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UBO Efficiency: The Art of Building Resilience Through an Operational Buffer While Flow Drilling

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Abstract

Advancements in technology, shifting drilling environments, and complex reservoirs have transformed the challenges in oil and gas well drilling. Regulations, best practices, and artificial intelligence have emerged to enhance safety.

Flow drilling is an Underbalanced Operation (UBO) is defined as drilling an oil and gas well while continuously circulating gas to the surface to be handled by surface separation equipment and ultimately flared. While this practice is a known operation in the oil and gas industry, gas expanding at surface can have catastrophic impacts on lives and the surrounding environment.

There are many benefits to utilizing underbalanced operations to create an operational buffer while flow drilling, including allowing for continuous control of the well and faster response times, which aids in maintaining constant bottomhole pressure and preventing any additional influxes from entering the wellbore.

This paper discusses the execution of Underbalanced drilling techniques in flow drilling applications in North America and the importance of adaptive control strategies based on a flow drilling matrix. UBO techniques enhance safety during flow drilling operations; however, the significance of an operational buffer helps mitigate the risks associated with well control events. This paper explores the complexities of flow drilling, its drawbacks, and successes in application and focuses on its relevance to underbalanced drilling projects.

Introduction

Modern day drilling operations face evolving challenges due to environmental changes and complex reservoirs. Some of these reservoirs can prove to be cumbersome requiring advanced Managed Pressure Drilling techniques in order to safely and efficiently drill and case the hole. Despite safety precautions, certain wells are still deemed dangerous, underscoring the requirement and importance of technical yet feasible solutions rather than simple conventional means. Flow drilling, which involves continuous gas circulation, is a common but potentially hazardous practice in the oil and gas industry. In unconventional plays, UBO offers benefits such as maximizing hydrocarbon recovery and minimizing pressure-related drilling problems; however, benefits may be lost if control of the well is not properly maintained. By utilizing a hydrostatically underbalanced mud in tandem with applied surface back pressure, flow drilling techniques can be safely applied with continuous well control practices and faster response times to manage the constantly dynamic wellbore conditions often seen during drilling operations. This paper explores the advantages and drawbacks of creating such an operational buffer during flow drilling, emphasizing its relevance to UBO projects and the need to consider well conditions and drilling judgment carefully.

Background

Historically, these wells were costly due to the fact large volumes of drilling mud were lost and the drilling operations would constantly be delayed to circulate out nuisance gas. Additionally, tripping and drilling operations were often challenging as a result of the narrowly margined well and high-pressure target requirements. By using the operational buffer method, MPD was able to immediately respond to low pressure loss zones faster while also safely handling any gas entering the wellbore to allow the rig to continue drilling ahead. By using offset loss well data, an operational buffer can be designed by how much dynamic surface backpressure and return gas flow MPD can safely handle while drilling without inducing losses or other downhole conditions. With the use of MPD, these previously difficult and complex wells are now possible to drill with the creation of an operational buffer.

Equipment Specifications and Acknowledgments

Although not a true UBD/UBO set up with multi-phase separators and gas injection units in regards to equipment, this technique utilized UBD/UBO principles with a hydrostatically underbalanced mud weight and Managed Pressure Drilling equipment. MPD equipment consisted of a dual MPD choke manifold system, a high-pressure RCD bearing, a Coriolis flow meter, and high-pressure piping, hoses, and valves. The MPD system was capable of handling up to 4,000 psi applied surface back pressure statically and 2,000 psi dynamically. A special note should be considered that MPD remained offline during instances where control of the well was compromised, in which secondary well control equipment was utilized to circulate the influx(es) out of the hole on the rig choke manifold. Only once well conditions are back in the green zone as per the pre-determined MPD Operational Matrix, MPD operations would continue to commence.

