High-Tech Mission on the Seafloor

Nicolas Rivet, Nord Stream Project Coordinator Hyperbaric Tie-Ins

Why are the Nord Stream Pipelines constructed in three sections?
Nicolas Rivet: Nord Stream designed its pipelines to operate without an intermediate compressor station, but with three different design pressures and pipe wall thicknesses as the gas pressure drops over its long journey from Russia to Germany. Therefore, it's possible to reduce the wall thickness of the pipelines as they progress and construct the pipelines in three sections.

What are the advantages of building the pipelines in sections?
NR: For one thing, the reduction in wall thickness has helped us save large quantities of steel. For another, building the pipelines in three sections enabled Nord Stream to deploy three pipelay vessels at the same time during a certain time period. For several months in 2010, three pipelay vessels worked simultaneously at different locations, around the clock, seven days a week. This sophisticated pipelaying schedule aided us in meeting environmental restrictions while enabling the construction vessels to work as efficiently as possible.

How are the three sections joined?
NR: The sections are welded together on the seafloor, at a depth of 80 to 110 metres. From a technical perspective, this is an extremely challenging job. A special ship is required to complete the task: the diving support vessel Skandi Arctic, regarded as the most modern ship in its class. It was designed to support diving operations taking place as deep as 350 metres. And it has the equipment required to cut, bevel, lift, and ultimately weld the steel pipes, which weigh several tonnes – all while underwater.

Is it possible to manage all the operations from the surface?
NR: The welding process is largely automated. But it's impossible without deploying divers. They install the equipment on the seafloor and monitor the procedures while the pipeline sections are cut, bevelled, and welded. It's a complex and exhausting activity – physically and mentally – and there are about 30 divers specially trained to perform underwater welding. Throughout all of this work, the divers live in hermetically sealed living quarters pressurised to match that at the seafloor, to avoid the need for long wait times during ascent and descent.

Who provides the welding equipment?
NR: The tie-in equipment is supplied by the Statoil Pipeline Repair System (PRS) Pool. Nord Stream has access to the PRS equipment through its membership in the pool.

How is the schedule arranged for the welding work?
NR: Line 1 went into operation in November 2011 and welding work was completed in summer of the same year. The mechanical completion of Line 2 is planned for spring 2012. Prior to underwater welding, the pipeline sections will be pressure tested to confirm their safety and integrity. Then, in late spring, the first welding work will begin. The join-up will be done in Finnish waters, some 297 kilometres from the starting point in Vyborg. In summer 2012 the second welding will be done underwater near the Swedish Island of Gotland.

Technip – A First-Class and Experienced Partner

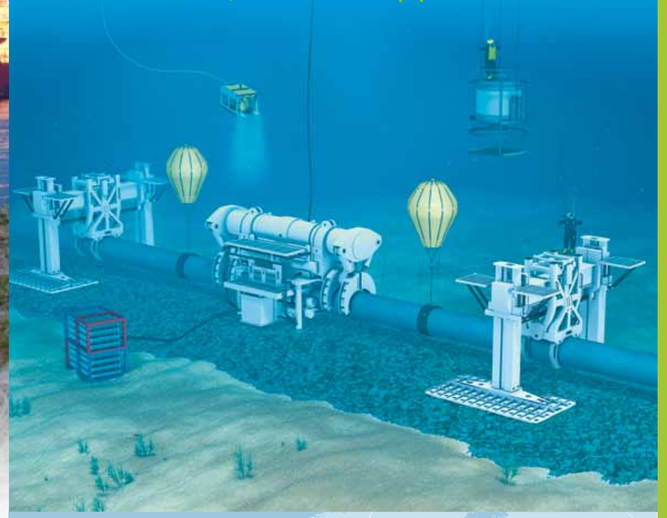
Nord Stream is working in collaboration with Technip on the underwater welding work of the pipelines. Technip is one of the world's leading companies in the area of onshore and offshore construction work for the oil and gas industries.

Founded in Paris in 1958, the company currently employs some 30,000 people in 48 countries. Technip has a fleet of 30 vessels specialised for building pipelines and other underwater construction work.

