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Recent MPD Application in Offshore Mahakam Depleted Formation – A Lesson Learned

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Abstract. Oil and gas wells are increasingly challenging to drill. The challenge is present when drilling in a field that has been produced for a long time which has reservoir pressure depletion. The depleted reservoir significantly changes formation properties when compared to a green reservoir including pore pressure and fracture pressure as the drilling window gets narrower. This condition have meaning the pressure difference between static and dynamic conditions in the well is small, which gives limitations on equivalent circulating density.

One of the techniques to overcome these problems is the application of Weatherford's Managed Pressure Drilling (MPD) technology. MPD is a drilling method to mitigate drilling hazards by building a closed drilling fluid return system. The closed system was established by utilizing a Rotating Control Device (RCD) and an Automated MPD Choke Manifold. Applying surface back pressure to maintain downhole pressure prevents fluids from entering the wellbore and keeps wellbore pressure low enough so as not to damage the formation.

Multiple simulations with Weatherford software were carried out by using different mud densities and the sensitivity analysis as the planned drilling parameters. MPD will apply 150 psi of Surface Back Pressure to maintain ECD during connection to meet safety rules and mitigate the hazard of high pore pressure at certain formation depths.

This paper presents a case study with the main objectives are engineering preparation overview, equipment utilization, actual operational side and detailed techniques of Managed Pressure Drilling mode executed. As will be explained further from this paper, target depth was successfully and safely drilled by utilizing MPD technique.

Keyword: Depleted Formation ; Equivalent Circulating Density Management ; Close-loop drilling

1 Introduction

The existing oil and gas reservoirs are produced continuously every day for a long time to meet the energy needs of the society. The higher cost that must be spent on exploration activities with the low possibility of obtaining new resources in a short period of time made the option of increasing oil production through exploration is not an economical option.

Massive exploitation without being followed by the discovery of new reserves results in energy needs depending on the proven reserves that were previously produced so that a quite high decline rate occurs in a reservoir due to the number of new drilling wells in the same area to boost hydrocarbon production to meet the annual lifting target.

Drilling on existing reservoir is preferred for increasing oil and gas recovery. For several fields that have been produced for a long time, drilling is a challenge due to narrow operational drilling window. This is effect of the long term production and especially related to reduced formation pressure

The operational drilling window is determined by disparity between the maximum pore pressure gradient and the lowest fracture gradient. The operational drilling window have varies value in every depth of the wellbore. Wellbore stability also take into account in determining the drilling window. The reduction reservoir pressure will lead to a reduction in pore pressure and consequently also a reduction on the fracture gradient.

Conventional drilling use mud weight and annulus friction lose pressure on maintaining a pressure in the annulus to prevent formation fluid from entering the borehole and avoid fracturing of the formation. Those variables are not effective and not easy to be manipulated in short time. Drilling a formation with narrow window is another challenge. Failure on maintaining bottom hole pressure can lead to NPT to handle unwanted situation such as loss and kick. MPD is a technique to drill safely that enable to manipulate bottom hole pressure by adjusting surface back pressure. Bottom hole pressure will be “walk the line” between fracture pressure and pore pressure throughout the well consistently.

2 Managed Pressure Drilling (MPD)

IADC defines MPD is as an adaptive drilling process used to precisely control the annular pressure profile throughout the wellbore. In order to accurately maintain the annular pressure profile to avoid the well from influx entering the wellbore. MPD Equipment create closed drilling fluid return system to control annular pressure profile through adding surface back pressure (SBP) by adjusting opening MPD choke percentage. In short, MPD control the bottom hole pressure easily. Application of MPD gives many advantage for safer drilling operation and enable unconventional drilling techniques such Constant Bottom Hole Pressure (CBHP) , Pressuried Mud Cap Drilling and Dual Gradient MPD.
In conventional drilling, bottom hole pressure is controlled by of hydrostatic pressure of the drilling mud and annular friction. While managed pressure drilling (MPD) uses a combination of surface back pressure

and annular friction lose pressure and accumulation hydrostatic pressure from mud weight to balance the formation pressure. The calculation of bottom hole pressure with MPD has one additional component, SBP (P_{sb}) , as described in the following formula :

$$BHP_{static} = P_{hyd} + P_{sb}$$
$$BHP_{dynamic} = P_{hyd} + P_{af} + P_{sb}$$