Planning and Execution

The operational buffer method was originally designed for a well in East Texas targeting the Austin Chalk formation, a known high gas concentration area. Challenges were expected to be encountered while drilling, and a need for safety and time saving was at the forefront. These original Austin Chalk wells were designed as up-dip long horizontal laterals with various abnormal pressure profiles. In previous cases, pressure overburden on the well would lead to losses so severe that the cost to drill became a considerable deterrent to drilling, requiring a search for a feasible and efficient technique. Instead of drilling ahead with an overbalanced mud weight, the decision was made to drill with a hydrostatically underbalanced mud weight to not only assist with reducing annular friction losses but also begin establishing an operational buffer. Along with the lower pressure loss zones, the well was also expected to encounter high pressures zones that are prone to gas influxes. To satisfy high pressure well conditions, MPD was required to utilize higher pressure rated lines and equipment such as using HCR valves as MPD flow isolation valves, 4″ Figure 602 hard piping upstream, and a high-pressure rated RCD bearing and element. To incorporate an operational buffer, dynamic choke pressure is applied with a hydrostatically underbalanced drilling fluid as a preventative effort to help mitigate and minimize fluid loss as soon as they are encountered. This provided more operating flexibility for the MPD system to react to diminishing well conditions while still being within the MPD operational matrix in order to continue handling additional potential high pressure gas zones. Dynamic surface backpressure SBP values are determined by analyzing offset well data. When loss zones were encountered, MPD would begin reducing applied surface backpressure in order to reestablish a barrel in-barrel out trend. In some cases where losses are so severe, MPD would assist with LCM sweeps by applying positive choke pressure at pre-determined strokes in an attempt to strategically "squeeze" and spot the LCM in place. Performing targeted LCM squeeze jobs helped condition and strengthen the wellbore proximate to previous thresholds.

Risks and Advantages

Incorporating an operational buffer is a critical technique that allows for safe handling of gas flow to the surface, which can be hazardous if not handled properly. MPD techniques can minimize influxes and specifically target problematic gas feeding zones, which if not properly managed can be costly due to the need to replace oil-based mud lost as a result of downhole induced losses or during the flaring process when circulating out gas. This process allows for continuous drilling in zones with anticipated abnormal pressure or no clearly defined drilling window, creating a wider ranged operating window for real-time adjustments to pore pressure or fracture gradient changes. In order to effectively apply the operational buffer strategy, operations require thorough pre-planning and understanding of the scope of the project and clearly defined operating limits imposed by the MPD operations matrix. Clear communication pathways and process flow charts should be created and discussed amongst all personnel regarding operational processes and procedures, potential operational risks, MPD and rig capabilities, as well as well control policies and procedures.

Establishing a detailed operational matrix with agreed-upon maximum operating pressures and influx volumes is essential for successful and safe MPD implementation in UBO projects.

Advantages of the MPD system rigged up include space and cost saving measures due to the smaller required. No additional space or equipment was required as no service gas unit generator was needed and that MPD tied into the existing atmospheric MGS (Fig. 1) on the rig. Because the rig MGS was properly sized for drilling operations, no additional MGS or multi-phase separator was required. Some additional cost saving measures include reduced base oil and mud additives consumption because of the use of a lower mud density and reduced well overburden.

Utilizing a hydrostatically underbalanced mud increased ROP and provided MPD with a larger operating window allowing for the flexibility in instantaneous changes to downhole conditions. It also minimized losses by reducing overall annular friction losses with the option to drop several points by removing surface backpressure when needed. And by incorporating flow drilling aspects, invasion of solids and mud filtrate into the reservoir is minimized, further increasing productivity and improving enhanced recovery efforts.

With minimal surface equipment utilized for this flow drilling operation, operating limits are constrained to the physical working pressure limits of the MPD equipment as well as the upstream surface piping and valves. Because the rig up did not consist of a multi- phase separator nor a gas flow meter, flow back volumes allowed in the wellbore while drilling was limited with no proper way of monitoring gas composition and flow rates at surface. And although a Coriolis flow meter was installed downstream of the MPD Choke Manifold, high gas concentrations at surface would render the flow out and density readings useless at times.

Without all the proper tools and equipment typically used flow drilling operations, the rig needed to rely on other means to establish baseline wellbore and gas behavior trends. For example, the pressure gauge on the mud gas separator was heavily monitored during drilling operations, indicating whether too much gas was at surface or not. The flare height was also used as a benchmark; however, it was only used as a visual reference in relationship to gas flow and did not consist of any actual data collection. Another example is using secondary drilling parameters when gas concentrations at surface result in erroneous Coriolis flow meter data. Secondary parameters monitored included but were not limited to previous standpipe pressure, flow paddle position, MPD choke position, MPD Surface Backpressure, MGS vessel pressure, gain/loss, and Active PVT levels.

