In today’s drilling environment, the industry is facing greater pressure-related challenges while developing mature and unconventional fields, both on land and offshore. Marginal wells can become more feasible by increasing efficiency and improving safety. Managed pressure drilling (MPD) is an enabling technology that can help accomplish these goals while also mitigating drilling risks. This document contains recommendations to help successfully implement MPD when formation pressures are above hydrostatic recommendations.
WHY ARE YOU USING MPD?

This may seem to be an obvious question, but MPD has many variations. The International Association of Drilling Contractors (IADC) has defined MPD as:

"An adaptive drilling process used to more precisely control the annular pressure profile throughout the wellbore. The objectives are to ascertain the downhole pressure environment limits and to manage the annular hydraulic pressure profile accordingly."

Simply put, MPD is an equivalent circulating density (ECD) management tool.

Drivers for the use of MPD include placing the wellbore on a closed loop, improving the rate of penetration (ROP), reducing potential damage to the reservoir, detecting kick/loss situations early, traversing narrow pressure environments, and possibly reducing the number of casing strings. Understanding the wellbore construction challenge will dictate what equipment and MPD service that a particular project will require. The simplest choice is to add a rotating control device (RCD) for additional rig floor safety to a complex fully automated MPD system required to traverse a narrow pressure zone. The Halliburton GeoBalance® optimized pressure drilling service can assist in developing the best solution for your wellbore construction challenges.

BEGINNING THE MPD PROCESS

For complex wells, MPD is not typically a call-out service. Halliburton should be engaged in the planning and engineering phase of the project. This is not to say that MPD cannot be called out as the need arises, but there are configuration and logistical planning requirements that must be addressed so that equipment can be successfully configured and integrated with the rig. For deepwater drilling operations, it is not best-practice to call out MPD services or equipment due to the logistics and rig integration requirements.

The operator should decide on the use of MPD prior to selecting the rig. Once the rig has been selected, it is normal practice and highly recommended to have a Halliburton GeoBalance MPD representative conduct and document a rig survey. The importance of the rig survey is to validate and work through MPD rig integration with the customer and rig contractor. Halliburton can develop the equipment layout drawings based on the rig survey, and update the relevant engineering and operations documents.
For surface stack applications, consideration should be paid to rotary beam and blowout preventers (BOP) stack height regarding placement of an RCD below the rig floor. For subsea BOP applications, there will be questions regarding riser integrated equipment, such as the RCD, riser gas handler system, stripping quick-close annular, drape hoses, etc. Determining if an RCD will be located below tension ring (BTR) or above tension ring (ATR) will require consideration of drilling environment, sea state data, telescopic joint and riser configuration, vessel type, and economics of integration with the drilling rig or vessel. If the vessel is MPD ready, typically a riser gas handler and RCD would be installed in the riser string and connected to a buffer manifold and MPD system located on the rig. If the vessel is not MPD ready, the process to integrate MPD-ready hardware BTR will require long lead times and significant advanced planning.

An ATR RCD may be implemented on rigs that are not MPD ready, but special considerations will have to be addressed, such as telescopic joint configuration, RCD placement, inner barrel drift, and flow line plumbing. Installing an RCD and riser gas handling systems on or in the riser string requires close coordination with rig operators and/or vessel owners to understand mechanical loading requirements, performance requirements, and rig integration solutions.

To help prevent premature RCD sealing element failures, close attention should be paid to the rig’s drillpipe configuration and condition. Drillpipe with abrupt tool joint shoulders, identification grooves, and excessive hard banding will greatly diminish the reliability of the element life. Halliburton RCD sealing elements have been thoroughly tested in accordance with API SPEC 16RCD “Specification for Rotating Control Devices” to develop performance envelopes under dynamic and static operation.

