SPE/IADC-221429-MS

100+ Deepwater MPD Wells Learnings

A. A. Fernandes, Petrobras, Santos, SP, Brazil; G. S. F. Vanni and F. S. Terra, Petrobras, Rio de Janeiro, RJ, Brazil

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

MPD offshore in deepwater is less than 20 years old. Over the last decade there was noticeable evolution of usage of MPD technology. The industry acceptance of what is considered the correct application of the technology has evolved over the years. The first barrier concept and well control practices now consider the capability and characteristics of MPD technology. This allowed the undrillable wells to be drilled with almost no penalty when compared to a conventional well intervention. The operational awareness improved, due to new capabilities of MPD techniques, leading to an improvement on the overall efficiency of the intervention.

The sustained use with better understanding of the benefits of the technology lead to more refined applications of MPD, while reducing the added operational time. New applications also were developed using existing equipment, widening the deployment extent of MPD during well construction and maintenance.

Still, major discussions are needed to further develop the technology on deepwater scenarios. Completion and workover are still not discussed in depth in the industry and operational concepts between different disciplines must align considering MPD advantages and limitations.

This paper presents key aspects of the evolution of MPD application based on the experience of drilling more than 100 wells using MPD on deepwater scenarios. Regarding the MPD evolution, a revision of the internal and external operations, through several papers and publications allows the identification of different factors that changed over the years.

Introduction

Conventional drilling on deepwater wells presents significant operational challenges, particularly in managing the operational window and reducing overbalance with increasing water depth. The increase of water depth reduces the total overburden at a given depth and, as a result, the formation resistance. At any depth of a well there is an upper and lower limit to the pressure that can be applied without operational problems. The sections of a well are designed to guarantee that the section can be drilled and isolated with the pressure inside the operational window of all open formations.

The reduced margin between pore pressure or lower collapse (lower limit) and fracture pressure (upper limit) can make conventional drilling not possible. The conventional approach of fine control of fluid density and rheology is not feasible for some deepwater wells. Usually, a minimal overbalance is applied in the well in relation to the lower operational limit, there a no industry standard on this, but the lower the overbalance the more prone to operational complications the section is. Fernandes et al [1] describes some challenges and increased complexity that comes with greater water depth and consequent reduced operational window. In some cases of deepwater wells the pressure difference in the well that comes from fluid circulation is greater than the operational limit, in these cases it is necessary to apply a different technique to achieve the well objectives with proper safety.

Managed Pressure Drilling (MPD) is an adaptive drilling process used to precisely control the annular pressure profile throughout the wellbore. MPD techniques allow for immediate adjustments to be made to the pressure in the wellbore, enabling operators to respond dynamically to changing conditions and to maintain a narrow pressure window. This is achieved by using specialized equipment such as rotating control devices (RCDs) for pressure retention, MPD chokes for pressure control, and flow spools for flow deviation, along other equipment.

Surface Backpressure (SBP) is the most common technique used in Managed Pressure Drilling (MPD). SBP applies additional pressure at the surface to control the well pressure. By manipulating the surface backpressure, operators can maintain a desired pressure profile in the wellbore, helping to manage formation pressures and prevent influxes or losses.

In deepwater applications, Pressurized Mud Cap Drilling (PMCD) and Floating Mud Cap Drilling (FMCD) techniques are utilized when drilling carbonate reservoirs offshore. Floating Mud Cap Drilling (FMCD) is defined by the International Association of Drilling Contractors (IADC) and the American Bureau of Shipping (ABS) as a technique where drilling is performed without returns while continuously pumping sacrificial fluid down the drill string and the annulus. This prevents the migration of formation fluids to the surface. The open-hole formation absorbs all the injected sacrificial fluid and drilled cuttings without assistance from surface pressure.

During FMCD operations, the fluid level remains below the rotary table level because the fluid pumped into the annulus has a higher density than the equivalent pore pressure density. Consequently, there is no direct indication of annulus conditions, leading to the technique also being known as blind drilling. To prevent hydrocarbon inflow or migration, a minimum downward flow rate through the annulus is necessary. Hydraulic simulators are employed to calculate the required flow rate to ensure operational safety. Currently, there is no industry standard procedure to guarantee that any hydrocarbon migration in the annulus is contained at the bottom of the well.

