Managing wellbore pressure while drilling

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TO MANAGE BOTTOMHOLE pressure (BHP) or annular pressure with drilling fluids in the hole, conventional drilling methods dictate that the rig's mud weight be increased or decreased. This is a very slow, time-consuming process. This action also produces significant problems for the ever-growing number of wells that demand more exact wellbore pressure management and less drilling flat time.

An important characteristic of managed pressure drilling (MPD) technology is use of a closed, pressurizable mud returns system that provides the ability to drill ahead and make jointed-pipe connections while maintaining the appropriate annular pressure profile. Proper annular pressure profile prevents both unintended well influx and formation damage. This variation of MPD technology also provides better control of the well and achieves more precise wellbore pressure management, containment and diversion of mud returns with fewer interruptions to the drilling process.

MPD CLOSED SYSTEM

The closed system relies on a choke connected to the mud returns port beneath the rotating control device (RCD) to control, almost instantaneously, the annular pressure profile by increasing or decreasing back pressure at the choke to compensate for changes in annular friction pressure (AFP) as annular flow is increased or decreased (Figure 1). This MPD process is a technology that literally permits "walking the line" between formation pore pressure and fracture gradient through precise control of the annular pressure profile.

The MPD closed system discussed here comprises a float valve (nonreturn valve, or NRV), rotating control device, an enclosed flow line, a flow choke manifold (Figure 2) separate from the existing rig well control manifold and, optionally, a degasser or mud/gas separator system. If used, the separator removes gas from the drilling fluid and dumps cuttings and drill fluid into the rig pit system for solids removal. This allows well influx to flow at a controlled rate while drilling is continued.

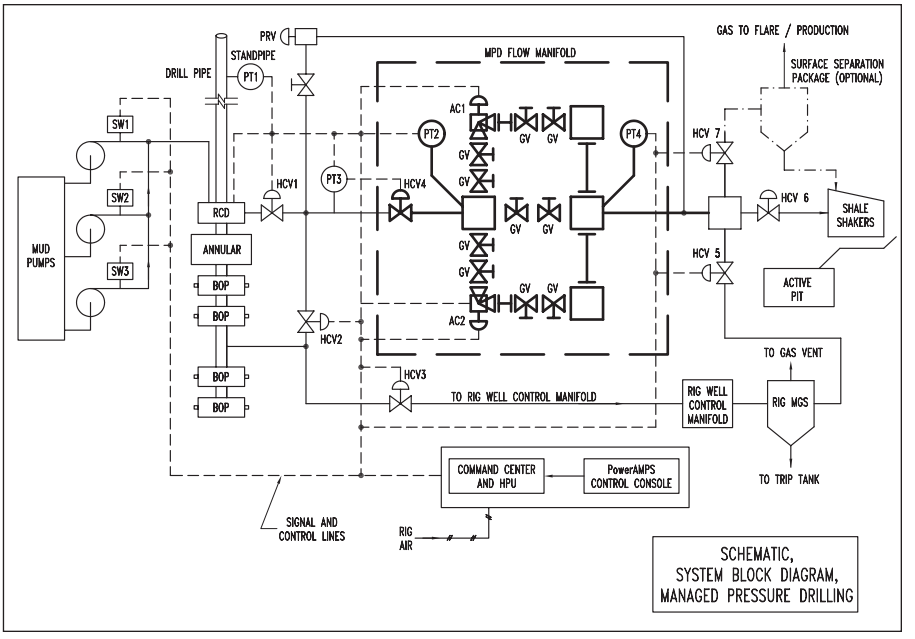
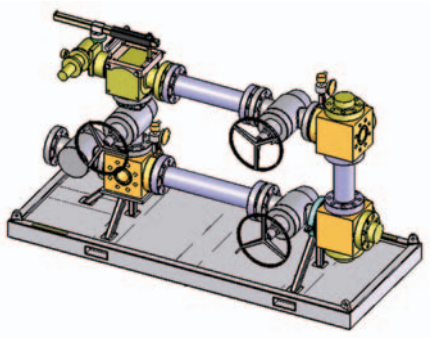


Figure 1 (above): an MPD rig-up schematic. Figure 2 (below): a choke manifold layout.