In the planning phase of a project, Halliburton GeoBalance® Services require the following data for both land and offshore operations:

- Pore/fracture/collapse pressure profile
- Planned trajectory/planned well path
- Planned drilling program
- Planned mud program
- Offset well daily drilling reports
- Offset well mud reports
- Offset well logging while drilling (LWD)/wireline logs
- Temperature profile (formation and flowline)
- Well geometry with casing details
- Bottomhole assembly (BHA)/drillpipe information
- Formation caliper data

**JOB STARTUP**

A rigsite visit can answer questions such as:

- Can the rig supply air for the chokes?
- Can the rig meet my power requirements?
- Can I use a rig pump as a backpressure pump?
- How do I integrate the rig pump diverter system?
- Is there enough clearance for the RCD?
- Will the drill pipe on rig cause premature element failures?
- How much MPD surface piping, size, and length is required?
RCDs are not created the same, and are all used for different reasons.
Offset pressure-while-drilling (PWD) data
Geological reports and seismic profile
Offset well leak-off, kick, or loss zones
BOP and annular details
Vessel and platform details
Riser/riser gas handling system package details
Sea states for surge and swab effects
Region of operation (regulatory)

With this data, Halliburton GeoBalance service can build a client-specific hydraulic model to determine the required equivalent circulating density (ECD) throughout the section. Fluid densities, flow rates, MPD type and service level, ECDs and choke pressures can be tailored to help keep the well hydraulically within the pressure windows. Particular detail will be paid to the choke pressures to help ensure that shallower formation fracture pressures are not exceeded as the well is deepened. Once the operational pressure environment has been determined, the choke trims can be selected to maintain the operational ECD pressure range and to stay within the surface pressure range of the selected RCD. Flow lines can be sized with pressure drop in consideration; any undue pressure drop in the flow line will limit the choke’s ability to control the bottomhole pressures. A piping and instrumentation diagram (P&ID) and valve number diagram (VND) can be developed based on the selected equipment, pressure ranges, rig types, etc., as outlined above. Additionally, operational and contingency procedures can be developed with the P&ID and VND referenced within.

It should be noted that the Halliburton RCD product line is the lynch pin of the system. API has specific and rigorous testing requirements per API SPEC 16RCD which Halliburton GeoBalance service has performed and successfully completed. This allows API monogramming of the Marine Sentry RCD 3000 and RCD 5000. Marine Sentry RCD 3000 is specifically designed to integrate into non-floating offshore rigs and can be utilized in above tension ring (ATR) applications for floating rig. API SPEC 16RCD testing encompasses dynamic and static pressure ratings and performance characteristics for the RCD bearings and sealing elements. Dynamic ratings consider rotating speeds and stripping parameters, and this dynamic rating will be factored into the planned drilling program’s maximum pressure parameters. It should also be noted that increased revolutions per minute (RPM) and higher flowline temperatures will typically de-rate the RCD dynamic pressure capability. It is recommended that the maximum choke/wellhead pressure design be maintained at 50 percent of API SPEC 16RCD test data for optimal performance.

For projects or rigs that will utilize MPD, it is recommended that a hazard identification/hazard and operability (HAZID/HAZOP) study be performed with key individuals from the rig’s contractor, operator, and services companies once the VND is updated. The purpose of the HAZID/HAZOP study is to help find any risks that were not identified with the procedures and contingencies. It is recommended that all items discovered during this event be closed addressed to beginning MPD operations.
EQUIPMENT

**Top** » The choke is the pressure regulator of the closed loop. There must be flow across the chokes on connections while tripping in order to control bottomhole pressure.

**Bottom Left** » The RCD forms the closed loop system and diverts flow to chokes.

**Bottom Right** » The rig pump diverter diverts flow from the standpipe manifold to maintain flow across the chokes.
EXECUTION

Execution of the project consists of following through on the planning and procedures developed in the planning stage in advance of mobilizing to the rig.

Load-out and Transportation
Due to the size, weight, and quantity of equipment, advanced planning is required to ensure on-time delivery to the rig. Depending on the remoteness of the location, planning for additional spares may be required to provide successful support. For land-based applications, a crane may be required onsite to facilitate offloading and loading of equipment.

