Pressurized Mud Cap Drilling Drastically Reduces Non-Productive Time in Soka Field, South Sumatera
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Abstract

The wells in Soka field in onshore South Sumatera, Indonesia are drilled through a fractured carbonate reservoir (Baturaja formation) where severe circulation losses and kicks while drilling are commonplace. Drilling in one of the wells in the field, Soka 2006-1 was suspended for two years due to total losses combined with gas kicks. Almost two months were spent after total loss of circulation was experienced trying to control and drill Soka 2006-1 to no avail. The well was plugged and abandoned on July 2006 with the intention of returning to it and finishing it once an appropriate approach can be developed to address the drilling issues that were encountered.

The approach chosen for re-entry operations in Soka 2006-1 was a managed pressure drilling (MPD) technique called Pressurized Mud Cap Drilling (PMCD). A rotating control device (RCD) is the main component used in PMCD operations, the objective of which is to eliminate the non-productive time (NPT) associated with drilling when loss – kick scenarios occur.

A new well, Soka 2006-6, was also planned to be drilled in the area using the same technique, but with the addition of a downhole isolation valve that was to be installed and cemented together with the last casing string above the section where losses are expected. The casing valve allows for safer and faster tripping operations and more importantly, can serve as a downhole lubricator that will help facilitate the running of the completion assembly in PMCD mode. A casing valve could not be installed in Soka 2006-1 as the casing string above the loss zone was already in place.

This paper describes the planning and implementation of the PMCD technique in both the Soka 2006-1 and 2006-6 wells and discusses the results of the drilling operations. Furthermore, it explains how drilling in PMCD mode allowed re-entry operations in Soka 2006-1 to reach the target depth in less than a day after total loss of circulation was again experienced, and how the completion assembly was run and cemented in PMCD mode.

Introduction

The Soka Field is located on the Musi Platform of the South Sumatera Basin. Figure 1 shows the stratigraphy of the South Sumatera Basin. One of the wells to be drilled in the Soka field is Soka 2006-6. This well is proposed to reach the oil column at the Baturaja formation. The well is designed to penetrate 681 feet of Baturaja limestone. Re-entry operations on another well, Soka D7 or 2006-1, is also planned to penetrate the Baturaja limestone by 371 feet, 95 feet of which consists of the oil column. Re-entry of Soka 2006-1 is intended to complete drilling operations on the well, which have been suspended for two years due to total circulation losses and accompanying gas kicks encountered while drilling in the upper section of the Baturaja Formation. Around one and a half months were spent after total loss of circulation was experienced trying to control and drill the original Soka 2006-1 well to no avail. It was plugged and abandoned on July 2006 with the intention of returning to it and finishing it once an appropriate approach was developed to address the drilling issues that were encountered. The utilization of the current Soka 2006-1 borehole for re-entry is intended to minimize drilling cost, since risk for drilling in Baturaja formation in this cluster is similar for other trajectories.
Medco E&P Indonesia, who operates the Soka field, planned to drill and complete Soka 2006-1 and Soka 2006-6 as producing wells. Both wells will require drilling an 8-1/2” hole to the top of the Baturaja formation and the final section will be a 6” hole that will be completed with a 4-1/2” liner for both wells. As a precaution against problems previously encountered while drilling Soka 2006-1, the productive interval is intended to be drilled using a managed pressure drilling (MPD) technique. The idea of MPD is to use a closed and pressurizable mud-return system to control bottomhole pressure in a way that eliminates many of the drilling and wellbore stability issues that are inherent to conventional drilling.