In the following sections, two sample wells utilizing the operational buffer are discussed in further detail.

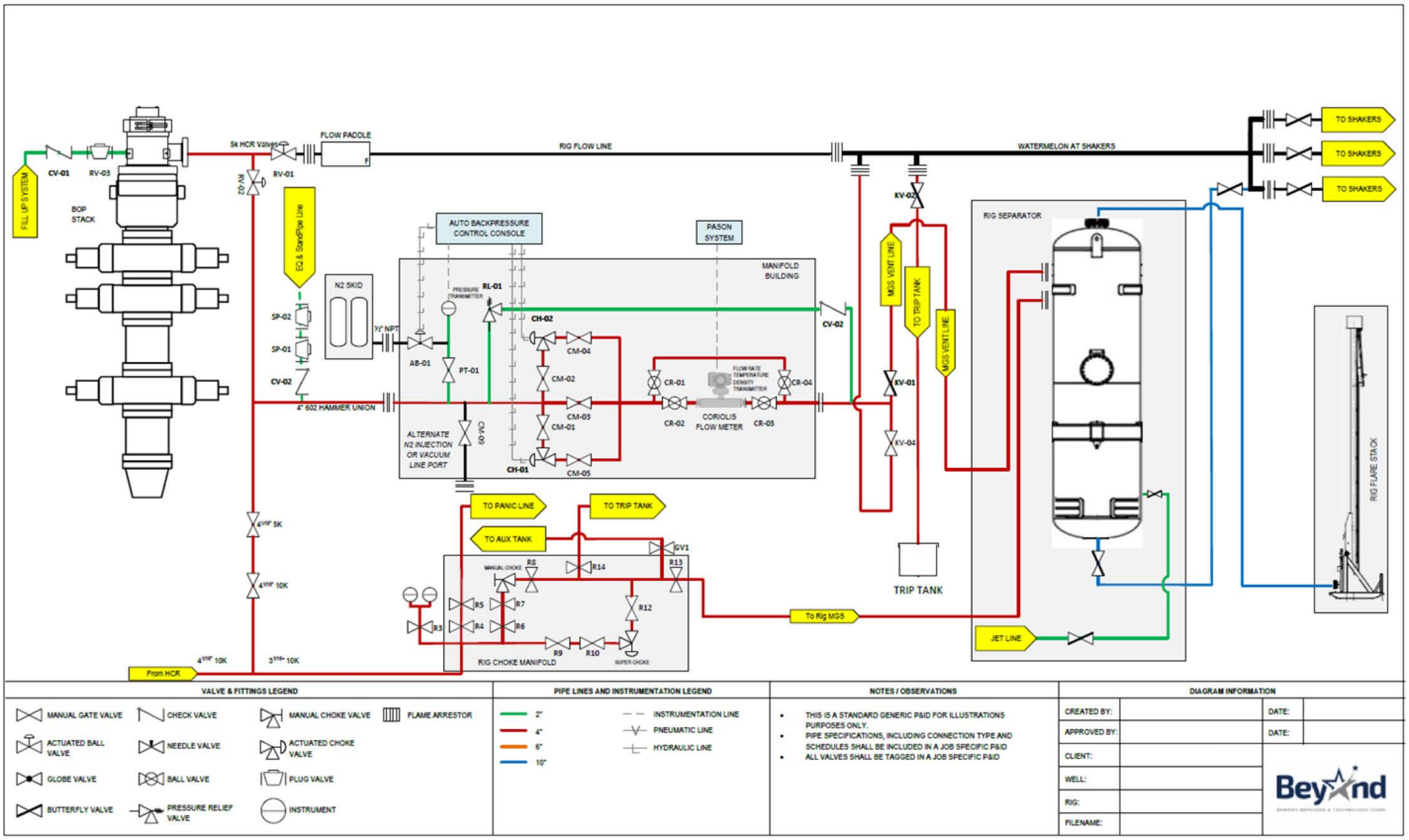

Figure 1—Process Flow Diagram

Subject Well #1

The original well's parameters are summarized in Table 1 below.

