WOUTER VERCRUYSSE AND MICHAEL FITZSIMONS

LANDFALL AND SHORE APPROACH OF THE NEW LANGELED PIPELINE AT EASINGTON, UK

ABSTRACT

To meet the growing energy requirements of the United Kingdom, a decision was made to lay a new offshore pipeline from Norway's gas-rich fields to the eastern coast of the UK. The pipeline would cross 1200 km from Nyhamna, Norway to Easington, UK, making it the longest offshore pipeline ever built. This article discusses the shore approach and landfall works which presented several unique challenges. These included environmental concerns because of the rapidly eroding clay cliffs along this section of the UK coastline, and technical demands to dredge at great depths in difficult soil and between two existing live pipelines.

INTRODUCTION

The 1200-km, 44-inch diameter Langeled pipeline from Nyhamna in Norway to Easington on the east coast of the United Kingdom is the world's longest offshore pipeline (Figure 1). Statoil ASA executed the work on behalf of Norsk Hydro. The new pipeline will provide up to 20 percent of the UK's gas requirement from October 2006.

The pipeline was pulled ashore in June 2005. Shore approach and landfall works were executed by Jan De Nul (UK) Ltd which was the principal contractor for the landfall works. The European Dredging Company (EDC), another member of the Jan De Nul Group, was responsible for the offshore dredging and rock placement. The offshore trench was excavated using the cutter section dredger, the *JFJ De Nul*, and backfilling the trench was performed using the trailing suction hopper dredger *Filippo Brunelleschi*. This TSHD also carried out pre-sweeping of offshore sand dunes. Rock placement at the Langeled-Cleeton pipeline crossing and in the nearshore section was executed with a side stone dumping vessel with rock imported from Norway.

CHALLENGES

Numerous challenges were taken into account during the execution of this landfall and shore approach operation. Amongst them were the unstable cliffs along the coastline at Easington which are subject to high erosion, with the land retreating at around 1-2 m per year. To allow for this and to minimise disturbance at the cliff face, a 380-m-long, 2-m-diameter curved tunnel beneath the cliff was built in order to contain the pipeline on its route from the beach into the terminal.

Above, work progresses off the UK's eastern coast at Easington, preparing the cofferdam and tie-in pit for landfall of the new pipeline.

Figure 1. Site map of the world's largest offshore pipeline extending 1200 km from Nyhamna,Norway to Easington, UK.

WOUTER VERCRUYSSE

Wouter Vercruysse graduated in 1992 with an MSc in Mechanical Engineering from Louvain University (Belgium) and joined the Jan De Nul Group in the same year. For the last 10 years he has been Project Manager on many pipeline projects in the North Sea, Singapore, Indonesia, Argentina, Taiwan and Sakhalin (Russia). For the Langeled Project, he was Project Manager for the offshore part, including shore approach trenching, offshore presweeping and gravel placement. He is now working as Project Manager of the Dolphin Pipeline Project in the United Arab Emirates at the Das Island Shipping Channel.

MICHAEL FITZSIMONS

Michael Fitzsimons graduated in 1975 with a Bachelor in Civil and Structural Engineering from Sheffield University (UK) and worked in the civil, marine and pipeline industry for more than 20 years before joining Jan De Nul in 2002. Since then he has been employed on many pipeline projects in Singapore, Indonesia and Sakhalin (Russia). For the Langeled Project, he was the Project Manager for the onshore and related pipeline works. He is presently project managing a pipeline project in Mauritius.

Another challenge was the presence of several marine pipelines at Easington also making landfall along the beach and land pipelines that feed gas from the terminals into the UK transmission grid (Figure 2).

The new 44-inch diameter gas line approaches the shore in a pre-excavated offshore trench some 20 km long and 1.5 to 2 m deep, sited between two existing live pipelines. This required trench excavation in open sea conditions through hard boulder clay at 37-m water depth at the offshore end which was previously unachievable by any dredger. For the shore crossing, a 240-m-long cofferdam plus a temporary beach platform were constructed to provide access in the intertidal zone to a tie-in pit, where the offshore pipeline section is connected to the onshore section.

