Spiraling lifts conventional limits

A new technology can tow pipe string in open water, position it accurately and lay it with less stress.

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Last year, Eurospiraal BV successfully tested the Floating Spiral method of surface-towing pipe strings in open water and laying line pipe in the North Sea with less pipe stress, more accuracy and reduced cost.

Conventional surface towing – floating the pipeline and towing it, with one tugboat pulling and another trailing – is a simple way to transport pipe over sea. Despite this, surface towing is just a minor player in offshore pipeline technology due to four limitations:

- the need for maneuvering on sea to avoid other traffic restricts the length of pipe string;
- the launching site requires a long welding yard onshore to protect it against side currents at sea;
- floating pipeline is subject to wave actions, which limits duration and timing of the sea voyage; and
- lowering a floating pipe requires labor on sea, and laying pipe along a curved corridor hardly is possible.

With the Floating Spiral method, the floating pipe is spiraled at the launch site. The inner diameter of the spiral is 500 times the outer diameter of the pipe. The pipe bends and returns to a straight position after unwinding at the laying site. This way, spiraling lifts the restrictions of conventional surface towing. This may bring surface towing right into the center of the pipelaying arena, comparing well with state-of-the-art pipelaying technology.

Lifting restrictions

Maneuverability. Figure 1 shows the maneuvering of a spiral. The spiral transports an 8-in. pipe with a length of 14 km. Despite the length of the string, the turning circle of the tow is close to the diameter of the spiral: 120 m.

Launch sites. At the launch site, the pipe extends just a few hundred meters into the open water, where anchored buoys bend the pipe and position the spiral. Ore-anchored buoys can guide this relatively short free span, which is resistant to side currents. Neither fjords nor abandoned airstrips are needed to make and launch the pipe. Almost any location in open water is usable.

Fatigue. Strips of soft, closed-cell foam welded to the pipe's anti-corrosion layer make the pipe buoyant when launched (Figure 2). Buoyancy is about 5% of the pipe weight in air. Therefore, in waves, only 5% of the pipe extends out of the water, notably in the crests of the waves (Figure 3). The water evenly supports the submerged part of the pipe, and the pipe is weight-loaded only over a small length in the trough. This results in far less stress buildup in the pipe than in surface-towed pipes supported by buoys. Buoys tend to follow the shapes of the waves and force the suspended pipe to do so as well.

Curved corridors. Unwinding the spiral while the line is towed along the lay corridor lifts the fourth surface-towing restriction. Once unwound, the pipe is lowered gradually by reducing the floats' air volume. Crews lay the pipe gradually, following the curvature of the corridor.

In deep water, the water pressure reduces the float volume. The soft foam of the welded-on strip floats is compressed to about 10% of its initial value at a water depth of 100 m, as the water pressure there is 10 times greater than at sea level. The change occurs around the 10-m mark. Above that level the pipe floats; below that level the pipe sinks. On the seabed, the compressed foam, present as just a thin layer of polyethylene, adds to the pipe protection.

In shallow water, the soft foam strips would not be compressed sufficiently to lose buoyancy when reaching the seabed. Instead, cradle floats are used with air compartments at either side of the pipe. Figure 4 shows how such a cradle supports a 40-in. pipe with a 4-in. layer of concrete ballast. Crews can press the air out of its compart-

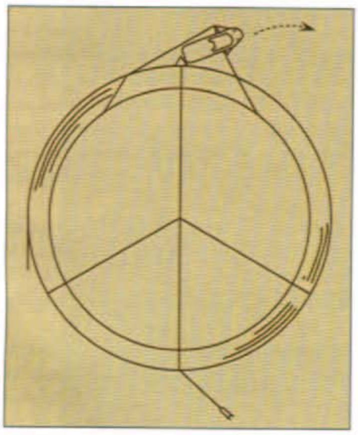

Figure 1. The spiral transports an 8-in. pipe with a length of 14 km.