Table 1—Well Parameters

Total Depth	**21,000 ftMD**
	13,500 ftTVD
Intermediate Casing Point	13,501 ftMD
Pore Pressure	15.2–16.1 ppg
Loss Limit	>16.75 ppg
Drill Mud Density	13.0 – 13.9 ppg
Kill Mud Density	18.0 ppg
Production Hole Size	6 ¾ in

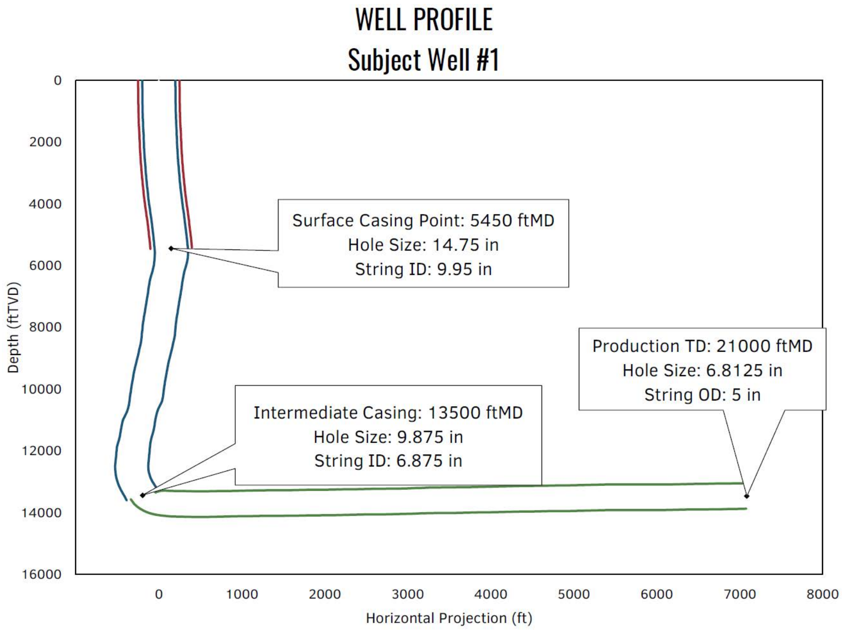

Figure 2—Subject Well #1 Profile

The main driver for MPD on subject well #1 was to maintain wellbore integrity. Challenges faced include drilling a slim hole past multiple exposed fractures, difficulties with managing losses while with running lower completions, and minimizing ECDs while performing cementing operations. In order to satisfy these well requirements, MPD needed to adjusted surface backpressures when encountering fractures and faults in order to minimize losses and control flowback to surface. When losses were severe, an LCM sweep was strategically squeezed in place so drilling operations could commence with near optimal operating parameters. The 6.75″ hole section was drilled successfully both maintaining constant bottom hole pressure when as applicable and by creating an operational buffer to minimize formation overburden and losses to formation. Well killing methods performed during bit trips and prior to the casing run included a combination of volumetric top fills with KMW while stripping out which allowed the kill fluid to be placed vertically higher in the wellbore with the bit at surface. While tripping in with the lower completions string, casing was initially filled with a pre- determined volume of light mud with a density lower than that of the drill MW. This assisted with losses encountered while running casing by allowing the rig to partially displace out some of the lighter density fluid into the annulus and thereby decreasing the overall hydrostatic pressure observed in the well. This process was repeated as needed until all of the lighter density fluid was displaced into the annulus or until casing was landed on bottom. This technique was an integral function of safely and efficiently drilling the production section of the well.

MPD introduces the idea of an operational buffer by applying positive choke pressure (Fig. 4) in effort to counter losses when observed while simultaneously staying within the operational matrix to be able to handle any high-pressure gas zones. Previous loss zones encountered were up to 1.0 ppg of drilling ECD, due to this the 800-900 psi buffer was enacted. If and when loss zones were encountered, MPD would relieve SBP to reestablish barrel in / barrel out flow. In some cases, an LCM sweep was circulated throughout the wellbore and MPD would then "squeeze" the LCM by applying positive choke pressure and attempt to recondition and strengthen the wellbore.

As previously mentioned, the well was also anticipated to drill into abnormal high-pressure zones as well. Due to this anticipated higher pressure an agreed upon MPD drilling operations matrix (Fig. 3) was established to safely handle any influxes entering the wellbore. The operations matrix focuses on the maximum volume of influx and maximum SBP available prior to shutting in the well on the BOP to be circulated through the rig choke. In order to successfully apply the operational buffer technique, establishing and clearly communicating an MPD operations matrix prior to drilling commences is a requisite function.