It is important to understand the local regulatory and client-specific requirements for any heavy-lift activities, both on land and offshore.

Typically, to execute the load-out and delivery, a load-out plan is developed to manage the import requirements for foreign locations, along with the staggered delivery of equipment, cranes, transport, and personnel. This load-out plan will also include rig interfaces, deck loading, and modifications based on equipment location on the vessel/rig.

Equipment Installation
Prior to any equipment being installed, the Halliburton GeoBalance representative can coordinate with the rig operator to help address any concerns regarding rig interface with the Halliburton equipment. This may include local electrical, air, water, and physical access points that may prevent or delay the installation of the equipment.

The installation phase of the Halliburton GeoBalance MPD equipment on land may take up to three days. For land applications, this would typically be an RCD, MPD choke skid, rig pump diverter (RPD), and associated piping. Offshore installations may include the above items, as well as a riser gas handler, mud gas separator (MGS), and flare line. For offshore installations, it is preferable to perform the installation while the vessel is in port to minimize logistical issues during installation. However, all of the Halliburton GeoBalance equipment can be installed with the vessel on location if required.

To help minimize time on the critical path, it is recommended that the MPD rig-up be conducted on a casing run or during rig maintenance activities. The RCD body should be installed during the BOP stack or riser installation, depending on rig type.

To prolong RCD life and help prevent premature element failures, it is highly recommended to verify that the rig is aligned with the BOP stack. For top drive rigs, extra attention should be paid to the alignment of the top-drive as it travels the length of the guide rail. Time spent to correct any misalignment can usually be recouped in the time and expense of changing elements due to failure. BOP stack and top-drive alignment should be monitored to help ensure optimum life of the RCD elements.
Equipment Testing
Prior to operating, all Halliburton GeoBalance MPD service equipment can be pressure-tested per a client- and job-specific Pressure Test and Commissioning procedure. It is recommended that the testing be performed while BOP test equipment is available or when BOP testing is required. Typically, the Pressure Test and Commissioning procedure utilizes the VND and the P&ID.

For the Halliburton GeoBalance automated MPD systems, a control panel and automation test is conducted to help ensure that the control systems are operating the automated system correctly. For the manual MPD systems, cycling of the valves and verifying gauge readouts can be documented. Verifying the function of all actuators and the inputs from various sensors are critical to the successful operation of the MPD equipment. All test data, both printed and electronic, can be captured and retained for future reference with data available upon request. Some third-party integration vendors, such as riser gas handler providers, may not have direct outputs for their data or may not be able to share their data in real time. In cases where Halliburton has integrated with a provider that cannot share its data, Halliburton GeoBalance representatives can help coordinate with the provider to get documented evidence that the system level test was completed successfully prior to any operations beginning.

For wells that will utilize managed pressure cementing (MPC), the planned surface pressures may be greater than the RCD’s limits. For this application, it may be necessary to use the rig’s annular preventer. To accomplish MPC and maintain the required pressures, a secondary MPD flow line that is tied into the mud cross is recommended. This secondary flow line must have a double isolation valve system that matches the pressure rating of the BOP’s, a valve being a high closing ratio (HCR) and the other being a manual. This line can act as an equalization line for RCD element changes and can provide a means of maintaining bottomhole pressure during element changes.

Training
MPD can be conducted by using different techniques and procedures, such as closed loop, pressurized mud cap drilling (PMCD), continuous circulation, etc., and it is important that time be allocated for training of crews. Starting a MPD job with a rig which has not performed MPD will require the crews to make changes to their routines and procedures, such as how to make a connection, kick detection, tripping, etc. Supervisors will require a higher level of training relative to the MPD techniques and procedures, typically on simulators and in the classroom. Training for the support personnel can be in a classroom session via a Drill the Well on Paper exercise to familiarize the crew with procedures; contingencies; and health, safety, and environmental (HSE) aspects of the operation. Once the MPD service has begun the operational phase, each pre-tour meeting should include an MPD topic that is relevant to the planned daily activity.
Once formal training has been concluded, it is highly recommended that time be allotted for a practice session and MPD fingerprinting prior to commencing MPD operations. The practice session should include simulating connections, changing the RCD elements, stripping and tripping speeds with or without pressure, checking for flow and slow pump rates, and verifying MPD signatures and BOP drills.