Pressurized Mud Cap Drilling (PMCD); also defined by IADC and ABS, is a drilling technique used to drill without returns by balancing the full annular fluid column using a Light Annular Mud (LAM) Cap in the annular. The formation takes in all the injected sacrificial fluid and drilled cuttings with the aid of surface back pressure. The density of the LAM is defined to be able maintain and monitor the surface backpressure during the operation. Periodically bullheading more of the LAM into the annulus helps control the surface backpressure within the operating limits and reinjecting formation fluid.

Although Managed Pressure Drilling (MPD) techniques have a long history of use on onshore and shallow water wells, the use of MPD technique and hydrostatic underbalanced mud was something not used on the deepwater scenario. Twenty years ago, there was no occurrence of drilling with MPD techniques on a deepwater well. The changes required to properly apply MPD SBP and contingent mud cap drilling were not clear. After 100 deepwater MPD wells, there are some clear lessons learned towards the best usage of the technique on wells with narrow (150 psi) to no operational window (0 psi) and minimal well overbalance to formation pressure (50 psi).

Evolution of RCD, Riser Equipment and Surface Piping

RCDs have been available since mid-70s, being utilized as safe containment of well returns in Air Drilling and Underbalanced operations with Surface BOP. In the United States, by 2005, 3 out of 4 land drilling operations drilled at least one section with a closed and pressurizable mud returns system, up from 1 in 10 in 1995. In the last 20 years, though Underbalanced operations did not increase greatly, it is clearly identified a greater usage of RCDs, both with Surface BOP application as with Subsea BOP applications. This is unequivocally because of increase of SBP MPD applications. The transition to fixed platforms, jackups, and other fixed drilling units was relatively simple. The move towards deeper water scenarios that presented challenges that needed to be overcome.

The first effort to use an RCD from a floating rig was in 2000. The aim was to drill deepwater reservoirs in Brazil providing an underbalanced drilling operation utilizing the RCD on top of the riser. Since then, from the mid-00s, this system evolved for the use of MPD system from floating rigs [3]. The first applications were in Southeast Asia in the drilling of the fractured carbonate formations, when total losses resulted in well control situations that were difficult to handle with conventional techniques and with poor overall results. These first applications used MPD Setup with Mud Funnel on top of a collapsed riser joint on Semi-Submersible Rigs, and had limitations on handling equipment, risk of mud spill to the environment and pressure limitations due to "adapted" setup.

With the development of MPD Setup with Triple Barrel Slip Joint on Semi-Submersible Rigs, and RCD with top flanges with higher tension capabilities, the then called above tensioner ring systems were introduced. They eliminated problems regarding mud spillage and equipment pressure rating, reduced the "man riding" time, but still posed constraints on rig heading, to cope with severe weather and slow equipment handling.

From 2013 the use of below tension ring RCDs systems became widespread deepwater offshore Brazil. These systems, all three commonly known generations, were used in more than 100 wells drilled in the last 11 years. Operations ranging from simple kick detection, to using hydrostatically underbalanced mud and finally circulating influxes within the primary barrier limits, were performed during this period.

The adaptation of MPD on floating vessels required a series of modifications to fifth and sixth-generation rigs, including retrofitting the riser and the BOP to accommodate the Rotating Control Devices (RCD). The MPD equipment were divided into two groups: riser equipment and surface equipment.

The obstacles for implementing MPD on offshore vessels that were overcome include:

a. Lack of crew competence,
b. Initial inability of service providers to conduct multiple simultaneous operations in deep waters, and
c. Non-existence of MPD equipment on offshore platforms.

Training was another important issue and remains a significant concern. There is a large number of new offshore platforms and very inexperienced drilling crews (Tolfo et al., Drilling Contractor Magazine 2016). Some crews have only two years of experience. For MPD operation, dedicated MPD training has to be conducted, as well as hands on training for all operations teams.

Even today, rig adaptation and the installation of the MPD riser joint, at the time of BOP deployment, still impacts the well construction significantly. Running the integrated riser joint can vary from 12 hours to 40 hours, depending on the joint generation, rig competency and procedures being utilized. The newer generation integrated riser joint mitigates shortcomings that the previous ones had with handling and installation time.

The standardized MPD implementation through the rig fleet the P&ID for the permanent surface piping, allowing multiple alignments necessary to the different modes of MPD, gave consistency cross the board. Today the surface system is required to have 3kpsi of working pressure, all the alignments have redundancy available to permit the continuous operation in case of failure; The standardized system allows:

the continuous monitoring of the bearing assembly seals by the trip tank; PMCD operations by pumping fluid through the annulus; multiple alignments to the mud gas separator with interlocked valves; PRV´s in each the connection to the distribution manifold: return hoses, and connection to the standpipe and rig choke manifold.