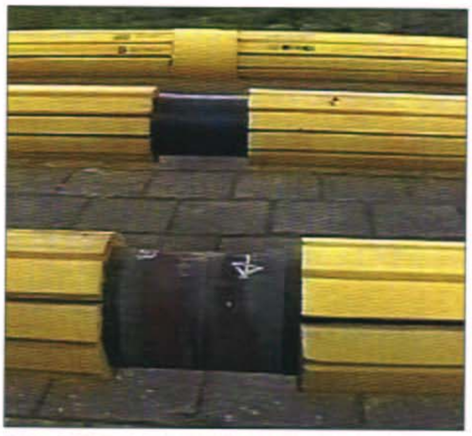

Figure 2. Strips of foam welded to the pipe make the pipe buoyant when launched.

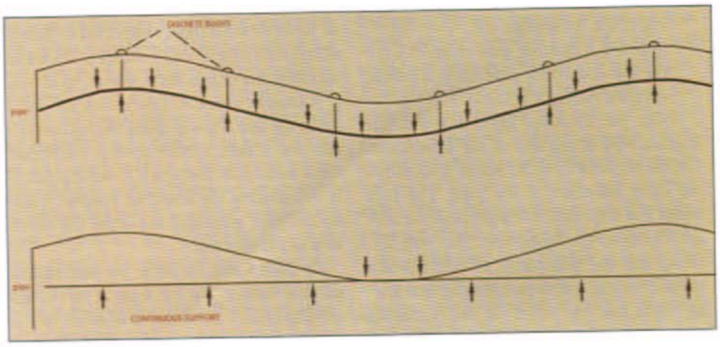

Figure 3. Only 5% of the pipe extends out of the water on waves.

ments in a controlled manner, lowering the pipe at low stress.

Figure 5 shows how the empty compartments of the cradle float form an artificial reef on the seabed. This reef promotes the deposition of sand, adding to the pipe's stability, mechanical protection and thermal insulation. It also provides a nursery zone for fish.

The draft needed for the Floating Spiral is hardly larger than the pipe diameter, so crews can tow and lay the spiral easily in such shallow waters as landfalls and along the Arabian coast, as well as in the Caspian and Baltic seas. In these shallow waters, the gradual reduction of pipe buoyancy is sufficient to lay the pipe at low stress. No stinger is needed. For enclosed waters such as the Caspian Sea, it is an added advantage that one standard container can transport all gear for making, towing and laying the spiral.

In deep water, a stinger suspended from the laying vessel lays the pipe. Submerged buoyancy tanks make the suspended stinger float at a depth ranging from 20 to 100 m. This means the pipe and stinger are below the splash zone, hardly influenced by lay vessel's heave motions. This keeps the pipe from slamming into the stinger.

When stormy weather approaches, the crew can lower the pipe in the suspended stinger below the wave level. The lay vessel can remain on the spot, heading the wind. This survival procedure is far less disruptive than aborting the pipe, as is practice for lay vessels with stern-mounted stingers.

The achievable high rate of pipe laying with a Floating Spiral reduces the need for such safety measures. There is no prime reason to lay at a rate lower than 1 m/sec. Maneuvering is, in fact, easier at higher speeds. Some 110 km of pipe can be laid per day at 1 m/sec. The crew does not need to wait for a wide weather window for pipe laying.

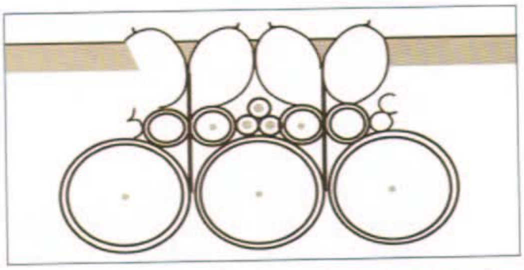

Figure 4. Cradle floats on either side of the pipe support this 40-in. pipe with a 4-in. layer of concrete ballast.

Splitting the transport part (spiral and tugboat) and the laying part (lay vessel and suspended stinger) allows for the use of small laying vessels, as laying vessels do not need storage capacity to transport the pipe. Smaller lay vessels position themselves dynamically, requiring far less fuel than present lay vessels. The agility of the small lay vessel facilitates the accuracy of following a curved track. It's a matter of waving the tail, not moving the dog.

State-of-the-art technology

The spiraling method lifts the limitations of conventional surface towing. And the advantage of surface towing – simplicity – is even strengthened. Cradle floats facilitate the laying of pipe and cable bundles.

The method's simplicity also keeps costs low. Apart from the economical benefit, the low stresses and great accuracy are important.

