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ADVANCED ONSHORE AND OFFSHORE PIPELINE COATING TECHNOLOGIES

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Abstract: The development of the oil and gas industry has provided great challenges and needs for new and innovative coating technologies to address many unique applications, such as cold climates and deep water environments. This paper highlights several unique, advanced and proven pipeline coating technologies and services which are designed to protect pipelines for onshore and offshore applications, including the High Performance Composite Coating system (HPCC), low temperature application technology for powder coating on high strength steels and Thermotite flow assurance technology. Case histories and technical data are presented.

1. Introduction

Corrosion is the primary factor affecting the longevity and reliability of sub-sea and buried oil and gas pipelines throughout the world. As a result, the pipelines are designed and constructed with an external corrosion resistant coating and protected simultaneously with an effective cathodic protection system. Over the past 50 years, oil and gas pipelines have been coated with a wide variety of different coatings, such as coal tar or asphalt enamels, polyolefin tapes, two layer extruded polyethylene coatings, single or dual layer fusion bonded epoxy coatings, heavy three or multi-layer polyolefin (polyethylene or polypropylene) coatings, etc. Different pipeline coating systems are dominant in different regions in the world, as shown in Fig.1. Whilst many of these pipeline coating systems have had varied degrees of success and have served the oil and gas industry well, there are still challenges that face the industry due to the many unique applications, such as cold climates and deep water environments. The industry therefore demands for new and innovative pipeline coating systems in order to meet these challenges.

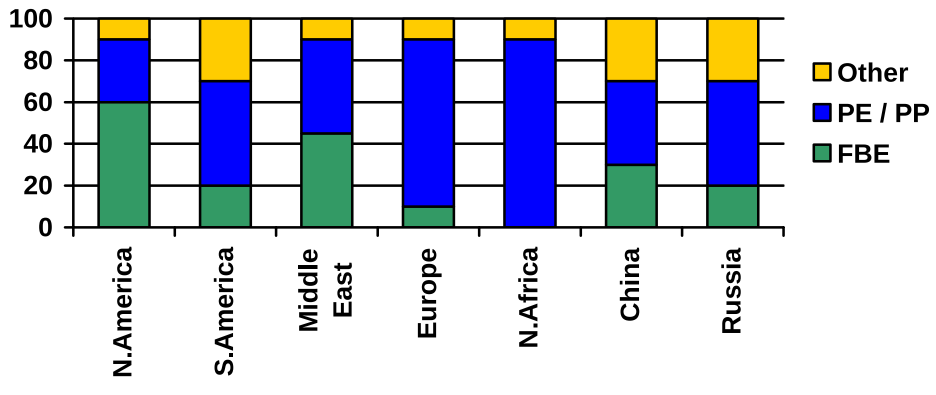

Fig.1 Pipeline coating market shares per region

As the world leader in pipe coating solutions and with more than 75 years of experience, over 27 pipe coating facilities on six continents and the largest team of technical and service specialists in the business, Bredero Shaw is dedicated to the development and manufacture of pipe coatings to meet the challenging needs of the oil and gas industry. This paper highlights several unique advanced and proven pipeline coating technologies and services which are designed by Bredero Shaw to protect pipelines for onshore and offshore applications, including the High Performance Composite Coating system (HPCC), low temperature application technology for powder coating on high strength steels, and Thermotite flow assurance technology. Case histories and technical data are presented.

2. High Performance Composite Coating system (HPCC)

The High Performance Composite Coating system (HPCC) is a single layer, all powder coated, multi-component coating system consisting of a FBE base coat, a medium density polyethylene outer coat and a tie layer containing a chemically modified polyethylene adhesive. All materials of the three components of the composite coating is applied using an electrostatic powder coating process. The tie layer is a blend of adhesive and FBE with a gradation of FBE concentration. Thus, there is no sharp and well-defined interface between the tie layer and either of the FBE base coat or the polyethylene outer coat. The adhesive and polyethylene are similar to each other and intermingle easily to disperse any interface. The coats are therefore strongly interlocked and behave as a single layer coating system without the risk of delamination. Delamination has been a performance issue with some three layer polyethylene coatings, especially under cyclic conditions. Being a single layer coating and thinner, the HPCC will have less internal stress development when subjected to large temperature changes. Fig. 2 shows a cross-section of the composite coating with a standard total thickness of 750 microns (30 mils). The thickness of the polyethylene outer coat can be increased to 1250 microns (50 mils) to create a total thickness of 1500 microns (60 mils) for heavy duty applications.