There is a real need of industry guidance on equipment standardization, testing, maintenance, recertification, and integration with the rig's systemsBody text 1 paragraph.

Body text 2 paragraphs.

Developing a new Well Barrier Concept

First barrier concept

The use of hydrostatically underbalanced fluids introduces a new approach to establishing the first well safety barrier envelope. The Rotating Control Device (RCD) and the Managed Pressure Drilling (MPD) system, which control surface annulus pressure, play a crucial role in the primary safety barrier.

According to the NORSOK Standard D-010, which outlines well integrity in drilling and well operations, Figure 1 – Conventional and MPD drilling diagrams, illustrates the differences in primary and secondary well safety barriers between conventional drilling and drilling with Surface Back Pressure (SBP) MPD using hydrostatically underbalanced fluid. These diagrams highlight the relevant distinctions between conventional operations and SBP MPD operations.

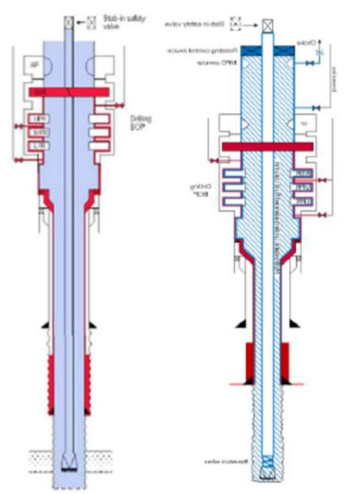

Figure 1—Conventional (left) and MPD drilling (right) first safety barrier diagramsBody text 1 paragraph.

The industry recognized the importance of documenting and sharing this knowledge to ensure consistency and safety across operations. At the time, regulatory agencies and industry best practice documents primarily considered the hydrostatic head exerted by hydrostatically overbalanced drilling fluid as the main component of the first well safety barrier envelope. This was deemed the "best practice" by the industry, and regulators adhered to this standard.

Another critical factor is tripping with MPD. When using hydrostatically overbalanced fluid, the tripping procedure closely resembles that of conventional operations, with careful attention to surge, swab, and tripping speed. However, using hydrostatically underbalanced fluid changes the tripping procedure, as the fluid itself does not serve as the first well safety barrier. Additionally, onshore and offshore tripping operations differ significantly, as the riser can act as a lubricator offshore, allowing tripping without the need to hydrostatically balance the well.

Well control

During the initial implementation of SBP MPD in deepwater offshore Brazil, the operational premise was to close the Blowout Preventer (BOP) upon kick detection and hand over well control to the rig crew. This posed a significant challenge: with the system's increased precision in kick detection, would the number of well control events increase? This challenge was addressed when industry subject matter experts (SMEs) established best practices that allowed for the circulation of small amounts of influx through the MPD system, which would typically go undetected by conventional rig equipment. After initial applications, it was deemed safe to circulate small influx anomalies with detected gain volumes of up to 2 barrels. Figure 2 demonstrates the detection of an influx of less than 1 barrel during a dynamic pore pressure test (DPPT). Analyzing various operations revealed advantages in well control situations.