- BHP_{static} = Bottom Hole Pressure while no circulation
- $BHP_{dynamic}$ = Bottom Hole Pressure while circulation
- P_{hyd} = Hydrostatic Pressure
- P_{af} = Annular Friction Pressure
- P_{sb} = Surface Back Pressure

3 MPD Equipment

Rotating Control Device (RCD)

Figure 1. Rotating Control Device Model 7875

IADC define RCD as “A drill through device with a rotating seal that contacts and seals against the drill string (drill pipe, casing, kelly, etc.) for the purpose of controlling the pressure or fluid flow to surface.”

RCD is equipment installed above annular BOP or riser depend on type of BOP installed on the well. RCD will seal annulus around drill pipe while drilling to create closed and pressurized system. RCD is consist three outlets, two bigger outlet for return flow from well and emergency fill up line and one small outlet for trip tank, bleed off and injection line.

The major function of RCD is for creating non atmosphere exposed return flow by dual sealing element installed inside the RCD Bearing. RCD enable divert return flow directly so that rig floor isolated from induced hazardous gas from downhole allowing drilling operation continue with safe.

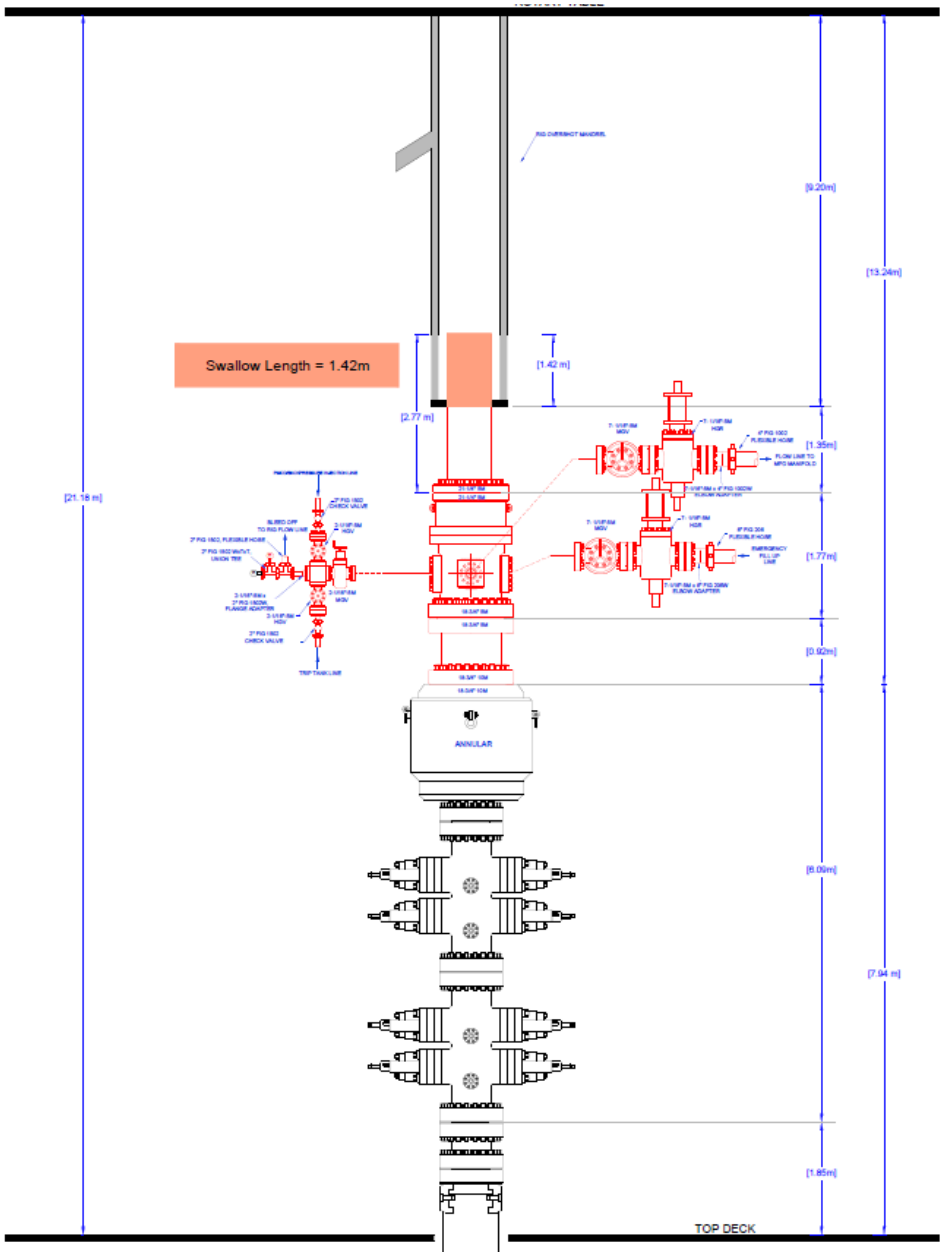

Figure 2. BOP Stack with RCD

MPD Choke Manifold

MPD Choke Manifold is a system that has two main components. First component is choke for applying surface back pressure in closed loop drilling. Second component is Flow Meter to measure precisely of return flow such as flow out rate, mud density and mud temperature. MPD Choke Manifold has an algorithm by analyzing data from those main components to identify influxes and losses in seconds on a real time basis.

MPD Choke Manifold has 2 chokes installed , back up choke is prepared in case of operated choke is failure or plugged by large cutting observed while drilling. Surface back pressure value is exerted by controlling the choke through computerized system , the choke will adjust surface back pressure as required additional pressure to achieve desired bottom hole pressure.

Figure 3. MPD Choke Manifold

4 MPD Operation

Pre-Job Study

