EC-DRILL®
CAPABILITY DOCUMENT
EC-Drill® pump module while being deployed on Marine Drilling riser, Gulf of Mexico
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Enhanced Drilling is a provider of specialist drilling technology and services to the international offshore oil and gas industry.

The company’s head office is in Straume near Bergen, Norway.

Offices and workshops globally include Oslo, Norway, Aberdeen in the UK, Houston in the USA, Perth in Australia, Baku in Azerbaijan, and St John’s, Canada. Enhanced Drilling has, for more than 30 years, built an enviable track record and world-class reputation for its innovative offshore drilling technology and services which have been deployed on more than 800 wells.

The company’s cornerstone solutions are:

- CTS - Cuttings Transportation System
- RMR® - Riserless Mud Recovery system
- MPC - Managed Pressure Cementing system
- EC-Drill® - Managed Pressure Drilling system
**EC-DRILL® - THE SIMPLE SOLUTION TO DRILLING THROUGH NARROW PRESSURE WINDOWS**

EC-Drill® is a Controlled Mud Level (CML) system based on controlling the liquid level in the marine drilling riser in order to manage the pressure profile in the well. It can be used in both shallow and deep water (including depleted wells), either from a jack-up, platform or a floating drilling vessel.

**A long-standing challenge solved**

EC-Drill® solves a long-standing challenge commonly associated with deep-water wells—drilling through a narrow pore pressure/fracture gradient window.

The technology is a logical extension of conventional drilling and an elegant solution to the challenge of Equivalent Circulating Density (ECD) limitations. This means familiar technology, rapid implementation and a small team uptake.

EC-Drill® does not use a rotating control device (RCD) and utilizes the rig’s Low Pressure drilling riser and subsea BOP. Its top-side footprint is limited, meaning easy rig integration.

**Seamless BHP management**

Using a Subsea Pump Module (SPM) connected to the drilling riser at a specified water depth, the fluid level inside the drilling riser can be adjusted to change bottom hole pressure. The system allows for dynamic adjustment of bottom hole pressure during all aspects of well construction, while drilling, while tripping and during wireline operations. This allows for instant application of trip margin, instant effective mud weight adjustment for losses, simple managed pressure cementing in addition to traditional MPD of compensation for friction pressure while drilling.

**Enhanced safety - early kick/loss detection**

An intrinsic benefit of the system is early kick/loss detection regardless of heave, pitch or roll. The system also incorporates fingerprinting functionality. The riser level is measured using highly accurate pressure sensors/gauges, which enables safe operations when the riser mud level is drawn down. The riser then functions as a compensated trip tank.

**Operates where back-pressure MPD is not optimal**

EC-Drill® is also suited for drilling in low pressure environments typically associated with depleted fields. The system can allow for use of more conventional drilling and completion fluids in sub-hydrostatic reservoirs with low levels of fluid loss.

The system has been proven to allow for drilling of longer horizontals during depleted in-fill drilling by reducing or eliminating losses due to friction effects.
CHALLENGES THAT EC-DRILL® ADDRESSES INCLUDE:

- Difficult to implement new technology
- Drilling depleted reservoirs
- Drilling karstified and fractured formation
- Limited horizontal reach
- Kicks while POOH
- Mud losses
- Time consuming to change mud weight
- Losses during cementing – remedial cementing
- Poor zonal isolation
- Losses during casing, liner and completion running
- Drilling Narrow Pore / Fracture Pressure windows
- Poor hole cleaning – stuck pipe, slow progress
- Formation damage
- Low rate of penetration (ROP)
- Losses during gravel packing – incomplete pack
- Difficulty getting completion to bottom
- Differentially stuck wireline tools, drilling or completion strings
BENEFITS THAT EC-DRILL® PROVIDES INCLUDE:

• Conventional well-control procedures and drilling methodology, high reliability system with proven track record

• Drill complex formations with longer laterals deeper into the pay-zone – increased recovery

• Early detection of losses and fast adjustment of BHP without circulating to a new mud weight

• Extended exposure in horizontal wells – increased opportunities in the pay-zone

• Early Gain/Loss Detection, trip margin easily applied by raising mud level

• Reduce Mud Losses – Operators have experienced mud-cost savings of 70 per cent per well

• Effective mud weight changes in minutes by adjusting riser fluid level

• Managed Pressure Cementing easily implemented on a routine basis

• Improved pre-cementing circulations rates and hole conditioning

• ECD management during drilling, running casing, cementing and completions – unique amongst MPD products

• Advanced control system allows precise control of BHP

• Improved hole cleaning – higher flow rates and mud weights

• Tight control over BHP allows for minimal overbalance minimizing formation damage

• Optimise overbalance to maximize ROP

• BHP management easily applied to complex operations

• Improved hole cleaning

• Able to control BHP and differential sticking while performing operation
QUALIFIED AND IN FULL OPERATION