The value of the Floating Spiral method is obvious when compared with the state-of-the-art in offshore pipelaying, the *Solitaire*. In this comparison, the spiraling method requires considerably less capital expenditure, offshore labor, fuel consumption and laying time.

Track record

The surface towing track record is one of the longest in pipe laying. Surface towing has been used for decades for inland transport of pipe over rivers, as well as for offshore applications in the U.S. Gulf of Mexico and North Sea. Spiraling of a floating pipe is not new, either. Routinely, dredgers make even more complex shapes of their dredging pipe floating on water.

To extend these old roots, Eurospiraal subjected the spiraling method to a detailed development program. In a three-year, U.S. $2-million program, the company addressed all aspects of the method.

Established pipeline engineering companies as well as Mannesmann Research Institute and the Maritime Research Institute Netherlands (Marin) executed most of the development and appraisal program. Det Norske Veritas monitors the program.

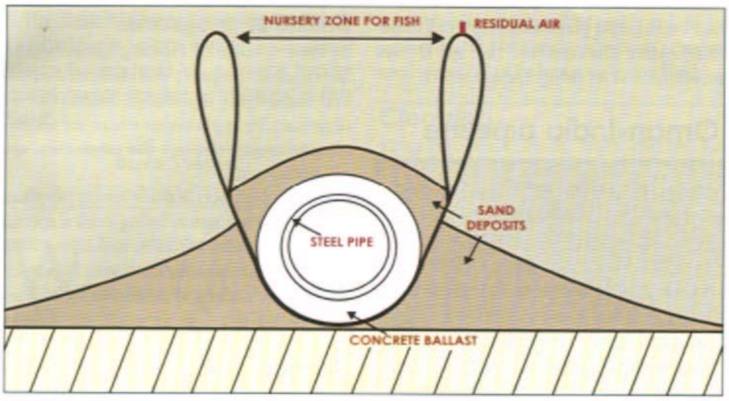

Figure 5. The empty compartments of the cradle float form an artificial reef on the seabed.

The development work comprises several studies.

Scale tests at 1:60. Conducted in the Offshore Basin and in the Marin tow tank, these tests demonstrated how a spiral survived a severe storm by swaying on the waves like seaweed.

Scale tests at 1:4. Mannesmann Research Institute custom-built an in-house test pool to examine the spiraling procedures.

Bending tests at 1:1. In a high overstrain, an 8-in. pipe deformed, but did not buckle when bent. The winding strain (0.2% at the spiral-pipe ratio of 500) is far smaller than the critical buckling strain (0.6% for an 8-in. pipe with a wall thickness of 14.3 mm).

Material properties. These tests studied the welds of the pipes used in the sea trials

the welds of the pipes used in the sea trials (HFI-welded pipe), the steel itself and the properties of the floatation strip foam and cradle floats.

Static finite element analyses. These tests examined spiraling, towing and laying procedures.

Time-dependent finite difference calculations. These tests studied buckling and fatigue behavior.

Fatigue lifetime calculations. A Marin program calculates the fatigue loads for any spiral configuration, at any sea route, in any season.

Sea trials. The final test, in autumn 2001, involved making a 120-m diameter spiral of an 8-in. pipe to test the winding procedure, towing and maneuvering.

The results determined the effective drag coefficient and turning ratio. The pipe was laid on the tidal plane and recovered thereafter. After the testing, the spiral was unwound and its straightness verified.

Oman-India pipeline

As a desk study, the Floating Spiral method was used to lay the Oman-India pipeline. At a length of 1,100 km, this 20-in. pipeline required a 950-m outer diameter spiral. At a laying speed of 1 m/sec, 100 km/day, crews laid the complete pipeline within a fortnight. This example may show the method makes surface towing fit for any pipe length, pipe diameter and water depth.

Business program

By these studies, the Floating Spiral method has reached the point that dedicated front-end engineering and design studies can be organized for applications where the technical advantages, not just the economics, are of special value.

Such advantages include laying pipelines in very shallow water; laying cables, special pipe and bundles of both; and laying long pipelines in deep water from agile lay vessels fed by a virtually unlimited supply of pipe transported as a floating spiral. ✣

Author

Sjef Beaujean is one of the founders of Eurospiraal BV in Venlo, Holland. As managing director, he is responsible for patents and licenses for the Floating Spiral method.