In a closed-loop system, the mud goes from the mud pit through the mud pump, into the standpipe down the drillstring, through the float valve and the bit up the annulus, exits the annulus below the RCD, through the choke(s), to the shaker or degasser, and finally back to the mud pit. The mud in the annulus is kept under pressure from pumps to choke by use of the RCD and the choke manifold. The RCD allows rotation of the pipe, as well as the entire drillstring, so both pipe and drillstring can continue to be worked.

WELL MODELING

The MPD system is fed data by a hydraulics well modeling program that reads and processes data, including hole depth and diameter, formation data, revolutions per minute (RPM) of the drillstring, rate of penetration (ROP), drilling fluid viscosity, density and temperature, etc, and then predicts the annular pressure profile. The annular pressure at any given point is the sum of three components: static mud weight, annular friction pressure (AFP) and surface back pressure (choke pressure). The static mud weight is essentially constant for any given period of time. Thus the two parameters, which can quickly change, are annular friction pressure (proportional to mud pump speed) and surface back pressure (controlled by the automatic choke system).

When the desired pressure profile has been determined, the choke is automatically modulated under model control to compensate for changes in AFP as the annular flow rates increase or decrease to achieve the desired annular pressure profile. The automated managed pressure (PowerAMPS) system used in this MPD system automatically modulates the choke, making micro-adjustments as necessary to maintain the desired annular pressure profile (Figures 3 and 4).

DRILLING AHEAD

These adjustments are straightforward when drilling ahead — the static mud weight, annular friction pressure and choke back pressure figures are relatively steady. The value offered by an advanced MPD system occurs when the rig is making connections, as the

required annular pressure profile can be maintained even when mud pumps are shut down for a connection.

In the enhanced MPD system, as the main mud pumps are slowed down and flow is decreased, the AFP decreases – the lower the flow rate, the lower the annular friction. This decrease in AFP must then be replaced with choke back pressure. The well model is continually sending new pressure updates, and the PowerAMPS system makes adjustments to hold the required pressure.

The difficulty in performing this process is that once the mud pump rate is slowed or stopped, there is no remaining back pressure for the choke to trap – essentially, a standard PID controller will try to close the choke too late. "Once the horse has left the barn, closing the door does no good."

Different systems are utilized in MPD to overcome this major problem. Some operators have tried manually controlling the choke and have reported some success. Others have added an auxiliary mud pump to start prior to rig mud pump shutdown and provide back pressure to