Pre-Job study were carried out to perform hydraulic modelling simulation to select get optimum drilling parameters which could maximize the use of MPD technology. The well have a major challenge of narrow drillling pressure window. The formation is clastic reservoir consisting of sandstone which is predicted to be depleted where the fracture gradient might be weaker with

high potential to induce losses. To ensure safety, Equivalent Circulating Density (ECD) of 0.42 ppg overbalance to the pore pressure is required during both dynamic and static conditions.

The method used for the evaluation is by plot the PP and FP data from each well in 8.5" hole section respectively. From overlaying the data, the drilling window will be generated from the highest value of PP line and the lowest value of FP line. Hence a flow modeling will be conducted to address the drilling window generated and ascertain the MPD strategy to be implemented for each hole sections.

Based on MPD sensitivity analysis, Predicted maximum pore pressure is 13.49 ppg and the lowest fracture pressure is 14.74 ppg. The 13.66 ppg Mud Weight is the selected Mud Weight for drilling to TD because it is statistically overbalanced mud weight. It is noticeable by using 13.66 ppg Mud Weight will be required as amount of 150psi Surface Back Pressure for static condition at TD to generate ECD 0.42 ppg above maximum Pore Pressure.

Operation

Mud Weight in the wellbore started with 10.83 ppg. Mud weight was gradually increased until the depth that predicted depleted pressure occurred. On that depth until TD , mud weight increased to 13.66 ppg and 150 psi surface back pressure will be applied during connection. Observed the equivalent circulationg density during dynamic condition without applying surface back pressure is in range 14.42-14.57 ppg. During drilling with MPD, drilling parameters are monitored all the time especially when connection. In the connection operation, mud pumps will shut off and annular friction loss will gone, called static condition. In this condition , bottom hole pressure should be added by surface back pressure. The basic principle of applying surface back pressure is diverting flow through the MPD Choke from back pressure pump. The MPD choke will adjust the choke to create pressure across the surface line that transferred to the annulus.