Halliburton GeoBalance MPD technology focuses on early kick detection, incorporating pressure while drilling (PWD) and the Halliburton Baroid Drilling Fluids Graphics (DFG™) hydraulics model, to help manage wellbore events in conjunction with the industry-adopted flow in/flow out mass flow balance technique. The advanced nature of the Halliburton technology requires the crew to understand and, if practical, participate in drills simulating kick events to gain an understanding of the differences between the DetectEV and ActEV™ MPD™ control systems and how they tie into the well control matrix.

Operational Matrix
Prior to drilling a well, the operational matrix must be agreed upon. The operational matrix consists of the parameters defining when an influx is declared as a well control event, and handoff to the rig team is required. As an example, the matrix could be based on the kick-tolerance volume that will exceed 50 percent of the RCD dynamic pressure rating or 80 percent of the Halliburton GeoBalance MPD choke pressure rating if the MPD flow line is integrated into the mud cross and the annular preventer is engaged on influxes.

BHA Considerations
The measurement-while-drilling/logging-while-drilling (M/LWD) tools are typically configured to account for large internal pipe pressure drops when pumps are brought down while some M/LWD providers have a fixed configuration. Using an integrated Halliburton RPD can allow for a broader suite of M/LWD providers and also minimizes connection time, thus mitigating the time required for M/LWD surveys. Halliburton closely coordinates with the M/LWD provider to ensure that the data frequency provided will be at a sufficient rate to incorporate into the DetectEV early detection system.

The greatest challenge for MPD during drilling will be making connections. Since the annulus will be pressurized, it is recommended to have a minimum of two non-ported drillstring floats (non-return valves) installed in the BHA.

Prior to drilling out of the casing shoe, we recommend to have a junk catcher installed or have an adequate choke bypass in place to minimize or prevent debris from collecting in the MPD choke manifold.
**MPD Drilling**

The switch to MPD drilling mode begins with the installation of the RCD bearing/sealing elements, performing functional tests on RCD and MPD equipment. The next step is to displace the current drilling fluid with the MPD drilling fluid based on the pre-well modeling that can be adjusted as pressure regimes dictate. Halliburton GeoBalance SetPoint (GBSetPoint) real-time hydraulic control systems can allow for automated control and pressurized circulation during the displacement process and the operational phase of drilling. The GBSetPoint control system utilizes the following, in real time, to assist greater accuracy in bottomhole pressure control, event detection, and managed pressure cementing (MPC):

- Multiple densities throughout wellbore
- Rheology throughout wellbore
- True vertical depth (TVD)/bit depths
- Flow rate
- Pipe rotation and movement
- Standpipe pressure (SPP) and controller
- Selectable control points (shoe, bit, custom)
- Injection and booster flow rates
- Surge and swab mitigation
- Cuttings loadings
- Fluid compressibility
- Thermal correction

Since the MPD system is controlling the well with a hydraulic model, managing fluid treatments and controlling a constant fluid density and rheology is essential. We recommend that, while making any fluid treatment, the fluid densities and rheological properties be monitored, and that any changes be reported to the MPD provider. The MPD provider will input these changes into the hydraulic model so that the various densities and rheological properties can be accounted for as it travels down the drillstring and through the various annular sections.

The control point for the MPD system will typically be at the bottom of the well, but there are scenarios where the control point may change. In laterals that are maintained at 90 degrees, it is recommend to control at the heel of the lateral while monitoring the ECDs at the toe. In some wells, the shoe may be the weakest point and the MPD control point will be at the shoe so that the fracture pressures are not exceeded. This would also apply to drilling depleted formations where the formation pressures have been reduced, resulting in narrow drilling windows. In some scenarios, formation pressures are the same pressure gradient for several thousands of feet. In this environment, the control will be at the top of the formations, and ECD will be monitored with depth to help ensure that it does not approach the fracture pressure.