• EC-Drill® reached TRL (Technology Readiness Level) 7 in 2015 with a major Norwegian operator and since used on more than 30 wells. TRL7 is defined as: ‘Proven technology - The technology has operated in accordance with predefined performance and reliability criteria, over a period of time sufficient to reveal time-related effects. The technology is now proven for use within specified operating conditions/limits’

• Approved for use by the regulatory agencies in the countries where it has operated

• DNV GL Certified according to drilling facility standard DNV-OS-E101

• 99.7% Uptime in operation

• Control System Hardware-in-the-loop tested - DNV GL Product Certified

• Deployed and operated from DNV GL and ABS-class rigs

• Field-proven components - builds on Enhanced Drilling’s 800+ track record with CTS, RMR® and MPC

CERTIFIED The Control System seen in the Office Tool Container onboard the COSL Innovator
EC-Drill® is unique among the MPD techniques in that it allows for efficiencies improvements over conventional drilling also when not required to enable the drilling process due to its low rig time usage required to implement the system:

a) average time to deploy the system is 4 hrs of critical path time, and 4 hrs of critical path time to recover the system
b) no Rotating Control Device (RCD) required. No time required to run and pull RCD
c) no need to change mud system to go onto MPD as with Surface Back Pressure MDP.
d) no need to change mud system prior to tripping, can trip with mud used to drill the hole

This allows for efficiency gains:

1) Enhanced kick/loss detection allows for faster detection of kicks and losses and avoiding developing hole problems
2) Ability to change the effective mud weight in minutes
   a) to add trip margin to trip out of hole
   b) if drilling into a zone with losses, mud weight can be reduced to correct level in minutes and verified
3) Allow faster casing tripping by compensating for surge effect by lowering level
4) Allow faster circulation prior to cementing by compensating for friction pressure with level reduction
5) Address cementing issues, which in some areas are more challenging than drilling issues
6) Inflow testing of production liners and casing can be performed in minutes
7) System can be used to control losses during reservoir drilling, allowing longer horizontal sections with less formation damage
8) System can be used to control losses during completion to control losses and minimize formation damage
9) System has been used to release differentially stuck WL tools and assist with differentially stuck pipe, including completions.

EC-Drill® Managed Pressure Cementing

An operator experienced issues with tagging to confirm abandonment plugs. This required the plugs to be repeated to achieve abandonment objectives. Investigation revealed that the height of the plugs increased hydrostatic to the point that the increased hydrostatic of the cement caused the plugs to be lost to the formation.

A Managed Pressure Cementing method was developed for placing balanced plugs. This method involves using EC-Drill to reduce the annulus hydrostatic pressure while the cement plug is placed and under-displacing to reduce the balanced fluid level in the drill pipe. With the use of this method, further abandonment plugs became routine and the P&A process became routine. When longer plugs were required, they were set in a single operation of two cement placement steps with appropriate compensation for hydrostatic increase.

Proven concept
An operator in the southern Barents sea offshore Norway has set 18 balanced plug using the EC-Drill system over a 16 months drilling campaign.

SIMULATION and JOB PREPARATION

EDR proprietary hydraulics model used for Managed Pressure Cementing planning and execution
TIMELINE - EC-DRILL® PROJECT
OVERVIEW FOR FIRST-TIME INSTALLATION

1 month
RFQ / ITT

1 month
Initial Well Screening

3 to 6 months
Rig integration and well evaluation study

Rig integration cost optimisation workshops

Hardware delivery and rig integration

Operations

1 month
3 to 6 months
Enhanced Drilling's offshore operators have an average of fourteen years' service with the company.

That translates into experience, knowledge and know-how when it comes to our technologies and using them in the field: the technologies that EC-Drill® builds on, used on more than 800 wells worldwide to date.

For EC-Drill®, the offshore crew ensures smooth running of the equipment and expert guidance through 24-hour operations:

**Day shift** 1 Supervisor, 1 Operator

**Night shift** 1 or 2 Operators

**KNOW-HOW** Enhanced Drilling's operators have an average of fourteen years with the company

**SYSTEM TRAINING**

Training requirements for the EC-Drill® system are extremely modest, as conventional well-control techniques are used.

We hold training for Enhanced Drilling, Operator, and Rig Contractor personnel. This training includes simulations using the EC-Drill control system and well simulator.

Courses are led by EC-Drill® experts on each specific topic, all of whom have been involved in previous EC-Drill® operations.

Our controls system is fully integrated in advanced immersive simulators to prepare the operational drilling teams for complex operations.