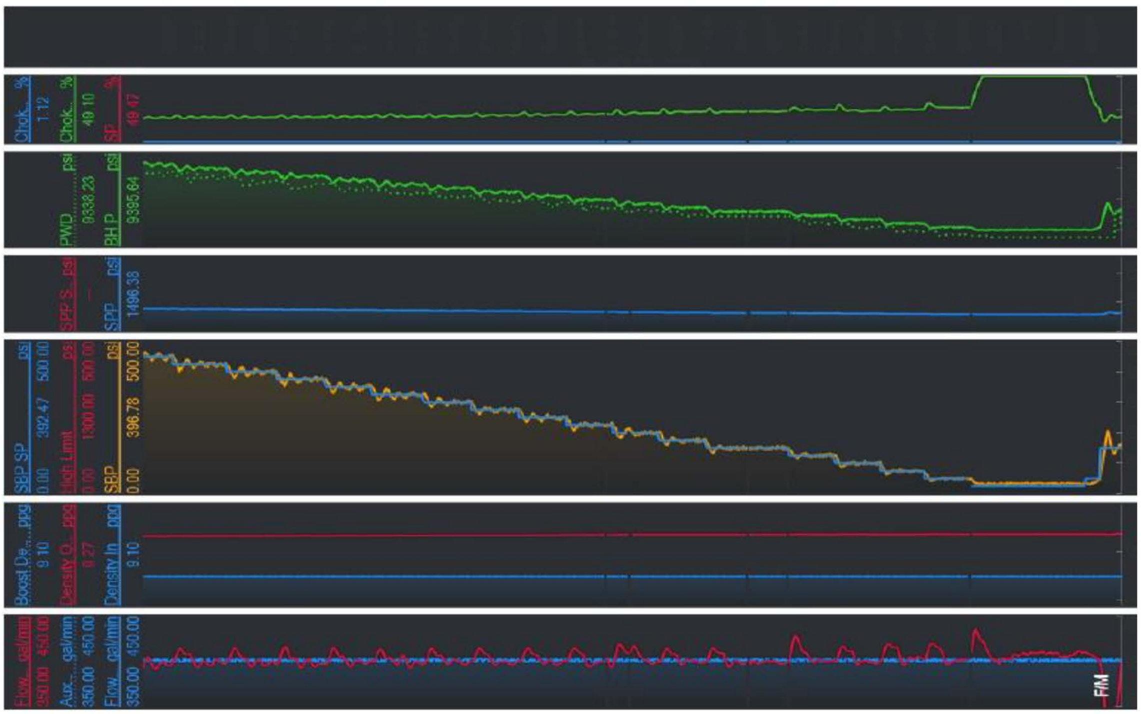

Figure 2—Influx detection on a dynamic pore pressure test

On floater rigs the circulation of an influx through the riser bypasses the limitations of the kill and choke lines' smaller diameters This eliminates the high-pressure losses associated with these lines, thereby expanding the operational window for kick circulation. Additionally, due to the riser's higher flow area, the rapid loss of hydrostatic head that occurs when the kick enters the kill and choke lines is significantly reduced, by more than an order of magnitude. Depending on the drilling phase diameter, it is possible to observe a reduction in the choke pressure, when the kick enters the riser. The riser's larger diameter also results in a significant reduction in the maximum surface choke pressure as the kick gets to the surface.

The booster line offers an added benefit by allowing the circulation of drilling fluid without any gas through it, reducing the concentration of gas in the fluid flowing through the riser. This effect can be used to decreases the peak surface pressure, peak gas rate through the separator, and the required reaction speed of the chokes for proper pressure management, keeping the same return rate after the kick pass through the BOP.

Considering an influx within the pressure limits of the riser and MPD system, controlling the influx circulation is easier compared to using the secondary well safety barrier. The system significantly reduces choke pressure, providing a wider operational window even with the limited pressure of MPD equipment compared to conventional well control equipment. The sensitivity of the MPD flow meter enhances influx detection compared to tank volume control and flow level variation at the flowline. Bacon et al. compared different methods for controlling a well after an influx using MPD and conventional techniques, demonstrating that control via MPD chokes can significantly reduce the volume of hydrocarbons inside the well.

Another advantage of circulating the influx through the MPD system is the ability to perform well control without closing any element of the BOP while maintaining drilling flow rates. This avoids the complexity and high risk of human error associated with stopping drilling operations and closing the BOP to control the choke directly. After circulating the kick out, reopening the BOP and removing residual gas below the closed BOP ram is necessary. Circulating through the riser and MPD system eliminates these steps, simplifying the influx removal process.

This simplification offers not only increased safety and reliability but also a significant reduction in the time elapsed from kick detection to the resumption of normal operations. These advantages are driving the industry to develop safer methods to handle larger volumes of kicks.

Drilling the undrillable and beyond

MPD allowed the undrillable deepwater wells to be drilled with almost no penalty when compared to a conventional well intervention. Narrow operational margins that would not be feasible to drill using conventional techniques can be drilled and completed using SBP technique. Reservoirs with no operational window and capacity to accept sacrificial fluid and cuttings can be concluded with the most adequate mud cap drilling technique.

The operational awareness of well conditions improved. Not only to direct measurements due to new capabilities of MPD, but also secondary methods that can be implemented on real time data and serve as additional protection to the operations. The implementation of MPD techniques, lead to an improvement on the overall safety of the intervention. At the same time, a new perception on how to perform the well control, led to additional safety improvements, as better and simpler measures can be taken to recover the control of the well.