**HYDROSTATIC PRESSURE**

This category includes pressurized and floating mud cap drilling. These techniques are highly dependent on an RCD, a good water supply, and means of keeping a fracture open. With both techniques, returns are not brought to surface; cuttings, formation pore fluids, and the water used to drill will be stored in the open fracture. The challenge with these techniques is maintaining sufficient pressure on the fracture to keep it open.
Formation Pressure Test

Once MPD mode has commenced, Halliburton may conduct a formation pressure test. The formation pressure test, which can consist of a leak-off test, formation integrity test, or pore pressure test, is conducted to define the operational pressure envelope. This process may be repeated to update the hydraulic model control limits, then the data can be used to refine the pore pressure models. These tests can be performed while drilling with the Halliburton GeoBalance MPD system. The limits of the operational pressure envelope can also be determined using output data from the Coriolis flow meter and choke pressures for verification of the formation tests.

Depending on changing formation pressure test results, the MPD program may require the drilling fluid to be statically underbalanced to the pore pressure to manage the ECD in narrow drilling windows. For this application, it is important that the statically underbalanced fluid be designed so that, while circulating, the chokes operate with a minimum of 100 psi of backpressure. The maximum pressure required for connections does not exceed 50 percent of the dynamic RCD pressure rating.

Most think of formation pressure in terms of equivalent mud weights, but, for accuracy, pressure should be thought of in terms of absolute pressure.

Connections

During this transient event, the Halliburton GeoBalance MPD system compensates for surge/swab pressures as the bit leaves the bottom, and also going back to the bottom due to connection makeup. The system also compensates for changes in circulation while the flow is diverted from the standpipe to the chokes with the Halliburton RPD. The Halliburton RPD can help minimize the time required to make a connection compared to the ramp-down/ramp-up time using backpressure pumps. To allow the choke speed to travel with the ability to manage the process, the flow rate transition is slower than conventional drilling. The Halliburton RPD has shown that the flow rate transition can be reduced by as much as 75 percent over the traditional process, which can translate to time and cost savings for the operator.

Slow Pump Rates

As with conventional drilling, slow pump rates should be taken. The only difference with MPD is that the MPD system will utilize a hydraulic model to determine wellhead pressure to apply based on flow rates. To determine the standpipe pressures while taking slow pump rates we recommend recording and subtracting the wellhead pressure once the slow pump rates, have been established.

Installing the RCD Bearing and Elements

The risk of differential sticking is typically lower when drilling near balanced in MPD mode. The RCD bearing and seal element change can be made without pulling pipe. In depleted zones or sections where MPD is used to stay below fracture pressure, it is recommended to pull above the depleted or permeable zones to minimize the risk of sticking.
Typically, the RCD bearing assembly is installed using a running tool. While some RCD bearings are latched using a manual clamp system, the Halliburton GeoBalance Marine Sentry RCD 3000 is equipped with a hydraulic latching system that can be visually verified for engagement. The control of the latching mechanism is managed locally at the HPU or from a remote human machine interface (HMI) located on the rig floor. The hydraulic power unit (HPU) also controls the function of the equalization valves, RCD vent valves, and RCD low-pressure riser drain pumps. This hydraulic latch system enables the latching of the RCD bearing and for the seal element assembly to be installed without personnel going below the rig floor.

The Halliburton GeoBalance RCD 5000 can also be outfitted with a hydraulic latch system.

For riser-based RCD installations, consideration should be made to the effects of sea state when installing the RCD. Since the RCD bearing and sealing element latching cannot typically be visually verified when installed BTR, a pull test or low-pressure test should be conducted to help ensure that the bearing assembly is located and latched according to operational procedures.

