Offshore drilling hazard mitigation: Controlled pressure drilling redefines what is drillable

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FOR THE PAST two decades, the means to safely and effectively practice managed pressure drilling (MPD) has been steadily evolving. Much of this advance has been on US land drilling programs, where the technology has become a status quo practice for reducing nonproductive time and mitigating well control issues related to downhole drilling hazards.

But offshore, a second and even more significant round of adoption is taking place. In its multiple variations, closed-loop MPD technology, aka “pressure-able mud systems,” is not only challenging fundamental concepts of how to drill a well, it is revising some not-so-old ideas about what is even drillable.

TECHNOLOGY FOR THE TIMES

The timing could not be better for two important reasons, operationally and financially. Most of the world’s remaining prospects for hydrocarbon resources will be more challenging to drill than those enjoyed in the past. In fact, many would argue that the easy ones have already been drilled. And with oil prices where they are today, drilling safely and cost-effectively while producing a good well in the process could not be more important.

In the increasingly narrow drilling windows presented by many contemporary offshore reservoirs, the ability of MPD to precisely control the annular pressure profile throughout the wellbore is proving to be a considerable advantage.

From these frontier applications, using MPD to “walk the line” between narrow or relatively unknown drilling windows, along with other capabilities, is yielding economic, operational and regulatory benefits that are driving a fast-paced adaptation of the technology.

In its mitigation of common but increasingly critical downhole drilling hazards, MPD shares a similar objective with two other innovative technologies – drilling with casing and expandable tubulars. While these technologies deal primarily with hardware to drill and case the hole, MPD addresses the fluid system and the relationship between wellbore and formation pressures. The growth of the three technologies in roughly the same time frame speaks directly to the progressively critical role of hazard mitigation in drilling modern offshore wells.

These downhole hazards manifest themselves in many ways, including excessive nonproductive time (NPT), cost overruns, well control problems and failure to reach the total depth objective. In effect, they are the reason a growing percentage of the world’s remaining oil and gas prospects are viewed as technically and/or economically undrillable.

VARIATIONS OF MPD

There are four variations of MPD. Each, or a combination of several, addresses most of the commonly experienced drilling-related challenges:

• Constant bottomhole pressure (CBHP) is applicable to prospects that have narrow or relatively unknown drilling windows, slow ROP, ballooning/breathing and well control risks.

• Dual gradient (DG) is applicable where it is necessary to remove some of the hydrostatic head pressure caused by a tall column of heavy mud in cuttings, typically to avoid gross overbalance conditions.

• Pressurized mud cap drilling (PMCD) is applied to deal with severe loss circulation and drilling in sour formations.

• Returns flow control (HSE) is applicable when one wishes to close the mud returns system under the rig floor for health, safety or environmental reasons, or as a complement to a “zero discharge” emphasis.

IMPRESSIVE MITIGATION

The development of MPD equipment and methodologies for a variety of applications – carried out from a full range of offshore drilling structures – is providing a drillable solution for many difficult and otherwise “undrillable” wells and reservoirs. For many prospects that can be drilled conventionally, MPD has been proven to be a better way to drill them.

A risk assessment study recently done in conjunction with the Drilling Engineering Association (DEA 155 JIP) determined
The study does not stand alone in its assessment of MPD’s potential. An October 2008 readership survey conducted on www.DrillingContractor.org ranked MPD second only to horizontal and directional drilling as being the technology most influential to drilling/completion over the next 20 years.

OFFSHORE GROWTH

With a long heritage in land applications, MPD entered the offshore market buttressed by a strong technical base and enabling equipment that have aggressively been adapted to a variety of applications.

Onshore in the US, Canada and Mexico, MPD is broadly used to manage drilling hazards and reduce NPT. Based on Weatherford’s assessment, more than 60% of US land programs drill at least one section with some form of controlled pressure drilling – about 45% are air-, mist- or foam-drilled, 10% are underbalanced drilling (UBD) applications, and the balance are one or a combination of the four variations of MPD.

Because NPT is significantly more costly offshore, MPD has much more to offer offshore drilling programs than the land drilling programs that pioneered the technique.

In the Asia Pacific region, where more than 100 MPD wells have been drilled since 2005, it is the preferred technology for mitigating severe lost-circulation associated with fractured carbonate formations. Using MPD, wells that experience kick-loss and near or total loss scenarios are being drilled to total depth without significant delay, resulting in major cost reductions.

For instance, a recent MPD application offshore India cut the time lost to downhole problems to only one day; versus an average of 10 days in offset wells. The reduction was achieved by reducing loss/kick cycles and other flat time associated with narrow pore pressure/fracture gradient margins – and increasing penetration rates.

