New Milestones in Subsea Blasting at Water Depth of 55m

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Abstract – Considerable rock construction and tunnelling activity takes place in Norway, annually excavating approximately 100 km of tunnels. The paper describes two tunnelling milestones in sub-sea tunnelling that were achieved in 1998: 1) excavation of a large sub-sea chamber with only 15 m to the sea bottom at 55 m water depth and 2) dry piercing to the sea bottom and pull-in of a pipeline without use of divers.

1. INTRODUCTION

Among the works performed for the Åsgard Transportation Project the following are described:
- Blasting for enlarging a sub-sea chamber to 11 m span. The chamber is located only 15 to 20 m below the sea bed at 55 m water depth.
- Cautious blasting in tunnel only 5 m from an existing condensate pipeline in operation.
- Piercing from the "dry" pull-in chamber to sea bottom by reaming up a 0.3 m pilot hole to 1.6 m.
- Pull-in of the 42” Åsgard gas pipeline into the "dry" chamber without use of divers.

These works have earlier been presented in Norway [1, 2].

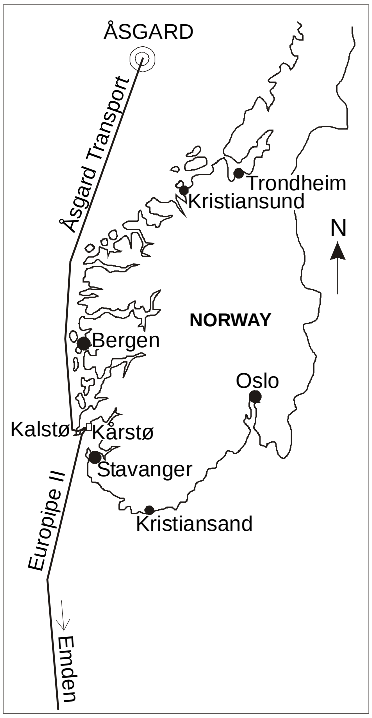


Figure 1: Overview

The offshore Åsgard oil and gas field is located Northwest of Trondheim. Gas from this field will be pumped through the 42” Åsgard Transport pipeline to Statoil's gas treatment plant at Kårstö. Here, natural gas will be stripped from the lean gas to bring the latter to sales specification before it is sent to Emden in Germany through the Europipe II export line (Figure 1).

Before arriving onshore from the North Sea the pipeline enters into an existing landfall tunnel at 60 m water depth to be protected from sea wave damage. This landfall tunnel was constructed in 1990 - 92 for the Sleipner condensate pipeline. It is 1350 m long with the deepest point 100 m below sea level. In the first 300 m, the tunnel is 5.3 m wide, in the rest the span is 6.2 m, as shown on Figure 2. The rock cover (overburden) is 30 to 60 m.

The ground consists of gabbro, often metamorphosed to a gneissic rock. The rocks are generally moderately jointed with Q-value 4 – 25 (fair to good). A few large weakness zones were encountered, having a quality Q = 0.01 to 1 (extremely to very poor). In addition, many small shears and minor weakness zones occur.

