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Distinct variations of managed pressure drilling exhibit application potential

As defined by IADC, specific variations of managed pressure drilling are able to overcome pressure problems and other drilling challenges that made some prospects undrillable for operators.

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In today's arena of drilling and production – arguably the most vital link in the upstream chain – a predominant challenge is to reach ever-deepening horizons efficiently, safely and cost-effectively. Since much of the low-hanging fruit has been plucked using conventional drilling methods, drillers must now drill deeper, faster and into increasingly harsher environments, all the while avoiding formation skin damage to ensure optimum production. Using conventional methods on such complex projects is often counter-productive at best, and impossible at worst.

Offshore exploration of sub-salt strata has introduced extremely difficult challenges to today's drillers, such as lost circulation (LC); hazardous kicks; logging issues (MWD circulating pressure limits); hazardous gasses escaping at surface; stuck pipe; overpressure above salts followed by pressure regression below; longer trips; and combinations of these problems. Onshore, similar problems are found, often compounded and aggravated by extreme pressure depletion.

The solution to many of these challenges is to apply precision drilling, whereby the driller maintains total and constant control over downhole pressure. The ability to determine and subsequently manage the annular hydraulic pressure profile, accordingly, is gaining favor among majors and independents faced with seemingly undrillable prospects.

The previous paragraph defines the impetus for managed pressure drilling (MPD), often called "walking the line." MPD largely draws on theory and tools developed for underbalanced drilling (UBD), which facilitates drilling of pressure-depleted formations, and to lessen skin damage for better productivity. Commonality of tools can cause the two techniques to be mistaken for one another, yielding an unwarranted, unfavorable opinion of MPD.

The major difference between the two is that MPD will never invite influx into the wellbore. Conversely, this is UBD's objective. The UBD process involves drilling into any formation, where the pressure exerted by the drilling fluid is less than the formation pressure. The technique reduces the hydrostatic pressure of the drilling fluid column, so that the pressure in the wellbore is less than the formation pressure. Consequently, the formation pressure will cause permeable zones to flow, if conditions allow flow at the surface.

In MPD, the driller seeks to stay slightly above or "at-balance" to the downhole pore pressure (PP), or as close to near-balance as possible during the entire section of problem hole, both during drilling and connections. Precise control of downhole pressure allows the driller to effectively drill within the window between PP and fracture gradient (FG) without setting casing prematurely. This window typically is narrower in deeper water environments or where pore pressures are greatly depleted.

DEFINING MPD
IADC's MPD Subcommittee, defines MPD as "an adaptive drilling process used to precisely control the annular pressure profile throughout the wellbore. The objectives are to ascertain the downhole pressure environment limits and manage the hydraulic pressure profile accordingly."

The subcommittee separates MPD into two categories -"reactive" (the well is designed for conventional drilling, but equipment is rigged up to quickly react to unexpected pressure changes) and "proactive" (equipment is rigged up to actively alter the annular pressure profile, potentially extending or eliminating casing points). The reactive option has been implemented on potential problem wells for years, but very few proactive applications were seen until recently, as the need for drilling alternatives increased.

Benefits of precise wellbore management can reportedly overcome 80% of conventional drilling-related barriers. Both offshore and onshore, drilling personnel have realized that MPD can lead to increased well control, increased ROP, greater bit life, less drilling flat time, fewer casing strings, less mud cost and safer applications.

EQUIPPING MPD
Although several variations exist, a successful MPD application is typically done with three key components: A closed, pressurized circulating system with associated MPD equipment; an optimal hydraulics plan designed before drilling a well; and skilled engineers familiar with the concept.

A closed circulating system enables safe drilling into horizons that potentially contain sour gas, because the mud returns system is not directly open to the atmosphere, Fig. 1. The system includes necessary MPD surface equipment (and in some cases, downhole equipment) to impose surface backpressure on the wellbore and control abnormally high or low formation pressures. This is done without the conventional "weighting up," every time an influx is taken.