In Indonesia, where carbonate formations like the Baturaja and Kujung are a great challenge, MPD is yielding similar savings in time and expenses while adding new prospects from the ranks of the undrillable.

Success in Asia Pacific is only part of the story. A global wave of MPD applications is being experienced in shallow-water and deepwater wells in the Middle East, Africa, the North Sea and the Gulf of Mexico.

Offshore Mexico, MPD is being used to address operation problems related to high gas pressure intervals and loss-circulation zones encountered in the same hole section. In 2007 and 2008 alone, more than 336 offshore wells were drilled using MPD methodologies (along with numerous onshore wells).

Fractured carbonate reservoirs are also a reason for MPD use offshore Africa. In one well, a low bottomhole pressures and 2% hydrogen sulfide (H₂S) gas were contributing to mud losses of 1,400 bbl/hr and low ROP. The PMCD variation eliminated expensive mud losses, prevented H₂S from reaching the surface, and increased the ROP from 40 ft/day to 220 ft/day (12 m/day to 67 m/day).

These global MPD wells are being drilled in surface and subsea environments using virtually every type of drilling structure, from semisubmersibles and drillships to jackups and platforms.

CONTINGENCIES

There is another consideration for MPD, one that is gaining ground in the industry as drilling expenditure uncertainties drive operators toward stronger contingency plans. MPD as a “Plan B” allows operators to react more efficiently and safely when dealing with unplanned downhole pressure environments. It’s also another reason why a growing number of insurance underwriters are requiring the use of RCDs on locations. Most RCD rental activity for US land-based programs falls into the “reactive” category, where a conventional fluids and well construction program is planned.

Much PMCD work in the Asia Pacific region falls into the reactive category as well. On average, operators incur severe or total loss scenarios on only about one out of five wells. These operators are increasingly implementing contingency plans as they balance out the cost of the contingency plan against a potential loss of the well.

At least one major operator has established an internal practice that suggests that if a drilling program manager does not prepare to practice PMCD in a region known to have severe loss-circulation issues, a formal HazId/HazOp process should be conducted to prove it’s better not to invest in a PMCD contingency.
Managed Pressure Drilling

The M7100 RiserCap RCD atop the marine riser of a floating rig, enabling pressurized mud cap drilling (PMCD) MPD, which can be applied to deal with severe loss circulation and drilling in sour formations.

It should be noted that when a MPD contingency is incorporated into a conventional-wisdom drilling program, planning, training, HazId/HazOps, equipment pre-qualification and applicable regulatory permitting should be considered as if MPD were the primary program.

NECESSITY’S CHILD

The techniques and equipment required for MPD evolved from air-drilling operation in the 1960s and underbalanced drilling in the 1990s. As various problems arose, innovative drillers adapted the technology to fit their particular needs. However, it wasn’t until about 2003 that a growing litany of techniques was recognized as a technology within itself, and the term managed pressure drilling was coined.

Air drilling, underbalanced and managed pressure drilling comprise a set of capabilities collectively described as controlled pressure drilling (CPD). These techniques, each with proven individual capabilities, enables an integrated solution to challenging prospects: air drilling the upper hole to mud transition depth for cost savings; MPD to deal with drilling hazards en route to the reservoir; and the reservoir section drilled using UBD and geosteering technology to access the sweet spots, maximizing well productivity. By adding surface mud logging to such a solution, the number of “undrillable” prospects in operators’ portfolios should be expected to diminish significantly.

Drilling challenges addressed with MPD are typically related to maintaining the equivalent circulating density (ECD) within the drilling window between formation pore pressure and the fracture pressure of the section being drilled. This balancing act occurs in narrow and relatively unknown downhole pressure environments, and frequently results in loss/kick well control scenarios, differential sticking, the risk of twist-offs and slow penetration rates.

In addressing these modern hazards, MPD challenges drilling conventions that have been prevalent since Spindletop, circa 1900. The old way involves pumping weighted mud down the drillstring such that it exits the bit nozzles with enough hydraulic energy to push the mud and cuttings up the annulus of the wellbore to the surface to an open-to-atmosphere mud returns system.

With a conventional circulating fluids system, the only way to affect an in-situ change of equivalent mud weight (EMW) is via the rig’s mud pump rates. This “Achilles’ heel” of conventional mud systems renders them incapable of dealing effectively with a growing percentage of the world’s remaining prospects.

MPD employs a fundamentally different approach that has more in common with process industries than historical drilling operations.

Process industries have for decades emphasized the importance of avoiding fluid systems that are open to the atmosphere. Like a pressurized process system, MPD is a closed-loop circulating fluid system. In this system, EMW is the mud’s hydrostatic head plus circulating annular friction pressure and the surface or subsurface application of backpressure.