A downhole isolation valve (DIV) was also planned for installation in Soka 2006-6 to provide a downhole barrier that prevents pressure from reaching the surface, should severe losses and subsequent kicks be experienced. The utilization of a DIV increases the level of safety of the PMCD operation and avoids the need to snub or kill the well for tripping operations. The well schematic for Soka 2006-6 provided in Figure 2 shows the position of the DIV in the casing string. To accommodate the DIV and increase the chances of its successful installation in open hole, the depth from 1,500 to 3,200 ft was to be drilled using an 8-1/2” x 9-7/8” bi-center bit, providing a larger hole in which the 7” full-bore DIV was to be installed with the casing. A DIV could not be installed in Soka 2006-1, as 7” casing had already been run. The production hole was drilled using a 6” rock bit and cased with 4-1/2” liner, which contained annular packers. One packer was planned to be set slightly below the gas – oil contact to isolate gas from the oil zone. This acts as an emergency zonal isolation if the cementing job fails due to lost circulation. Managed Pressure Drilling would be applied in drilling to Target Depth (TD). The detailed well schematic for Soka 2006-1 is shown in Figure 3. An 800 HP truck-mounted rig was used to drill both the Soka 2006-1 and 2006-6 wells.

Managed Pressure Drilling (MPD) Systems

Managed pressure drilling (MPD) is defined by the International Association of Drilling Contractors (IADC) as “an adaptive drilling process used to more precisely control the annular pressure profile throughout the wellbore.” The objectives of MPD are “to ascertain the downhole pressure environment limits and to manage the annular hydraulic pressure profile accordingly.” Pressurized mud cap drilling (PMCD), one of the variants of MPD technology, is intended to eliminate the non-productive time (NPT) that normally results while drilling fractured carbonate formations due to the time wasted attempting to cure circulation losses. PMCD is seen as an effective alternative to time-consuming, conventional “loss, kick, cure” cycle operations. It takes advantage of the natural ability of the fractured formation to swallow the drilling fluid and the drilled cuttings. Figure 4 provides the surface equipment installed to put the PMCD system in place.

Rather than attempting to cure these losses, PMCD works with and drills through the loss zones. It involves both an annular and a sacrificial fluid system. The annular fluid is maintained in the annulus and its density should be slightly less than the equivalent pore pressure at the top of the first fracture encountered. It will be injected into the annulus while drilling to push migrating gas back into the fractures. The sacrificial fluid system, commonly composed of freshwater, will be pumped down the drill string during PMCD operations. High viscosity (hi-vis) fluid pills will also be used to make sweeps before every connection, to help ensure that the hole is properly cleaned while on PMCD mode.

The method involves pumping at a pre-determined rate down the drill pipe with sacrificial fluid and pumping down the annulus with annular fluid to stop any gas from migrating up the annulus. The pump pressure and the back pressure on the annulus will ensure that the system is maintained and that the well is at all times full of fluid. Additional pumps from the cementing unit might be required if the rig pumps are insufficient for handling the volume and the flow rate of all the drilling fluids needed.

The annular velocity at which the annular fluid is pumped is designed to force any formation gas back down the annulus. The speed of gas migration is a function of the density difference between the fluid and the gas and to minimize the migration speed it is important that the annulus fluid is as low weight as possible. Increased viscosity is sometimes deemed as an effective barrier to gas migration.

Drilling operations are conducted normally until losses are experienced. Minor losses are cured conventionally with lost circulation material (LCM), but when losses reach unmanageable levels, operations change to PMCD. PMCD differs from normal mud cap in that the annulus fluid column is weighted to deliver a hydrostatic pressure slightly below the reservoir pressure. This results in a small back-pressure being held by a rotating control device (RCD) at the surface. This back-pressure can be monitored to record any changes in the reservoir pressure or to detect the migration of gas upwards through the annular fluid.

Historically, the two main considerations when doing pressurized mud cap drilling are that it requires highly conductive formation exposure and a large fluid supply. Highly conductive formation exposure means that the formation must be able to accept the amount of fluids and cuttings that are pumped into it during PMCD. There must therefore be extensively fractured formations in the reservoir being drilled for PMCD to be feasible. A large fluid supply is required during PMCD since a
The first of these two criteria are met by the Soka 2006-6 and 2006-1 wells. The wells to be drilled are located in South Sumatera, where previous wells drilled have proven the fact that partial or total loss of circulation normally takes place when Baturaja is penetrated. For fluid supply, extensive preparations will have to be made for a sufficient amount of water for PMCD operations. A river, which was located three kilometers away from the rig site, was used as a source of sacrificial fluid and a number of water trucks were on standby at the rig site for additional water if and when needed.