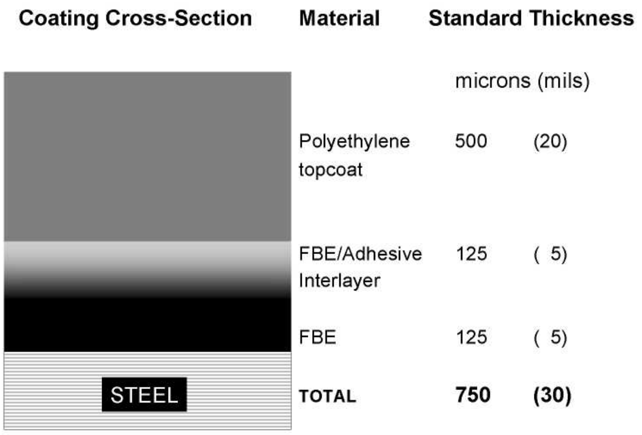

Fig. 2 Cross-section of the HPCC coating system

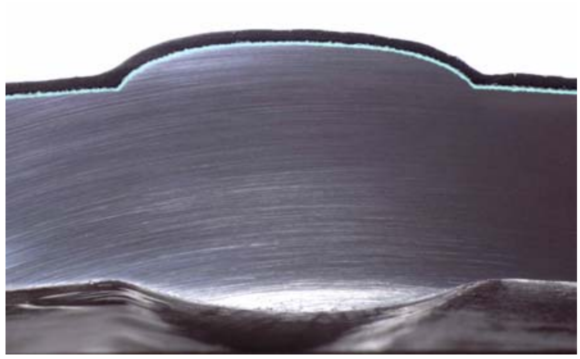

Fig. 3 Excellent coating coverage over a weld profile

In a typical three layer PE system, the polyethylene layer is applied by side extrusion for large diameter pipes and by crosshead extrusion for smaller diameter pipes. However, the problem with extrusion is poor coverage of the raised welds especially where the profile is pronounced. There is a tendency of the so called “tenting effect” to form voids at the weld neck area, which produce pinholes and entrap water during the cooling stage. Rollers have been used to compress the molten polyethylene around the weld seam with some success in regular welds. There is also a reduction of coating thickness at the top of the weld in typical three layer systems, which results in increased material usage to achieve the minimum required coating thickness. Powder coating avoids the above problems and provides additional advantages of being able to coat large diameter pipes or weld seams easily and saving coating materials by up to 60% (Fig. 3). The HPCC coating uses a specially designed process for applying the various powder components. The process provides versatility in customizing the thickness of the components of the coating system, as well as producing the unique structure. During this process, the coating solidification front also moves from the steel-FBE base coat interface towards the outer surface, thus minimizing the formation of voids, which can be formed when the outer surface freezes before the bulk of the material.

The HPCC coating system is covered under CSA Z245.21 System B2 - a coating system comprised of a powdered epoxy primer, a powdered copolymer adhesive, and a powdered polyethylene outer layer. The HPCC system provides excellent adhesion to the pipe surface with inherent shear resistance properties, flexibility at low temperatures, impact and cathodic disbondment resistance, and very low moisture permeability. The selected materials allow for operating temperatures in wet environments of up to 85°C and installation temperatures down to -40°C[1]. Fig. 4 and Fig. 5 give the impact resistance and flexibility of the HPCC system at various temperatures as examples to highlight its excellent performance properties, comparing with FBE, dual layer FBE, and 3 LPE.