The Halliburton Marine Sentry RCD 3000 also monitors pressure between seal elements, speed, and vibration. This data is used to determine the operational state of the equipment and help allow for planning a preventive changeout of the bearing assembly before seal failure.

**Continuous Monitoring and Event Detection**

During MPD operations, many providers rely on a flow-in/flow-out mass flow measurement system to determine influxes. Some providers rely on mass flow balance plus surface pressure sensor data to make the influx determination. Halliburton GeoBalance proprietary control systems, DetectEV and ActEV, incorporate PWD plus the above-mentioned trends, as a minimum. The DetectEV system is the Halliburton GeoBalance application designed specifically to identify wellbore events, while the ActEV system is the real-time event controller.

The DetectEV system monitors for well events using signature-based algorithms that can be used in MPD mode or offline. This system has been used in stand-alone early kick detection applications. The DetectEV algorithms monitor and use mass flow data, choke positions, standpipe pressure, and downhole PWD data to evaluate the current conditions against the signatures. In the event that the DetectEV system triggers an influx alarm, the ActEV system is designed to validate if a true influx exists or if the event was a surface gas anomaly. If the influx is determined to be outside of the MPD operational matrix, the ActEV control system will manage the event up to the limits of the equipment, or the weakest point in the well until the rig’s shut-in procedures can be implemented. At the point the well is shut in, it is recommended that the MPD system be isolated from the well by closing the flow line High Closing Ratio (HCR) and manual valves.
Checking for flow during MPD can easily be performed by taking the chokes out of automated mode when the well is not in a flow transient condition and placing the chokes in a fixed position. If the well is in an underbalanced state, an increase in wellhead pressures can be noted. Checking for flow is managed by the Halliburton ActEV control system. Through automation, the ActEV system can have the MPD system react as quickly as a two-minute window to help determine if an event is an influx or gas anomaly. The system can either manage the event or turn it over to the rig.

**Tripping**

During MPD operations, it may be necessary to develop a tripping strategy. As previously mentioned, typically for MPD operations, the drilling mud weight is statically underbalanced, and, by using surface back pressure generated by the choke restrictions, a dynamic overbalanced state can be maintained. In order to trip successfully, a strategy to manage the bottomhole pressure during tripping events needs to be developed. This tripping strategy should include pre-well modeling. Tripping speeds should be fully understood for pressure requirements and may be modified during the well construction process based on the actual conditions.

Many regulatory and ensuring bodies require the following from the ABS classification of drilling systems for kill weight muds:

a. One complete hole volume (100 percent, including drilling riser as applicable) of drilling fluid with sufficient density to kill the well shall be available on site at any time in case of any emergency.

b. Supplemental facilities may be installed in order to store any needed additional volumes of kill fluid on the rig.

c. Additionally, sufficient weighting materials shall be available on site to weight up another hole volume (including riser as applicable) with a 1.5 safety margin.

d. If combined pit storage capacity is not adequate to meet this requirement, consideration may be given to the presence of additional bulk storage capacity, combined with the rig’s on-the-fly mixing capabilities. This is a higher-risk alternative, and will not be acceptable in every instance.

These requirements hold true for MPD with the exception that these fluids could be utilized as a means to help secure the well during tripping; however, it is still required to displace the entire well. Halliburton offers an alternative method by using the GBSetPoint control system and a Halliburton GeoBalance barrier pill at a specific control point in the well.

The process of spotting the barrier pill to trip to a planned spotting control point in the well involves tripping with surge/swab engaged. During tripping, the problems associated with pressure still exist. To help mitigate the issues of formation pressure and integrity due to surge/swab, depth, and lateral position, the control point selectable feature of the Halliburton GBSetPoint control system allows the MPD service to select a point in the well to control bottomhole pressure while monitoring multiple points. To assist with surge/swab mitigation, the GBSetPoint system is continuously
monitoring the acceleration of the drill pipe and calculating running speeds based on acceleration. These values are fed into the GBSetpoint hydraulic models for bottom hole pressure control.

