e-cd™ System

MANAGED PRESSURE DRILLING

HALLIBURTON

e-cd eni circulating device

e-cd™ (Eni Circulating Device) System

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 aids in accomplishing these goals while mitigating risks. Traditional MPD with surface backpressure requires a rotating control device (RCD), backpressure pump, chokes, and a full crew in order to safely and effectively drill at, or slightly above, reservoir pressure.

The e-cd™ circulating device is an Eni-patented system offered by Halliburton as a simple solution for MPD operations. It enables continuous circulation, or the ability to maintain uninterrupted flow of drilling fluid circulation, while making drill pipe connections. Although requiring significantly less equipment, the e-cd system still addresses many of the same challenges as surface backpressure MPD, particularly related to the cycling mud pumps while making connections. The system is designed for both drilling and tripping in and out of the hole, and can also be used to properly run liners to depth.

PROVIDING CONSTANT EQUIVALENT CIRCULATING DENSITY AND CONTINUOUS HOLE CLEANING

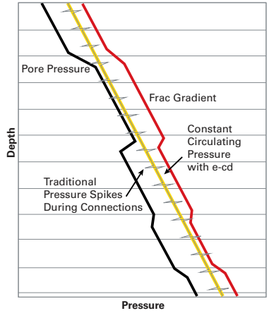
On and off pump cycling during the drillpipe connection in conventional rotary drilling causes bottomhole pressure (BHP) fluctuations. When the pumps are on, frictional pressure and fluid rheology remains constant. When the pumps are turned off, the frictional pressure effect no longer contributes to the downhole equivalent circulating density (ECD), but instead contributes only to the hydrostatic pressure of the drilling fluid acting on the openhole section. The differences in downhole pressure between pumps on and off can cause BHP to either exceed fracture pressure or fall below reservoir pressure. These conditions can increase chances of non-productive time related to hole instability, fluid loss, reservoir influxes, differential sticking, and stuck pipe.

On and off pump cycling also reduces the effectiveness of the drilling fluid to carry cuttings out of the hole. While pumps are turned off, cuttings fall down the wellbore in vertical wells and in transitional angles in horizontal wells. This can increase the chances of well pack-off and stuck pipe.

Continuous circulation has helped enable operators to improve drilling success and reach total depth (TD) for challenging projects with narrow pore pressure and fracture gradient by maintaining BHP during the drillpipe connection, in high-pressure/high-temperature (HP/HT) wells by providing dynamic cooling benefits, and in extended-reach horizontal wells by continuously circulating the cuttings.

In the majority of installations, the e-cd system is utilized as a stand-alone solution. It is also a good option for floating drilling vessels where major modifications to the rig are not required to make the rig "MPD ready," particularly a surface backpressure MPD application requiring riser modifications. In wells where dynamic control is required during all steps of the drilling process, continuous circulation can be used in conjunction with a full MPD package to solve even the most difficult drilling challenges.

Pressure Management with e-cd™ Continuous Circulation



This view shows the process of adding a new stand. A new stand has been installed on the top drive, but before the side port connection has been removed.

History of e-cd™ System

The e-cd™ system is the first sub-based continuous circulation system brought to modern drilling operations. It has been used successfully in over 170 wells in 20+ countries from 2006–2020 with over 26,000 connections. No other offering has matched the proven track record and reliability of the e-cd system.

HOW IT WORKS

Prior to drilling operations, the length of the open hole is considered to determine how many e-cd™ subs are required to drill the openhole section that requires continuous circulation. The e-cd subs, which have the same thread as the drillstring, are pre-installed on the top of stands of drillpipe and racked back in the derrick.

A three-valve isolation is incorporated into the rig's standpipe that introduces an inlet and outlet connection for the e-cd diversion manifold. During drilling operations, the standpipe flow is diverted through the diversion manifold, through the top drive, and downhole with a gate valve and plug valves into the diversion manifold inlet and outlet, as shown in Figure 1.

Once a stand with a sub is drilled down and the string is set in the slips, the continuous circulation process can begin. First, an operator will perform a pressure check at the side port of the sub to ensure that the side port flapper is properly sealing. Then the operator will remove a safety cap on the sub and connect an adapter and diversion flowline hose to the sub, which is connected to the manifold. Through a series of steps within the diversion manifold, the flow is diverted from the top drive through the top of the sub to the side port of the sub, all without inducing pressure surges. The fluid above the sub is bled off, which causes the top drive isolation flapper to close so that the driller can safely disconnect the top drive and bring in a new stand of pipe.

Once the new stand is connected, the e-cd system uses a small pump to fill up the new stand with drilling fluid.

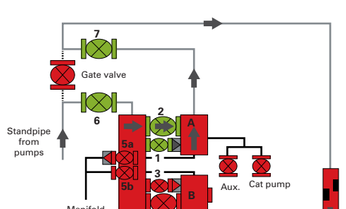


Figure 1. Standard flow path during drilling operations

The flow is diverted back from the side port to the top drive. Then, the side port hose is removed and the safety cap is replaced. Throughout the drilling process, the pumps are not turned off, maintaining constant BHP.

