



Equinor Martin Linge

Multi-well drilling and gravel-pack completion campaign



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Equinor claims a new world record for the highest-density openhole gravel-pack (OHGP) carrier fluid, accomplished using a cesium/potassium formate-based fluid in four slim-hole high-pressure wells on the Martin Linge field, offshore Norway. This achievement surpasses the previous record of 1.84 g/cm³ (15.4 lb/gal), also held by a cesium formate-based fluid, set in Egypt on the Raven field.

Equinor drilled and completed a series of four wells using gravel packs on the high-pressure Martin Linge field in the Norwegian sector of the North Sea. The preferred slim-hole gravel-pack completion solution posed several technical and environmental challenges for gas production. After careful consideration, cesium/potassium formate brine was identified as the optimal low-viscosity gravel-pack carrier fluid. This brine was selected for its ability to provide the necessary overbalance, adhere to stringent equivalent circulating density (ECD) requirements and meet rigorous HSE standards.

Challenge: Sand control. This was made more problematic by uncertain pore- and fracture-pressure gradients prior to drilling the first well, and a particularly narrow ECD window of +/- 0.10 to 0.12 g/cm³ (+/- 0.8 to 1.0 lb/gal).

Solution: Cesium/potassium formate brine-based fluids, not only used as gravel-pack carrier fluid, but employed in all operational phases from reservoir drilling through to upper-completion installation.

Results: Smooth sand-screen installation with no plugging, 100% gravel-packing efficiency, good flow rates within the extremely narrow ECD window and seamless fluid transitions helped bring the wells on stream early. Expected production was described by Equinor as “world class”, doubling the previous production startup figures for the early Martin Linge wells, which were completed with expandable sand screens and oil-based mud.

Breaking new ground

Equinor developed a casing design consisting of a slim-hole reservoir section, completed with 4" 250 µm sand screens. Effective sand control, crucial for long-term production, made the OHGP-completion strategy the optimal choice.

This strategy required a gravel-pack carrier fluid compatible with both drilling- and screen-running fluids. Equally, the brine could not cause formation or completion damage, and had to meet Norway's strict HSE requirements. Given its track record with Equinor and previous success on the Martin Linge field under Total, the team at Equinor decided that cesium formate fluid was the right choice, employing it up to a record-breaking OHGP-completion density of 2.06 g/cm³ (17.2 lb/gal).

Location:	Norwegian North Sea
Reservoir:	Brent sandstone
Depth:	4,150 m TVD
Section:	169–238 m
Hole size:	5.875"
Inclination:	30°
Reservoir fluids:	Gas and gas condensate
Pressure:	Maximum ~910 bar (13,206 psi)
Bottomhole temperature:	Maximum 135°C (275°F)
Fluid density (all operations):	1.83–2.12 g/cm ³ (15.3–17.7 lb/gal)
Fluid density (OHGP carrier fluid):	1.98–2.06 g/cm ³ (16.5–17.2 lb/gal)
Fluid:	Cesium/potassium formate

Clean, Cleaner, Clear

Fluid compatibility was achieved by selecting cesium/potassium formate brine-based fluids, designed and supplied by Sinomine Specialty Fluids, for all operational phases.

Following the successful cased-hole cleanout of solids-laden oil-based mud, formate-based fluids were used to drill and complete the reservoir. Fluid-system continuity throughout the operations ensured the reservoir was only exposed to non-damaging formate filtrates, which removed any associated risks of formation damage by solids-laden fluids. It also provided seamless transitions between the various operational sequences, right through to upper-completion installation, using Sinomine's 'Clean, Cleaner, Clear' philosophy.

For the gravel-pack operations, clear cesium/potassium formate brine is the optimum choice as a carrier fluid for the 20/40-size high-density ceramic proppants. The low-viscosity Newtonian nature of the formate brine facilitates optimum placement of proppants at low flow rates of 500 to 600 lpm.

Sinomine successfully designed and supplied cesium/potassium formate brine-based fluid formulations that could be utilised in all phases from reservoir drilling through to upper-completion installation.

- **Clean:** A low-solids formate managed-pressure-drilling drill-in fluid, designed to:
 - Maximise drilling performance
 - Minimise reservoir damage
 - Maintain stability of the wellbore to facilitate drawdown tests used to confirm the operational window
 - Stabilise the wellbore during lengthy openhole operations
- **Cleaner:** A low-solids formate tripping- and screen-running fluid, designed to:
 - Prevent screen plugging
 - Prevent seepage losses while running the lower completion
 - Maintain stability of the wellbore to facilitate extended openhole logging runs
- **Clear:** A formate-brine gravel-pack carrier fluid, designed to:
 - Exhibit very low Newtonian viscosity
 - Minimise ECDs

A clear upper-completion formate brine, designed to:

- Provide overbalance during upper-completion installation

The benefits are clear

The Martin Linge wells were successfully brought into production safely within the operator's scheduled time, after undergoing a seamless transition through all fluid operations from drilling and screen running to gravel packing and upper-completion installation.

Sand screens were successfully installed in the low-solids screen-running fluid without screen plugging. Gravel packing was performed with 100% packing efficiency using cesium/potassium formate brine as high as 2.06 g/cm³ (17.2 lb/gal) at 15.6°C (60°F), which is believed to be a world-record high-density carrier fluid. The low-viscosity brine allowed sufficient flow rates to be achieved within the extremely narrow ECD window to perform a trouble-free OHGP operation.

During field startup, no breaker solutions were required and no sand production or plugging were observed. The productivity of these wells was expected to be double that of those completed with expandable sand screens and oil-based mud during the earlier Total development. The use of formate fluids for drilling and gravel-pack completions ensured that these productivity expectations were met successfully.

In its press release from the opening of the Martin Linge field published on 27 January 2022 entitled "Martin Linge officially opened today", Equinor states:

"Since production started on 30 June 2021, Martin Linge has delivered world-class production efficiency for a new field in the startup phase."

Well name	Density (g/cm ³)	Comments	Completion type	Completion length (m)	Screen mesh (μm)	Packing efficiency (%)
Well 1	1.98	Drill reservoir. Run screens, gravel pack and upper completion	Gravel pack	258	250	100
Well 2	2.06	Drill reservoir. Run screens, gravel pack and upper completion	Gravel pack	246	250	100
Well 3	1.98	Drill reservoir. Run screens, gravel pack and upper completion	Gravel pack	235	250	100
Well 4	2.06	Drill reservoir. Run screens, gravel pack and upper completion	Gravel pack	281	250	100

Literature

Nilsen, S. J., Obrestad, H. U., Kaarigstad, H., Mansurova, N., Solvoll, T. A., Løchen, J., Howard, S., Abrahams, B. and Busengdal, C. (2024, March 13). Reservoir Drilling and Openhole Gravel Packing with High-Density Cesium Formate Fluids in a High-Pressure, Marginal Mud Window Environment at Martin Linge. *SPE Journal* 1–13. SPE-212487-PA. doi.org/10.2118/212487-PA.

Jøntvedt, E., Fjeldheim, M., Løchen, J., Howard, S., Leon, S., Busengdal, C. and Richard Gyland, K. (2018, February 7). Deployment of Cesium Formate Drill-In and Openhole Completion Fluid in the Martin Linge High Pressure, High Permeability Gas Reservoir Enhances Total's Operational Efficiency and Radically Improves Well Performance. *Proc., SPE International Conference and Exhibition on Formation Damage Control, Lafayette, Louisiana, USA*. SPE-189550-MS. doi.org/10.2118/189550-MS.