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Challenges in Heavy Crude Oil—Grane, an Overview

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Abstract

At current production, Grane field supply the market with more than 220,000 barrels of oil per day. Innovative solutions were needed to produce the heavy oil from the field.

The Grane field started production on September 23, 2003. It is the first heavy oil field on the Norwegian continental shelf. Close cooperation between Hydro's operations, project development team, contractors and partners forms the basis for completing the Grane facilities. The project was delivered on schedule, below budget and without high-potential incidents.

A pre-drilling campaign comprising 12 wells allowed production start-up shortly after completion of the offshore commissioning phase. The drainage strategy of the reservoir is based on gas injection with gas imported through the North Sea gas transportation system. Reserves of more than 700 million barrels will be drained by 31 production wells. The strategy is to reach the expected 60% recovery factor by drilling multilateral wells.

The 22,000-tonne process, drilling and accommodation installation exports Grane's crude to the Sture Oil Terminal on Norway's west coast, via a 212 kilometer long, 28'' pipeline. Hydro's high-pressure, multiphase flow loop located at the research center in Porsgrunn has been used to design the topside process and topside process equipment in cooperation with contractors. The operations comply with Hydro's "zero discharge" philosophy.

Introduction

This paper presents the challenges Hydro as an operator faced during the field development and production ramp-up period.

It will briefly describe Grane's solutions and experiences into plateau production.

At peak production, Grane is one of the top-producers in the Norwegian offshore sector. It is estimated that the field will account for 7 percent of all Norwegian output. This ensures many good years for the Sture terminal, which is one of Norway's most important ports for exporting oil to the market.

Timeline

1991	**December** Hydro discovers the Grane field (Well 25/11-15 and named 'Hermod' at the time)
1996	**Summer** Hydro performs the Hermod Extended Well Test (EWT)
1998	Hydro proposes to inject CO_2 captured from a gas power plant onshore for pressure support of the production wells.
1999	**December** Hydro submits the plan for development and operation (PDO) of Grane to the Ministry of Petroleum and Energy in Norway and the PDO is approved June 14, 2000.
2000	**May to December** Contract award of the platform's production module, value of NOK 3.5 billion to Kværner Oil and Gas (at the time). Aker Maritime is awarded the contract for the platform's drilling module, value of NOK 1 billion. Aker Verdal is awarded the contract for the steel jacket, value of NOK 670 million. Veidekke ASA and Murphy Pipelines LTD are awarded the EPCI contract for the onshore section of the oil pipeline, value of NOK 140 million.
2001	**March to September** Kværner Oil and Gas is awarded the contract for the platform's power generation module and Living Quarters, value of NOK 500 million. Contract for production drilling awarded to Odfjell Drilling Management AS; worth aroun value of NOK 430 million. And in September, the pre-drilling of nine production wells and three injection wells is started with the semisubmecible drilling-rig 'Scarabeo 6'.
2002	**April** Aker Kværner is awarded the contract for hook-up and completion of the platform modules. **October** Cost savings in procurement and in the selection of technical solutions results in an updated cost estimate by the management committee for the Grane licence. This indicates that the Grane field will be NOK 1,5 billion below a total budget of NOK 16,5 billion. **December** All platform modules are completed and tested at Aker Kværner's shipyard in Stord, Egersund, Stavanger and Verdal.
2003	**Januar**y Contracts for well equipment at a total value of NOK 600 million are awarded to Halliburton, Weatherford and Baker Oil Tools. This bidding process was the largest carried out on a net-based electronic system in the international oil industry. **February** Completion of the Grane jacket at Aker Verdal. **April-June** Installation of all platform modules on the field. **September 23, 2003** Production start on Grane.
2004-2010	Plateau production is expected to be maintained until 2010.
2006	**January** Start drilling the first two-branch production well. Planning of subesa satellites to the Grane PDQ.
Appr.2018	Planned drilling of water production well. In phase two of the Grane field's production l life span, water will be imported from the Utsira formation to replace the oil that is produced.
Appr 2025	Development of gas production phase

Hydro Oil and Energy

Hydro has been the second-largest producer of oil and gas in the Norwegian offshore sector since Norway's petroleum industry started in the early 1970s. Hydro has steadily built up its experience and expertise to become one of today's leading offshore companies in the world. Hydro also leads in the development of new technology and aspires to be the safest company operating and creating high value in Norwegian waters.