ENVIRONMENTAL PROTECTION

The installation of pipelines from offshore through shallow water to a beach always poses challenges, but the rapidly eroding clay cliffs along this section of the UK coastline made the Langeled pipeline a special case (Figure 3). Each year, approximately 1 to 2 m of cliff disappears into the sea. This has been going on for thousands of years, removing numerous villages from the map. In Roman times the coast was three miles further offshore. Protecting the Langeled landfall section of pipeline from this erosion called for particular measures.

Engineering studies of the erosion required that the pipeline be installed deep within

Figure 2. Location of the Langeled pipeline in between the existing pipelines.

Figure 3. View of the existing cliffs along the coastline.

the cliff. With minimum environmental impact being a prerequisite, open excavation was not an option. The solution was to install a tunnel to carry the pipeline from the new gas terminal (sited 380 m safely inshore of the eroding cliff) to a tie-in pit on the beach, passing under existing pipelines, roads and other land features.

A sheet piled cofferdam extended the pipeline trench from the tie-in pit through the tidal zone of the beach to 60 m beyond the low water level (Figure 4).

Figure 4. Longitudinal profile of the 380-m microtunnel extending from the entry shaft to the cofferdam into the dredged trench.

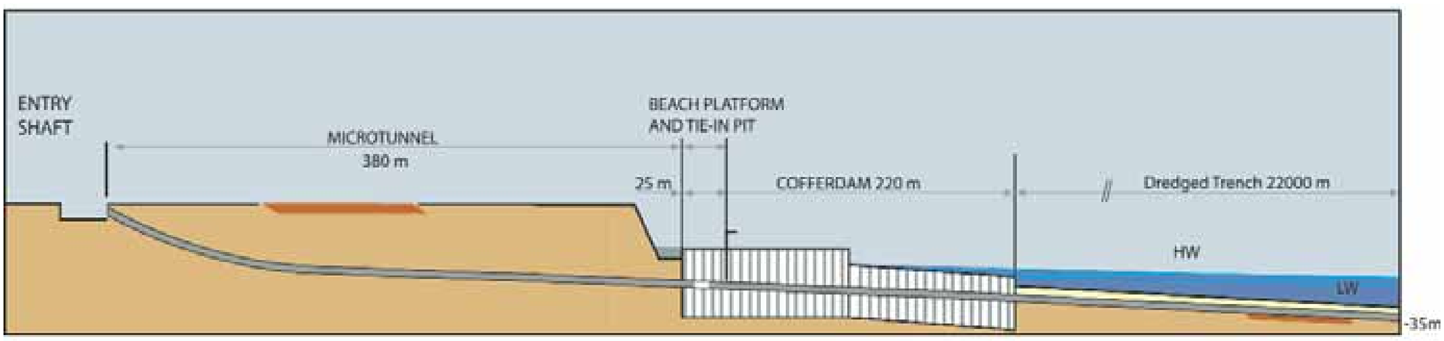


Figure 5. The Tunnel Boring Machine arrives at the tie-in pit.

Another option that was considered, but rejected, included extending the tunnel offshore so the pipeline could be pulled directly from the lay barge. However, the combined risk of constructing a longer tunnel with the marine challenges was considered to be unacceptable.
To ensure there would be no delay, both the tunnelling and cofferdam were scheduled to be completed in advance of the arrival of the lay barge and this was executed as planned.

TUNNEL CONSTRUCTION

Work on the tunnel started in Autumn 2004 with the clearance of the site and the installation of the tunnel shafts. The tunnel, with a 2.4 m outside diameter, was installed using a tunnel-boring machine (TBM). Concrete pipes, 2.5 m long, were lowered into the entry shaft where powerful jacks pushed the pipes and the TBM forward to form the tunnel (Figure 5). The TBM was able to steer its way and a vertical curved alignment was followed that avoided the need for a deep entry shaft.

The soil conditions were stiff clay with occasional boulders. The forward face of the TBM's earth balanced shield was set up with picks and water jets to cut the clay and cutting discs to break up the boulders. To minimise ecological impacts, seawater was pumped down to the face of the TBM, which flushed out the sediment as a mixture with seawater.