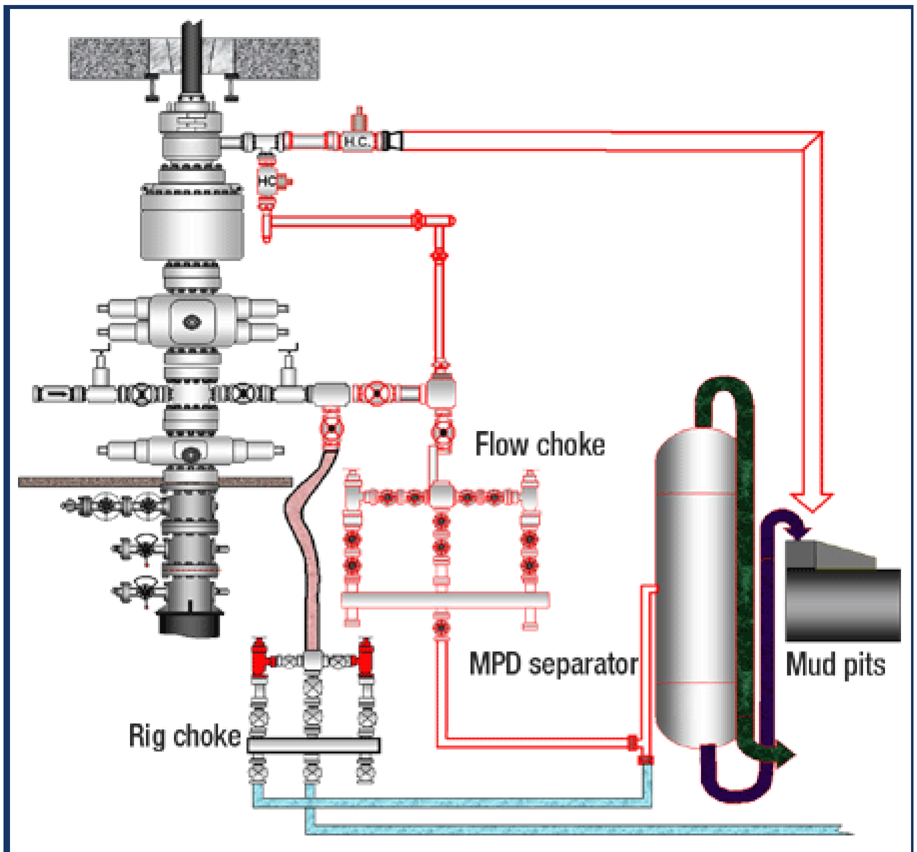

Fig. 1. Closed circulating system with MPD equipment.

Annular backpressure can be controlled at the surface through a flow choke manifold to precisely maintain the downhole pressure regime and avoid blowouts. Other vital equipment includes a rotating control device (RCD) placed appropriately above the BOP stack, a flare line and an adequate mud-gas separator.

Hydraulics design is actuated by the closed circulating system and MPD equipment. Successful MPD requires a proactive plan to illustrate the entire pressure profile and how to control the pressures, specifically in high- or low-pressure zones, high or low permeability, fractured zones, sub-salt strata, etc. The hydraulics design should include mud type, mud densities, mud pump circulation rates, backpressure to be imposed at surface, drilling rate, cuttings size and velocity, wellbore geometry, and at what depths these factors need to be manipulated or changed.

The PP profile in a given openhole section must be determined as closely as possible prior to drilling the section with MPD. This may be accomplished by a detailed PP analysis using log data, seismic data, RFT pressures and virgin production pressures. Leak-off tests and formation integrity tests may be used to verify the FG or leak-off profile near casing seats. Robust computer modeling software is also essential to a precise downhole hydraulics plan.

CONSTANT BOTTOMHOLE PRESSURE

Encountering lost returns immediately upon resuming circulation after making a connection is an indicator of a tight drilling window. If the well did not kick while making the connection, this indicates that the hydraulic friction pressure (when pumps came back on) added to the existing static mud weight (MW) caused the equivalent circulating density (ECD) to exceed the FG somewhere in the open hole. However, if the driller decreases the mud density to avoid exceeding the FG upon pump startup, a kick is likely to occur when the pumps are off.

In Constant Bottomhole Pressure (CBHP) MPD, the objective is to maintain a constant annular pressure profile, whether drilling, making connections, or tripping. It has proven viable when drilling into formations where offset data show narrow PP/ FG margins, or kick/ loss scenarios may exist. Using a competent hydraulic model as a road map, the driller can manipulate fluid density, fluid rheology, annular fluid level, hole geometry, annular backpressure at the surface, and hydraulic friction. This allows him to precisely maintain the downhole pressures, to stay as close to balanced as needed to avoid fracturing the formation or, conversely, taking a kick. The driller can squeeze through narrow pressure margins that could not have been drilled with conventional means or without setting additional casing strings.