Hydro is currently the operator of 13 oil and gas fields in the Norwegian offshore sector. They are the Oseberg Field Center, Oseberg Øst (East), Oseberg Sør (South), Oseberg C, Brage, Njord, Troll B and Troll C, Heimdal, Grane, Tune, Vale and Fram. The last three are sub-sea installations.

The Oseberg Field Center is Hydro's largest installation. For a long time, Oseberg was Norway's highest-producing oil field and will soon become one of the country's largest gas fields. Troll Oil is currently Norway's most productive oil field, despite the fact many once thought its oil could not be recovered. In 1999, Hydro installed Troll Pilot, the world's first sub-sea wellstream separation unit.

Currently, the most challenging project is the Ormen Lange gas field development, situated 120-kilometers northwest of the Møre coastline. Processing will take place onshore at Nyhamna on the west coast of Norway. The gas will be exported to Easington on the east coast of England through a 1,200-kilometer long export pipeline. www.ormenlange.com

The Grane field

The discovery of the Grane field in 1991 has shown how important it is to have an open mind and try out new exploration and development methods. The Grane reservoir bears little resemblance to most other oil fields on the Norwegian shelf.

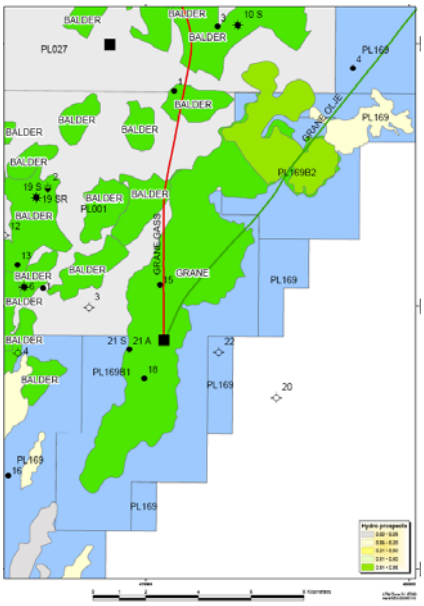

Figure 1. The Grane feild

Most fields contain relatively thin oil in reservoir rock types from the Jurassic age around 135 to 195 million years ago. The Grane oil, on the other hand, is heavy and lies in sandstone from the Tertiary period, around 60 million years ago.

The Grane Unit field area of 92 km^2 is located 180 km west of the Norwegian island of Karmoy.

One of the largest fields

Grane is one of the largest known oil discoveries under development and production on the Norwegian continental shelf. The field is one-third the size of the giant Oseberg acreage, but twice as large as Brage. Its expected reserves are estimated at 120 MSm^3 (about 755 million barrels) and, at the end of 2005, only 15% had been produced during the first two-and-a-half years of operation.

According to the original design basis, the processing capacity should be 214,000 bpd and it should flow through the 212-kilometer long pipeline from Grane to the Sture terminal north of Bergen. In the last weeks of 2005, production reached a record high 235,000 bpd.

The Grane Unit comprises production licenses PL169B1, PL169B2 and PL001. It is linked up into a production system with the Oseberg field and the Sture terminal.