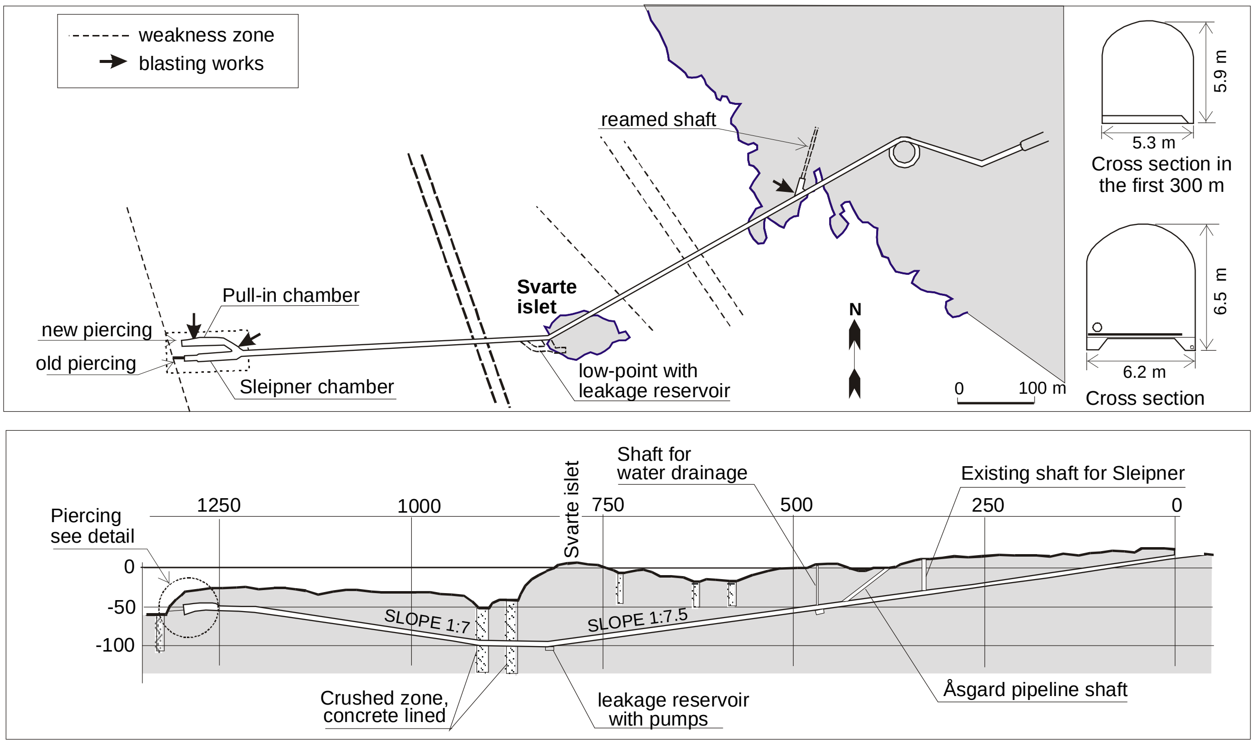


Figure 2: The conditions at the Kalstö landfall tunnel

The rock support in the tunnel was tailored to the rock mass conditions encountered. No support was performed where few joints occurred, else the support was shotcrete and fully grouted rock bolts. Concrete lining was only applied at of the large weakness zone near the low-point of the tunnel, making a total of 38 m, or 3 % of the tunnel length.

After completing the Sleipner condensate pipeline installation in 1992 the tunnel was flooded with sea water. Therefore, prior to commencing the work for Åsgard in 1997 the tunnel had to be dewatered, and the necessary supplementary rock support performed.

2. BLASTING WORKS PERFORMED

An extra piercing chamber had already been excavated in 1991, see Figure 3. Some modifications in the landfall tunnel and chamber had, however, to be made for the installation of the Åsgard gas pipeline. This consisted of the excavation of 3500 m^3 by drilling and blasting, partly performed as close as 5 m from the existing Sleipner condensate pipeline, which was in operation.