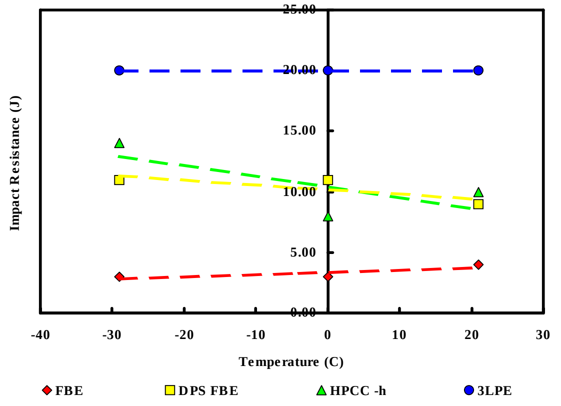

Fig. 4 Impact resistance

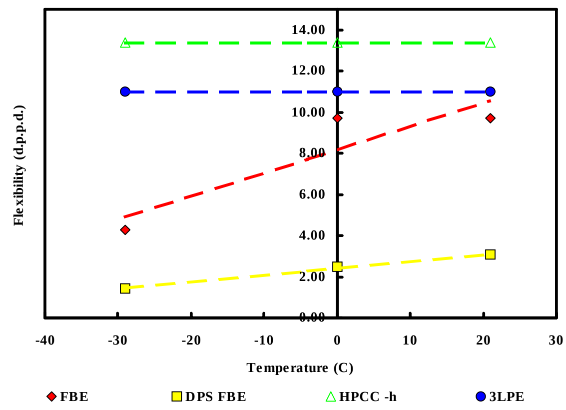

Fig. 5 Flexibility

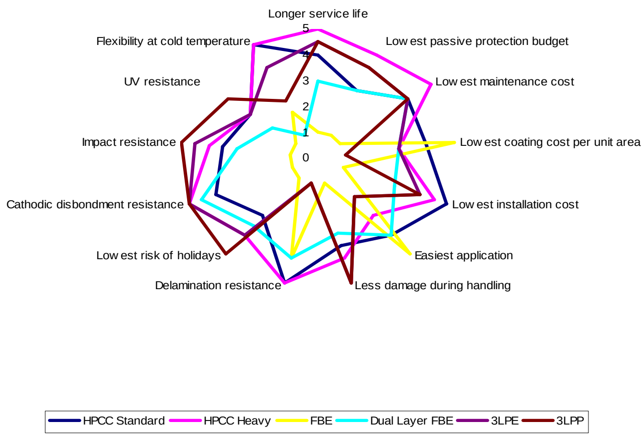

Fig. 6 A qualitative model for comparing pipe coatings

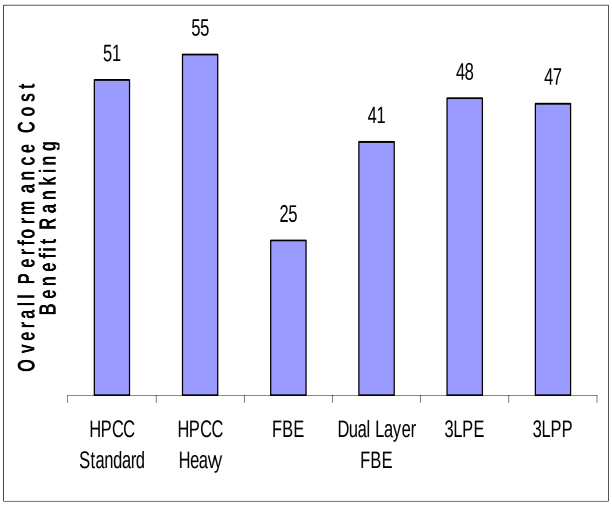

Fig. 7 Overall ranking of HPCC versus other coatings

An ideal pipeline coating system shall be environmentally friendly, worker-safe, durable and able to expose little or no metal/substrate surface to the environment. It must also be resistant to environmental, mechanical and chemical damage during application, handling, burial and insulation. It should be capable of being applied efficiently and effectively under the restricted environmental and work conditions in the field. Finally, it should come at a reasonable cost. Unfortunately, there is no quantitative model that has yet been established to predict with any real accuracy the long term integrity that a pipeline coated with a pipe coating (such as the HPCC system) will provide as compared with the same pipeline coated with other available coating systems. Installation cost, maintenance budgets, cathodic protection costs and repairs have a significant influence on the overall coating cost of a pipeline project. The cheapest coating solution is rarely the best one in the long term. A qualitative model has been proposed by the authors in Fig. 6 and Fig. 7 to estimate the overall long term performance-cost benefit rating of various pipeline coating systems, by totaling the ranking of each critical performance and cost item associated with a pipe coating project from 1 to 5 (with 1 being the lowest and 5 being the highest). The results indicate clearly that the HPCC systems (standard and heavy) will provide the highest performance-cost benefit return among all common pipeline coating systems used today.