One factor that was not envisioned at the beginning of MPD deepwater implementation was the expansion of the application beyond drilling and tripping procedure. Although the interface between drilling and completion always must consider the well and operational conditions, the first projects had the focus of reaching TD rather than using MPD for the entire well construction. In the initial projects the well would be delivered to the completion team in the same conditions of a conventional well.

Over the years, the well design group verified an opportunity for gain in efficiency. Schnitzler et al [5] and [6] demonstrates part of the continuous expansion of where MPD can be applied before using conventional drilling and completion techniques. Based on those scenarios it was necessary to adapt the completion project to comply with MPD benefits and restrictions.

After some projects, the design group noticed opportunities with MPD rigs and unconventional scenarios. The usage and better understanding of the benefits of technology lead to more refined applications of MPD, while reducing the time impact. New applications also were developed using existing equipment, opening the range of MPD during a well construction and maintenance. Instead of relying on a conventional first safety barrier, completion and workover projects could consider the first safety barrier that can be established with different MPD techniques.

Total losses on a conventional workover requires the combat of losses until the stabilization of the well. For a stimulated well that means that there will be a duplicated job, the first to combat losses and them the need to restimulate the well for proper production or injection. Total losses are part of MCD, the adaptation of the technique for completion and workover allied with changes on the intervention equipment configuration allowed not only simpler operational sequences, but also a more precise and effective operation with greater operational awareness. Comparing operational times of some types of workovers with new MPD interventions the use of the equipment for a different concept manages to save time and bring simplicity to the operation.

The changes on completion equipment are important to give the operational group flexibility on how to do the well construction. A deepwater well with over 200 psi of operational window can be completed using conventional techniques, in this scenario it is simpler and faster to abandon MPD usage as it is not needed and might complicate the operation. Scenarios with smaller operational windows demand the use of SBP technique, while scenarios with no operational window are completed using a MCD technique. The Design and R&D groups defined the new requirement of the lower and upper completion to be flexible for the different scenarios without impacting the total time of construction of the well.

Ongoing developments

MPD joint deployment

The drilling riser, that in the past was something that some people consider that it would burst in case of use of the diverter lines, now must withstand the SBP of the MPD system (up to 2000 psi). That is possible with the MPD riser joint, that integrates a rotating control device (RCD), flow spool, and other MPD equipment into the riser system. The MPD riser joint associated with the MPD manifold and surface MPD lines permits that different MPD techniques to be applied.

Due to the size, weight, and connection's location (moon pool area), the deployment of MPD riser joints requires previous planning and coordination. As it is on the critical path of work it has direct impact on the time and cost of the intervention. Therefore, the deployment is a critical factor in deepwater drilling application. Aranha et al [2] and [3] describes the impact on the deployment time on a typical MPD campaign with uncertainty of need on the use of the techniques.

From an operator's perspective, until this moment, there is not a MPD riser joint that is easily deployable and have good operational life on the RCD components. Although there was clear development from the first MPD joint, at the same time there are campaigns with uncertainty on the necessity of usage of MPD. These uncertain application wells might have a reactive strategy of installation due to the impact on time of MPD when compared to conventional operations. The deployment of the MPD joint is the main factor of additional time when compared to conventional operations.

Training and knowledge maintenance

MPD is an umbrella for a variety of operations, the application deepwater is not restrained to drilling operations as it was on the first applications. Different MPD techniques have been used for completion and workover operations. The new applications can be done to guarantee the safety of the operation, but in some cases the use of MPD can bring overall optimization (reduced time) and simplification of the intervention.

The different applications and evolution of MPD, highlights the importance of technical knowledge retention within the industry. Ensuring that knowledge is retained and transferred effectively is critical for maintaining operational safety and efficiency.

Until this moment, the industry does not have a universal training and certification mechanism. Although operators, regulators, drilling contractors and service providers recognize the importance of MPD training, there are considerable differences among industry participants, some provide a one and only training, while others do periodical and continuous training. No matter the strategy, it is fundamental that the crew involved in MPD activities have the proper operational awareness.

It is expected that by the end of 2024 the industry will have a MPD certification and training curriculum in a similar way that we have well control certification. The regular training and certification programs are essential for involved personnel to stay updated with the latest technologies and procedures. These programs should cover both theoretical knowledge and practical skills, ensuring that operators can handle advanced equipment and manage complex drilling, completion, and workover scenarios.