Figure 6. The tunnel soil treatment plant installed by Envisan. Insert left: the treated water containing less than 5 g/L of sediment; insert right: flocculents being added.

Figure 7. A sheet piled cofferdam was installed by land based equipment working at low tides from a specially constructed causeway.

Tunnel Soil Treatment Plant

Envisan, Jan De Nul's environmental branch company, was subcontracted to design, build and operate the tunnel soil treatment plant (Figure 6). First, the tunnel sediment mixture was collected in purpose-built settlement lagoons. The clay and crushed rock were then removed from the seawater by a combination of natural settlement and flocculents; the remaining water was returned to the sea with less than 5 g/L of sediment. The settled clay was treated and reused at the beach site, while the remaining slurry soil was transported to licensed landfill sites. In this way some of the sediment from the tunnelling had a beneficial use.

CONSTRUCTION OF COFFERDAM AND TIE-IN PIT

With the tunnel activities progressing, a separate team formed an access point from the cliff top to the beach, where a platform was established to provide a safe working area above the high tide level. Within this platform, the 13 m deep tie-in pit was sheet piles ready for the arrival of the TBM. Extending 220 m from the beach platform, a sheet-piled cofferdam was installed by land-based equipment working at low tides from a causeway constructed alongside the cofferdam (Figure 7).
As a result of the stiff clay, pre-augering had to be executed over most of the length in order to allow the sheet piles to be installed at the required depth.

TRENCH DREDGING AND MARINE BACKFILLING

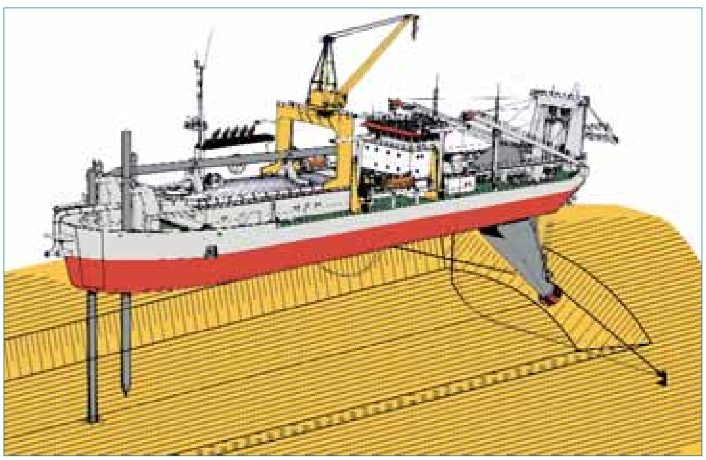
Beyond the cofferdam the pipeline trench was formed by dredging and, given the size of the project, a powerful cutter suction dredger had to be enlisted to carry out this work. The CSD *JFJ De Nul*, 27 240 kW vessel, was able to excavate the trench, even in very hard clay with boulders, in weeks rather than months. This contributed to lessening the environmental impact of the project (Figures 8, 9 and 10).

The CSD *JFJ De Nul* was connected to a 500-m-long floating hose, which deposited the soil to one side of the trench to be used later for backfilling. To stabilise and protect the nearshore pipeline, the trench was extended 22 km offshore from the cofferdam where dredging took place up to 37 m deep, a depth previously unreachable by any other dredger in these soils. For the first kilometre, gravel was placed by side stone dumping vessel to provide added stability and to protect against frost upheaval. Gravel was also placed in the cofferdam section of the pipeline trench.

The marine trench has been backfilled with the dredged clay from the stockpile using the *JFJ De Nul* for the first 1.5 km and the 11,300 m^3 capacity trailing suction hopper dredger *Filippo Brunelleschi* for the remaining trench.

Figure 8. Nearshore trench being dredged by CSD JFJ De Nul.

Figure 9. Schematic drawing of the JFJ De Nul at work.