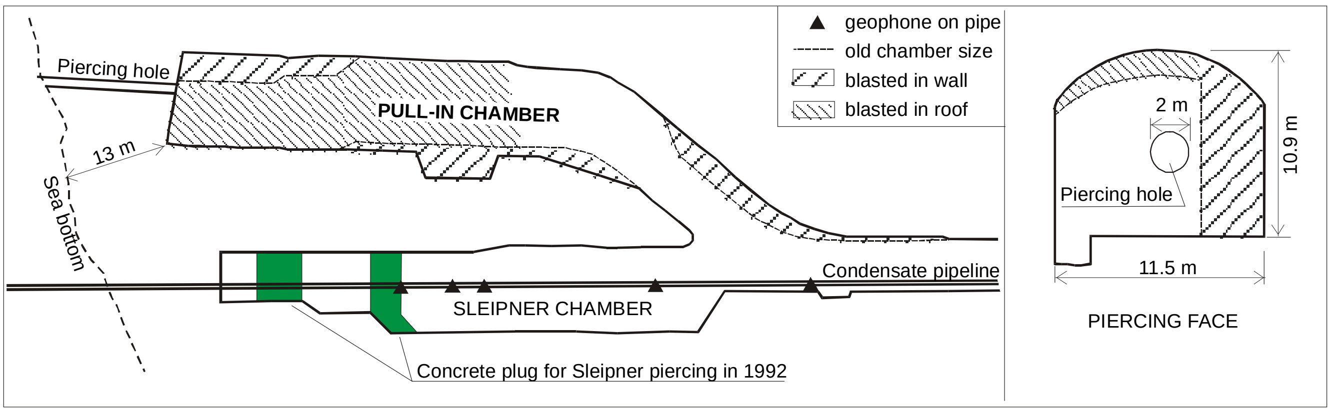


Figure 3: Left: Plan showing areas enlarged in the pull-in chamber from blasting. Right: Cross section of chamber.

The existing Statpipe piercing chamber was enlarged to accommodate the pull-in of the Åsgard gas pipeline. Located at 60 m water depth with only 15 to 20 m rock cover, the chamber was widened from 8 m to 11 m span, and the height lifted from 7 to 9 m.

The large dimensions of the piercing chamber and the water depth caused extra challenges during the blasting, rock support and piercing works. The small rock cover of only 15 - 20 m resulted in low rock stresses, which imposed an extra risk for joint opening and development of water leakage.

There were strict requirements to avoid damage of the Sleipner condensate pipeline. Therefore, the following measures were taken:

- Prior to commencing the work, a full-scale test-blasting program in the piercing chamber was carried out to determine the drilling, charge and ignition plan.
- The condensate pipeline was protected with rubber and fibre mats, timber, concrete slabs and gravel during the blasting works.
- The vibration velocity limit was set to 30 mm/s. During blasting, the vibrations on the condensate pipeline, surrounding rock and concrete foundations were closely monitored. See Figure 3.
- An experienced engineering geologist from Norconsult closely followed-up the tunnel works and the need for rock support and water sealing by grouting.

Upon completion of the rock blasting and rock securing works, the piercing operation could start.

3. PIERCING TO THE SEA BOTTOM

Piercing of tunnels to the sea bed is not a new concept in Norway. In connection with hydropower plants, some 600 - 700 of so-called "lake taps" or "bottom piercings" have been used [3 to 6]. For the landing of pipelines from the North Sea, this vast experience has been utilised.

At Kalstö, two other landfall solutions had earlier been applied:

- For the Statpipe in 1982, a prefabricated concrete culvert, which involved extensive use of divers.
- For the Sleipner condensate pipeline in 1992, a concrete pull-in chamber was constructed to perform the piercing operation; a method using divers.

A main goal for landing of the Åsgard gas pipeline was to pull in the pipeline without use of divers.

3.1 Preparations

The piercing was performed using a well planned drilling and reaming procedure. The client, Statoil, determined the specifications and the method to be applied, while the contractor, AF Spesialprosjekt, was responsible for the planning and performance of the works in compliance with the strict specifications, both to HSE and QA/QC. For this, AF Spesialprosjekt had experience from similar operations, among others for the Troll Phase I Project in 1991-1995, comprising 3 piercings at 160 – 170 m water depth [7, 8].

A special steel structure, the so-called seal tube system (ESD-valve, pipe receiver, stripper valves, drill string bearings, flushing system etc.) was developed and delivered by Statoil to provide a “dry” piercing and pull-in operation into the piercing chamber.