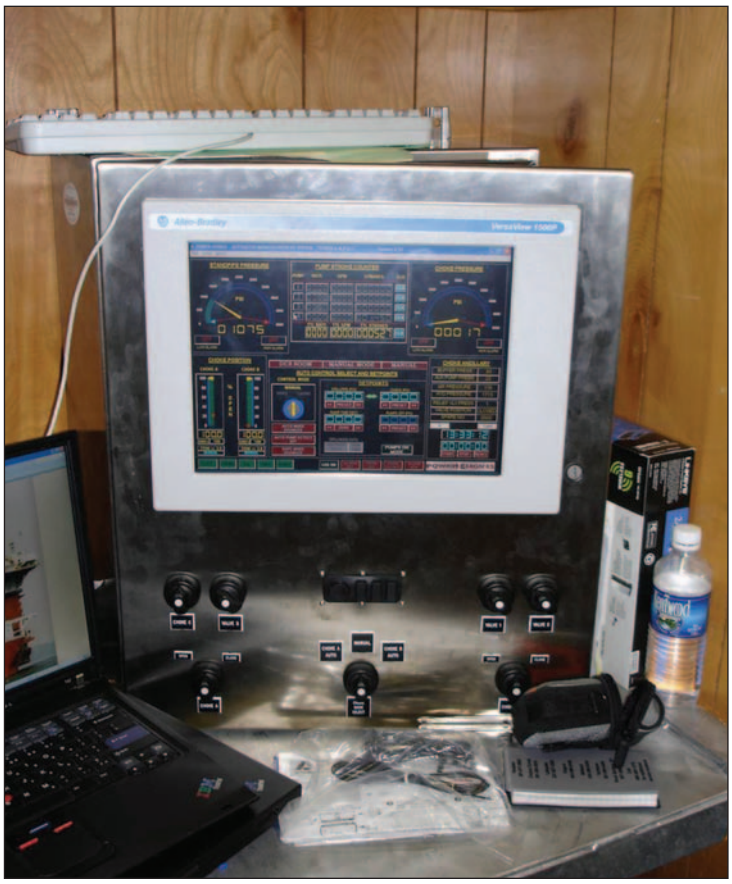


Figure 3: The Automated Managed Pressure System continually receives new pressure updates from the well model and then automatically modulates the choke to achieve the desired annular pressure. The Main Operating Screen is shown here.

the annulus, controlled by an automatic choke.

The mechanism described here requires neither the auxiliary mud pump nor any attempt to precisely control the choke manually. Instead, a communications link is established between the MPD automatic control system and the mud pump operator (or the mud pump control itself). The link allows precise coordination of choke position and pump speed. Thus annular friction pressure loss can be compensated by increased choke back pressure.

The control algorithm incorporated into this system is predictive rather than reactive such as an ordinary PID control. The choke control system calculates the proper mud pump speed and associated choke position to maintain the correct bottomhole pressure. It also monitors the mud pump speed to verify the proper response. If or when the mud pump speed varies from the planned speed (as in the case of an unplanned shutdown of the mud pump), and choke position is adjusted instantaneously to compensate and to maintain the correct BHP.

The Power Relief Valve (PRV) is an important safety feature for both hole/shoe integrity and MPD system protection. The PRV is independent of the MPD system control and has its own dedicated hydraulic power source and UPS system. Regardless of what may befall the rest of the MPD system (line plugging, computer or PLC failure, signal failure, etc), the PRV is in place to prevent an overpressure that could damage either the formation, the MPD piping or the rotating control device.

The Power Relief Valve is placed on the mud returns line below the RCD and before the choke manifold. The PRV will open and dump excessive pressure caused by a plugged line downstream of the RCD, or by an operational error, which could result in backpressure that would damage the formation or mud returns system. The PRV modulates open and closed to maintain a safe bottomhole pressure.

Once the connection is made, the process reverses because the main mud pumps must be brought back online. When pumping downhole begins again, AFP is increased and choke back pressure is reduced to compensate. The well model sends new data to the PowerAMPS system, which then modulates the new choke position as required until rig pumps are at full speed.

Figure 5: Installing the flow choke manifold section of the closed-loop MPD system.

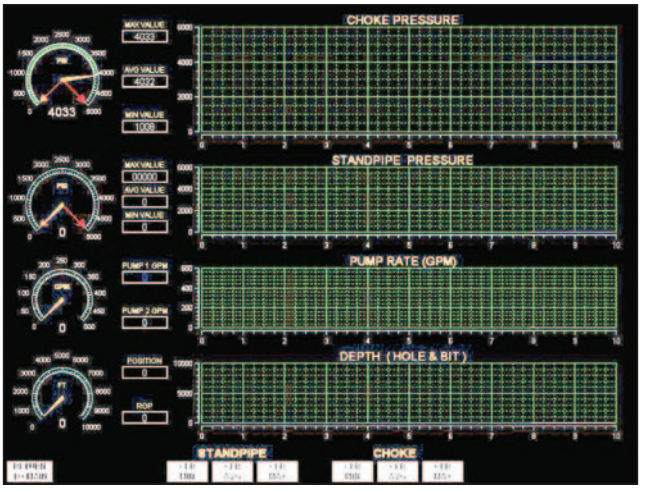


Figure 4: Trending Screen of the Automated Managed Pressure System allows access to all previous drilling data.

A BRIGHT FUTURE

The MPD system is an enabling technology whose potential benefits address many long-standing drilling and wellbore stability-related issues — elimination of pressure surges when stopping and starting circulation, improved drilling fluid management, enhanced ECD control, improved hole conditions, and perhaps most important, the ability to drill more efficiently within narrow pressure environments. The areas of application for MPD technology seem to be as broad as the improvements it brings to the conventional drilling process.

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