Soka 2006-6 and 2006-1 MPD operations are classified under the IADC Well Classification System for Underbalanced Operations (UBO) and MPD as 4 – C – 5. This means that the risk level involved is pegged at Level 4, which denotes that hydrocarbon-bearing formation is being drilled. It also means that the maximum anticipated shut-in pressure is less than the UBO/MPD equipment operating pressure rating and that catastrophic equipment failure will likely have immediate serious consequences. “C” in the code means that the application category of the operation is mud cap drilling. IADC defines category “C” as “drilling with a variable length annular fluid column which is maintained above a formation that is taking injected fluid and drilled cuttings without returns to surface”. Lastly, “5” in the code stands for the information that the fluid system used for drilling is of a single liquid phase, as air and nitrogen injection is not planned and is not needed in this particular application.

The MPD surface equipment involved a rotating head, complete with a 7-1/16” flowline connection, a 2-1/16” auxiliary connection and a 13-5/8” bottom flange connection for mounting on the top of annular BOP, valves and rotating head accessory items. The rotating head used had a rotating / working pressure rating of 1,000 psi and a static pressure rating of 1,500 psi. Valves and pipework, consisting of a 5-1/8” 5,000 psi full bore manual and hydraulically operated flowline valves (one of each), plus 2-1/16” hydraulically operated valves (2 of each) for the trip tank and bleed-off/equalization lines, along with pipework, elbows, connections and fittings required to complete the PMCD equipment spread were also provided. Two drillstring floats were also utilized to prevent any backflow up the drillstring when making connections, as back-pressure is applied to the annulus to prevent influx during connections.

The downhole isolation valve (DIV) is a surface controllable downhole valve system that is run as an integral part of the casing string to increase safety and eliminate snubbing during the drilling operation. It is used whenever the drill string is retrieved from the well or deployed into the well while surface pressure exists. When it is necessary to pull the drill string out of the hole, the drill string is tripped out until the bit is above the valve. The valve is then closed. Pressure above the valve is bled off and the drill string can be safely removed. The drill string can then be tripped back into the well until the bit is just above the DIV. The pressure in the well is equalized and the DIV is then reopened, and the drill string is run to continue the drilling operation. Operation of the valve is accomplished through the application of pressure through its control lines, for opening or closing, respectively.

The PMCD system for the Soka 2006-6 and 2006-1 well was set up in stages. The RCD, valves and pipework needed for PMCD was installed before the 6” hole section was drilled, and was used while drilling this section to divert the flow of returns. The PMCD system was not used immediately, as the 6” section was drilled conventionally until fractures / mud losses were encountered. The decision to start MPD was determined based on the severity of losses encountered and the results of an injectivity test.

**Soka PMCD Results**

For Soka 2006-6, the DIV and RCD were installed before drilling of the reservoir section started. The DDV installation was of the permanent type and it was successfully installed at 2780 ft. The MPD + DIV equipment were not utilized to the fullest during the drilling of the 6” section of the hole as the circulation losses and gas kicks encountered while drilling the reservoir were not severe in nature. The extensive planning, training and on-site operations performed on this well however served as a strong foundation for the subsequent Soka 2006-1 PMCD operation.