Managed Pressure Drilling Operations Matrix

RCD Model	Atlas 4.5" with Ares 3078 Bearing Assy	Well Name	Subject Well #1

Influx Volume (bbl)		Max RPM	Surface Annular Pressure Dynamic Conditions (pipe moving): Less than	Min	Max	Greater than	Surface Annular Pressure Static Conditions (pipe static): Less than	Min	Max	Greater than
		0	2,000	2,000	2,000	2,000	2,000	2,000	4,000	4,000
		60	1,600	1,600	2,000	2,000				
		120	1,600	1,600	2,000	2,000				
Less than	5.0		Manageable. Continue drilling	Continue drilling; Increase MW system to decrease WHP		Secure well. Evaluate next planned action	Manageable. Continue operation	Continue operation; Increase MW system to decrease WHP		Secure well. Evaluate next planned action
Min Max	5.0 10.0		Continue drilling; adjust MW system to increase BHP	Continue drilling; Increase MW system to decrease WHP and increase BHP		Secure well. Evaluate next planned action	Continue operation; adjust MW system to increase BHP	Continue operation; Increase system to decrease WHP and increase BHP		Secure well. Evaluate next planned action
Min Max	10.0 15.0		Cease drilling; adjust MW system to increase BHP	Secure well. Evaluate next planned action		Secure well. Evaluate next planned action	Stop operation; Adjust MW system to increase BHP	Secure well. Evaluate next planned action		Secure well. Evaluate next planned action
Greater than	20.0		Secure well. Evaluate next planned action	Secure well. Evaluate next planned action		Secure well. Evaluate next planned action	Secure well. Evaluate next planned action	Secure well. Evaluate next planned action		Secure well. Evaluate next planned action