Data Acquistion Unit stored all parameter from installed sensor. The drilling parameter such as ECD , Flow In , Flow Out , WOB , ROP etc. are recorded every second. MPD connection example is demonstrated in Figure 3.

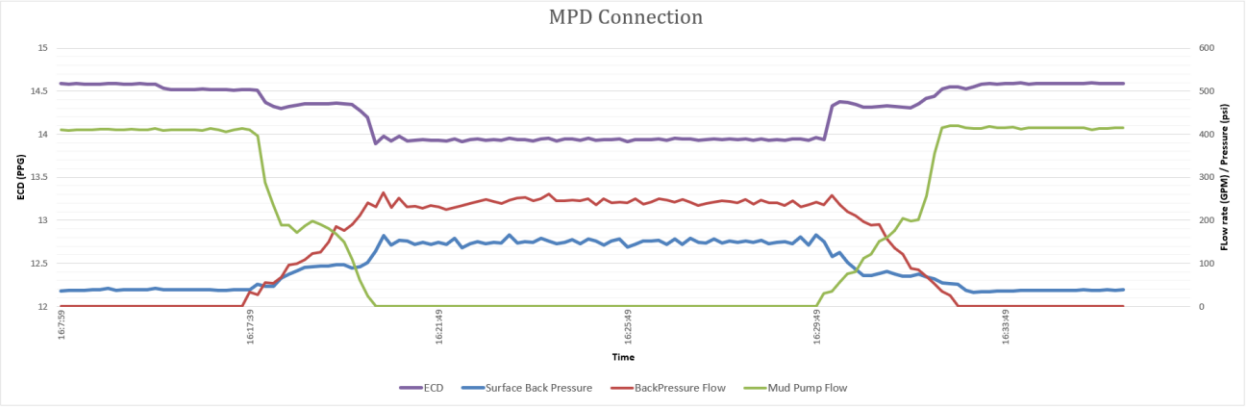

Figure 3. MPD Connection

The graph shows how MPD Connection made during drilling. The ECD of well is maintained at 13.91 – 13.95 ppg during static condition , it is 0.42 ppg above maximum pore pressure 13.49 ppg as per hydarulic modeling simulation result. In the first step of connection , Mud Pump flow will reduce gradually and automatically annulus friction lose in the will reduce as well. While on the same time backpressure pump increased gradually to exert surface back pressure to compensate the reduction of annulus friction lose. Flow from backpressure pump will across the MPD Choke Manifold. The aperture of Choke on MPD Choke will adjust automatically until get the desire value of surface back pressure.

Until mud pumps shut off completely and surface back pressure 150 psi is miantained , the drilling connection is enable to perform while keeping ECD 13.91 ppg. Once connection was made , Mud Pump increase and Backpressure pump reduce by stages simulatenously. The Drilling activity enable to continue with safe while MPD monitoring the drilling parameter to TD