Once at the spotting point, the barrier pill will be pumped and sufficient volume will be spotted to help sustain separation of fluids. The bit will be pulled to above the barrier fluid and plug will be allowed to set. After the plug is set, the precalculated volume and kill weight mud is pumped, using the GBSetPoint control system to track volumes and manage bottomhole pressure accordingly. Once the kill mud is pumped, the RCD bearing and sealing elements can be removed and conventional tripping can resume. Conventional surge/swab recommendations can be followed during this tripping event.

By following these tripping strategies, the bottomhole pressure management objectives of the MPD service can be maintained. Additionally, using the GeoBalance barrier pill can provide the economic benefit of reduced mud conditioning costs while preventing gas migration. GBSetPoint real-time hydraulics provide improved tripping speeds and reduction of nonproductive time (NPT) due to formation instability. These same techniques can be used while running casing and for MPC.

Managed Pressure Cementing (MPC)

Once the well has reached total depth (TD), the pressure issue that led to using MPD still exists, and with running of casing and cementing, the open wellbore will be subjected to extreme stresses.

The challenge for cementing is developing a slurry design that will maintain the primary barrier while the cement is liquid and that will generate minimum friction while being pumped. This is where MPC has evolved from MPD, and, in essence, MPC is a fluid management technique to help maintain the bottomhole pressures within the operational window.

The main difference from MPD and MPC is managing and tracking the various densities, rheologies, and flow rates as the fluids travel throughout the well. The GeoBalance team has integrated its GBSetPoint real-time hydraulics model with Halliburton Cementing’s iCem® service. This integration supplies real-time fluid densities, rheologies, pressures, temperatures, and flow rates so these parameters can be tracked throughout the circulation and surface pressures can be more accurately applied, helping supply constant bottomhole pressure control.

Even though the MPD equipment will be the same, the MPC technique is not a continuation of MPD. MPC requires proper engineering and collaboration between the cementing and MPD engineers. Engineering will begin with the pre-well model. Communication with each other must be maintained as the well is being drilled to ensure that the final cement design is compatible with the fluid in the hole. At this time, an understanding of the pressure schedule will be developed, and the MPD engineer will determine whether any light fluids in the system can be brought to surface without exceeding the pressure limits of the equipment.
Continuous Circulation System (E-CD™)
The E-CD™ system is a method of MPD that enables a continuous circulation system (CCS) to maintain uninterrupted flow of drilling fluid to the well via the drillstring during connections while drilling and tripping out of the hole. The pumps are never turned off while making connections or tripping. This can keep the bottomhole pressure (BHP) constant during these activities; help maintain fluid rheologies and temperatures; and keep the cuttings moving at all times, enabling continuous hole cleaning. The E-CD™ system is a great tool to complement the benefits of using backpressure MPD technology. It is important to note that the E-CD™ system can also be used in conjunction with most conventional drilling programs.

Cycling the pumps on and off during connections in conventional rotary drilling causes fluctuations of the BHP. When the pumps are turned on, these pressure fluctuations are related to annular frictional losses and mud gel pressure losses. When the pumps are turned off, the frictional losses are no longer contributing to the downhole equivalent circulating density (ECD), and the hydrostatic pressure of the drilling fluid is the only force acting on the openhole section. These pressure fluctuations can cause problems such as exceeding the fracture gradient pressure and/or falling below reservoir pressure. These conditions increases chances of drilling problems such as hole instability, reservoir influxes, and stuck pipe. The on/off cycling of pumps also reduces the effectiveness of the drilling fluid to carry cuttings out of the hole. While pumps are turned off, cuttings tend to fall back down the wellbore in vertical wells and to the bottom of the hole and at transitional angles in horizontal wells. This increases the chance of incidents such as well pack-off and stuck pipe.

The E-CD™ system helps improve the chances of drilling success for some of the more challenging projects such as wells with narrow gradient between pore and fracture pressure.