Another factor that is not completely covered by the industry is Knowledge Management for MPD operations. A trained crew is different from a crew that trained and used MPD on complex scenarios. The increased complexity of MPD operations demands robust knowledge management systems to capture and disseminate critical technical information. These systems can include databases of best practices, lessons learned from past projects, and detailed equipment manuals. By making this information readily accessible, companies can enhance decision-making and problem-solving capabilities. Unfortunately, the knowledge management is something that has a large variation in application, with some companies being able to maintain top performance with rotating crews and market dynamics, while others are fully dependent on individual knowledge inside the organization.

So far there is no direct way to guarantee that the best knowledge management is appropriate to ensure optimal operational safety and efficiency.

MPD software

For deepwater applications the control of the MPD chokes is done through software. The rig movement (heave, pitch and roll) associated with the compressibility of the system makes the proper control difficult and sometimes impossible to be done with manual operation. More importantly, the software control allows that different control methods and contingencies to be implemented in the code.

The initial MPD software control solutions presented instability and led to different operational problems, including well control situations. There was a clear gap between the intention and system capabilities, in some cases, the software shortcomings demanded increased responsibility from the MPD operator, which considering human factors, is not something sustainable or safe enough considering the complexity of the environment.

Although there was considerable development on MPD control software, from an operator's perspective it cannot be considered that the MPD software control is something independent from provider and user. Unfortunately, it is still not an old occurrence that a software or MPD operational error impacts the first safety barrier of the well. In those cases direct actions are needed to reestablish well safety. There is an ongoing industry discussion within SME's and international groups to address software reliability.

Further discussion is needed to further develop the technology on deepwater scenarios. Completion and workover are not discussed in depth in the industry and operational concepts between different disciplines must align.

Industry activities

The IOGP's Well Control Systems Subcommittee has identified several challenges and gaps in the implementation of Managed Pressure Drilling (MPD) in the industry. One of the main issues is the lack of industry standards and functional guidelines for adjustable chokes and pressure relief valves in MPD applications. The existing well control equipment standards do not adequately address the specific functions and operational needs of MPD systems. This gap has been addressed through OEM procedures, recommended practices, and operators' procedures, but there is a need for consolidated guidelines and recommendations to ensure increased safety, efficiency, and reliability of MPD components in the industry.

Another problem highlighted by the IOGP is the lack of standards and guidelines for well monitoring and detection systems in MPD operations. These systems play a crucial role in notifying operators of early kicks and losses, but there is a need for dedicated guidelines to ensure the reliable functioning of well monitoring equipment. This includes aspects such as gas management guidelines, high accuracy flowmeters, and well control procedures for circulating potential influxes through the riser. The industry would benefit from the introduction of guidelines and recommendations to address these challenges and enhance the overall performance of MPD systems in the industry.

API recently approved a SRRR to elaborate a document that will establish guidelines and recommended practices for the development and testing of MPD software. This document was drafted by IADC but cold stacked in 2023. Also a cross-review of all SC 16 standards all be conducted to verify their interfaces with MPD and incorporate relevant regulations, focusing on the API S53, API 16D, API 16Q, and API 16F standards. The API S53 standard will include specific requirements for MPD, particularly concerning the frequency of tests.

Conclusions

Managed Pressure Drilling (MPD) has been successfully deployed in deepwater scenarios on more than 100 wells. One of the main challenges in the deepwater environment is the significant cost and the limited number of wells drilled compared to onshore operations. While an onshore rig can perform and apply MPD on several wells within a short period, deepwater wells often require hundreds of days to complete. MPD is typically necessary only while drilling specific sections of the well, and in some cases, it might not be required at all.

The retention of knowledge and the proper application of MPD are areas where improvement is needed among all parties involved—operators, drilling contractors, service providers, and regulators. Although there has been notable development in MPD operations from all involved parties, there is clear room for growth. Enhancing knowledge retention and application will lead to more efficient and effective MPD operations in the future.

Another factor for greater application of MPD, is the development in the completion and workover stages, particularly for wells in the Campos and Santos Basins. The flexibility provided by MPD allows for better and more diverse use of rigs, offsetting the additional costs and time required compared to conventional interventions. This adaptability enhances the overall efficiency of well completion and workover processes.

MPD operations have considerable impact in well control. It is not advisable to perform an MPD intervention with a conventional well control mindset. Well control has seen significant advancements with the integration of MPD. The ability to manage wellbore pressures more precisely has led to better use of resources and improved safety. While the physical limitations of the equipment are well understood, the best procedures for MPD in well control continue to be refined and discussed among industry professionals.