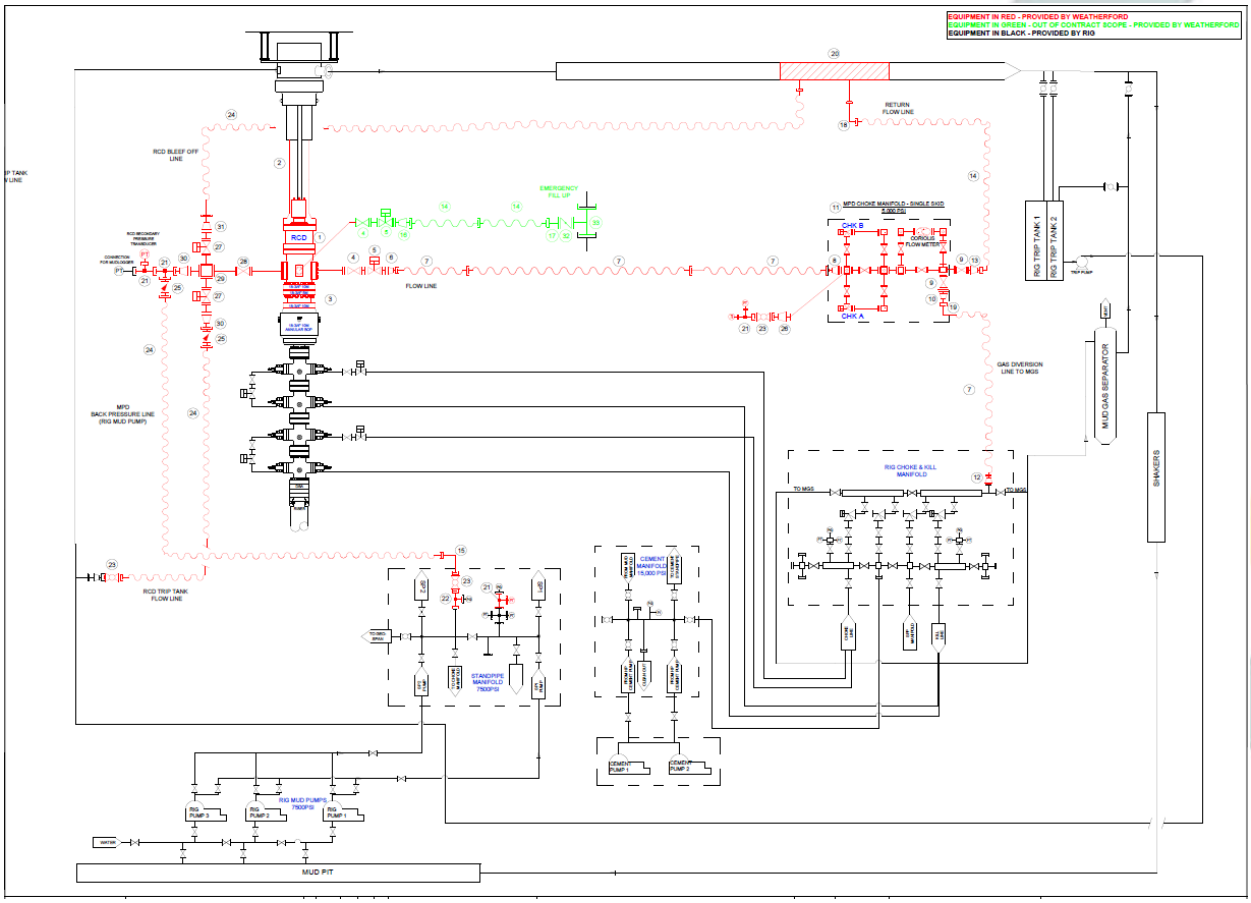

Figure 4. Piping and Instrumentation Diagram

5 Conclusion

Drilling through depleted formation is a challenge. The pore pressure and fracture pressure have vary value throughout the well. Heterogeneous formation resulting difference of degree of depletion throughout that will lead to narrow pressure window. This means the pressure difference between static and dynamic conditions in the well is tiny, which gives strict limitations on the equivalent circulating density.

Utilization of MPD in Mahakam Offshore field exerting drilling operation performed safely and success without any influx induce to wellbore. The reservoir target depth was successfully and safely drilled by utilizing MPD technique. Maintaining the equivalent circulating density at all the time especially when during connection by softly diverting the drill string flow during the connection to MPD pressure control for governing annulus pressure using an automated MPD choke is key. Drilling hazard related to narrow pressure window significantly reduce.

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