



Total E&P Norge Martin Linge 2017

Drilling and completion



Cesium/potassium formate reservoir drill-in fluid (RDF) and solids-free brine redefine performance standards for drilling and completion of a high-pressure gas reservoir section through highly permeable sandstone with interbedded shale/coal. The fluids delivered outstanding operational performance and an above-target productivity index (PI).

Challenges: To overcome previous well performance issues related to non-productive time, low rate of penetration (ROP), stuck pipe from hole instability in shale/coal intervals, completion damage and low productivity.

Solution: A combined cesium/potassium formate reservoir drill-in and screen-running fluid, coupled with a completion brine, designed to overcome earlier challenges and provide high performance.

Results: Well drilled and completed successfully without incident. Compared to previous wells, ROP was 84% higher and PI increased by over 100%.

Location:	Norwegian North Sea
Reservoir:	Brent sandstone
Depth:	3,800 m to 4,150 m TVD
Section:	216 m
Hole size:	8.5"
Inclination:	30°
Reservoir fluids:	Gas and gas condensate
Pressure:	~742 bar (10,762 psi)
Bottomhole temperature:	Maximum 135°C (275°F)
Fluid density:	2.07–2.13 g/cm ³ (17.3–17.8 lb/gal)
Fluid:	Cesium/potassium formate

The Martin Linge field in the Norwegian section of the northern North Sea consists of a gas/condensate reservoir in the upper sands of the Brent group, located at 3,800–4,150 metres true vertical depth (TVD). It features porosities of 20% to 30% with permeability from 0.5 to 10 Darcy.

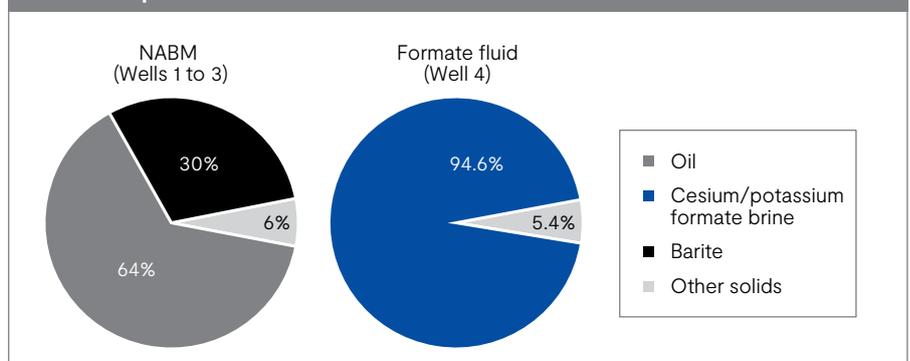
Earlier challenges sideline NABM

Three previous Martin Linge wells were drilled in difficult well conditions, which led to several unexpected challenges.

Whilst drilling in overbalance with barite-weighted non-aqueous based mud (NABM) containing approximately 1,400 kg/m³ added solids, ROPs of only 2–3 m/hr were predominant, along with stuck-pipe and several occurrences of hole instability. This was particularly evident through coal sections with one well suffering collapse and subsequent side-tracking.

Despite additional cleanup operations due to probable screen plugging, initial production tests on these wells delivered PI values less than half of those expected. The unforeseen challenges prompted a change in fluid strategy for the fourth well.

Solids comparison: NABM vs. formate fluid



Total reduced solids with over 30% by using formate fluid. The amount dropped from approximately 1,400 kg/m³ in each of the first three wells to 100 kg/m³ in Well 4.

Low-solids formates give high returns

The 216 m, 8 ½" reservoir section of Well 4 was drilled with our low solids cesium/potassium formate RDF, which reduced solids by 90%.

The sag-free, low-solids, low-rheology fluid provided a superior environment for drilling efficiency. Operations were safely completed after only 33 hours without incident or fluid-related non-productive time (NPT).