A hypothetical scenario involving a 14.0-ppg BHP well with a 14.6-ppg illustrates just such a narrow window that can be drilled effectively using the CBHP variation of MPD versus conventional methods, Fig. 2. Drilled conventionally, a 14.1-ppg static MW would be used to slightly overbalance a 14.0-ppg formation during connections.

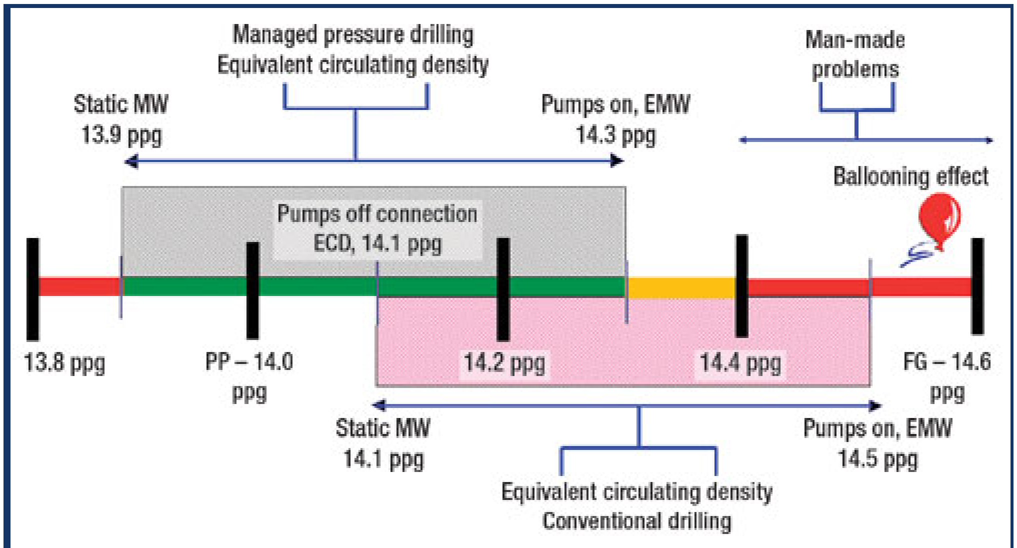

Fig. 2. MW/ PP relationship with and without ECD.

When pumps come on, the ECD jumps to 14.5 ppg, due to the annular friction pressure, and can cause man-made problems like fracturing or ballooning, characterized as a loss followed by trapped pressure or an influx into the wellbore. Using CBHP MPD, a lighter MW (13.9 ppg) is used, and pressure is applied at the surface to prevent underbalance during connections. This maintains EMW greater than 14.0 ppg and balances the formation. When pumps come on, the ECD jumps to 14.3 ppg as the backpressure is released, well below the FG and man-made problems area of the chart.

Although a lighter MW than PP may be used in CBHP MPD, this does not make it a UBD application. Since the total EMW is greater than the PP, it is classified as an MPD application. In the event that incidental influx should enter into the wellbore, it can be contained appropriately and managed, using MPD equipment up-hole.

PRESSURIZED MUDCAP DRILLING

Mudcap drilling (MCD), sometimes called pressurized mudcap drilling (PMCD), is gaining popularity for operators drilling into massively fractured formations, especially when productive fluids are sour. It allows drilling through severe lost circulation zones without the non-productive time usually associated with lost circulation and conventional well-control techniques. Penetration rates are increased significantly, as well.

MCD is a form of "blind drilling" that evolved during the exploitation of the Austin Chalk in Texas and Louisiana. In the Austin Chalk formation, cross-flow from pressured fractures to depleted fractures caused costly fluid losses and dangerously high surface pressures. Drillers, who were using the flow drilling technique at the time, began pumping water down the annulus while injecting down the drill pipe to bring annular pressures below the operating limit of the RCD. As drilling continued and the trend was exploited further, MCD evolved.