Surface application of backpressure via a rotating control device (RCD) and choke is the most common method of manipulating the EMW, but some MPD applications accomplish EMW adjustment via various means of “lifting,” such as injecting lighter fluids into the annulus return path and using downhole or subsea pumps.

The result is an ability to more precisely manage the wellbore pressure profile by adjusting the equivalent weight of the mud in the hole at the time. This management yields many advantages, fundamentally changing the critical nature of drilling hazards, often to the point of negating them entirely.

With MPD technology, narrow drilling windows can be navigated to a greater depth with little or no interruption to drilling progress to fight hazards. And by drilling with a lower-density fluid, ROP is increased, usually with a reduced mud cost.

The development of a technology that enables time- and temperature-corrected mass balance accuracy of measurement and analysis of flow and pressure-profile data truly enables management of the circulating fluids system with “process industries” capability. Very small amounts of formation fluids influx and mud losses are detected, allowing the actual, not predicted, drilling window to be revealed and responded to safely, efficiently and typically with less non-productive drilling time.

By ascertaining the actual pore pressure and fracture pressure margins as drilling continues, MPD enables adjustment of mud density while drilling-in the current stand of pipe. Managing EMW with
MPD can also conserve casing points, offer early kick detection while drilling and ensure a large enough hole at the total depth objective for the well to be economically viable.

While the savings thus afforded by MPD can be significant, the economic threshold is relatively low. The “rule-of-thumb” cost of an MPD package is generally between 2% and 5% of the spread cost rate of a drilling rig. For a 35-day well, more than 5% of time (42 hrs) must be saved to recover the cost of the package. In most MPD operations, even when rigged up only for safety or as a contingency to a conventional wisdom fluids and well construction program, the value to the drilling program is easily justified.

VARIATIONS ON A THEME

There is often some initial confusion about what constitutes MPD. The reason is there are a number of variations in the technology – four primary and several subcategories. These variations must be understood in context of the type of non-productive drilling time each is intended to address.

If the challenge is a narrow or a relatively unknown drilling window, constant bottomhole pressure (CBHP) MPD is used. This variation includes two subcategories – friction management, used in HPHT or extended-reach wells, and continuous circulation methods for wells where the annular friction pressure must be constant and to prevent cuttings settling in extended-reach horizontal wellbore sections. CBHP MPD is uniquely applicable for subsalt and other drilling prospects where formation and fracture pressures are a relative unknown.

Pressurized mud cap drilling (PMCD) is the most common MPD method used in Asia Pacific. It is used to control wells that experience, or have a likelihood of, total losses and kicks in the same wellbore. To use this technique, the losses must be large enough to take all of the fluids pumped down the drillstring and all of the cuttings generated during the drilling process. If even partial circulation is possible, the CBHP method should be used instead. Ultimately, this variation is expected to be used in deepwater where heavily depleted old pay zones must be drilled to reach deeper pay zones of virgin pressure.

The dual gradient (DG) concept is most applicable to deepwater drilling because all but the most robust of pay zones would be grossly overbalanced from the tall column of heavy mud and cuttings in a marine riser. Hydraulically speaking, true DG (with a subsea BOP and marine riser system) tricks the wellbore into thinking the rig is closer by a means of subsea artificial lift, typically via subsea pumps or an injection of lighter liquids or gas in the annulus returns path. Riserless mud recovery is another application of DG technology showing great promise. The use of subsea RCDs is required in the former and advisable in some of the latter DG methods.

Where annular pressure control is not the objective, HSE or returns flow control (RFC) techniques are an essential part of MPD that efficiently diverts annulus returns away from the rig floor. If the insurance underwriter requires a RCD on location for HSE reasons only, the technique to consider is the HSE variation. The RFC system minimizes unnecessary operations of the BOP, provides assurance in presence of shallow geohazards, and allows pipe movement while circulating out tight-gas influx or dealing with gas-cut mud.

THE HOLE AHEAD

Wellbore hydraulics for the majority of the world’s remaining prospects will unquestionably be more challenging than has been enjoyed in the past. Depletion and the requirement to drill in deeper water further aggravate the challenge. Most experts would agree that most of the “easy” prospects have already been drilled.

For offshore assets, managed pressure drilling, in all its variations and combinations thereof, is providing a novel means of dealing with a litany of drilling-related hazards. As part of a suite of controlled pressure drilling technologies for reducing costs, improving production and mitigating downhole problems, MPD joins drilling with casing and expandable tubulars in providing state-of-the-art drilling hazard mitigation capability.

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