Remarkably, the cesium/potassium formate RDF delivered significantly

higher ROP, while reducing weight on bit by over 50%. This was achieved with a minimal equivalent circulating density (ECD) contribution of 0.40 g/cm³ (2.07 g/cm³ equivalent static density (ESD)/2.11 g/cm³ ECD). Drilling with formate fluid was problem free and, even though rates were restricted, ROP increased by 84%. Lower pump pressure and reduced fluctuations in ESD/ECD caused significantly less stress on the formation. Furthermore, the formate fluid's shale-stabilising properties kept the troublesome shale sections stable. Three coal zones were successfully penetrated with no incidents of stuck pipe or evidence of hole enlargement. The simple and robust formulation ensured the fluid remained in excellent condition throughout the operation, with only minimal maintenance required.

Sweet as PI

After target depth (TD) was reached, the RDF was tested over API 270-mesh screens and immediately passed all production screen test requirements for screen-running fluid. The 250µm production screens were run and set smoothly with no obstructions. As the previous three wells, 2.13 g/cm³ (17.8 lb/gal) cesium/potassium formate completion brine was used for successful upper completion installation. The well started flowing immediately without a filter-cake breaker or cleanup. Initial PI was 100% to 125% above expectation, which is more than twice the level of earlier wells.

A Total reservoir engineer commented: *"On the next wells, we will not need to allocate time for cleanup. The well is fully clean"*.

Eirik Jøntvedt, senior specialist engineer, Total E&P Norge, summarised by saying: *"Cesium formate-based drilling fluid has outperformed the previous NABM. We have been very happy with Sinomine's and M-I SWACO's professional service and, of course, the reservoir fluid. It has quickly delivered a well with high production potential without operational problems. I don't know of any other fluid that could have done this given the specific challenges faced."*

Conclusions

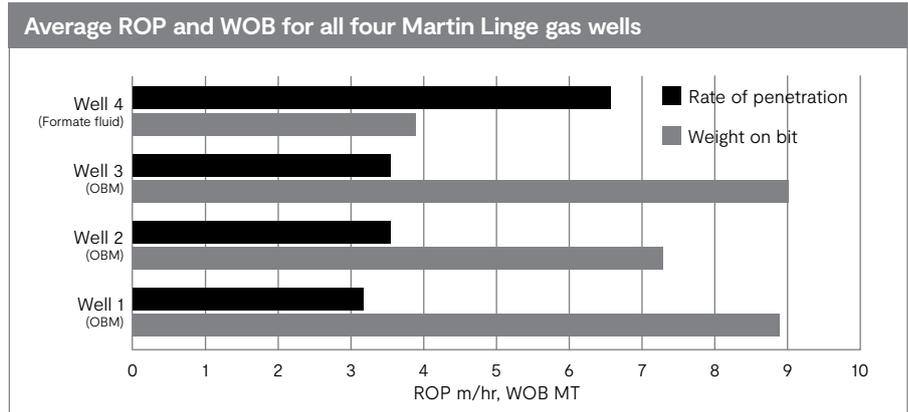
Cesium/potassium formate fluid outperformed the NABM on all criteria. When comparing Well 4 to the first three wells, our formate fluid delivered significant benefits over the solids-laden alternative:

New standard for operational efficiency

- Significantly faster reservoir drilling and completion
- Sag-free and stable fluid gives high level of safety
- Simple, robust fluid design easily maintained throughout the entire operation
- Use of same fluid ensures seamless transition from drilling to completion, including trouble-free screen running
- Problem-free operations without well control incidents or fluid-related NPT

Exceptional drilling performance

- High ROP with low WOB
- Optimised hydraulics reduced formation stress through minimal difference between ESD and ECD.
- Formate fluids improve drilling dynamics, including lower stick/slip levels
- Excellent hole cleaning
- Improved wellbore stability including lower stick/slip levels and improved wellbore stability



The well drilled with cesium/potassium formate fluid increased ROP by 84%, while reducing WOB by over 50%.

Enhanced production potential

- Well fully clean before production test
- No breaker fluid required for completion
- Well flowed immediately with no indication of formation or completion damage
- PI was 25% above the anticipated level
- Only well to date that meets or exceeds all operator expectations

Literature

Jøntvedt, E., Fjeldheim, M., Løchen, J., Howard, S., Leon, S., Busengdal, C., and Richard Gyland, K. (2018). 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, SPE doi:10.2118/189550-MS, 7 February 2018.

Løchen, J. and Leon, S. (2018). Total E&P Norge benefits from new fluid strategy for drilling and completions, World Oil, June 2018.