Figure 3—MPD Operational Matrix

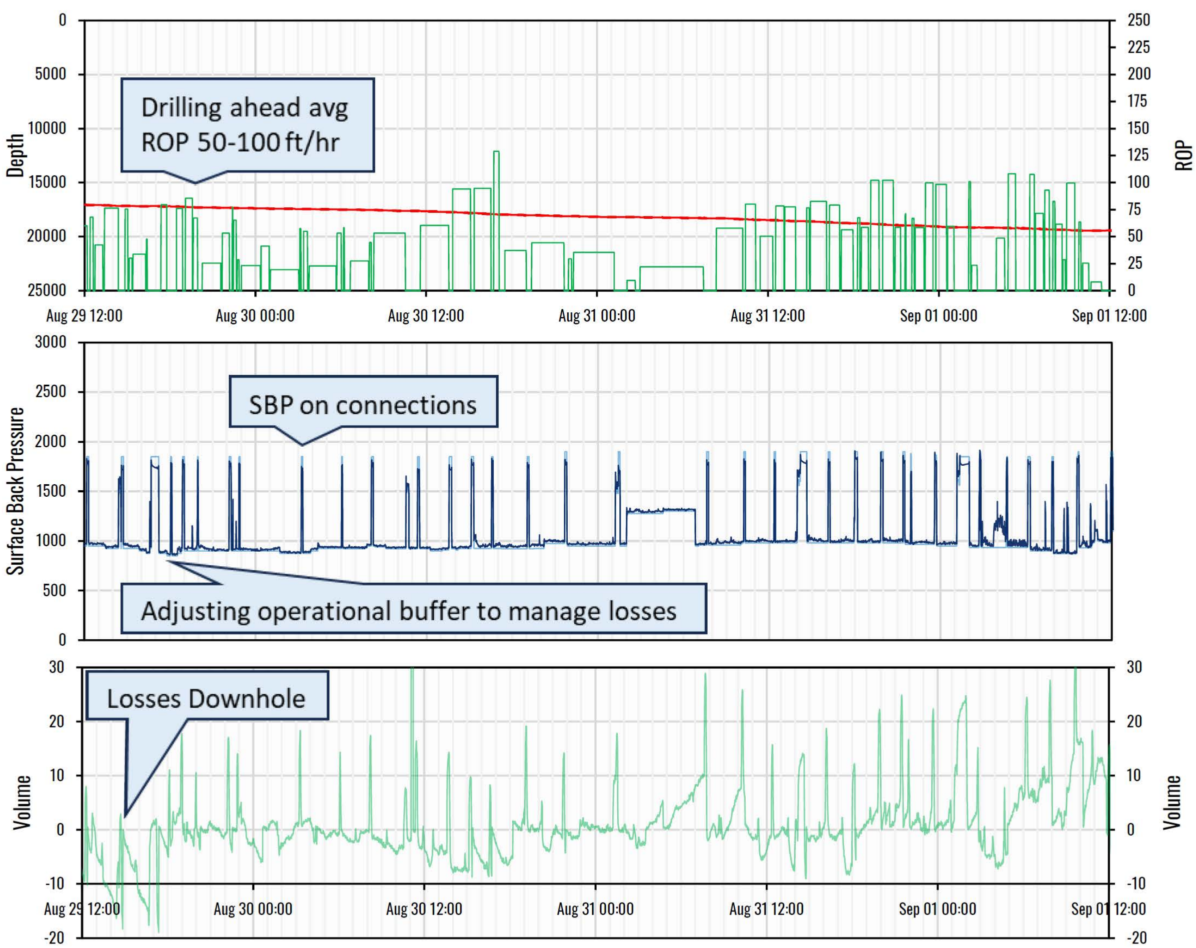

Figure 4—800-1100 psi Operational Buffer

When drilling subject well #1, a 15.2 ppg target EMW was maintained at the bit with a hydrostatically underbalanced mud weight of 13.5 ppg from the intermediate casing shoe (13,501 MD') with MPD online applying 800-900 psi until the first "weak" zone was encountered at #16,300'. Upon encountering the weak zone and still suffering losses with a fully open MPD choke, a decision was made to allow the MW to drift down to 13.1 ppg to combat losses. Upon reducing the DMW to 13.1 ppg, MPD was able to reestablish the operational buffer of 850 psi and drilling operations continued with MPD decreasing SBP to minimize losses and increasing SBP when gains were observed. During this time the operational buffer ranged from 850-980 psi, and no significant events occurred to cause a break in drilling. As drilling operations continued, the rig observed they had drilled out of target and was unable to get back into the target formation with optimal drilling parameters and the decision was made to perform an open hole sidetrack at 15,000' MD and re- drill the lateral in the Austin Chalk. Upon sidetracking, a decision was made to raise the DMW to 13.6 due to the anticipation of higher- pressure zones ahead, and the SBP required could potentially exceed the upper limit of the MPD operations matrix. Drilling continued in the target formation with an established operational buffer of 500-800 psi. Approximately 1000 ft from TD, the decision was made to increase the DMW to 13.9 ppg again due to the upper limits of the operation matrix, and the operational buffer was successfully reduced to 450-550 psi until TD was reached. The open hole sidetracked lateral was successfully drilled with no NPT events or influxes. MPD maintained a target EMW of 15.5 – 16.1 ppg while drilling and during pump offs events. Surface back pressure was adjusted accordingly based on mud properties and drilling parameters.

The 6.75″ production hole section was drilled successfully both maintaining constant bottom hole pressure when applicable and by creating an operational buffer. This technique was an integral function of safely and efficiently drilling the production section of the well. Prior to establishing the operational buffer technique, reaching TD in lateral production section in this area would take approximately 60-80 days and prove costly with mud volumes lost. However, after utilizing the operational buffer technique drilling time to reach TD was reduced to 30-50 days with significant mud cost savings.

Subject Well #2

The second subject well's parameters are summarized in Table 2 below.

Table 2—Well Parameters

Total Depth	**25,550 ftMD**
	14,000 ftTVD
Intermediate Casing Point	14,060 ftMD
Pore Pressure	14.4–15.1 ppg
Loss Limit	< 16.2 ppg
Drill Mud Density	14.0 ppg
Kill Mud Density	17.5 ppg
Production Hole Size	8 ¾ in