During MCD, an RCD is used to seal the annulus, and a weighted viscous mud is pumped down the annulus, Fig. 3. A sacrificial fluid (usually fresh or brine water) is injected down the drill pipe while drilled cuttings are transported up and deposited into vugs or fractures above the bit. (Vugs are natural cavities formed in certain formations, due to leaching out of soluble materials.)

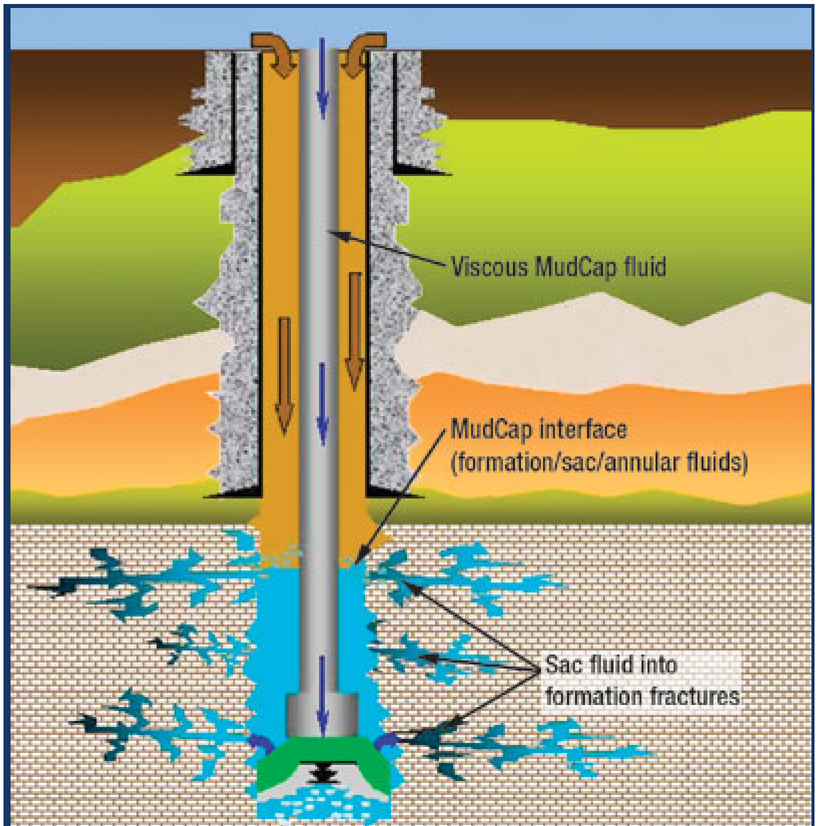

Fig. 3. A typical mudcap drilling application.

The annular fluid prevents hydrocarbon migration to the surface and subsequent high pressures. The pressurized mudcap enables drillers to continue with lower annular pressures. In essence, the MCD technique allows an operator to continue drilling through fractures or faults to total depth with reduced trouble time and cost, minimizing mud losses to the formation.

DUAL GRADIENT MPD

The Dual Gradient variation of MPD involves injecting a light fluid into the annulus to effectively change the hydrostatic head in part of the wellbore. This method can adjust the BHP by a pound per gallon-equivalent (ppge) or more without changing the base MW. The intent is not to reduce BHP to underbalance but rather to avoid fracing the formation with gross overbalance. The light fluid (nitrogen, mud with glass beads, less dense liquid, etc.) can be injected via a parasite string or concentric casing. The pressure gradient above the injection point is decreased, while the gradient below remains the same, hence the name, Dual Gradient.

"In essence, the driller is tricking the formation into thinking the rig is closer than it actually is," said Don Hannegan, P.E., vice president of Weatherford International. Dual gradient MPD has been used almost exclusively onshore.

HEALTH, SAFETY AND ENVIRONMENT

The closed system used in MPD is considered by many to be inherently safer than conventional rig-ups, due to the control afforded over the wellbore pressure. Many insurance underwriters are now requiring wells to be drilled with specialized surface equipment, and regulatory agencies, such as the MMS, are also becoming familiar with the benefits that a closed circulating system provides.

Herein lies the basis for HSE MPD, one of the variations categorized by the IADC. Although the technical application may vary, HSE MPD utilizes the benefits of a closed, pressurized mud returns system versus an open-to-atmosphere system. It is typically applied when dangerous conditions threaten to halt the drilling or subsequent production of a well.