Connection time is roughly the same as standard connection time, when considering all aspects of the connection. The additional time in making the side port connection is generally offset by not having to ramp pumps up and down, circulate connection gas, or spend time with the hole cleaning activities normally required prior to the restart of operations. The total time for side port connection to removal is approximately 3–5 minutes.

The e-cd™ Plus system maintains the benefits and case history of the manual e-cd system, but increases safety by removing personnel from the red zone in single pressure barrier applications, while also improving efficiency and reducing overall connection time.

The e-cd Plus system enhances the process by replacing the manual connection procedure with an automated system that uses a delivery arm or an overhead lift to attach a tool to clamp to the e-cd sub. Once a tool is attached, a remote station automatically controls all steps of the side port connection and flow diversion, providing a live look at the operation and instantaneous feedback of all components within the system, as well as integration with real-time rig data.

For applications where continuous circulation during the connection process is critical, but where dynamic pressure control is required during all phases of drilling, tripping, and other processes in the most challenging wells, the e-cd and e-cd Plus systems are great tools to complement the benefits of traditional MPD technology.

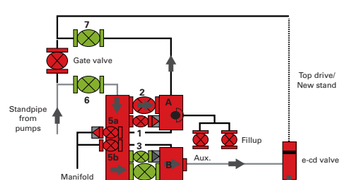
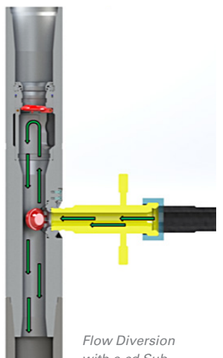


Figure 2. Standard flow path during a connection



Flow Diversion with e-cd Sub

One of the biggest benefits in this application is the ability to maintain dual phase fluid composition during the connection process, significantly reducing overall connection time and maintaining accurate BHP control.

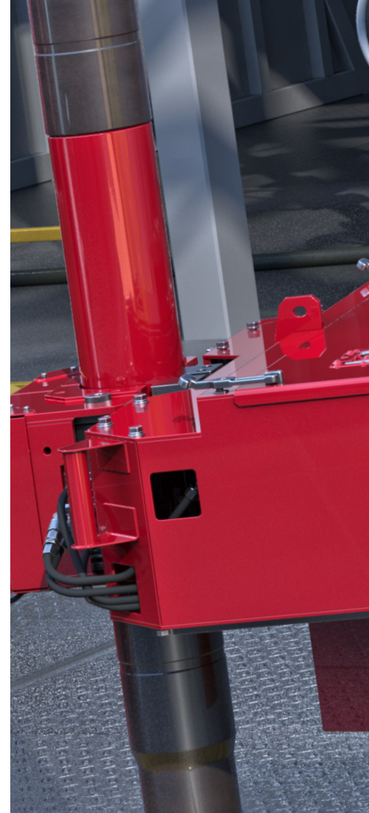
With the combination of the two technologies, the operator is not only able to maintain BHP, but is also able to remove the increase in backpressure that is generally required during the drillpipe connection process – therefore, increasing RCD element life.

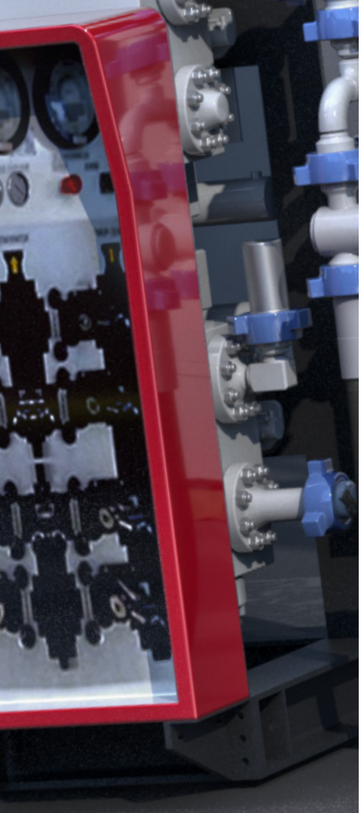
In other rig installations that require Nitrogen (N_2) injection during the drilling process, such as sub-hydrostatic drilling in conjunction with MPD or underbalanced drilling (UBD), the subs are designed to operate in nitrified conditions. In fact, one of the biggest benefits in this application is the ability to maintain dual phase fluid composition during the connection process, significantly reducing overall connection time and maintaining accurate BHP control.