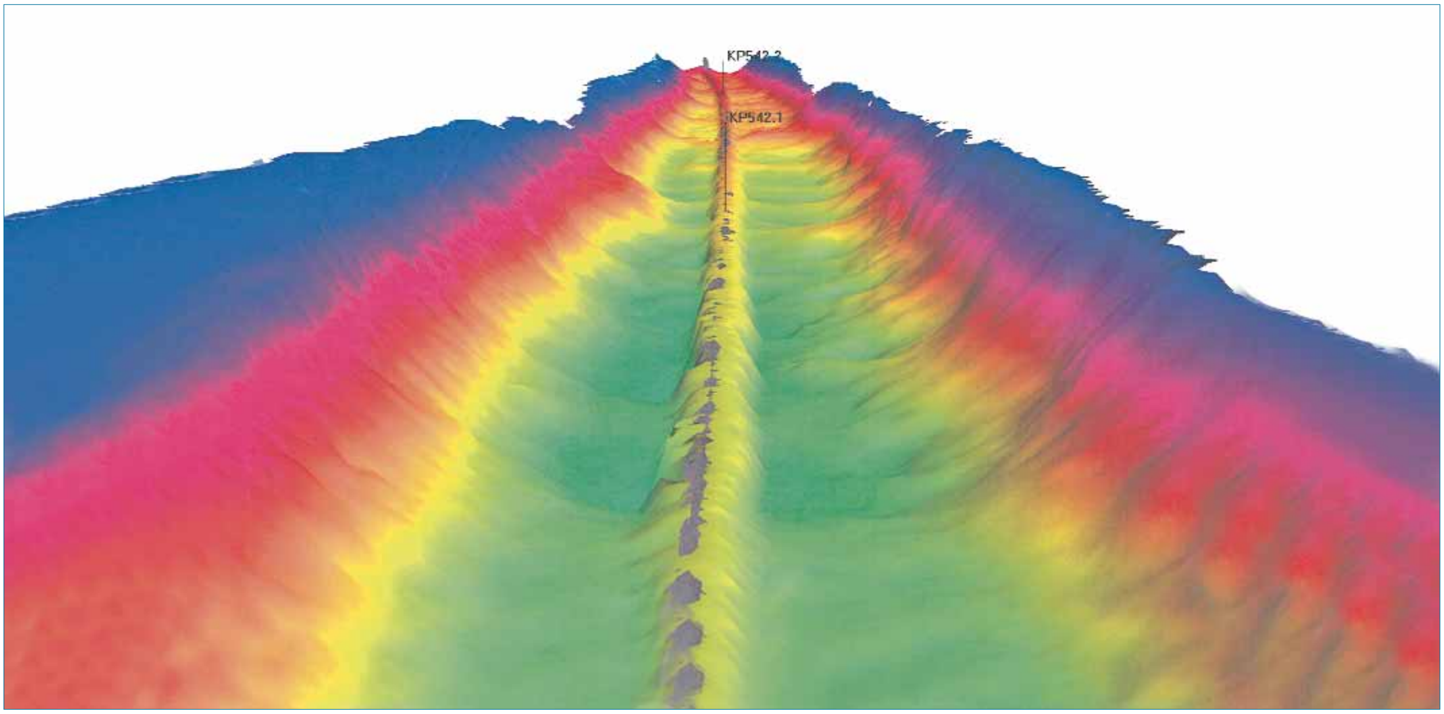


Figure 10. Three-dimensional view of the pipeline trench dredged in hard boulder clay by the CSD JFJ De Nul.

OFFSHORE PRE-SWEEPING

The TSHD *Filippo Brunelleschi* was also used offshore to level pre-sweeping sand waves to prepare the seabed in order for the pipeline to be installed within allowable stresses and free-spans. These pre-sweeping works were executed in water depths up to 70 m (Figures 11 and 12). Real-time stress and free-spans analysis were performed on board of the dredger in order to verify the dredged longitudinal profile. This provided day-to-day on-line information for the project team onboard the dredger.

Figure 11. The trailing hopper dredger Filippo Brunellschi was used for seabed levelling at 70 m water depth.