After piercing, the rock face had been reinforced with rock bolts and shotcrete, the following works were performed:

1. Drilling of several probe holes to check the distance to the sea, and to collect information about the rock quality and water leakage conditions.
2. Rock grouting/injection of the rock masses in the piercing area to prevent potential water leakage.
3. Rock mass reinforcement by fully grouted rock bolts in a pattern adjacent to the planned piercing hole.
4. Blasting of a 2.2 m diameter and 4 m deep “cylinder” along the piercing hole centreline for seal tube system anchoring purposes.
5. Drilling of grouting, casting and sea water holes for future casting around the Åsgard pipeline.
6. Installation of the seal tube system with:
   - Anchoring systems (casting and rock bolts).
   - Mechanical installation (steel structures, pumps, valves, computer systems, hydraulic systems, etc.).
   - Testing and commissioning.

After extensive grouting works the water leakage into the piercing chamber was reduced to 30 l/min.

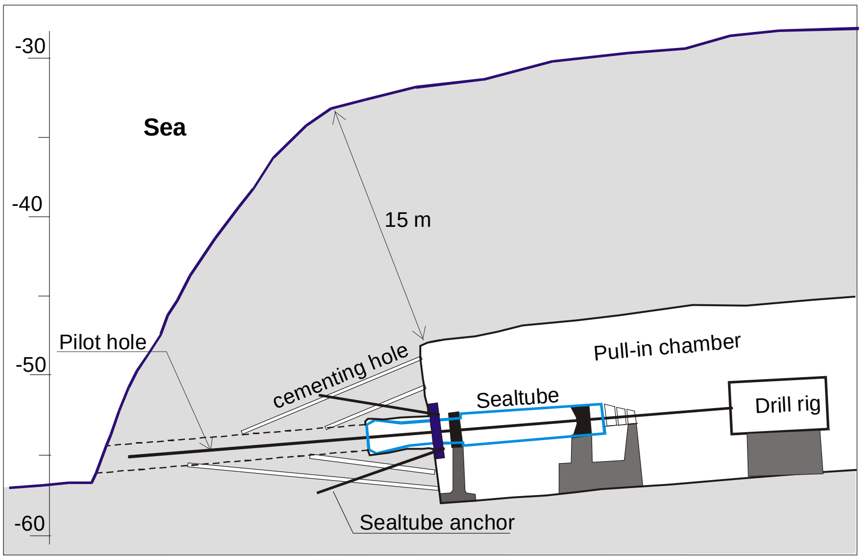


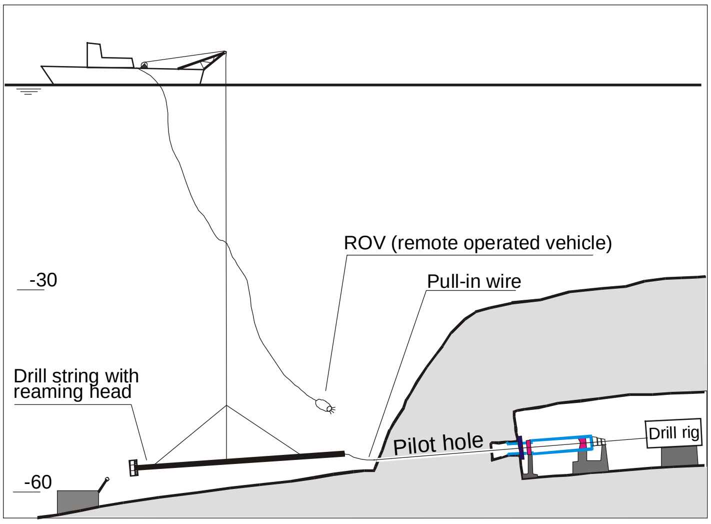
Figure 4: Layout of the piercing with the small pilot hole (made by directional drilling). The cementing holes were used for filling cement grout around the pipeline in the piercing hole after pull-in.

