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Advanced insulation maintains thermal integrity of subsea systems

Silicone-based resin combined with glass microspheres is one of the newest subsea insulation materials.

By NINA M. RACH, Senior Editor

An important part of designing offshore production systems, particularly in deep, cold water, is providing sufficient thermal insulation.

This subsea manifold was insulated with Novolastic HT and installed on Murphy Oil's Azurite field offshore the Congo in 4,470 ft (1,360 m) water depth in 2008 (Image courtesy of FMC Technologies Inc.)

Fluids are produced at high temperatures, and equipment must be capable of handling extremely hot fluid while submersed in water close to freezing. Subsea lines are insulated to maintain produced liquid hydrocarbons at a sufficiently high temperature to prevent precipitation of wax and formation of gas hydrates, particularly during a production shutdown. Typically, subsea christmas trees, manifolds, jumper piping, sleds, and similar components have been insulated with specially formulated syntactic phenolic foams or epoxy-based materials.

There has been an accelerated need for new elastomers in the last 10 years in parallel with deepwater subsea projects. According to Janardhan Davalath, product manager of subsea process systems and flow management at FMC Technologies in Houston. The industry is looking for high-performance materials, and companies are investing heavily in R&D to meet market demand.

Common failure modes

The most common failures in wet insulation are cracks and collapse caused by extreme compression. Cracks can result from inappropriate application of materials or a lack of flexibility of the insulation material and can propagate down to the corrosion coating, causing spalling and inducing corrosion. When material is not strong enough to resist compression and collapse, its thermal conductivity increases, and its ability to insulate decreases.

The industry has made significant progress in increasing the reliability and integrity of wet thermal insulation materials to cope with increasing water depths and pressures. But materials that may have been sufficient at 3,000 to 4,000 ft (914 to 1,219 m) water depths are not necessarily suitable for deeper water, and failures could be magnified, said Eric Heuring, global product manager of thermal insulation at FMC.

In addition to having excellent thermal insulation properties, materials need to protect against corrosion, resist seawater and impacts, be incompressible yet flexible, and not degrade during the life of subsea projects, which is often 20 to 25 years or longer.

GoM

Many Gulf of Mexico (GoM) projects developed in 2,000 to 7,600 ft (610 to 2,316 m) water depth have subsea equipment encased with epoxy-based thermal insulation (Novotherm). These include Shell's Manatee, Oregano, Serrano, Crosby, and Na Kika fields (7,600 ft); ExxonMobil's Marshall, Mica, and Madison; Anadarko's Navajo; and BP's Atlantis (7,000 ft or 2,130 m).

But deeper projects require a different formulation.

When BP was planning its Thunder Horse project in 1999, FMC had to consider production temperatures greater than 250°F (121°C) in designing and insulating the subsea equipment (*E&P* November 2003). Materials scientists at FMC began developing a new class of

thermal insulation to stay ahead of the curve and by 2001 had a new product based on room-temperature vulcanizing silicone resin compounded with hollow glass microspheres to reduce density and lower thermal conductivity.

Silicone and glass

The glass microspheres, provided by Minnesota's 3M, have a mean diameter less than 60 microns, are relatively thick-walled, and provide good crush strength. The silicone resin contains titanium and is easily mixed without the exothermic reaction seen in epoxy-based formulations.

Marketed as Novolastic HT, this flexible, self-bonding insulation is an integral part of FMC's high-pressure, high-temperature subsea completion systems. Inventor Dwight D. Janoff and FMC were granted two US patents (issued in June 2004 and May 2005) on its formulation.

The silicone rubber-based insulation is pliable and has superior tensile elongation (250 to 300%) compared with syntactic foam (0.5%). This allows for thermal or mechanical expansion or movement of piping such as flowline jumpers without cracking or breaking the insulating layer. It is thermally stable to 350°F (177°C) and is not subject to hydrogen stress cracking. It can be cast in place using molds around the components (most common method), pre-cast, or bonded to itself onto metallic components.

Novolastic HT is available in non-glare white and yellow.

Lead time

Currently, about eight to 10 weeks' lead time is required to order materials, fabricate mold, and cast the insulation for specific pieces of equipment. Molds are built of galvanized steel, wood, or injection-molded plastic (for complex geometries). Although tolerances for insulation are not extremely tight, engineers nonetheless use Autocad, Solid Modeling, Pro-EE, and Uni-graphics to design the molds.

Novolastic is shipped as a liquid (55-gallon drums and 5-gallon buckets), mixed, and cast in place. According to Heuring, insulation for a 15,000-psi subsea tree requires about 500 gallons of fluid, poured into a half-shell mold, and takes only about six hours to cure. Since the curing process is not significantly exothermic, the product can be cast in thick sections.

Material properties of Novolastic thermal insulation.

Property	Value	Testing method
Thermal conductivity (dry)	0.095 BTU/ft-hr-°F (0.165 W/m-K)	ASTM C518
Thermal conductivity (wet)	0.096 BTU/ft-hr-°F (0.167 W/m-K)	ASTM C518
Heat capacity	0.346 BTU/(lb-°F) at 212°F (1.45 J/(gm-K) at 100°C	ASTM E1269
Thermal diffusivity (dry)	0.0042 ft2/hr (0.00039 m2/hr)	DSC
Specific gravity	0.05	ASTM D792
Compressive strength	640 psi (4.4 MPa) @ 50% compression	ASTM D575
Tensile strength	435 psi (3 MPa)	ASTM D412
Tensile elongation	285%	ASTM D412
Poisson's ratio	0.49	ASTM E132

The thickness of the insulation depends on the cool-down requirements, Davalath said. An operator typically wants insulation designed for an eight- to 16-hour shutdown or perhaps as long as 21 hours. The purpose is to manage hydrate formation in trees and manifolds, which is dependent on water temperature and produced fluid properties. The purpose of insulating jumpers is to manage wax deposition.

FMC uses about 75% of the Novolastic it produces to insulate its own equipment, and the remaining 25% is sold for insulation systems on other equipment, according to Heuring.

Worldwide use

Novolastic was first used in 2002 for ExxonMobil's Zafiro Southern Expansion Area project offshore Equitorial Guinea and BP's Thunder Horse in the GoM, followed by dozens of projects in the GoM, Africa, Brazil, and Asia. The most recent include Shell's Perdido project in the GoM, Gumusuit offshore Malaysia, and BC-10 offshore Brazil; Murphy Oil's Azurite project offshore Congo; and Total's Pazflor project offshore Angola.

In several of the projects, the field-measured cool-down times were better than design.

FMC is looking at product developments for projects with production temperatures above 400°F (204°C).

Qualification process

An ISO working group (TC67/SC2/WG19, *www.iso.org/iso/iso_technical_committee?commid=49532*) composed of industry experts was formed in mid-2008 to work on a standard for qualifying wet thermal insulation coatings for pipelines, flowlines, equipment, and subsea structures.

By December 2009, ISO 12736 was through preliminary, proposal, and preparatory stages and was in committee stage, with a Committee Draft registered and study initiated.

The working group will convene again in March 2010 to review all of the comments, said FMC materials engineer Elizabeth Whitsitt.

In the US, API is the technical advisory group (TAG) for TC67/SC2. API will review the proposed standard, formulate a position, and then recommend a vote to ANSI, which votes on behalf of the US. As a wet insulation expert, Whitsitt sends her recommendations to the API TAG to help them formulate their opinions. And thus a new standard may emerge. EXP