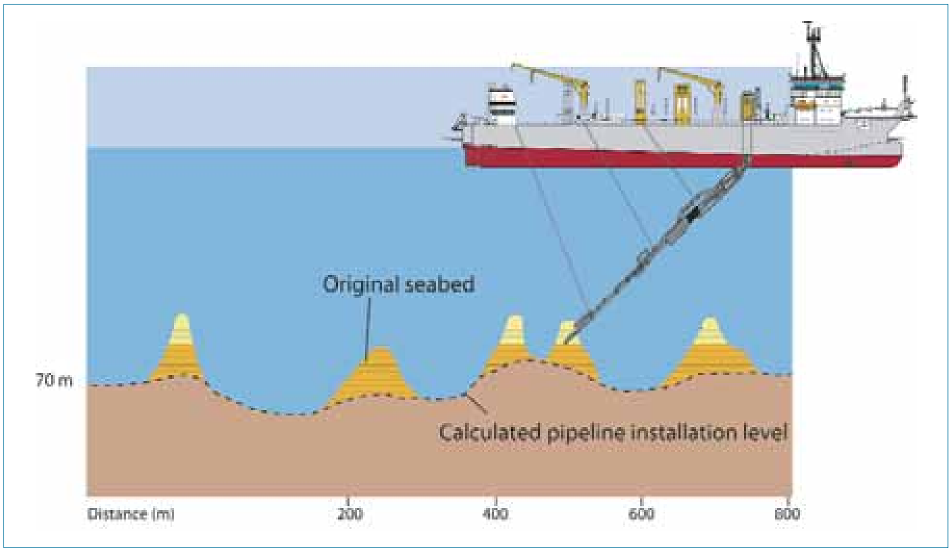


Figure 12. Schematic drawing of the Filippo Brunelleschi levelling the seabed for pipeline installation.

PIPELINE CROSSING AND GRAVEL INSTALLATION

Another challenge at Easington was the presence of several marine pipelines making landfall along the beach and land pipelines that feed gas from the terminals into the UK transmission grid. The new works were executed in between two existing live pipelines, one of which had to be crossed approximately 6 km from the beach.

At the crossing, mattresses were installed to separate the pipelines and following the laying of the new Langeled pipeline, rock was placed to provide protection. The rock, imported from Norway, has been installed by a dynamic positioned side stone dumping vessel (SSDV) (Figure 13). Inside the cofferdam and over the nearshore section of the trench, the pipeline was also covered with gravel in order to avoid frost heave.

High tidal currents appear at the east coast of the UK. Therefore, an acoustic Doppler current profiler was installed on the SSDV to profile the currents. Based on these measurements, the position of the SSDV was adjusted continuously resulting in improved placement accuracy during high tidal currents.

