Offshore

Foinaven Field injection lines Swagelined for special conditions

Polyethylene and carbon steel combine corrosion-resistance, strenth for West of Shetland field

BP's Foinaven Field is in some of the deepest, most challenging waters of the North Sea and as such has demanded radical innovations in subsea technology, diverless installation and maintenance. The field is on the Atlantic frontier, 119 miles west of the Shetland Islands in a 1,300-ft to 2,000-ft deep trough. Besides water too deep for divers, severe currents made complex by the interaction of warm Gulf and cold Arctic streams, extend almost to the seabed.

Water depth has caused an emphasis on the reliability of the subsea equipment designed for diverless installation and up to 25 years of maintenance-free service life. Although every effort was made to use methods and products which had previously been proven in the North Sea, a different approach was used for the water injection flowlines.

A new type of water injection flowline

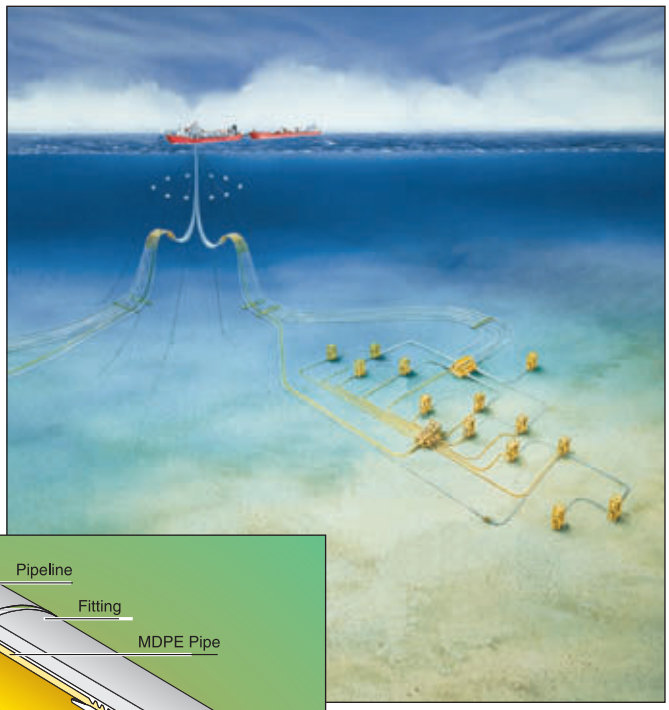
Early in the design phase of the Foinaven project, it was thought traditional water injection lines might not remain maintenance free for 25 years. Inconel andr super duplex stainless steels have the necessary strength and corrosion resistance but are extremely expensive.

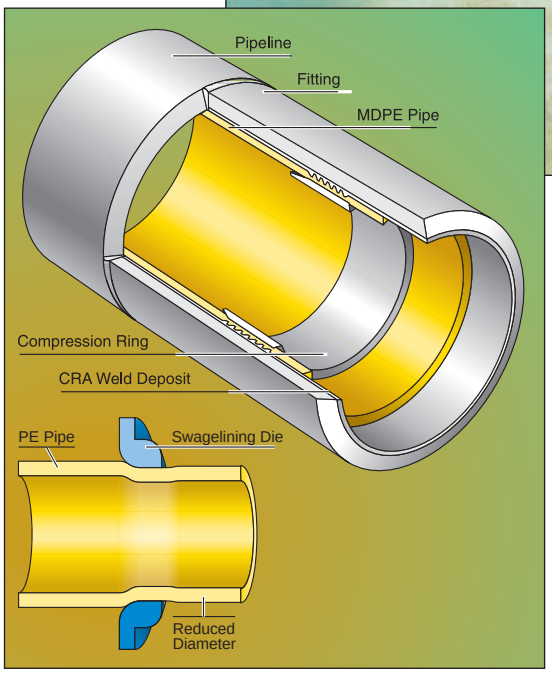
The McDermott Marine Construction Ltd (MMCL) design team decided to test the concept of Swagelining standard carbon steel pipe with thin-walled, non-pressure rated, medium density polyethylene (MDPE) pipe. The steel pipe, it was reasoned, provided the requisite strength and the PE pipe protected the steel from internal corrosion.

Swagelining was developed by British Gas fas a means to replace existing gas distribution mains without digging. It has also been used successfully in such distribution systems as potable water and forced sewer mains. In previous applications polyethylene pipe was rated for direct burial and did not rely on existing pipe for strength. In effect, the existing pipe is a conduit for the PE pipe whose sections are usually joined with conventional electrofusion fittings.

The Swagelining process has also been used for many years to install PE pipe in existing onshore gas and industrial pipelines. However, in these installations the lined steel pipe has been rejoined with flanged fittings unacceptable in the Foinaven oil field because of their leak potential. British Gas solved the problem by developing a welding technique to join lined pipe sections to be joined without flanges.

