The Next Wave in Flow Assurance Technology

NEPTUNE™ Advanced Subsea Flow Assurance Insulation System

Winner of 2013 OTC Spotlight Award
Where Safety Is Paramount, Streamlined System Design Reduces Risk for Error

The NEPTUNE™ Advanced Subsea Flow Assurance Insulation System is a simple, all-in-one system engineered to withstand the increasingly harsh conditions associated with subsea oil production, both now and in the future.

Designed in response to direct requests from offshore operators, the NEPTUNE System is the result of an intensive, multi-year research and development effort led by Dow. To ensure the system could meet customers’ stringent design requirements, Dow also conducted rigorous production-scale testing in collaboration with globally recognized and respected flow assurance insulation system coaters.

This robust, end-to-end flow assurance insulation system is intended for use in applications from the wellhead to delivery point, including line pipe, field joints and subsea architecture.

True, Complete End-to-End Insulation Solution

With its streamlined design, uniform properties and simple application, the versatile, portable NEPTUNE™ Advanced Subsea Flow Assurance Insulation System is designed to help shorten production time and minimize project risk. An innovative, homogeneous, solid insulation layer is molded for line pipe, field joint and subsea equipment coating, using standard, available industry equipment. This enables reliable, effective processing and ease of use across a wide range of environmental conditions.

HYPERLAST™ Flow Assurance Systems from Dow have been used for more than 25 years in over 500 successful projects worldwide.

Total thermal protection across temperature extremes
-40°C to +160°C (-40°F to +320°F)

Line Pipe
Field Joint
Subsea Architecture

NEPTUNE™ P Insulation Coating for Line Pipe
NEPTUNE™ C Insulation Coating for Subsea Equipment (trees, manifolds, jumpers, PLEMs, PLETs)
NEPTUNE™ F Insulation Coating for Field Joints

Where Safety Is Paramount, Streamlined System Design Reduces Risk for Error

The NEPTUNE™ Advanced Subsea Flow Assurance Insulation System is composed of two layers:
1. NEPTUNE™ Flow Assurance Insulation Coating – Proprietary hybrid polyether thermoset – suitable for line pipe, field joint and subsea architecture applications
2. NEPTUNE™ Fusion Bonded Epoxy Anti-Corrosion Coating – Based on patented Dow resin technology

The simple, dual-layer composition of the NEPTUNE System provides a distinct advantage compared to competitive technologies, which can include up to seven layers. This simplifies the application process and reduces the potential for error.

The complete NEPTUNE System is fully qualified and compatible with current industry production methods, enhancing ease of use. The robust system provides excellent mechanical and thermal performance.

Less is more ... the simplified composition of the NEPTUNE™ System contributes to its exceptional performance as a true end-to-end insulation system.

The Legacy of Innovative Flow Assurance Solutions Continues

Global energy consumption is reaching new heights, but oil and gas reserves are becoming more difficult to reach. As a result, producers are going further to access reserves – including the harsh environments found miles offshore and deep beneath the sea.

Dow has a long heritage of developing solutions to help producers access these valuable resources from both onshore and offshore environments, safely and responsibly.

As an example, HYPERLAST™ Flow Assurance Insulation Systems from Dow have been used for more than 25 years in over 500 successful projects worldwide. HYPERLAST Systems are currently recognized as leading solutions for the flow assurance needs of the oil and gas industry, with more than 40 locations and systems houses located around the world.

Continuing the strong legacy of the HYPERLAST line, Dow has created a breakthrough in flow assurance wet insulation technology, specifically designed to perform across a wide range of subsea conditions, including the extreme temperatures and pressures experienced in the most remote areas of subsea oil and gas production: NEPTUNE™ Advanced Subsea Flow Assurance Insulation System.

2012 Winner of World Oil Best Production Technology Award for NEPTUNE™ C Insulation Coating in conjunction with Trelleborg Offshore
The NEPTUNE™ Advanced Subsea Flow Assurance Insulation System is designed to deliver peace of mind in the challenging environments of subsea production operations.

In addition to its easy application, the NEPTUNE System also outperforms existing subsea flow assurance wet insulation technologies, combining excellent thermal properties with the highest and widest service temperature range of any complete wet insulation system on the market.

From the extreme chill of arctic start-up and deepwater service conditions to the intense heat of subsea oil production – the NEPTUNE System delivers tested performance at temperatures from -40°C to +160°C.

Why choose the NEPTUNE™ System?