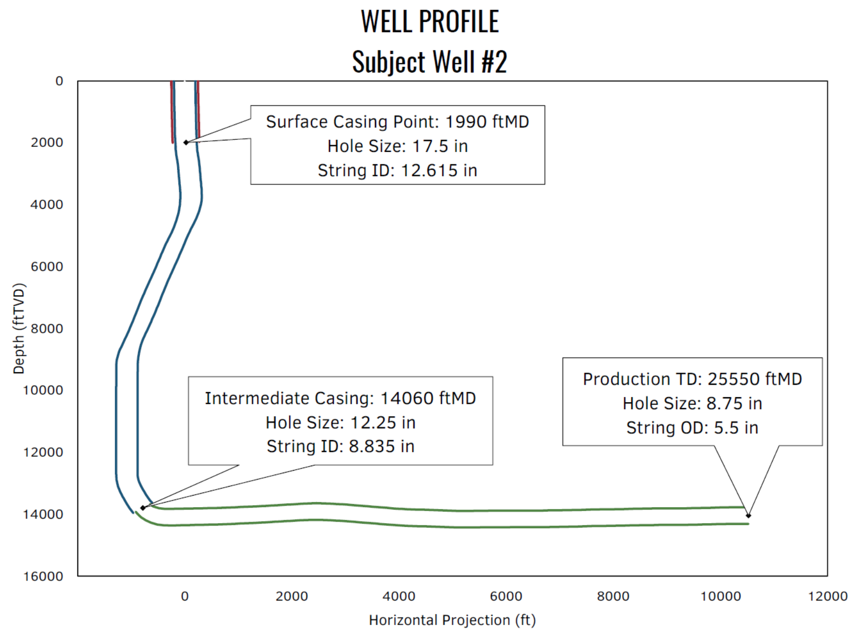

Figure 5—Subject Well #2 Profile

The main driver for MPD on the second subject well was to maintain wellbore stability in the lateral production section. The well was not anticipated to feed in high volumes of gas, however there was a known fault line near the planned TD. Due to the expectation of low pressures and weak formations, high pressure equipment was not necessary for this application and standard equipment was setup on location. Drilling operations commenced with MPD online targeting a 15.1 ppg EMW at the heel with a balanced mud weight of 14.0 ppg. The friction created from flow was sufficient to satisfy the dynamic target, allowing the surface MPD choke to remain fully open. However, under static conditions, MPD was required to trap 800 psi during pumps off events to satisfy the EMW target. No significant drilling operations were noted while drilling the lateral section; however, conversations began to arise about how to combat the encroaching fault as the rig approached TD. The operational buffer method was suggested to allow sufficient time for crucial decision making while maintaining the ability to maintain bottom hole pressure if losses were encountered at the fault. The flow rate was slightly reduced from 500 gpm to 450 gpm as the fault line was approached, however flow rates could not be reduced any further as there was a minimum rate required to maintain optimal drilling parameters and proper hole cleaning. Therefore, the decision was made to enact the operation buffer by applying 200 psi of surface backpressure (Fig 6) until the bit reached TD. Upon drilling into the fault, MPD began to reduce SBP until the surface choke was fully open to re-establish a barrel in-barrel out trend in flow. In addition, multiple LCM sweeps were built and circulated throughout the wellbore as a contingent effort to strengthening the wellbore. The LCM sweeps proved to be effective as MPD was able to reestablish positive choke pressure. Once TD was reached, the bit was subsequently tripped out of the hole with MPD maintaining a 14.6 ppg EMW. Although the planning and execution phase did not initially anticipate the abnormally high-pressured zones during the drilling operation, there was a known low-pressure fault was encountered in the latter portion of the lateral section. To address this, an MPD operational buffer was suggested and enacted during the final days of drilling. As a result, the operational buffer proved to be effective, enabling the bit to safely reach TD with minimal losses and no influxes.