In Soka 2006-1, a 6” bit was run to penetrate the two (2) cement plugs that were previously put in place when the well was temporarily abandoned. Once the lower plug was penetrated, severe and total circulation losses were suddenly encountered and gas migration up the annulus immediately followed. The decision was made to switch to PMCD mode. The first step taken was to close the 5-1/8” HCR valve on the RCD flowline, followed by the continuous pumping of 2 – 2.5 barrels per minute (bpm) of viscous mud through the annulus using the cement pump. When the HCR was closed, annulus pressure was 300 psi, but annulus pumping decreased this to 80 psi. Freshwater was injected thru the string at a rate of 250 gallons per minute (gpm). Drilling in PMCD mode was stabilized by managing casing pressure between the range of 80 psi (low) and 150 psi (high) and continuing to wash down to bottom. A high viscosity pill (10 barrels) was also pumped after every connection and drilling continued with an average rate of penetration of 40 - 80 ft/hr and a torque of 1000 - 1100 klbs.
Standpipe pressure (SPP) was maintained at 320 – 360 psi. Once a measured depth of 3740 ft was reached, ROP gradually slowed down to a range of 7 to 21 ft/hr, which indicated that the bit had penetrated basement rock formation, and this continued until target depth (TD) was reached at 3831 ft. Figure 5 shows the standpipe and casing pressure parameters during the PMCD operation.

After TD was reached, a 20-barrel lost circulation material (LCM) pill was pumped to attempt to plug the zone causing circulation losses as it was assumed that the fractures have already been filled up with cuttings generated during the drilling phase. After it was spotted, the LCM was allowed to soak using freshwater but casing pressure increased again to 300 psi. Another attempt to spot LCM was made but there were no indications seen that the LCM was taking effect. Because of this, the decision was made to inject a bentonite diesel oil (BDO) plug inside 7” casing to attempt to seal off losses and prevent gas kicks, thereby allowing the tripping operation to be performed safely. Three BDO plugging attempts at 20 barrels each were made. The third attempt successfully isolated the casing from the gas coming from the open hole, preventing it from migrating to the surface. This was confirmed by zero casing pressure at surface.

Once the wellbore was sealed, a 4-1/2” liner with a reamer shoe and two annular packers was run. The BDO plug was tagged while washing and reaming down to the 9-5/8” casing shoe. Circulation was normal while running the liner until a depth of 3330 ft was reached and total circulation losses were again experienced. The decision was made to continue running the liner using PMCD mode. Annular injection of 2 - 3 bpm was used to control gas migration as indicated by a casing pressure read-out of 0 - 50 psi at surface, allowing the liner to be run. However, problems were subsequently encountered with the annular packers. Despite of this, the liner was still successfully installed and cemented in PMCD mode.

Conclusions

The Pressurized Mud Cap Drilling (PMCD) technique was used to drill wells in the Soka field in order to provide a safe, practical and effective means of continuing drilling operations when total circulation losses and positive casing pressure occur. In Soka 2006-1, this was especially important given the fact that PMCD had to penetrate from 3331 to 3831 ft (500 ft), where total lost circulation and kicks were encountered. There was no non-productive time (NPT) associated with PMCD, as there was sufficient hole cleaning and good ROP performance during the drilling of the reservoir section of the re-entry operation. This performance, which only required 19 hours and was made possible with MPD / PMCD methods, is in stark contrast to the one and a half months previously spent to attempt to control and drill the well to TD using conventional methods that ended up with the well getting abandoned for two years, and clearly established the economic and operational viability and applicability of PMCD methods when productive sections with high total loss circulation risks are drilled.

Acknowledgement

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References


Figure 1. Stratigraphy of South Sumatera Basin

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<tr>
<th>SYSTEM</th>
<th>SERIES</th>
<th>TECTONIC SUMMARY</th>
<th>TYPE STRATIGRAPHIC COLUMN</th>
<th>SOURCE ROCK</th>
<th>RESERVOIR ROCK</th>
<th>SEAL</th>
<th>TRAP</th>
<th>TIME OF OIL GENERATION</th>
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Figure 2. Soka 2006 – 6 Well Schematic