The next-generation NEPTUNE System provides a distinct combination of:

- Uniform thermal and mechanical properties – simpler to engineer (see Table 1)
- High flexibility at extremely low temperatures – for ease of installation in extreme weather conditions and low service temperatures (see Table 2)
- Excellent hydrolytic resistance spanning the entire temperature range – from -40°C to +160°C – the NEPTUNE System has been rigorously tested (see Tables 3 and 4)
- Breakthrough solid insulation coating – validated for use in water depths to at least 4,000 m (13,123 ft)
- Consistently high insulation performance across all system components – with a thermal conductivity of 0.15 W m⁻¹ K⁻¹ – which means a thinner insulation coating can be used
- Full compatibility among all system components – contributes to comprehensive insulation protection in line pipe, field joint and subsea equipment coating applications
- Simplified application methods on standard industry equipment – fewer layers and robust composition help reduce schedule risk
- Fully qualified at lab, pilot and production scale – all testing backed by comprehensive, third-party-witnessed data

Simple + Reliable + Versatile = Smart Choice

The NEPTUNE™ Advanced Subsea Flow Assurance Insulation System offers excellent thermal efficiency and the highest service temperature of any complete wet insulation system on the market.

Table 1: Typical Properties of NEPTUNE™ Advanced Subsea Flow Assurance Insulation System

<table>
<thead>
<tr>
<th>Property</th>
<th>NEPTUNE™ P</th>
<th>NEPTUNE™ F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation method</td>
<td>Reel, S-lay, J-lay</td>
<td></td>
</tr>
<tr>
<td>Subsea service temperature</td>
<td>-40 to +160°C (40 to +320°F)</td>
<td></td>
</tr>
<tr>
<td>Thermal conductivity under SST</td>
<td>0.15 W m⁻¹ K⁻¹</td>
<td></td>
</tr>
<tr>
<td>Density (ASTM D792, 23°C)</td>
<td>1.1 g cc</td>
<td></td>
</tr>
<tr>
<td>Heat capacity (ASTM E1269, 0 to 160°C)</td>
<td>1.4 to 2.3 J g⁻¹ K⁻¹</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: High-Temperature Performance of NEPTUNE™ P and NEPTUNE™ F Insulation Coatings

<table>
<thead>
<tr>
<th>Property</th>
<th>NEPTUNE™ P</th>
<th>NEPTUNE™ F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature, °C</td>
<td>Elongation at Break, %</td>
<td>Temperature, °C</td>
</tr>
<tr>
<td>-40</td>
<td>65</td>
<td>-40</td>
</tr>
<tr>
<td>50</td>
<td>64</td>
<td>50</td>
</tr>
</tbody>
</table>

Flexural Fatigue Test

In the Flexural Fatigue Test, a pipe structure coated with NEPTUNE™ P Insulation Coating for line pipe was also coated with NEPTUNE™ F Insulation Coating for field joints, then cycled 100,000 times to 0.1% strain, with no signs of cracking or disbondment, demonstrating the system’s flexibility and its resilience to vibrations that may be experienced during production.

Thermal Shock Test

In the Thermal Shock Test, a pipe structure coated with the NEPTUNE™ System was subjected to sudden changes in temperature – cycling between 4°C and 160°C to simulate hot oil flowing through a cold pipe with no signs of cracking or disbondment. This test demonstrated overall mechanical integrity of the system under temperature variations that may be experienced during start-up.
Proven Application on Full-Scale Flow Assurance Coating Plants

Through close collaboration with our Approved Applicator Network, full-scale coating performance of NEPTUNE™ P (line pipe) and NEPTUNE F (field joint) materials has been validated. Multiple line pipe coating trials have been completed at Bayou Wasco Insulation’s new facility in New Iberia, La., U.S.A. This complements previous coating trials performed by Wasco in Malaysia and provides global reach of the NEPTUNE System to serve owner-operator needs across multiple geographies.

Simple, Robust Field Joint Coating

A simple, robust and repeatable field jointing process for NEPTUNE™ F Insulation Coating for field joints was developed in conjunction with Pipeline Induction Heat (PIH Ltd. UK). The process provides a high-integrity field joint, with simplified design for spool base operations (initially). This compact, mobile process can be moved across geographies as needed to complete coating work for offshore projects. The joints derived from this process have also been tested and post-tested (Table 4).