Our EC-Drill® course for external participants covers areas such as:

- EC-Drill® Technology
- Benefits / applications of EC-Drill®
- Equipment
- Operations
- Problems addressed by EC-Drill®
- Well-control considerations
- Impact on Well design
- Hydraulics Program use
- Impact on Rig operations
- Impact on Well Drilling - procedures, etc.
- EC-Drill® equipment design options
- Introduction to the Control System

Please note that more advanced courses are available on request.

**DEDICATED TRAINING FACILITIES**

The training room in Straume, Norway
CASE STUDY - EC-Drill® saves $24MM per well in Gulf of Mexico

Three-well campaign, Gulf of Mexico, 2012

Common challenges included:

- Fractured carbonates
- Deep water
- Hole cleaning issues
- Losses
- Well ballooning
- Slow ROP
- High number of casing strings

Well No.3 - water depth 2180m (7152ft)

EC-Drill® was used to:

- Drill a narrow margin 17 1/2” section - LOT 9.4 ppg (1.19 SG) at 20” shoe - PP 9.1 ppg at section TD (0.3 ppg /0.03 SG window).

- Cement 13 3/8” casing.
  No losses - Good cement job.

- Cement 9 5/8” – Good cement job.

- Remedy losses in the 8 1/2” section - Weak reef zone FG 8.4 ppg (1 SG)

- P & A, final inflow test by simply reducing riser level (5 minutes with no need to circulate lighter fluid)

The 8 1/2” section could not have been drilled without EC-Drill®.

Well Specific Objectives

- No losses Achieved ✓
- Stable well Achieved ✓
- Improved hole cleaning Achieved ✓
- Increased ROP Achieved ✓
- No gas in top of riser Achieved ✓
- Good cement jobs Achieved ✓
- Zero NPT Achieved ✓

EC-Drill® benefit and value?

- 20 days Rig Time saved @ $1.2MM/day

$24MM saved per well

‘EC-Drill® performed very well, delivering on expectations and fully meeting well objectives. The contractor delivered an excellent service.’

Drilling manager, Cuba August 2012

‘DRILL THE UNDRILLABLE’
The EC-Drill® Suction Pump Module is deployed in the GoM, 2012
CASE STUDY - EC-Drill® saves 70 per cent in mud costs on well

“We’ve met the objectives and we are very happy with the results.”
Drilling design specialist, Equinor, drillingcontractor.com April 2014

Troll Field, Norwegian Continental Shelf, 2014

The first use of EC-Drill® on the NCS, at a water depth of 330m (1,082ft). Drilling objectives included:

- Reduce losses while drilling
- Improved casing/liner cementing quality
- Drill longer laterals, reach targets
- Drill faster and trip faster
- Increase pump rates to improve hole cleaning

Three laterals were drilled in a sand reservoir, of which the longest was 3.6km (11,811ft).

Results

- 9.5km (31,168ft) drilled
- Suction Pump Module was submerged for 89 days/2,136hrs
- 790hrs drilling
- 25bar BHP reduction
- Zero NPT

First Use Success criteria

- Successful deployment and recovery of the EC-Drill® system
- Reduced BHP/ECD during drilling of the reservoir sections (With 200m reduced riser level achieve 20-30 bar reduced BHP)
- Stable riser level real time (Control system adjust pump speed)
- Controlled lifting of riser level to check for accumulated gas
- Volume control during entire operation
- Reduced mud consumption
- Avoid losses
- Operates within conventional well control

Achieved ✓

70 per cent mud cost savings on a single well alone
CASE STUDY - EC-Drill® Instant kick detection on deepwater well

A multi-national operator used EC-Drill®’s instant kick detection service to complement and enhance conventional kick detection methods during deep-water exploratory drilling in the Gulf of Mexico.

It is well known in the industry that deep-water drilling with oil based or synthetic oil-based muds presents distinct challenges to timely detection of influx or losses.

Limitations of conventional kick methods

Although effective, conventional methods of kick detection have limitations and can allow influxes into the wellbore at a rate and volume that make well control more difficult.

Normal drilling in deepwater environments presents its own set of challenges, including the potential for an influx while making a connection. Statistically, 70 per cent of kicks occur during connections (Fraser et. al., 2014)*.

Instant kick detection - a game-changing EC-Drill® option

To improve kick detection response times, the operator used EC-Drill®’s optional ‘instant kick detection’ service. During kick drills and while drilling, EC-Drill® demonstrated that it is capable of detecting kicks with both its pump performance and riser pressure sensors.

EC-Drill® detects Influx 40 seconds faster than flow-out measurements

These sensors are the first indicators and are capable of detecting flow anomalies at least 40-60 seconds faster than conventional flow-out methods and a full 20 seconds earlier than mud pit volume totaliser methods (see Figure 1). The drill crews using the system

INSTANT KICK DETECTION Fig 1 shows how an influx is detected immediately by the riser pressure sensor (blue) followed by the EC-Drill® pump speed (green) 10 seconds later. After 48 seconds the flow increase is detected by the flow measurements from the coriolis.

concluded that the EC-Drill® method of making the riser above the pump a new and 'first in-line' trip tank is more accurate and more reliable than conventional kick detection methods.