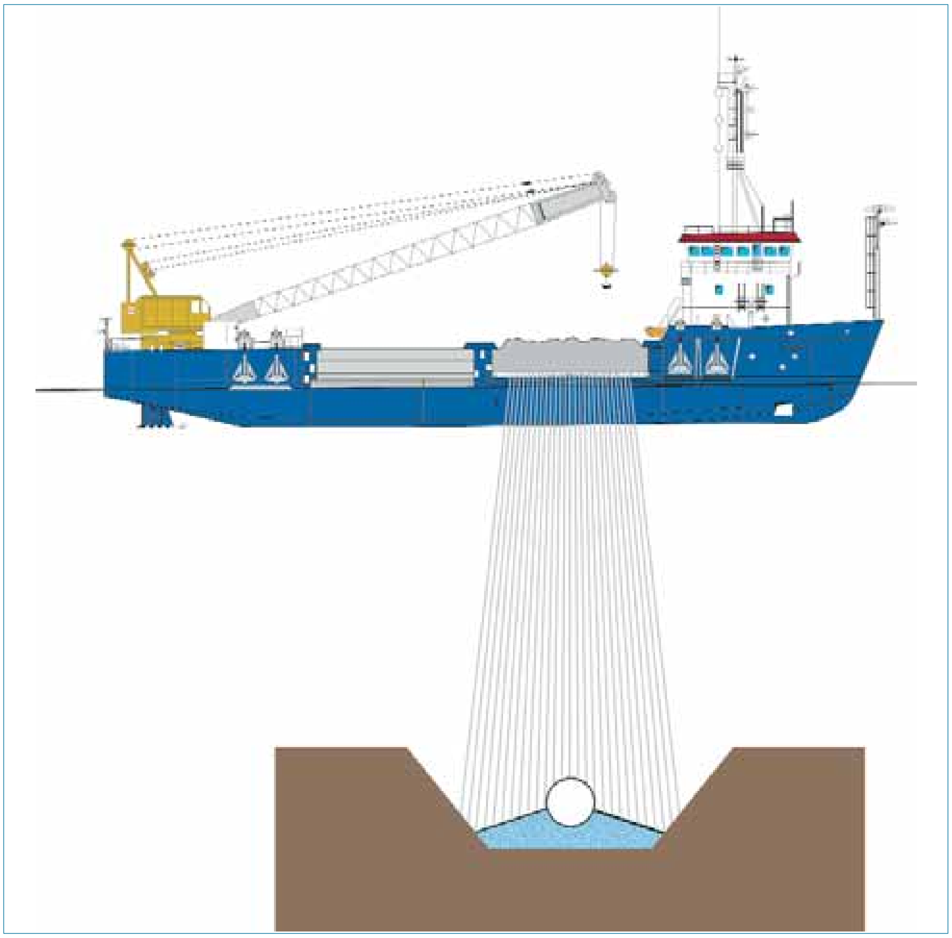


Figure 13. Installation of the rock by a dynamic positioned side stone dumping vessel.

PIPELINE INSTALLATION IN THE TUNNEL AND TO THE TERMINAL SITE

On completing the installation of the 380-m-long tunnel, a 60-m-long, 6° ramp with a rail track was constructed from the terminal end leading into the tunnel. At the far end of the tunnel, a winch system was set up in the tie-in pit on the beach.
Four 12.2-m-long pipe sections could be positioned on the ramp. With a cycle time of 24 hours for the welding, non-destructive testing and coating, the pipeline was progressively pulled into the tunnel (Figure 14).
A rubber neoprene coating was specified for this section of the pipeline to give added corrosion protection in the tunnel. Polyurethane collars were factory fitted to the pipeline to protect the coating as the pipeline was pulled through the tunnel. The landfall scope of work also included a section of trenched pipeline that extends approximately 300 m from the tunnel into the main terminal (Figure 15).

Figure 14. Welding the onshore pipeline.

OFFSHORE-ONSHORE TIE-IN AND BEACH PULL ASSISTANCE

The 15-km nearshore section of the landfall pipeline was installed by the lay barge *Togmor* from Allseas which entered the floatation channel prepared by the *JFJ De Nul* and anchored at the end of the cofferdam. A 500 t winch was set up behind the beach platform and the pipeline was pulled from the lay barge, along the cofferdam, and into the tie-in pit (Figure 16).

Figure 15. Installation of a spool piece for connection to the main terminal.

A seal was made around the pipeline at the entrance to the tie-in pit so it could be pumped dry and the onshore pipeline can be tied into the offshore pipeline. Following the tie-in, the tunnel was grouted to seal the pipeline.

CONCLUSIONS

The need to establish additional gas supplies for the United Kingdom led to the decision to build a new pipeline from Norway to the eastern coast of the UK. A number of challenges were present at Easington, the site chosen for landfall. The shore approach and landfall works had to take into consideration environmental issues, including protection of the heavily eroded cliffs along the coastline. The tunnel construction proved a good solution to this problem.

In addition, utilising a soil treatment plant for processing the soil from the tunnelling allowed the beneficial re-use of sediment on the beach site. This proved to be environmentally sound, efficient and cost-effective.

Figure 16. The tie-in between the onshore and offshore pipeline sections was executed at 13 m below low water level.

The need to dredge at great depths as well as to manoeuvre between already existing live pipelines added to the need for extreme care and the use of the latest generation of newly developed seagoing self-propelled cutter dredger.

With the completion of the project, the pipeline and tunnel have been buried and all beach construction work and the access road have been removed to restore the area to its natural state.

Unlike other forms of engineering projects where the finished product can be proudly shown to friends and colleagues, once the Langeled site was reinstated, there were no visible presence and no environmental impact to the shoreline of the landfall that safely feeds the UK with energy.