The closed mud returns system prevents drilled cuttings and gas from entering the open air on a rig, thereby reducing exposure to H_2S gas and decreasing the risk of flash fire on the rig floor. Because it affords precise control over the pressure regime throughout the wellbore, a case can be made that it is inherently safer than conventional operations in wells subject to the loss-gain, ballooning-kicking environment described above.

The HSE MPD variation recently proved beneficial for a major operator while drilling an offset from a production platform offshore Vietnam. Industry sources reported that cuttings coming to the surface released methane gas, and the combustible mixture was observed by the readout. Subsequently, production lines were shut down and a substantial loss in production was looming.

The operator applied the HSE variation, using a closed circulating system to send the methane to a flare line, which allowed the production lines to be reopened. Drilling ahead with a Marine Diverter Converter RCD, typical drilling-related problems were avoided by being able to quickly react to unexpected, downhole pressure environmental limits. In this case, reactive MPD served as a type of insurance policy with cost-effective premiums.

A SHIFT TOWARD MPD

Today, an estimated 75% of US land rigs drill at least one section with a closed, pressurized mud returns system, a dramatic increase from 10% in 1995. A majority of these projects do not invite influx, as in true UBD, but they incorporate some aspect of the pressure managing techniques described in this article.

The momentum shift toward precision drilling illustrates the industry's acknowledgement that MPD has viable application potential among today's premier drilling projects. Shell Malaysia applied MPD from the moored *Stena Clyde* semisubmersible offshore east Sarawak, Malaysia. After dealing with near-total losses while drilling into cavernous carbonate, PMCD was applied with inexpensive saltwater as sacrificial fluid and a mudcap slug down the annulus to reach TD, utilizing a marine RiserCap control head.

Since that success, Shell Malaysia has reportedly applied PMCD on seven to nine wells, where total losses have been witnessed. These applications are akin to the reactive category of MPD, since drillers tool up at the beginning with the necessary tools for MPD, but drill conventionally until reaching a cavernous formation, or experiencing early warnings, such as mud losses. Drillers then insert the bearing assembly, pump down the backside and use sacrificial seawater to do PMCD as a reaction to problems in the formation.

Shell E&P recently became the first operator to apply MPD from a TLP rig in the Gulf of Mexico. After encountering pressure depletion and lost returns on the *H&P 201* rig, Shell E&P used the Dynamic Annular Pressure Control system to maintain constant pressure downhole.

In 2005, Transocean and Santos combined the use of surface BOP technology and MPD aboard the *Sedco 601* semisubmersible, offshore Indonesia in a water depth of 2,240 ft. The formation is prone to total lost circulation, well control problems and stuck pipe when drilled conventionally. Their solution was a combination of PMCD and CBHP, an innovative technology blend that incorporated the Weatherford Model 7100. The achievement on the *Sedco 601* was the first use of a RCD to control annulus pressure while drilling with a surface BOP from a floating rig.

The *Sedco 601* crews and Santos previously utilized this blend in conjunction with a conventional subsea BOP and marine riser to drill an abnormally pressured well in a water depth of 145 ft. The *Sedco 601* has drilled more offshore wells in surface BOP mode than any other rig in the industry.

Aboard Transocean's *Trident* jackup, Chevron employed PMCD after total losses were encountered offshore West Africa. Chevron used the Weatherford 7100 head to control annular pressure to drill the well. And due south of Galveston, Texas, in the Gulf of Mexico, Unocal used CBHP from a production platform to drill into narrow PP/ FG margins using a surface BOP stack.

MPD ON THE HORIZON

Several events are planned for 2006, including the SPE/ IADC MPD & Underbalanced Operations Conference and Exhibition, to be held March 28-29 at the Moody Gardens Hotel in Galveston, Texas. (http://www.iadc.org/conferences/MP6_Call.htm).

The Drilling Engineers Association is organizing DEA 155, a Joint Industry Project entitled "A Probabilistic Approach to Risk Assessment of Managed Pressure Drilling in Offshore Drilling Applications" to compare MPD with conventional drilling. The MMS is willing to contribute 20% of the current budget for this initiative, the results of which are posed to affect the entire drilling industry.

MPD is becoming recognized not as a "last-ditch" drilling option, but as a safer, faster, more effective means of accessing hydrocarbons once thought unattainable.

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