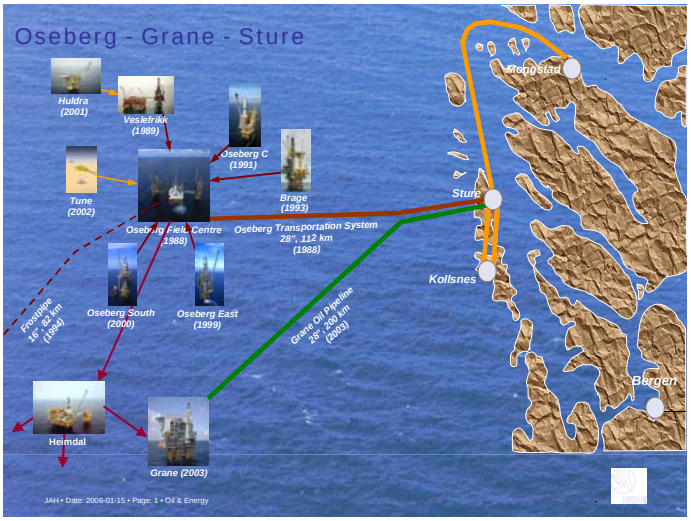

Figure 2: Hydro has a 38 % ownership stake in the Grane Unit

Heavy crude oil at low pressure

With reserves at a depth of 1,700 meters below the seabed, and water depth of just 128 meters, this development might at first sound simple to anyone used to working with Norwegian offshore oil and gas fields. Grane, however, has been described as a challenging field - and this is mainly due to the heaviness of the oil (19°API) and low pressure (~170 bar) in the reservoir. Natural gas has to be compressed into the injection wells to press the oil out of the reservoir. Injection gas is imported from the Heimdal Gas Center, 50 kilometers away, through an 18'' pipeline.

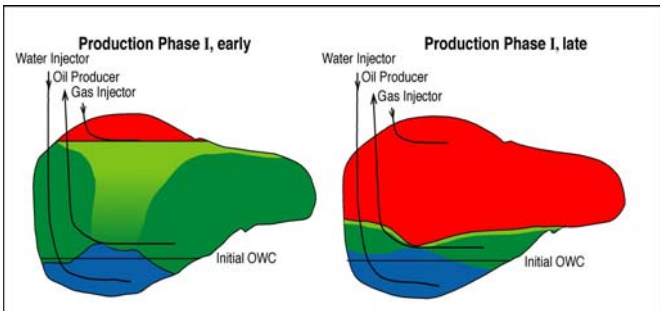

Figure 3. Production strategy

This solution will provide a far greater rate of recovery compared with injecting water for pressure support, which is the most usual drive mechanism. After about 20 years of operation, the injected gas can be produced and sold.

Hermod extended well test and hydropower

During the summer of 1996, Hydro performed an extended well test on the Grane reservoir to get better data on reservoir characteristics. The name of the test project was Hermod. The test confirmed that permeability was about twice that of

theoretical values based on data obtained from appraisal drilling earlier in the 1990s. This extended testing helped Hydro better understand the reservoir and formed the basis for the Grane field's design developed throughout 1998 and 1999.

In 1998, Hydro initiated a design where one development alternative was to inject CO_2 from Hydrokraft's onshore gas-power station, next to Hydro Aluminium's smelter at Karmøy. CO_2 would be transported in super-critical condition through a pipeline to the Grane field and injected into the reservoir to maintain pressure, increase recovery of oil, and provide gas lift in the production wells. One of the major challenges in using super-critical CO_2 was material selection, as CO_2 together with water is extremely corrosive.

Later, this proposed development concept became commercially unattractive and susbsequently led to postponing preparation of the field development plan for another year and a half.

At the end of 1999, the partners in the production licence agreed on a Plan for Development and Operation (PDO), which was then submitted to the Norwegian authorites. The PDO was approved by the Norwegian parliament in June 2000 and main contracts for the platform were awarded accordingly.

Topside process

The process has been thoroughly designed to handle the three-stage separation of the heavy oil. It consists of two large separators and two parallel electrostatic coalescers. In July 2005, a Vessel Internal Electrostatic Coalescer (VIEC) system was installed in the separators to further improve the process. The oil is processed at a high temperature (90-100°C) Detailed studies and tests formed the basis of the emulsion breaker system used. Tests performed in the reseach center at Porsgrunn were an important basis for the process design.

Figure 4. Element of the VIEC system

Precision drilling

A total of 39 wells are planned on Grane, 31 of which will produce oil. To ensure efficient production and to improve the recoveryfactor, the wells must be drilled precisely nine meters above the level where oil and water meet in the reservoir.