3.2 Drilling of the piercing hole and pull in of the 42" Åsgard gas pipeline

The piercing operation can be divided into the following steps, as shown in Figures 4 and 5:

- Directional core drilling of the first 56mm diameter pilot hole until 3 metres from the sea bed. The hole was then enlarged to 76 mm diameter using a standard core drilling rig.
- Installation of the seal tube system, which was anchored to the rock face.
- Installation of a drill rig behind the seal tube system for reaming of the pilot hole
- Reaming of the 76 mm hole to 308 mm (12¼") diameter including drilling of the remaining 3 m to the seabed.
- Drill string was then disconnected from drilling rig and the messenger wire attached to the drill string. Marine vessel (DSV) pulled the drill string with messenger wire attached out of the piercing hole and up to on the vessels deck. A new drill string with the 1.6 m dia. reamer head was then connected to the messenger wire and lowered down to the sea bed.

- The drill string was then pulled into the 12¼" pilot hole and the reaming of the 1.6 m diameter hole started. Initially, the reaming was performed very carefully to minimise vibrations from the drill string/reamer head. Drilling debris/cutting ships was removed by a water jet system installed behind the reamer head. See Figure 6.
- Upon completion of the bore hole, the drill string and messenger wire were pushed/pulled out and hoisted onboard the DSV.
- The 90 mm dia. pull-in wire was then attached to the messenger wire and pulled into piercing chamber via the seal tube system and finally connected to the winching system.

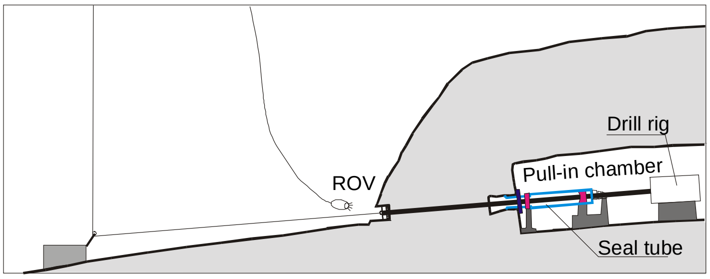


INSTALLATION OF REAMING STRING

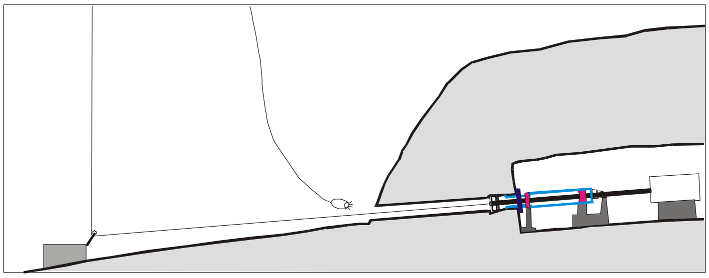
ROVs (remote operated vehicle) equipped with video cameras were used for all sub sea works (connections, inspections, etc.). All sub sea activities was closely monitored in the observation/control centre via TV-links and UHF radio communication (land – sea – tunnel).

Figure 5: After the pilot hole had been drilled, the reamer was pulled into the hole.

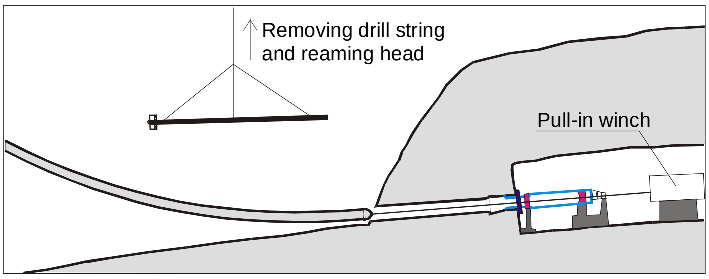
The pipeline was later pulled in from the lay barge (LB 200) using a linear winch with a pull capacity of 500 metric tons, see Figure 5. After the pull in the Åsgard pipeline was anchored to rock by grouting between the pipeline and piercing borehole walls



START OF REAMING THE PILOT HOLE TO 2 m DIAMETER



REAMING OF PILOT HOLE FINISHED



REMOVING OG REAMER HEAD AND PULLING-IN OF PIPELINE

All the challenges were solved and accomplished according to schedule and given specifications, thanks to well-planned preparations and great achievements from all parties involved.

Figure 6: The reaming of the pilot hole and the later pull-in of the pipeline.

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