3. Low Temperature Application Technology for Powder Coating on High Strength Steel

High yield strength steel is often used for constructing oil and steel pipes because they allow the reduction of pipe wall thickness. In addition, due to the increasingly high price of oil, the development of non-traditional oil and gas sources has become very attractive. Frontier oil and gas in Canada provides one example of this. Frontier areas include the Mackenzie-Beaufort area, the Arctic Islands and the Labrador basins. Due to the incredibly cold temperatures in these areas, many issues concerning the strength and flexibility of pipelines have developed. Pipes that would be flexible enough to bend and shift whenever frost heaving occurred are necessary to sustain consistent flow. Frost heaving occurs whenever the ground changes from hard during the winter months to soft during warmer temperatures. This has the effect of causing any material that is built underground to shift with it. To address this issue, more flexible and high yield strength grades of steel such as X80 or higher were developed. A coating on the high strength steel pipes for Frontier areas should withstand the extremely cold temperatures and retain the flexibility needed to protect the pipes. In addition, there is a need for a coating with indentation and impact resistance at -40°C /-50°C.

Applying a coating to a high yield strength steel pipe is a great challenge. Typically one usually heats the steel pipe to 240°C before applying a FBE coating or a FBE primer for HPCC or 3 LPE. However, such a high temperature causes the metallurgy of the high strength steel to change, making the metal more brittle. The steel will thus be inefficient for cold climates. In order to keep the mechanical properties of high strength steel, the FBE coating should be applied to the steel at an application temperature of less than 200°C.

A special HPCC coating system and special application processes associated with the system have been developed at Bredero Shaw, which allows the coating to be applied at an application temperature as low as 180°C.

Since 1992, HPCC coating system has been used in more than 20 pipeline projects in Canada and in the U.S. Pipe diameter sizes and lengths vary from 406 mm (16”) to 1067 mm (42”) and from 171 m to 545 km. Among them, an example is TransCanada PipeLines Peerles Lake Project. TransCanada PipeLines is a leading North American energy company with a network of about 41,000 km (25,600 miles) of pipeline that transports most of Western Canada's natural gas production to the fastest growing markets in Canada and the United States. TransCanada's new pipeline facilities in the areas of Peerless Lake/Godin Lake are an important step in providing additional gas service to the oil sands region, a significant growth market. The Peerless Lake Project consists of 17.7 km of 610 mm (24”) diameter X70 line pipe near the community of Wabasca, in Northern Alberta. This project was looped with a 3.6 km section of NPS 36” called the Godin Lake Loop. The 3.6 km NPS 36” pipe was coated with HPCC at the Bredero Shaw Camrose, Alberta plant. The process worked smoothly and the plant quality tests gave excellent results. Inspection of the pipe prior to shipping, revealed that no holidays were present in the coating. Once in the field, HPCC performed very well as no damage was observed during the unloading and stringing process. On this job, the HPCC coated pipe was successfully bent at temperatures as low as -45°C without damaging the coating.

4. Thermotite Flow Assurance Coating Technology

Client specifications for subsea insulation and flow assurance systems have been limited historically to a consideration of the heat loss per unit area of a given radiant surface (U-value). In many cases however it is not the steady state performance of the system that is the principal driver for insulation, rather the transient behavior during heating / cooling cycles. The three main determinants of transient system performance are the thermal conductivity (k-value), density (ρ) and specific heat capacity (Cp). Thermophysical properties of subsea thermal insulation systems vary with time under the combined effects of pressure, temperature and exposure to water. Various validated models have been designed pertaining to compression, creep and water absorption for those precise materials used in the system, and how the combined effect of these factors influence k-value, ρ and Cp. [2]