Nord Stream
The new gas supply route for Europe

Deep Dive: Joining the Pipeline Sections

The Nord Stream Pipelines are laid in three sections that are then welded together underwater to form the full 1,224-kilometre pipelines



Nord Stream AG

Nord Stream AG is an international consortium of five major companies established for the planning, construction and subsequent operation of two natural gas pipelines through the Baltic Sea. The majority shareholder OAO Gazprom holds a 51 percent stake in the pipeline project. Leading German energy companies Wintershall Holding GmbH and E.ON Ruhrgas AG hold 15.5 percent each, and the Dutch natural gas infrastructure company N.V. Nederlandse Gasunie, along with the leading French energy provider GDF SUEZ each hold a 9 percent stake. The combined experience of these companies ensures the best technology, safety and corporate governance for this project, which aims to provide a secure energy supply for the European Union (EU).

The Nord Stream Pipeline system through the Baltic Sea is the most direct connection between the vast gas reserves in Russia and energy markets in the EU. When fully operational in 2012, the twin pipelines, each 1,224 kilometres long, will have the capacity to transport a combined total of 55 billion cubic metres of gas a year – that is enough to satisfy the energy demand of more than 26 million European households. The European Parliament and Council designated the project as being of "European interest." This status is given to projects that strengthen markets and reinforce security of supply.

Contacts

For more background information, visit our website at:
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A Ship in the Centre of the Action

> All of the activities surrounding the underwater welding work of the pipelines are directed from the dive support vessel Skandi Arctic, which is fitted with the equipment required to carry out such missions. The divers, who will be working in deep sea conditions, will live in hermetically sealed accomodations.

The Skandi Arctic is the largest, most modern dive support vessel in the world. It was designed for operations in depths of up to 350 metres. The ship was built by STX Europe, and became operational in 2009. It is owned by Doftech DA, a joint venture of Norway's DOF Subsea AS and Technip Norge AS. The ship measures approximately 160 metres in length, with a beam of 27 metres. It features a helicopter landing pad, and uses a dynamic system for positioning, which means it can position itself accurately without the use of anchors. The crane at the stern of the ship can lift loads of up to 400 tonnes. The Skandi Arctic carries two remotely operated underwater vehicles (ROVs), along with the special underwater welding machinery that had to be modified specifically for the dimensions of the Nord Stream Pipelines.

The Skandi Arctic was prepared for its mission in the Norwegian port of Haugesund.

The life support crew monitors the divers in the pressurised chambers on board the vessel.

The crane at the stern of the Skandi Arctic can lift loads of up to 400 tonnes.

Six Chambers for 24 Divers

Since the divers work at great depths, the Skandi Arctic is equipped with special diver accommodations. This dive system is hermetically sealed, and a ravel of cables, pumps and valves ensures that it is constantly pressurised to the same level faced by the divers when working on the seafloor. These modern accommodations consist of six chambers, offering enough room for 24 divers. These chambers are linked by a series of hatches and tunnels. Added to this are two decompression chambers whose pressure can be slowly adjusted to match the "normal" pressure of the outside world. In case of emergencies, two pressurised lifeboats can be accessed directly from the diving chamber. The breathing air in the accommodations contains helium instead of nitrogen, as the latter becomes a poisonous gas when put under high pressure. Helium has the disadvantage of absorbing heat. As a result, the thermostats are duly turned up to keep the divers from being subjected to constant cold. The entertainment options for the divers are rather modest: there's an internet connection and a screen with a beamer.

Living and working under pressure: The 24-man system is the living space for divers.

From the pressurised divers' accommodation down to the seafloor and back: The divers live and work under constant pressure during the welding stage.

The sections of the Nord Stream Pipelines are welded at depths of up to 110 metres. The underwater work is highly specialised, and there are about 30 divers in the world trained to carry out this work. At depth, the water pressure is so great that a fast ascent would cause gas bubbles to form in the blood, which would result in serious physical harm. In order to avoid the long wait time during descent and ascent, the divers on the Skandi Arctic live in special accommodations pressurised to match the pressure on the seafloor. Three at a time, divers enter a diving bell, and are taken to the seafloor, where they work an eight-hour shift. The divers assist in setting up the diamond saws, apply the welding plugs, install the bevelling machines, attach the lift bags, and monitor the entire welding process. Between deployments, they rest in their quarters, a structure that resembles a small space station. It consists of six chambers, which can accommodate up to a total of 24 divers. They work for 14 days straight, and then spend up to six days in decompression. They are given a medical exam before and after each deployment.

How the Segments Are Connected

> Each of the two Nord Stream Pipelines is laid in three sections. After the construction phase is completed, these sections will be welded together subsea. The process is largely automated, but will be completed with the assistance of specialised divers.

