

# 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 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%.

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 meters 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/m<sup>3</sup> 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 clean-up 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.

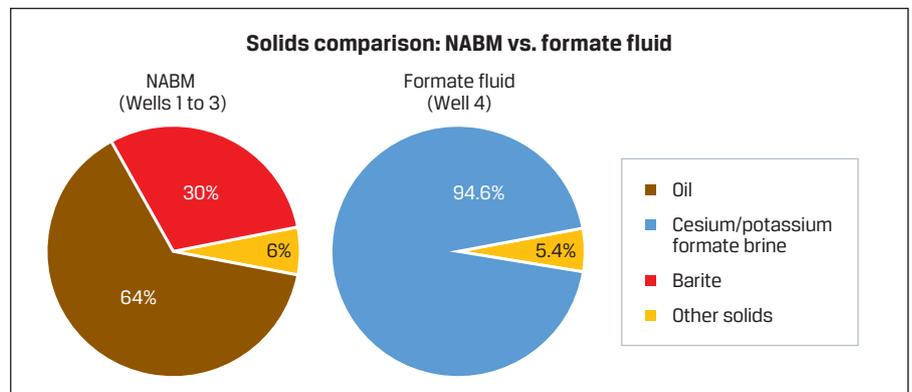
### Low-solids formates give high returns

The 216-meter, 8½" reservoir section of Well 4 was drilled with our pre-mixed, ready-for-use 2.07 g/cm<sup>3</sup>/17.3 lb/gal cesium/potassium formate RDF. With just 100 kg/m<sup>3</sup> added calcium carbonate bridging material, solids were reduced by over 90%. This low-solids fluid was designed in conjunction with Schlumberger (MI-Swaco) and Total to meet the drilling challenges previously encountered and to deliver high performance.

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

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

reducing weight on bit by over 50%. This was achieved with a minimal equivalent circulating density (ECD) contribution of 0.40 g/cm<sup>3</sup> (2.07 g/cm<sup>3</sup> equivalent static density (ESD)/2.11 g/cm<sup>3</sup> ECD). Due to stuck-pipe and gas control challenges while drilling with the NABM, Total set ROP to a maximum of 15m/hr in shale sections and 5 m/hr in pay zones and coal beds. Drilling with formate fluid was problem free and, even though rates were restricted, ROP increased by 84%.



Total reduced solids with over 30% by using formate fluid. The amount dropped from approximately 1,400 kg/m<sup>3</sup> in each of the first three wells to 100 kg/m<sup>3</sup> in Well 4.

Lower pump pressure and reduced fluctuations in ESD/ECD caused significantly less stress on the formation. Downhole bit and BHA vibrations, such as stick-slip, were greatly reduced. Furthermore, the formate fluid's shale-stabilizing properties kept the troublesome shale sections stable. Taken together, these improvements provided superior hole conditions and drilling efficiency. 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**

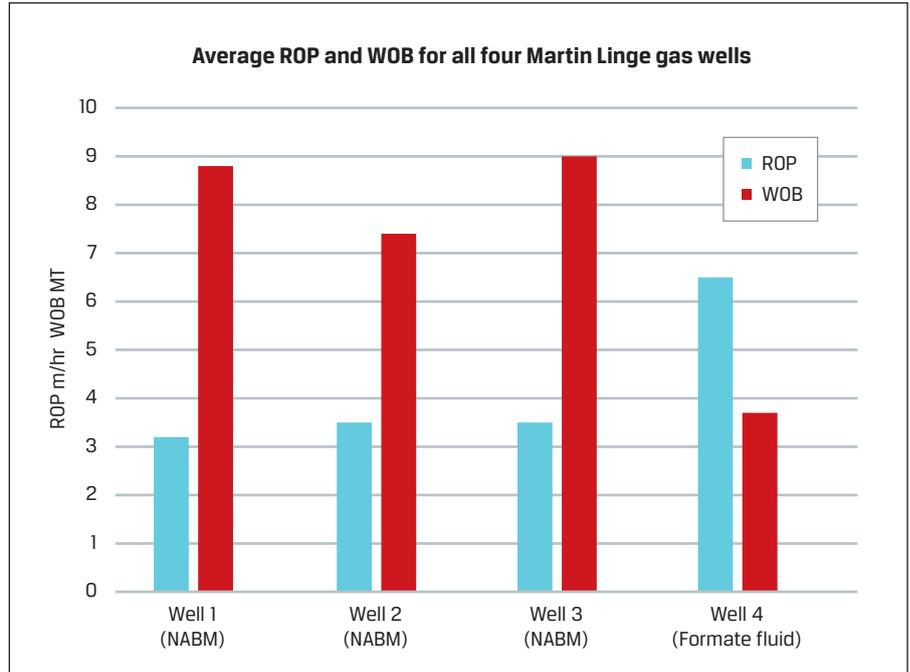
After target depth (TD) was reached, the RDF was tested over API 270-mesh screens and immediately passed all production screen test requirements for screen-running fluid. The 250µm production screens were run and set smoothly with no obstructions. As the previous three wells, 2.13 g/cm<sup>3</sup>/17.8 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 clean-up. The well is fully clean".

Eirik Jøntvedt, senior specialist engineer, Total E&P Norge, summarized by saying: *"Cesium formate-based drilling fluid has outperformed the previous NABM. We have been very happy with Cabot'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:



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

**New standard for operational efficiency**

- ◆ Pre-mixed fluid delivered ready for use
- ◆ 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
- ◆ Minimum difference between ESD and ECD
- ◆ Optimized hydraulics minimize formation stress
- ◆ Formate fluids improve drilling dynamics, including lower stick/slip levels
- ◆ Excellent hole cleaning
- ◆ Improved wellbore stability

**Enhanced production potential**

- ◆ Well fully clean before production test
- ◆ No breaker fluid required for completion
- ◆ Well flowed immediately
- ◆ PI was 25% above the anticipated level
- ◆ No indication of formation or completion damage
- ◆ 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.