**Instant kick detection - reduce risk, enhance safety**
The implications of being able to detect kicks and losses far ahead of conventional methods are significant, from overall safety and reduced risk to equipment and personnel, to drastically improved ability of crews to manage and control an influx that has been minimised by early detection and early response.

PREPARATION
Readying the EC-Drill's pump module for deployment, Gulf of Mexico

The operator gains a 'step change' in kick detection with this technology.

**EC-Drill® is more accurate and more reliable than conventional kick detection methods.**
Control Container (can be rig-integrated)
- Weight: 13T (metric) 12 3/4 (imp)
- Dimensions (m): 4.3 x 2.4 x 2.7
- Dimensions (ft): 14.1 x 7.8 x 8.8

Office Tool Container (can be rig-integrated)
- Weight: 6.5T (metric) 6 1/3 (imp)
- Dimensions (m): 4.3 x 2.4 x 2.7
- Dimensions (ft): 14.1 x 7.8 x 8.8

Subsea Pump Module
- Weight: 13T (metric) 12 3/4 (imp)
- Dimensions (m): 4.1 x 2.1 x 1.5
- Dimensions (ft): 13.4 x 6.8 x 4.9

Umbilical Winch
- Weight: 15-20T (metric) 14 3/4 - 19 2/3 (imp)
- Dimensions (m): 3.8 x 2.5 x 2.7
- Dimensions (ft): 12.4 x 8.2 x 8.8
CASE STUDY - EC-Drill® Harsh environment application

Exploration and appraisal in karstified formation, Barents Sea, 2018

After an extensive screening process of available technologies, the operator selected EC-Drill® as the tool to handle a potential total loss scenario in the Barents Sea. During the course of the subsequent multiwell exploration and appraisal drilling campaign, EC-Drill® moved from being primarily a contingency tool to being a technology used in all the operations of the well construction, including drilling, running casing, cementing, coring, wireline, completion and P&A operations.

Well bore pressure control
EC-Drill® allows very precise control of the wellbore pressure by regulating the height of the fluid level within the riser. This is achieved by using a Subsea Pump Module mounted on the riser and returning the mud and drilled cuttings through a dedicated Mud Return Line. Drilling operations are performed with various riser levels depending on the section requirement. For Barents conditions, a typical reduction of 5 to 15 bar is used. EC-Drill® allows for very precise control of the pressure in the well while circulating cement slurry in the annulus around the casing or the liner and maintaining high displacement rates.

Cementing with EC-Drill®
Preventing losses during the cement displacement combined with optimum cement weight and displacement flowrate ensure a correct zonal isolation. EC-Drill® is also used to set optimal cement plugs in P&A phases. EC-Drill® contribution in coring operation is similar to drilling and losses zones are controlled by adjusting the hydrostatic pressure immediately with existing pressure, eliminating additional time spent on circulating new mud.

Preventing differential sticking with EC-Drill®
Reducing the hydrostatic pressure is also beneficial during wireline operations and reduces the risk for differential sticking. It also allows for recovery from differential sticking events by simply lowering the fluid level in the riser.

99.7 % EC-Drill® uptime, an extremely reliable service.
The service in the Barents sea has shown an excellent reliability in this multiple wells campaign. 99.7% uptime has been registered during the drilling campaign.

EC-Drill® usage: Increasing the operational envelope

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Technology is just one part of the solution - people and teams remain at the heart of any success.

For this reason our training programmes, training simulators and our ‘Drill the Well at Desk’ exercises are all designed to support and make the integration process as easy as possible.

To discuss how EC-Drill® can deliver a step change in the drilling envelope and what it can do for you, please contact solutions@enhanced-drilling.com or call one of our office locations worldwide (listed on the back cover).
CONTACT

NORWAY
Head office:
Smålonane 16, P.O.Box 351
5343 Straume
Tel: +47 56 15 40 00
Fax: +47 56 15 40 01

AUSTRALIA
Level 2,
16 Milligan Street,
Perth, WA 6000.
Tel: +61 (0) 8 9360 4000
Fax: +61 (0) 8 9360 4089

CANADA
169 McNamara Drive
Paradise, NL,
A1L 0A7.
Tel: +1 709 237 8587

AZERBAIJAN
Garadagh District,
Salyan Highway 17km,
Baku AZ 1063
Tel: +994 51 984 6000

UNITED KINGDOM
Broadfold Road,
Bridge Of Don
Aberdeen, AB23 8EE
Tel: +44 1224 826124

USA
1095 Evergreen Cir. Ste 200
The Woodlands, TX 77380
Phone: +1 281 212 3199