The intervention time and the robustness of MPD software have shown continuous and considerable development compared to initial deployments. These advancements have made MPD interventions more efficient and reliable. However, there is still room for improvement, and further enhancements in these areas could significantly impact the frequency and number of future MPD interventions in deepwater scenarios.

MPD has proven to be a valuable technique in deepwater drilling and completion, providing significant benefits in well control, completion, and workover operations. While the technology and its application have advanced considerably, ongoing efforts to improve knowledge retention, procedural development, and software robustness will continue to enhance the effectiveness and efficiency of MPD in deepwater scenarios.

References

1. Fernandes, A. A., Vanni, G. S. F, and F. S Terra. "MPD Deepwater Evolution and Interinstitutional Development." Paper presented at the Offshore Technology Conference, Houston, Texas, USA, May 2024. doi: https://doi.org/10.4043/35301-MS
2. Aranha, Pedro Esteves, Colombo, Danilo, Fernandes, André Alonso, Vanni, Guilherme Siqueira, `, Reinaldo Akio, Benevenuto de Campos Lima, Cláudio, Lima, Gilson Brito, and Júlio César de Faria Alvim Wasserman. "Strategic Evaluation of Managed Pressure Drilling: An Application on Brazilian Dynamic-Positioning Rigs." *SPE Drill & Compl* **34** (2019): 216–222. doi: https://doi.org/10.2118/185281-PA

3. Aranha, Pedro Esteves, Fernandes, André Alonso, Vanni, Guilherme Siqueira, Terra, Felipe de, Tomita, Reinaldo Akio, Tolfo, Marcos Coradini, and Danilo Signorini Gozzi. "Strategic Evaluation of MPD Application on DP Rigs." Paper presented at the IADC/SPE Managed Pressure Drilling & Underbalanced Operations Conference & Exhibition, Rio de Janeiro, Brazil, March 2017. doi: https://doi.org/10.2118/185281-MS
4. Fernandes, André Alonso, Ferreira, Davi Valle, Schnitzler, Eduardo, de Castro, Fabiano Hamilton, do Carmo, Isadora Luisa de Paiva Goncalves, Santana, Pedro Menezes, and Roger Savoldi Roman. "Perforating Using MPD Techniques: Design and Execution." Paper presented at the SPE/IADC Managed Pressure Drilling & Underbalanced Operations Conference & Exhibition, Kuala Lumpur, Malaysia, September 2022. doi: https://doi.org/10.2118/210542-MS
5. Schnitzler, Eduardo, Alonso Fernandes, André, Savoldi Roman, Roger, Pereira da Silva, Paulo Henrique, Medina Ascaneo, Willian, Storani de Almeida, Renato, and Guilherme Bolfarini Harami. "Using MPD Techniques for Lower Completion Replacement: Unleashing a Powerful New Solution for Challenging Workover Interventions." Paper presented at the SPE Annual Technical Conference and Exhibition, Dallas, Texas, USA, September 2018. doi: https://doi.org/10.2118/191401-MS
6. Schnitzler, E., Gonçalez, L. F., Ascaneo, W. M., Gonçalves, F. F., Almeida, R. S., and M. Marques. "First Openhole Intelligent Well Completion in Brazilian Pre-Salt." Paper presented at the OTC Brasil, Rio de Janeiro, Brazil, October 2017. doi: https://doi.org/10.4043/28102-MS
7. Carpenter, Chris. "MPD Monitoring Technique Allows Rapid Redesign, Flexibility." *J Pet Technol* **71** (2019): 44–46. doi: https://doi.org/10.2118/1019-0044-JPT
8. Siqueira Vanni, Guilherme, Alonso Fernandes, André, Tacio Teixeira, Gleber, Vieira Martins Lage, Antonio Carlos, Leibsohn Martins, André, de Souza Terra, Felipe, de Souza Cruz, Marcelo, Rodrigues G. da Silva, Fabio, and Cristiano Édio Dannenhauer. "Real Time MPD Optimization in Challenging Scenarios." Paper presented at the SPE/IADC International Drilling Conference and Exhibition, The Hague, The Netherlands, March 2019. doi: https://doi.org/10.2118/194097-MS
9. Tomita, R. et al., 2015. Successful Case History of Drilling Through Major Loss Zone Using MPD/PMCD Techniques on a Santos Basin Well. Paper presented at the SPE Annual Technical Conference and Exhibition, Houston, Texas, USA, September 2015. Paper Number: SPE-174836-MS. https://doi.org/10.2118/174836-MS.
10. Fernandes, A. A., Gozzi, D. S., Nogueira, E. F., de Souza Terra, F., Vanni G. S, & Filho, R. S. F. (2015, April 13). MPD/MCD Offshore Application on a Dynamic Positioning Rig Society of Petroleum Engineers. doi: 10.2118/173825-MS.
11. Alcantara Santos, Otto Luiz. "Technology Focus: Well Integrity (January 2020)." *J Pet Technol* **72** (2020): 63. doi: https://doi.org/10.2118/0120-0063-JPT
12. Bacon, W., Sugden, C., Brand, P., Gabaldon, O., & Culen, M. (2016, April 12). MPD Dynamic Influx Control Mitigates Conventional Well Control Pitfalls. Society of Petroleum Engineers. 179185–MS
13. Bacon, W., Sugden, C., & Gabaldon, O. (2015, March 17). From Influx Management to Well Control; Revisiting the MPD Operations Matrix. Society of Petroleum Engineers. 173174–MS
14. Culen, M. S., Brand, P. R., Bacon, W., & Gabaldon, O. R. (2016, April 12). Evolution of the MPD Operations Matrix: The Influx Management Envelope. Society of Petroleum Engineers. 179191–MS
16. Fernandes, A. A., Tomita, R. A., Junior, A. C. R., Abdu, J. P. S., Vanni, G. S., Grandi, R. F., … Silva, L. F. M. (2017, March 28). Overview of Different Applications for MPD and MCD Techniques on Deepwater Wells. Society of Petroleum Engineers. 185279–MS