Consistent Simulated Service Test Performance

The Simulated Service Test (SST) is the true test for how an insulating material will perform in service. In the SST, pipe structures are subjected to high hydrostatic pressures, cold water temperature (4°C) to simulate ambient seawater environments and high service temperatures for 28 days, with three planned system shutdowns. This test allowed the overall heat transfer coefficient to be determined and validated the system’s consistency in cool-down time throughout the aging cycle – a critical factor for flow assurance system reliability. To date, six SSTs have been completed across the NEPTUNE™ family of materials (including NEPTUNE Fusion Bonded Epoxy Anti-Corrosion Coating) with internal pipe temperatures of 160°C and above, and hydrostatic pressures up to 300 bar (3,000 meter seawater). Typical thermal conductivity performance over the course of a test is shown in Figure 1.

Post-SST Property Validation

Following an SST conducted with a 160°C internal pipe temperature, the insulation material was sectioned and tested for consistency of mechanical properties throughout the body of the coating, spanning the hot/dry interface near the pipe (point A in Figure 2) to the cold/wet interface with the salt water (Point D in Figure 2). The NEPTUNE™ System showed good consistency of mechanical properties throughout the entire range of exposure conditions that would be expected in an actual service condition (Table 3).

Table 3: Tensile Strength and Elongation Along Various Locations in the Cross Section of the Coating

<table>
<thead>
<tr>
<th>Location</th>
<th>Tensile Strength (MPa)</th>
<th>Elongation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A – Pipe-NEPTUNE™ Interface</td>
<td>9.9</td>
<td>53</td>
</tr>
<tr>
<td>B – Body of NEPTUNE™ 1</td>
<td>10.6</td>
<td>57</td>
</tr>
<tr>
<td>C – Body of NEPTUNE™ 2</td>
<td>10.0</td>
<td>52</td>
</tr>
<tr>
<td>D – Water Interface</td>
<td>10.1</td>
<td>53</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>10.2</strong></td>
<td><strong>54</strong></td>
</tr>
</tbody>
</table>

Installation Bending Test

In the Installation Bending Test, the parent pipe structure coated with NEPTUNE™ P Insulation Coating for line pipe was also coated with NEPTUNE F Insulation Coating for field joints. The structure was then subjected to five bending and straightening cycles (7.5 meter radius bending former; 30 meter radius straightening former) at 8.7°C ambient and test conditions. Visual examination following the test revealed no indication of damage to either coating, as well as no joint disbondment or cracking, demonstrating the system’s ability to withstand rigorous subsea installation procedures.

After completing the simulated reeling test, a subsequent SST was conducted with a 160°C internal pipe temperature on this NEPTUNE P and NEPTUNE F line pipe system. The insulation coating was sectioned at key points along the pipe, including the joint interfaces, and tested for mechanical properties. NEPTUNE P and NEPTUNE F coatings were individually tested for tensile properties, along with the field joint bond (NEPTUNE P to NEPTUNE F). The results, summarized in Table 4 below, demonstrate high material and joint interface integrity after bend testing and exposure to SST conditions.

Table 4: Tensile Strength and Elongation of a NEPTUNE™ P and NEPTUNE F System After a Simulated Reeling Test and SST

<table>
<thead>
<tr>
<th>COATING</th>
<th>Tensile Strength (MPa)</th>
<th>Elongation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEPTUNE™ P Post-Reeling and SST</td>
<td>9.0</td>
<td>59</td>
</tr>
<tr>
<td>NEPTUNE™ F Post-Reeling and SST</td>
<td>9.2</td>
<td>56</td>
</tr>
<tr>
<td>NEPTUNE™ F to NEPTUNE P joint</td>
<td>6.5</td>
<td>28</td>
</tr>
</tbody>
</table>

Rigorously Tested and Qualified, the NEPTUNE™ System Is Ready to Meet Your Flow Assurance Needs

Next-generation flow assurance performance is here today with the NEPTUNE™ Advanced Subsea Flow Assurance Insulation System. Contact a Dow representative today to learn more.

Providing Comprehensive Solutions for Market Needs

Dow is committed to maximizing value for our customers by offering innovative, customized solutions tailored to the ever-evolving needs of the oil and gas industry. Backed by the extensive resources and global footprint of The Dow Chemical Company, we offer advanced chemical innovation, intimate industry knowledge and exceptional service.
To Learn More...

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*Toll-free service not available in all countries.

For more information: www.dowflowassurance.com/neptune

www.dowoilandgas.com

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