- 13-3/8" Casing, K-55, 54.5-ppf, at 258-ft MD
- 2-7/8" Prod Tubing
- 9-5/8" Casing, K-55, 36-ppf, at 1,890-ft MD
- DIV at 2,780-ft MD
- 7" Casing, K-55, 23-ppf, at 3,315-ft MD
- TOL 4-1/2" x 7" at 3,100-ft MD
- 4-1/2" Casing, P-110, 15.1-ppf, at 3,861-ft MD
Figure 3. Soka 2006 – 1  Well Schematic

- **2006**
  - 13-3/8” Casing, K-55, 54.5-ppf, at 225-ft MD
  - 9-5/8” Casing, K-55, 36-ppf, at 2,002-ft MD
  - 13-3/8” Casing, K-55, 54.5-ppf, at 225-ft MD
  - 8.5” Original Hole at 3,397 ft MD
  - 2-7/8” Tubing
  - KOP Sidetrack at 2,123 ft MD
  - Cement Plug I: 2,500 ft MD – 2,700 ft MD
  - Cement Plug II: 1,900 ft MD – 2,100 ft MD

- **2008**
  - 13-3/8” Casing, K-55, 54.5-ppf, at 225-ft MD
  - 9-5/8” Casing, K-55, 36-ppf, at 2,002-ft MD
  - 13-3/8” Casing, K-55, 54.5-ppf, at 225-ft MD
  - 8.5” Original Hole at 3,397 ft MD
  - 2-7/8” Tubing
  - KOP Sidetrack at 2,123 ft MD
  - TOL 4-½” x 7” at 3,100-ft MD
  - 4-½” Casing, P-110, 15.1-ppf, at 3,725-ft MD
  - 2ea ECPs

Figure 4. PMCD System Rig Up

- **Rig A/V (TVD)**
- **RCU**
- **RIG ELECTRIC (T) SUPPLY (116)
- **RIG POWER UNIT**
- **1/4”**
- **1/4”**
- **HYDRAULIC CONTROL PANEL**
- **GPM MONITOR (CRW)**
- **2 Plugs**
- **MCU PULL UP LINE**
- **Hydraulic cylinder**
- **13.5” BOP**
- **Annular BOP**
Figure 5. Soka 2006-1 Re-entry PMCD Graph

Total Lost Circulation, Initial Switch to PMCD
- Replaced thru string 250 gpm - Drilling began from 3312 to 2002 ft.

17 Nov 2006
18:00 - 19:30 Switch to PMCD Mode, close 5/8” ROP, continue with pump 2 bbl thru annulus, using Halco pump.
- Decrease casing pressure from 390 psi to 60 psi, injected fresh water thru the string at rate 250 gpm.
- Keep casing pressure 60 psi (left) and 100 psi (right), continue wash down to preserve hole.
- 19:30 - 24:00 Drill new formation using PMCD Mode from 3305 ft to 3296 ft. Continue pumping string 250 gpm and annulus with rate of 2-3.5 bbl/min using all fresh water to keep CP 60 - 150 psi.
- Pumping high viscosity pill 10 bbls every 50 bbls down the hole. Drill ahead with WOP 20 - 30 ft/hr, torque 1000 - 1500 ft-lb, string pump 320 psi.
- 18 Nov 2006
- 24:00 - 20:00 Drill ahead using PMCD Mode from 3285 ft with ROP 20 - 30 ft/hr, torque 800 - 1100 ft-lb, string SPP 320 - 350 psi. Pumping high viscosity pill 10 bbls every 50 bbls down the hole. Continue pumping string 250 gpm and annulus with rate of 2-3.5 bbl/min using all fresh water to keep CP 60 - 150 psi.
- ROP Thai gradually slowed (7-7.5 ft/hr) when pressured basement rock formation (3749 - 3831 ft) and finally drilling reached TD at 3831 ft (TD).

CP, SPP Vs Depth

- Casing Pressure (psi)
- Standpipe Pressure (psi)

3749 ft - Estimated Top of Basemement Rock Formation