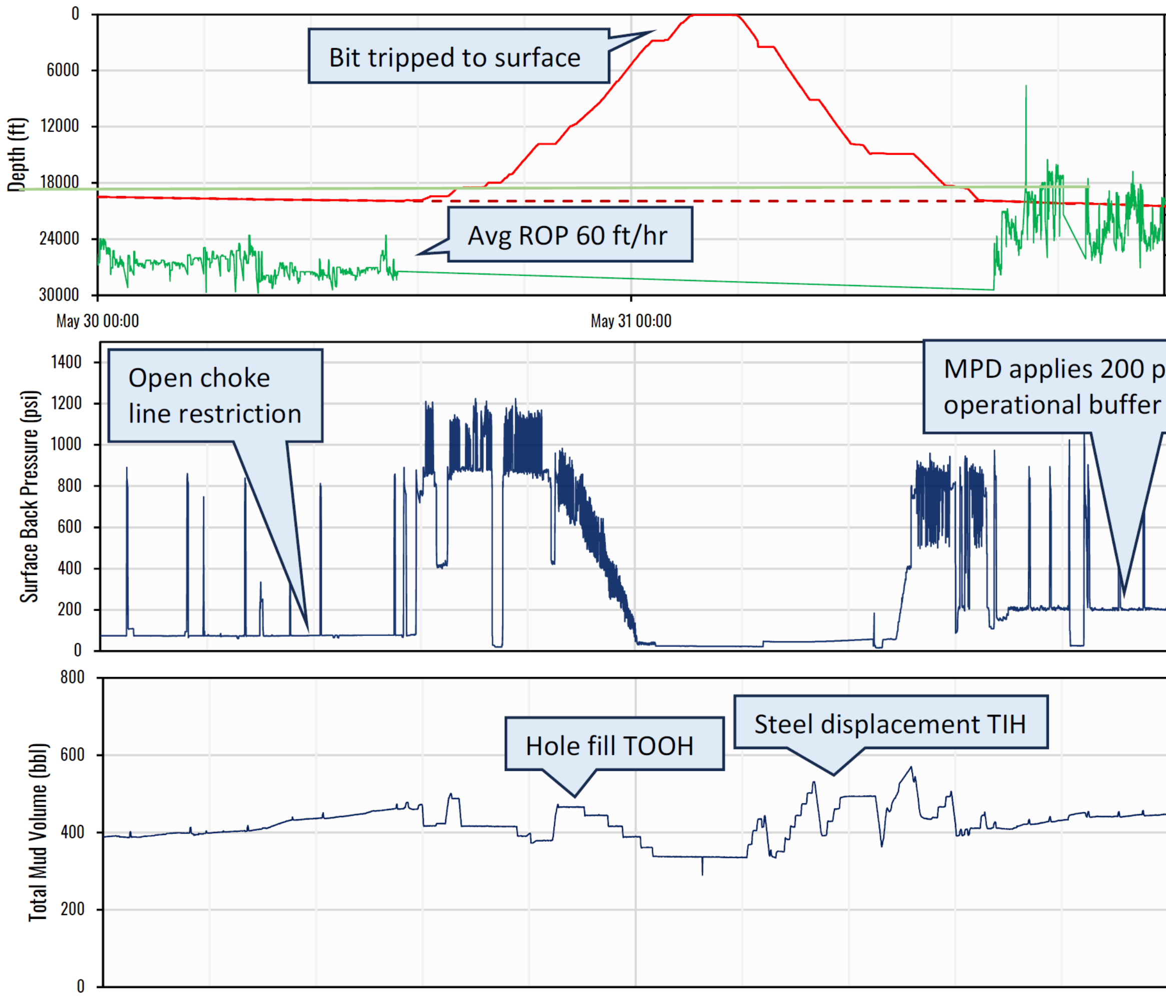

Figure 6—200 psi Operational Buffer

Conclusion

In conclusion, the operational buffer method, although not applicable to every well with narrow drilling windows, provides a comprehensive method to reduce the risk of fluid losses in challenging formations, while simultaneously allowing continuous gas handling abilities at surface. When encountering or anticipating severe losses, this proven technique allows for quick manipulation of bottom hole pressures so that a barrel in-barrel out trend can be re-established without having to reduce mud weight densities during operations. It also allows time for critical decision making when needed, further minimizing the time and costs associated with fluid management during critical operations. There are many risks and advantages associated with the operational buffer technique, however, with careful pre-planning and effective communication, the rig can be successfully prepared to handle both expected operational challenges and anomalies. Lastly, it's important to note that establishing a detailed operational matrix with agreed-upon maximum operating pressures and influx volumes is essential for successful and safe MPD implementation in UBO projects.

Acronyms and Definitions

DMW Drill Mud Weight
BHP Bottom Hole Pressure
EMW Equivalent Mud Weight
ESD Equivalent Static Density

MPD	Managed Pressure Drilling
TD	Total Depth
RCD	Rotating Control Device
SBP	Surface Back Pressure
LCM	Loss Circulation Material

References

API RP 92U, 1st Edition, American Petroleum Institute, Washington, USA, 2008:R2013