Once the three sections of a pipeline have been laid down, they are first subjected to pressure testing. They are flooded with treated seawater, gauged and pressure tested to confirm their safety and integrity. Once the three segments have passed pressure testing, they are ready to be welded together. This is when the Skandi Arctic comes into the picture. All the welding work – at a depth of 80 to 110 metres – will be overseen from this diving support vessel. The ship is home to a crew of specialists who work above and below the sea. The sections are welded together in a welding habitat. The process is automated, but is supported by divers. Worldwide, there are only about 30 technical divers qualified for this job. The vessel has a 24-man dive system on board that is a pressurised living space for the divers who will work on the welding. They eat, sleep and live here for the duration of the 17-day operation. A survey of the pipeline segments is done before the equipment and divers can be allowed down to the seafloor to begin the welding work. If the results are satisfactory, pipe handling frames are lowered to the seafloor. These frames will move the ends of the overlapping, parallel pipeline segments into position to line them up for welding after they have been cut to the right length.

Precision Work

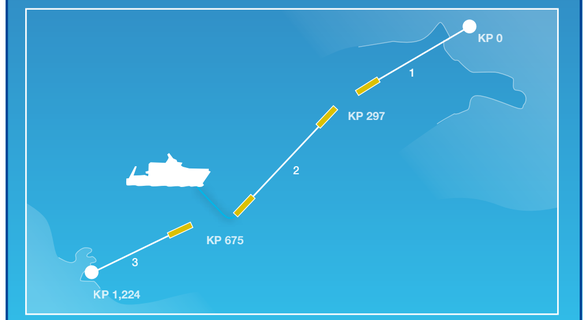
Divers place a diamond wire cutter at the end of each segment to cut throught the thick high-tensile steel. Each cut takes one and a half hours. The lengths of pipe must be exact – right down to the millimetre. Once the pipeline segments are cut, a welding plug is inserted at each end. These are inflated to ensure that they seal perfectly, and will prevent water in the pipelines from later leaking into the dry zone of the welding habitat. Before the segments are lifted and shifted into place, a bevelling machine gives the pipeline ends a smooth finish, thus preparing them for welding. Three pipe handling frames position the pipeline ends. They are needed to lift the sections and align them for welding. The frames can lift up to 150 tonnes, and move the sections vertically and horizontally. A number of lift bags that help lift the sections are also attached. Once filled with air, the bags can lift up to 20 tonnes.

Dry Zone on the Seafloor

The welding habitat is then lowered from the Skandi Arctic and positioned precisely over the two pipe ends. Compressed diving gas is used to push water out of the opening at the bottom of the station to make it a dry zone where the divers can work without diving equipment. This also leaves the two pipeline ends dry – the steel can't be welded in the water. Before welding begins, the bevelled pipeline ends are measured to ensure they meet exact specifications. The welding process now begins. For about 24 hours, a 25-kilogram welding head rotates around the fitted pipeline ends – the entire process is controlled remotely from aboard the Skandi Arctic. The divers monitor this process from within the welding habitat. The completed weld is inspected using ultrasound. If the weld is perfect, the welding station is lifted back aboard the vessel. The pipe handling frames lower the pipeline back to the seafloor, and a remotely operated vehicle (ROV) inspects the area to once again ensure the pipeline is exactly where it should be on the seabed. Once confirmed, the rest of the equipment is retreived.

Why Are the Pipelines Laid in Three Sections

The gas that is fed into the pipelines in Russia isn't at the same pressure as the gas that flows out of the pipelines in Germany. Along the way it loses a considerable amount of pressure. In Portovaya Bay, the pressure starts at 220 bar, at the mid-way point it has dropped to 200 bar, and in the final portion of the pipelines it registers only 100 bar. As the pressure drops, so does the wall thickness of the pipes used in the pipelines. The walls are thickest at the beginning of the pipelines, and thinnest at the ends. The initial change in thickness occurs 297 kilometres from the start of the pipelines in Portovaya, and then reduces further at about the half-way point some 675 kilometres from Portovaya Bay. Tapering the thickness of the pipeline walls saved vast amounts of steel in the construction process. Building the pipelines in three sections also enabled three different pipelay vessels to work simultaneously for several months in 2010, making it possible to meet the ambitious construction schedule while taking the Baltic Sea's sensitive ecosystem into account. If work had to be stopped in one particular area due to ecological reasons, such as during seal mating season for example, construction could still continue on another section of the pipelines.