At a Glance

FEATURES

- Pumps remain on during drilling or tripping connections
- Metal-to-metal flapper valves for both axial and radial sealing mechanisms
- High-flow-rate, side-entry port with threaded engagement for safe flow diversion
- Axial flapper (top-drive isolation flapper) does not require manual intervention on the rig floor to open and close
- Axial flapper valve closes, acting as additional safety barrier with backflow
- Non-spring-loaded axial valves ensure compatibility with:
  - Wireline/slickline intervention operations
  - Pumping of balls or darts when running liners
- Various levels of automation, depending on operational needs
- Seamless integration with Halliburton MPD operations and software, minimizing additional surface backpressure during the connection
- Compatible with premium connections





BENEFITS

- Enables drilling difficult formations with small pore pressure/fracture pressure windows by maintaining a constant pressure regime along the well profile
- Reduces kick/loss conditions by maintaining constant ECD and BHP
- Provides constant hole cleaning and solids transport to reduce stuck-pipe and pack-off incidents, and solids loading
- Removes pressure cycling during the connection to reduce wellbore ballooning and improve borehole stability
- Eliminates possible mud rheology changes and bottomhole temperature variations affecting ECD that normally occur during pipe connections
- Maintains constant circulating temperature to increase life of downhole tools
- Eliminates connection gas and enables continuous monitoring of background gas during pipe connections
- Eliminates need to wait for bottoms-up prior to making a connection in critical well applications
- Eliminates backpressure control equipment required to maintain constant BHP, and reduces potential transition errors during connections
- Maintains real-time monitoring of downhole parameters, such as downhole pressure (ECD) and temperature to provide enhanced BHP control
- Enables continuous monitoring of drilling gas data during pipe connections (no need to wait for the stabilization of gas trend before performing connection operations)
- Improves rate of penetration (ROP) through continuous hole cleaning
- Combines seamlessly with MPD to offer the most fine-tuned BHP control while also increasing RCD element life
- Maintains measurement-while-drilling (MWD), logging-while-drilling (LWD), and pressure-while-drilling (PWD) data during drillpipe connections

Products

E-CD™ CIRCULATING SUB

- Dual flapper configuration
- Axial flapper as check valve while performing connection
- Side-port-enabled access to the drillstring, including dual metal-to-metal seals with side flapper and barrier plug
- 10,000-psi working pressure designed to API 7.1
- Global inventory of subs with multiple thread types, with others available upon request

E-CD™ DIVERSION MANIFOLD

- Available in 5,000-psi, 7,500-psi, and 10,000-psi pressure ratings
  - 10,000-psi version is automated and designed to pair with the e-cd plus system
- Enables safe diversion from top drive to side port connection and back when making connections
- Includes valves and transmitters to equalize pressures and ensure soft pressure buildup to minimize water hammer or pressure effects
- Designed for high flow rates up to 1,200 gpm
- Provides access to bleed-off and fill-up lines
- Compatible with high-density fluids
- Air over hydraulic control panel and valves, with automated electric system available

e-cd™ Circulating Sub

e-cd™ Diversion Manifold

e-cd™ Plus System

E-CD™ PLUS SYSTEM

- Mirrors manual e-cd™ system function, but replaces human operator with automated process
- Both the automated diversion manifold and the e-cd Plus tool operated from a remote station
- Digital readout of pressure and position of all major functions on the manifold and the e-cd Plus tool displayed in the software for unprecedented control
- Compatible with existing circulating subs
- Improves speed to reduce overall connection time
- Undermount delivery arm or overhead lift line system delivery options to the drillpipe

In addition to the major system components listed above, the following components will be provided:

- Independent drillpipe stand fill-up pump
- Mud saver/bucket
- Standpipe manifold/rigid lines to tie manifold into rig's standpipe
- Workshop
- Office
- Equipment basket
- For e-cd Plus system, accompanying hydraulic power units (HPUs) and remote station for automated control
- Bales (if required due to added length of e-cd sub on each stand)

Candidate Evaluation

With a strong track history for providing MPD services and flow modeling capabilities, Halliburton should be engaged in the planning and engineering phase of the project. It is a required practice to have a Halliburton representative conduct and document a rig survey to properly plan for the execution phase of the project, including development of equipment layout drawings and any relevant engineering and operations documents. With well-specific data provided, Halliburton can build a client-specific hydraulic model to determine the required ECD throughout the hole sections, and then to deploy our technologies and advise on the tangible benefits of e-cd continuous circulation.

Below is a list of the most important questions to answer when evaluating whether the e-cd or e-cd Plus system could be the right solution for solving your drilling challenges:

- Does the candidate well have narrow margins between the pore and fracture gradient, such that pumps on/off during connections can cause stability issues?
- Does the candidate well present concerns with hole cleaning and solids transport related to pumps off? Does it have trouble reestablishing steady state after connections?
- Is the candidate well lithology well understood? Will real-time ECD changes likely be required? Depending on the lithology, a combination of surface backpressure control and MPD may be advisable.
- Does the candidate well present concerns with mud rheology related to pressure spikes when cycling pumps during connections?
- Does the targeted section have any portion with unstable rock layers, plastic shales, salts or coal seams?
- Does the candidate well present concerns with wellbore ballooning leading to kicks/losses?
- Does the candidate well present concerns with differential sticking and/or stuck pipe with higher mud weights?
- Does the candidate well present concerns with cuttings bed formation during/after connections?
- Does the candidate well present concerns with running liner to depth?
- Does the candidate well fit any of the following types?
  - Exploratory
  - HP/HT
  - Geothermal
  - Horizontal
  - Extended reach

If the answer is "yes" to any of the above questions, then e-cd continuous circulation could be right for you.

Contact Us

We will work with you every step of the way to achieve the results you need. Contact us at testingandsubsea@Halliburton.com.

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