17. F., Lage, A. C. V. M. , da Silva, J. F., & Santos, H. (2006, January 1). Field Trials of a Managed-Pressure Drilling System Demonstrate the Actual State of the Technology. Offshore Technology Conference. 18038–MS
18. Gabaldon, O. R., Brand, P. R., Culen, M. S., Haq, I. U., Gonzalez-Luis, R. A., Silva, T. P. D., … Bacon, W. (2017, March 28). Case Study: First Experience of Developing an Influx Management Envelope IME for a Deepwater MPD Operation. Society of Petroleum Engineers. 185289–MS
19. Hannegan, D. M., & Fisher, K. (2005, January 1). Managed Pressure Drilling in Marine Environments. International Petroleum Technology Conference. IPTC-10173-MS
20. Hannegan, D. M., SPE 2006-2007 Distinguished Lecturer Series, "Managed Pressure Drilling"
21. Nas, S., Toralde, J. S., Wuest, C., Offshore Managed Pressure Drilling Experiences in Asia Pacific, SPE/IADC 119875-MS, SPE/IADC Drilling Conference and Exhibition, 17-19 March, Amsterdam, The Netherlands, 2009
22. Schnitzler, E., Fernandes, A. A., da Cunha, C. B., de Oliveira, F. S., Vanni, G. S., Grandi, R. F., … de Jesus, R. A. (2017, March 28). Completion Considerations for MPD Deepwater Offshore Wells. Society of Petroleum Engineers. 185299–MS
23. Tolfo, M.C., Nogueira, E.F., Fernandes, A.A., Terra, F.S., Vanni, G.S., Genaro Filho, L., To support pre-salt drilling strategy, Petrobras converting 15 rigs to be MPD-ready by year-end, in Drilling Contractor Magazine, May/June Apr **27**, 2016., Fernandes, A.A., Vanni, G.S, Martinello, I.A., Terra, F.S., Sales, I.M, Guedes, J., Vasconcelos, K.S. "Evolving Well Control Procedures with MPD on Floaters" SPE/IADC-194553-MS 2019
24. Steve Nas, SPE, Weatherford Solutions: "Deepwater Managed Pressure Drilling Applications". *SPE Paper* **Number 132049**.
25. IADC/SPE-191099-MS Complete MPD Rigs: Is This the Future? Ben Gedge, Regional Marine & Engineering – PVD Well Service Co Ltd; Norman Yaw, David Postel, Jeff Mardon, and Herbert Frohlich, Regional Marine & Engineering; Bot Viet Nguyen, Ban Nguyen Thanh, and Duc Vu Hong, PVD Well Service Co Ltd; Brian Barbee, Ensco; Helio Santos, Safekick; David Gouldin, Seadrill