The three sections of the Nord Stream Pipelines are joined at kilometre points 297 and 675.

Nord Stream Underwater Tie-Ins

> Each of the two Nord Stream Pipelines is constructed in three sections. Once completed, the sections are welded together to form the 1,224-kilometre pipelines. The "tie-in" process takes place on the seabed in an underwater welding habitat. Welding operations are remotely controlled from a support vessel, and divers assist and monitor the subsea construction work.

The three sections of the Nord Stream Pipelines each have different wall thicknesses following the direction of the gas flow. Gas pressure reduces as it makes its way through the pipelines. Therefore, the walls are the thickest at the start of the pipelines at Portovaya Bay, Russia, and thinnest at the landing point at Lumin, Germany. The pipelines are built in three sections corresponding with the different wall thickness of the pipes. Once the three sections are laid, they are gauged and pressure tested. Then the Skandi Arctic dive support vessel moves in to begin connecting the segments underwater. The first connection takes place in Finnish waters at a depth of about 80 metres at kilometre point (KP) 297. The second connection takes place in Swedish waters at KP 675 at a depth of about 110 metres. The Skandi Arctic transports and operates all of the equipment necessary to move, lift, cut and weld the pipeline sections together. The sections are connected in an underwater welding habitat in several automated steps assisted by technical divers. Once the weld is tested, the subsea equipment is retrieved. The hyperbaric tie-ins of Line 1 and Line 2 were completed in summer of 2011, and summer of 2012, respectively.

Skandi Arctic: Dive Support Vessel

Diving System
The Skandi Arctic has a 24-man dive system on board. The pressurised system is a living space for the divers who will work on the welding. They eat, sleep and live here for the duration of the tie-in process.

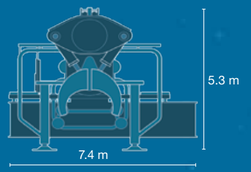
Remotely Operated Vehicle

Umbilical Cable
All subsea equipment is connected to the dive support vessel by an umbilical cable. This cable supplies the power required to operate the subsea equipment and transmits data from underwater cameras and welding equipment to the ship. The vessel also remotely controls all underwater processes through the cable.

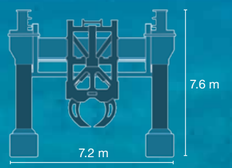
Diving Bell
A three-man diving bell brings the divers from the diving system where they live, to their subsea work area. Divers work an 8-hour shift, and then return to the diving system to rest.

Tie-In Equipment

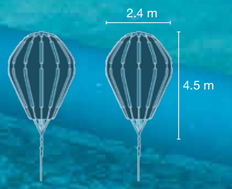
Equipment supplied by Statoil PRS Pool



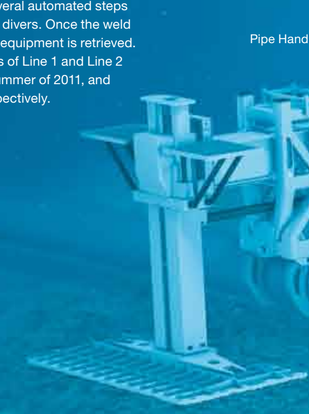
Welding Habitat
The welding habitat supplied by Statoil PRS is a dry zone where divers work without diving equipment to set up the automatic welding machine. The welding is completely controlled from the dive support vessel.



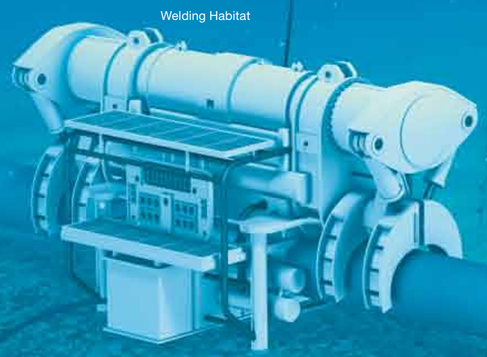
Pipe Handling Frame (PHF)
The PHFs move the pipeline ends into tie-in position. They can lift up to 150 tonnes. They not only lift the pipeline sections, they also shift them sideways to align them for welding.



Lift Bags
Lift bags are installed on the segments and filled with air. Once filled, the bags can lift up to 20 tonnes, helping the PHFs to manipulate the extremely heavy pipeline segments.



