

Case Study  
i-Frac CEM™

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A cemented, multi-zone,  
ball-drop activated,  
frac sleeve completion  
in the North Sea

**3 Stages – 56 Sleeves – 3 Balls**

## i-Frac CEM™ - North Sea

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### Background

A well in the North Sea needed to be completed as a near horizontal producer in four zones using a cemented liner with acid stimulation through multiple entry points. Stimulation of similar wells had historically taken 40-50 days with associated costs and deferred production. The operator was looking to find an alternative completion design.

We proposed our unique i-Frac CEM lower completion system. The system allows for more than 20 sleeves per stage to be installed in a cemented liner and opened sequentially with a single ball. A number of stages can be run in a single well.

The i-Frac CEM sleeves were installed and cemented on a standard 5" liner. Nozzle configurations were designed to gain a limited entry effect throughout the reservoir section and sleeves were carefully spaced out for an optimal acid matrix stimulation job. Three balls were dropped to open a total 56 sleeves in three zones. The stimulation was completed in 1½ days versus the 40-50 days previously experienced when stimulating with plug-and-perf.



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i-Frac CEM technology allows for more than 20 sleeves per stage to be installed in a cemented liner and opened sequentially with one ball.

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### The Challenge

The well was part of a major complex in the Norwegian sector of the North Sea. This is one of the most important oil and gas fields in Europe. The field produces from formations of the early Paleocene and late Cretaceous ages. The reservoir rock is fine-grained and dense, but with high porosity, and the reservoir is typically naturally fractured chalk with a tendency for movement and compaction.

The target well was to be completed as a near horizontal producer in 4 zones. Total depth was 4,921 m (16,145 ft). The production section was 839 m (2,753 ft) at TVD of 2,700-2,900 m (8,865-9,514 ft). Well conditions indicated a cemented liner, rather than packer isolation. Prior to production the well required acid matrix stimulation, and optimal stimulation would require multiple entry points in each zone.

In previous wells, plug-and-perf had been used for the stimulation. Experience suggested this would take around 40-50 days with corresponding significant costs of vessels, equipment and personnel and the added HSE headaches associated with perforating. The operator needed to find an alternative completion design that would reduce the overall cost of the stimulation and bring the well online earlier.

It was with a mix of enthusiasm and mild skepticism that the operator decided on the i-Frac CEM system. Quite understandable, as this completion would be a record breaking multistage frac system. Installing a single ball multi-valve frac system as part of a cemented liner and operating up to 19 sleeves per zone was new to the industry.

Our truly unique i-Frac system was already successful and field proven in openhole applications, but this installation was pushing the system to new limits. Through a combination of innovation and engineering expertise the i-Frac CEM system was developed for use in cemented applications.

Questions were raised whether a ball drop activated system was able to operate flawlessly after pumping cement through the sleeves and whether a cementing dart could pass all the seats without being excessively worn or accidentally opening any of the sleeves prematurely. Critically, would the cement break down under pressure from inside to allow flow of stimulation fluid through the nozzles?



### Solution

The proposed solution was the unique i-Frac CEM lower completion system. The system allows for more than 20 sleeves per stage to be installed in a cemented liner and opened sequentially with a single ball. A number of stages can be run in a single well.

For this well, the i-Frac CEM sleeves were installed and cemented on a standard 5" liner. All frac sleeves were made up to assemblies onshore to save time during the liner running operation. The i-Frac sleeve nozzle configurations were designed to gain a limited entry effect throughout the reservoir section and sleeves were carefully spaced out for an optimal acid matrix stimulation job. During the cementing job, the dart bumped at theoretical pumping volume and a positive pressure test on the liner was conducted. The 5 sleeves in the lowest zone were opened with coil tubing. The three balls were dropped to open the remaining 56 frac sleeves in three zones. The first ball operated 19 sleeves, the following ball operated 19 sleeves and the last ball operated 18 sleeves. This was all conducted in 1½ days versus 40-50 days previously experienced when stimulating with plug-and-perf.

### Results

We have been producing frac sleeves for the U.S. unconventional market for quite some time and, challenged by the Operator's request, decided to adapt the design to run in a cemented application.

The solution featured sleeves with active ball seats in various sizes to accommodate the various zones. The shifting mechanism is triggered by pressure buildup behind the ball when sealing in the ball seat. The active ball seats allow the ball to pass through once the sleeves are shifted to the open position. The last ball seat in each zone is fixed and provides isolation to the lower zones. A total of 56 sleeves were operated by dropping three balls.

Full scale testing was conducted prior to installation. This included cementing and operating of sleeves as well as pumping the cementing dart through small ball seats. All tests proved to be more successful than was initially anticipated by all parties. No cement residues were left in the i-Frac sleeves, the sleeves opened at nominal pressures and the cementing dart showed no significant signs of wear after passing 80 ball seats. Full scale contingency tests were also conducted by a team led by the Operator's completions engineer. This included milling of balls and ball seats with a tractor. All tests proved successful. Prototype production and full scale testing was conducted and the full batch of sleeves was made available to the client in just 8 weeks from initiation.

# Case Study Snapshot

### Challenges:

- Reduce the overall cost
- Reduce the operational risk
- Reduce the HSE risk
- Ensure expected production rates
- Bring the well online earlier

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### Solution:

- i-Frac CEM system
- Configurable frac sleeves installed in a cemented liner
- Zones were defined by frac sleeves with the same ball seat ID
- Three zones were operated with ball drop
- Three balls were used to open a total of 56 sleeves

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### Results:

- Three zones stimulated in 1.5 days, versus 40-50 days in previous wells
  - No intervention required
  - Eliminated HSE risks from perforation
  - Production rates as expected
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