The basic system design consists of circulating subs with radial and axial valves and a flow diverter manifold. The circulating sub is placed on top of each stand, and, when making a connection, the flow is diverted from the top drive to the radial valve, allowing flow down the drillstring to continue. With flow though the radial valve, the standpipe is bled off and the axial valve closes, allowing the top drive to be disconnected and a connection to be made. The reverse takes place once the connection is made and drilling resumes. Since the system requires additional piping and space to install the independent drillpipe stand, fill-up pump, and other equipment, it is recommended that a visit to the rig site be done as soon as possible to perform a rig survey to determine the feasibility of this service.

Continuous Circulation System (Future Development)
Development of an automated CCS is currently underway. The new system will remove personnel from the “red zone” by automating the connection of the high-pressure hose between the side inlet port of the E-CD circulating sub and the E-CD manifold during the connection process. Field trials of the automated system are scheduled for summer 2016.

InSite Anywhere® service can provide customers with the ability to see their wells being drilled with a web browser. In the above example, the hydraulic operating window is only 40 psi, and PWD is being utilized to correct the model friction as the well is being drilled through a tectonically stressed fracture network. The natural fractures in this well were in the productive zone, and there was only a 40-psi difference between pore pressure and fracture pressure.

DetectEV and ActEV control systems are the well event handlers. The DetectEV system looks at trends or signatures of established curves that would indicate an event. The ActEV system can determine if the event is controllable by the MPD system or whether the event should be turned over to the rig.
Value of Halliburton MPD Services
There is immediate value in having a single provider for MPD, RCD, and engineering. Additionally, the advantages of implementing a fully integrated Halliburton GeoBalance MPD service helps customers by providing the following in most drilling, casing, and cementing operations:

» Improved formation pressure and stability control
» Safer drilling environment
» Fewer casing strings
» Reduced drilling costs through increased tripping speeds, increased ROP, possible reduction in casing strings, and faster MPD connection times
» Advanced client-specific pre-well planning and engineering
» Ability to drill tighter formation windows
» Fully automated wellbore pressure control
» Fully integrated, continuous feedback system
» Ability to perform automated MPC
» Greater accuracy of bottomhole pressure control

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<td>Land and marine RCD monogrammed to API SPEC 16RCD</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Real-time RCD monitoring of pressure and bearings</td>
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<td>Continuous circulating system</td>
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<td>RPD</td>
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The pressure issues that led to using MPD do not disappear once total depth has been reached. For this reason, Halliburton has developed the only automated Managed Pressure Cementing system. This automated managed pressure cementing system provides two-way communication between the MPD control system and the real-time Halliburton iCem® system.
SUMMARY

» The Halliburton GeoBalance GBSetPoint can provide more refined control and monitoring of multiple points and fluid properties within a wellbore to more accurately control bottomhole pressures.

» Halliburton GeoBalance DetectEV and ActEV control systems can provide real-time kick detection, and control the event using surface pressure control, thus allowing clients to initiate their well control procedures as required.

» Halliburton GeoBalance Marine Sentry RCD 3000 is an offshore, purpose-built API SPEC 16RCD-monogrammed RCD that fully complements the Halliburton MPD system.

» The Halliburton GeoBalance rig pump diverter can enable faster ramp-up and ramp-down times during connections, thus allowing for faster MPD connections – in some cases, up to 75 percent faster connections vs. conventional MPD connection techniques with a backpressure pump only.

» Halliburton GeoBalance barrier pill helps minimize the need to fully displace the well with a kill weight fluid.

» All Halliburton GeoBalance MPD control systems can allow for fully automated or manual control of the fluids in order to help provide the highest accuracy of bottomhole pressure control.

With all of the above systems fully integrated into a drilling program, Halliburton clients can attain better formation pressure control and stability, higher ROP, faster tripping speeds, increased HSE performance, and lower drilling costs.

CONTACT US

We will work with you every step of the way to achieve the results you need. Contact us at Welltesting@Halliburton.com.
Sales of Halliburton products and services will be in accord solely with the terms and conditions contained in the contract between Halliburton and the customer that is applicable to the sale.

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