This precision can be achieved by means of a new drilling tool, developed jointly for the pre-drilling campaign by Hydro and Schlumberger Oilfield Services, called the Ultra Deep Resistivity Tool. This has proven highly efficient at measuring the distance to the contact point between oil and water during drilling.

It is forecasted that production will remain at plateau level up to around 2010, when it is expected to decline. Plateau production will be prolonged by use of multilateral wells. Based on Hydro's experience from multilateral wells drilled on Oseberg in the late 1990s and later developed into five- and six-branched wells on the Hydro operated Troll field, the next step in the drilling program will focus on both two and, later, three branches on Grane. Current plans for Increased Oil Recovery (IOR) are based on 12 additional well targets in excess of the single-target wells.

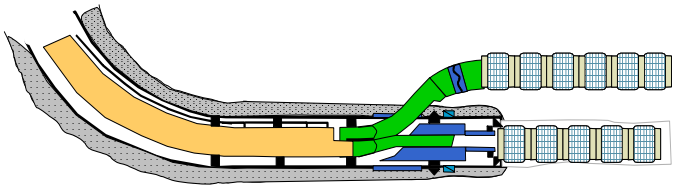

Figure 5. Multilateral well design

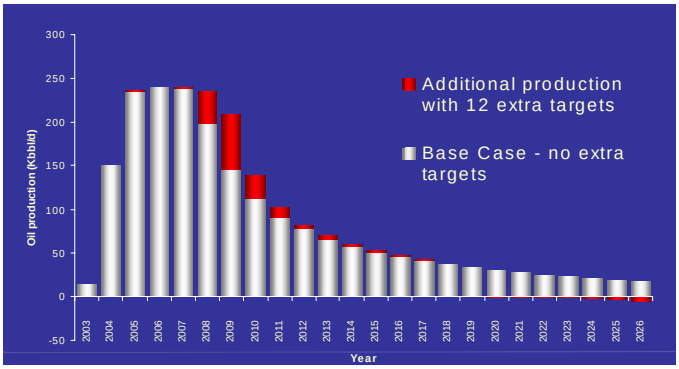

Figure 6: Multilateral wells give increased recovery

The use of seismic MWD has been tested with support from the Grane Unit partners. The methology offer opportunities to "see" 300 to 400 meters ahead of the drill bit.

Figure 7. The Grane platform

Discharges minimized

The environment and environmental safety are very important to Hydro. The company develops and applies environmental technology that can contribute to energy optimization and reduction of emissions and discharges.

Grane has a total installed power production of 2x28 MW and a heating system of 65 MW. Three gas turbine engines, two for power generators and one for the compressors, cover the energy production. Two of the gas generators on the platform are low-NOx units. Extended use of modern heat-recovery technology in the process and utilities helps reduce

and/or prevent environmental impact. It has been shown that the best environmental technology increases production efficiency and provides environmental benefits.

Even in the pre-drilling phase, Grane met requirements set by the Ministry of the Environment by using water-based drilling fluids. In the production phase, cuttings, drilling fluids and produced water are returned to the reservoirs. Recycling flare gas makes it possible to avoid pilot flaring during normal operations.

Gas from Heimdal and oil to Sture

Figure 8. Heimdal gas centre

Gas is imported to Grane via the Hydro-operated Heimdal facilites to Grane. Oil is transported in a 212-kilometer pipeline to the onshore Sture terminal in western Norway.

The Heimdal Gas center, situated 180 kilometers northwest of Stavanger, provides a connection hub for the processing and distribution of gas. Heimdal has been in operation since 1985, and was originally operated by Elf. Its operatorship was later transferred to Hydro. It is an integrated Process, Drilling and Quarter platform and suppoted by a riser platform from which gas is transported to Grane for use as pressure support during oil production. The imported gas is also used to run generators and compressors on Grane. In addition to handling gas export to Grane, Heimdal also receives gas from the Oseberg Gas Transport (OGT) system and Huldra field. The Vesterled pipeline links Heimdal up to the gas transport system from Frigg to St. Fergus, Scotland, and to the Statpipe system to Europe.