Pipe Handling Frame



Welding Habitat

Lift Bag

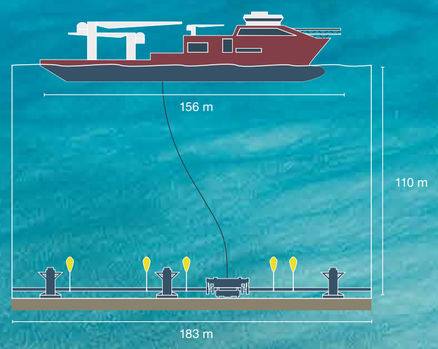
Pipe Handling Frame

Emergency Gas Quad
If there is a problem with the supply from the vessel, the emergency gas quad can supply the habitat with breathable gas for up to 72 hours.

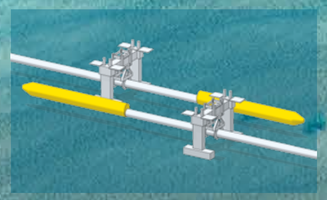
Gravel
Gravel has been strategically placed on the seabed prior to pipelaying in the tie-in locations in order to provide a stable foundation for the equipment used in the subsea construction work.

Hyperbaric Tie-In Setup

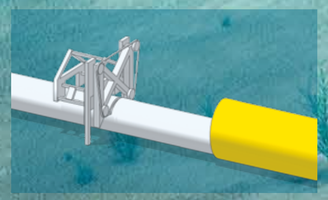
All hyperbaric tie-in activities are handled from the Skandi Arctic dive support vessel. She carries all of the equipment necessary to perform the underwater welding. She also accommodates a crew of welding and diving specialists. All of the equipment, including pipeline handling frames, lift bags, the cutting tool and the welding habitat, are deployed and operated by the vessel.



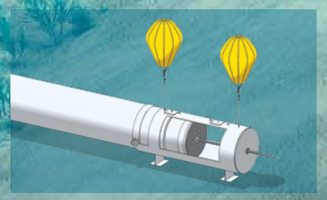
Tie-In Sequence



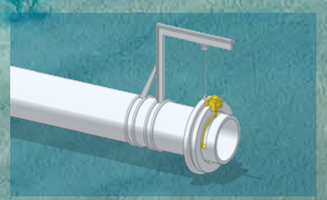
1. Performing "As-Found" Survey
Prior to sending the divers to the tie-in site, an as-found survey is performed to check that everything on the seabed is as it should be. For example, it confirms the exact position of the pipelines.



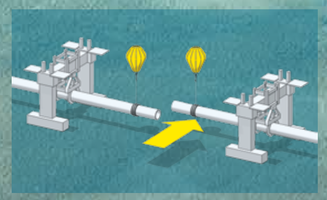
2. Cutting the Pipeline
The pipeline segments lay parallel to each other and overlap. Therefore, the ends of each segment must be cut before they can be lined up. A diamond wire cutter is used to cut through the high-tensile steel.



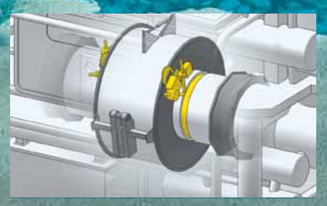
3. Installing the Welding Plug
A welding plug is inserted into each end of the pipeline segments. The plugs are inflated for a perfect seal to separate the water in the pipeline segments from the dry welding area of the habitat.



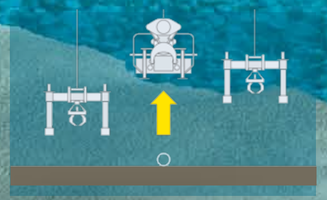
4. Making the Final Cut and Bevelling
Using a bevelling machine, the pipeline ends are given a smooth finish to prepare them for welding within the habitat. The surfaces are measured to ensure they meet exact specifications.



5. Lifting and Shifting
Three pipe handling frames (PHFs) will be used to lift and shift the pipeline ends. The frames are needed to lift the pipeline segments and line them up before the welding can start.



6. Welding the Segments
The pipeline segments are welded together inside the welding habitat. All welding operations are controlled from the dive support vessel. The weld is inspected using ultrasonic testing.



7. Retracting the Welding Equipment
Once the welds are inspected and approved, the habitat is retrieved back onboard the vessel. Using the PHFs, the pipeline is lowered onto the seabed, and a remotely operated vehicle surveys the area.

Infographic produced by KircherBurkhardt, 2012
3D-Graphic not true to scale

Nord Stream
The new gas supply route for Europe

Technip