About 50,000 ft of new 10-in. steel pipe and 9,300 ft of eight-in. pipe has been lined in lengths of 1,650 ft at the Ardersier, Scotland spoolbase of MMCL subsidiary, McDermott Subsea Constructors Ltd (MSCL). These lines were then joined together using welded fittings and the pipeline coiled onto a 21-ft diameter drum.. Each reel holds between 32,000 ft and 39,000 ft of lined pipe. MSCL's specially designed reel ship, Norlift, transported the reels to the Foinaven field and laid the pipe on the seabed. When production begins in the fourth quarter of 1996, three water injection lines will operate at pressures as high as 4,350 psi, injecting 165,000 b/d of water back into the reservoir.





The Swagelining Process

Swagelining uses PE pipe which has an outside diameter slightly larger than the inside diameter of the pipe to be lined. During the installation process, the PE pipe is pulled through a die to temporarily reduce its outside diameter by about 7%. This reduction allows the PE to be easily pulled through the outer pipe. When the pulling force has been disconnected, the PE pipe begins to return to its original diameter. Within hours, the PE pipe will be pressing tightly against the inside of the outer pipe.

New compression fittings

Charlie Tighe, Director, QA Weld Tech Ltd, Middlesbrough, England, was responsible for the fabrication of the new compression fittings which made the use of PE-lined pipe possible. These fittings were jointly designed and developed by British Gas and MMCL.

The process we employed was state-of-

Polyethylene-lined pipe sections are welded and reeled onto a 21-ft diameter reel on the Norlift.

the-art techniques of weld cladding using hot wire, fully automatic T.I.G. welding. We are able to program the welding parameters to ensure that the procedures which have been developed and tested for this critical application are repeated exactly," he explained. "The project was on a fast-track requirement, so we worked extended hours to ensure that the project met the exacting quality requirements, and was completed on time and to budget," he said.

The fittings were fabricated from sections of the same carbon steel pipe that was being lined by the Swagelining process. Each fitting was machined to enlarge its inside diameter. Then welding inlay was used to replace the material that was removed with a special corrosion resistant alloy (CRA). After the correct amount of CRA had been deposited, the inner surface of the section was again machined to achieve the specified profile. Each compression fitting was then fully inspected for inlay thickness and CRA chemistry.

The interior of the finished piece had the same inside diameter as the original pipe, except for raised ridges in the center of each section. At this point, the fitting was ready to be welded onto each end of the 1,650-ft lengths of steel pipe. Later, after the PE had been installed inside the steel pipe, a compression ring made of the same CRA material would be inserted to press the PE pipe into the ridges. This would form a permanent connection between the PE pipe and the outer pipe. Since the PE pipe stopped short of the ends of the steel pipe, sections of lined pipe could be welded together without melting the PE.

This technology has been so successful we are planning to use it in other applications around the world, both on land and under the sea," Tighe explained.

Jack Ross, Project Manager, A Hak Ltd, West Lothian, Scotland, was the Swagelining contractor who lined the steel pipe. He said MSCL decided to assemble the steel pipe in 1,650-ft sections simply because that was the length of the pipe storage racks on the site. "The pipe was delivered in 39-ft lengths," he said. "So we could weld 42 of them together before we ran out of room."

The final staging point

A compression fitting was welded onto each end of the 1,650-ft pipe sections before they were cleaned for the Swagelining operation. A cleaning pig was pulled through the pipes to remove any sharp edges from the weld root." A short section of PE pipe was machined to the final Swagelining size and pulled through the steel pipe. The section would then be examined for any signs of excessive scoring.

A winch was set up to pull the PE pipe through the steel pipe. The pulling force of the winch was set to not exceed the half-yield of the PE pipe. "Yield" is defined as the point at which the PE pipe could be permanently distorted by the pulling force.

The PE pipe is cleaned and lubricated just before it enters the reducing die. As it passes through the die, the outside diameter of the PE is reduced by 7%. Afterwards, it maintains its reduced diameter until the tension on the winch is removed. At that point, the PE begins to relax and slowly return toward its original diameter. Of course, the inside diameter of the steel pipe prevents the PE from completely achieving its original size. Within hours the PE has swelled as much as possible and is pressing tightly against the host pipe along its entire length.

After the PE pipe has completely stabilized, a compression ring is inserted into the fitting at each end of the lined section. This forces the PE pipe into the ridges inside the fitting. This grips the PE pipe and creates a permanent seal between it and the steel pipe.

Once the rings have been inserted into each end of the pipe section, the excess PE pipe is carefully cut away. At this point, each pipe section is given a preliminary air test at 7 Bar (100 psi). Later, the 1,650-ft sections were welded together as they were wound onto a huge reel aboard the Norlift.

"The project was very successful," Ross said. " Now we know we can Swageline and weld long lengths of pipe in a very, very short period of time. We averaged 1,650 ft a day."

Installation on the seabed

When the reel ship is properly positioned at sea, the outer end of the pipe is connected via cable to a weight on the seabed," McKay explained. "Then the ship moves forward in the desired lay direction, paying out the pipe under a carefully monitored range of parameters. At the end of the line, the pipe is again laid down on the seabed via a cable," he said.

Currents in the pipelay area ran up to 4 knots and were almost completely unpredictable as well as variable through the water column. However, the 2.2-mile sections of lined pipe were laid to an accuracy of 3 ft in water over 1,600 ft deep.