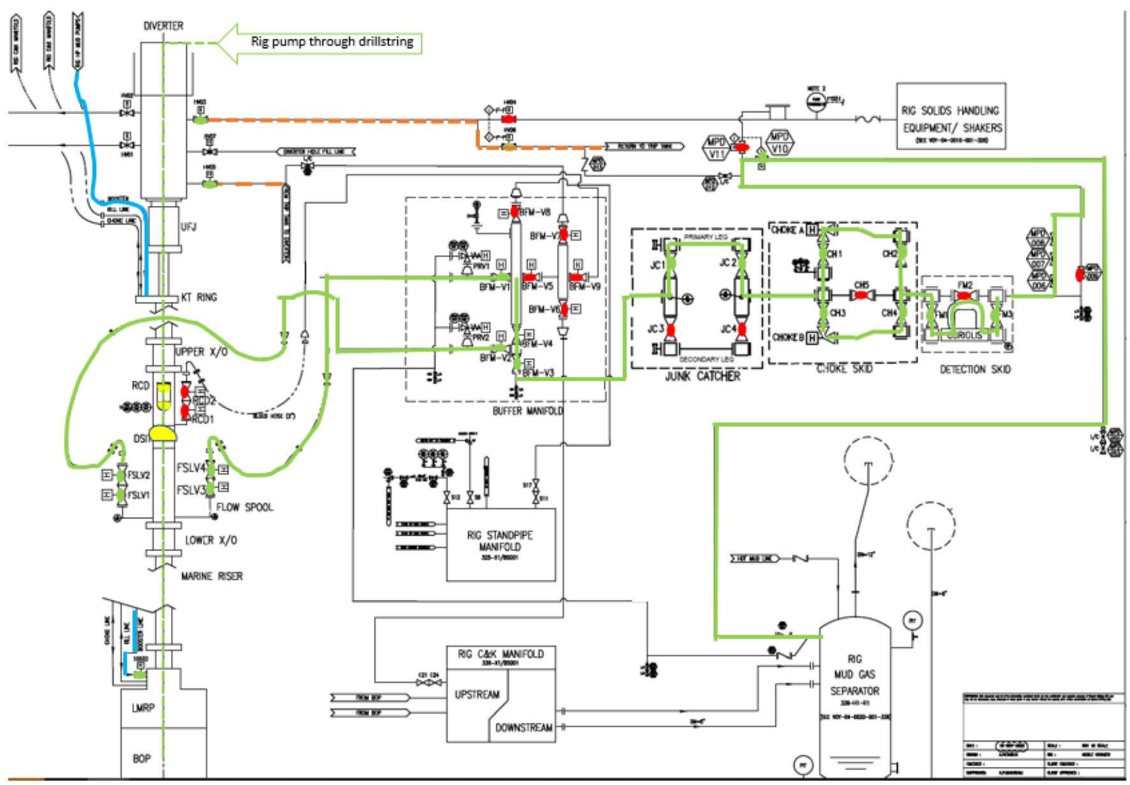

Figure. 5—Flow Path when influx is within 3000ft from surface and returns are diverted to MGS.

Results & Lessons Learned

The use of the MPD system and procedures contributed to optimize the drilling operation, mud weight management and overall operational safety providing EKLD capabilities and accurate annular pressure control while drilling, connections, tripping and CBHP displacements. The list below includes the main highlights of the operation:

- Effective CBHP MPD techniques applied establishing a primary barrier with a MW + SBP in all hole sections and effectively reach TD in four different sections.
- Required SBP was adjusted and maintaining constant to minimize borehole stress fluctuations and to react to borehole stability issues.
- EKLD capabilities provided confidence to drill through well targets while precisely monitoring flow out of the well; two small-detected/controlled influxes were managed and circulated out with MPD.
- SBP was adjusted during rollovers maintaining the target ECD/EMW and ensuring well remained overbalanced.
- Integrated training enabled the first MPD deployment on this drillship safely drilling the four different sections, demonstrating the added value of having the MPD system especially when an influx is encountered while drilling, not only enhancing safety but optimizing the operation.

Acknowledgements

The authors want to thank Shell, Noble and Weatherford for allowing the publication of this paper including all personnel involved in this project.

Nomenclature

ABP - applied back pressure
BH - bottom hole
BHA - bottom hole assembly
BHP - bottom hole pressure
BTR - below-tension ring
CBHP - constant bottom hole pressure
DSIT - dual string isolation tool
ECD - equivalent circulating density
EKLD - early kick and loses detection
ESD - equivalent static density
FAT - factory acceptance test
FIT - formation integrity test
HPU - hydraulic power unit
IRJ - integrated riser joint
LOT - leak off test
MD - measured depth
MGS - mud gas separator
MPD - managed pressure drilling
MW - mud weight
PRV - pressure relief valve
PWD - pressure while drilling
RCD - rotating control device
SBP - surface back pressure

SPP - stand pipe pressure
TD - total depth
WOB - weight on bit