Over 200,000 barrels of oil daily from Grane to Sture

The oil from Grane is exported to the Sture terminal, which is an important shipping point for crude oil. During platau production, Grane will export over 200,000 barrels of oil per day to Sture.

Figure 9. Sture export terminal

A new fiscal metering station based on ultrasound technology has been installed at the export-terminal for measuring flow in the heavy crude oil. It is the first time this technology has been used on a large scale.

The oil is heated for storage from around 7-10°C on arrival, up to 30°C. It is then transferred to caverns in the mountainside, with a 238,000 cubic meter (1.5 million barrels) capacity, before it is transported to the market by crude vessels.

Sture also receives crude oil and condensate from the Oseberg area via a 115-kilometer long oil pipeline from the Oseberg Field Center. The terminal has two jettys that can receive tankers up to 300,000 DWT, five crude oil caverns with a capacity of one million cubic meters, one LPG cavern with a capacity of 60,000 cubic meters and one 200,000 cubic meter ballast water cavern.

In May 2004, facilites were in operation to blend 6% of heavy Grane crude into the Oseberg Blend, which is facing increasing content of condensate. This blend is exported as New Oseberg Blend (NOB) without diminishing the value of Oseberg oil in the market.

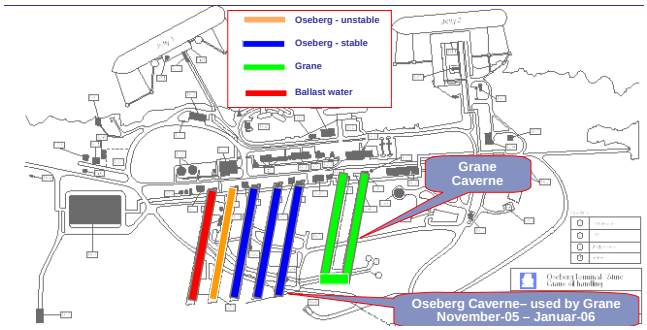

Figure 10. Sture: Oseberg-Caverne utilized by Grane during emulsion problems

During a period in October and November 2005, Grane experienced production reduction with extended formation of emulsions in the separation system. Oil and water was not properly separated on the platform due to the emulsion. It was then arranged with the Oseberg Blend shippers that one of their rock caverns would be used for settling the water before exported at the specified 0.5% BS&W. Designed flexibility in piping arrangement and pump capacity, as well as cooperation from the shippers at the export terminal proved to be highly valuable in securing stable Grane crude production.

Licensees

In addition to operator, Norsk Hydro Produksjon, with a 38 percent ownership share, the following companies are partners in the Grane Unit:

ExxonMobil - with 25.6 percent interest in Grane

The company has been directly involved in the design of Grane since 1999, when it set up an engineering group that worked alongside Hydro to draw up the development plan.

During the project execution and later ramp-up of the production, ExxonMobil has been very cooperative and generous with its global competence, and is regularly participating with their experience.

Petoro - with 30 percent interest in Grane
Petoro is a state-owned company that was established as a direct result of a parliamentary resolution to set up new administration of the state's direct financial interest (SDFI) in petroleum activities on the Norwegian continental shelf. Petoro's main task is to create the greatest possible value from the state's oil and gas portfolio.

ConocoPhillips Norge – with 6.4 percent interest in Grane
This is the third-largest private energy company in Norway. It is the operator of seven Norwegian development licences and co-owner of an additional 25. Cooperation with ConocoPhillips Norge has been very good through the development phase and its global expertise in heavy crude oil production and drilling has been made available to the operator team.

Cautionary Note

The United States Securities and Exchange Commission permits oil and gas companies, in their filings with the SEC, to disclose only proven reserves that a company has demonstrated by actual production or conclusive formation tests that are economically and legally producible under existing economic and operating conditions. We use certain terms in this presentation material, such as expected recoverable resources, or P50, that guidelines strictly prohibit when filing with the SEC. Investors are urged to closely consider the disclosure in our Form 20-F, SEC File No. 1-9159, available from Hydro at our corporate headquarters: Norsk Hydro, N-0240 Oslo Norway. You can also obtain this form from the SEC by calling 1-800-SEC-0330.

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