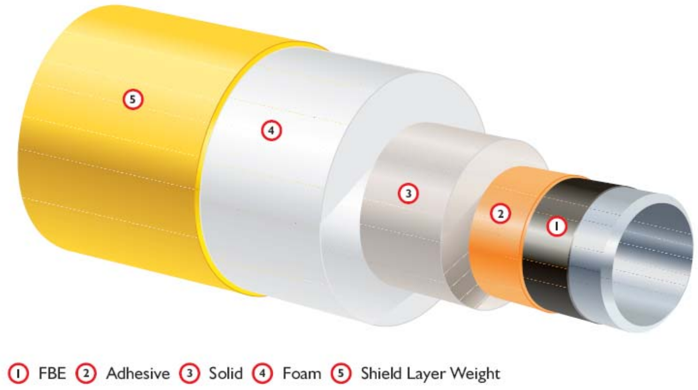

Fig. 8 A Thermotite 5-layer system

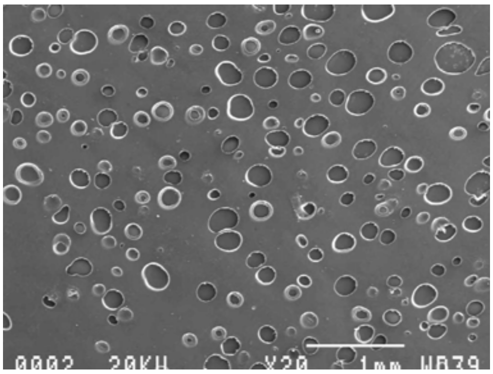

Fig. 9 SEM of Thermotite high performance polypropylene PP foam

Using the limit state design approach, Thermotite insulation and flow assurance coating technology has been designed for meeting the need for anti-corrosion as well as the insulation and flow assurance requirements. The Thermotite technology consists of a multilayer polypropylene composite with Fusion Bonded Epoxy as the layer to the steel. Specific requirements for protection or thermal insulation are taken care of through the bespoke system design. Resistance to the effects of compression and creep, typical for deep water and high temperature, can be catered for by adjusting the density and nature of the layers. Fig. 8 shows the Thermotite 5-layer System build up. The three-layer anti-corrosion coating is applied by a side or cross head extrusion process and the quality tested and approved, prior to the application of the thermal insulation layers (two-layer; PP Foam and outer shield). The thermal layers and outer shield or weight coating polypropylene, are applied simultaneously in the thermal insulation lines, by a cross head extrusion process. The method secures a fixed outer diameter and homogenous foam structure with no air inclusions.

The special PP foam material (TDF®) used in the Thermotite systems has a much finer foam cell structure (as shown in Fig. 9), compared to traditional structural PP foam. It provides improved high melt strength, high creep resistance and stiffness, making it possible to deploy in deep waters beyond 1500 meters. For deeper water application, the multilayer insulation system is used in seven-layer solutions, where reinforcement such as glass microspheres is often included in a matrix of solid PP to form a syntactic foam. This extends the depth and temperature performance of multilayer polypropylene systems, with an end of life k-value 0.185W/m.K, and achievable U-values in the range 3 to 4 $W/m^2.K$.

Since 1991, Thermotite insulation and flow assurance coating systems have been used in many major offshore pipe applications in North Sea, Gulf of Mexico, South China Sea, and other areas, representing a total insulated length of 660 km and a total coated length of 1005 km. Thermotite systems can be designed for water depths up to 3000 m and temperatures up to 155°C. The system is also suitable for installation by any method, including reel lay. To complement the Thermotite system, a proprietary injected polypropylene field joint insulation system is available that results in industry leading end-to-end thermal and mechanical performance critical to the integrity of a flowline and or riser development.

The Thunderhorse field is located in the Gulf of Mexico and will be developed using one of the world's largest semi-submersible floating production platforms. The project is operated by BP Exploration & Production Inc (BP) who has 75% equity interest and Exxon Mobil who has the remaining 25%. It is the largest discovery to date and is capable of producing 250,000 bbls of oil per day at peak rate with production due to start in 2005.

A Thermotite seven-layer flow assurance coating system was used in the BP Thunderhorse Project. Table 1 outlines the detailed coating configuration of the system.

Project:	**Thunder Horse Project**	
Client/Oil Company:	**BP (Operator)**	
Location:	Gulf of Mexico (GoM)	
Installation/ship:	J-lay/Balder	
Production year:	2004-2005	
Steel dimension:	Flowline: 329 x 35mm 273 x 30mm 219 x 38/30mm	SCR: 323.9 x 40mm 273.1 x 33.mm 219.1 x 35mm
Steel grade:	Carbon steel	
Coating dimension:	Flowline: 73.6/76.6/102.6/ 89.6mm	SCR: 67/60/50mm
Design Temp. /U value:	132°C/5 W/m^{2}K	
Water depth:	2200 m	
Design life:	20 years	

Table 1 A Thermotite seven-layer flow assurance coating system for BP Thunderhorse Project

Layer	Flowline	Thickness	SCR riser	Thickness
1.	Epoxy (FBE): EP-F 2004	300 µm	Epoxy (FBE): EP-F 2004	300 µm
2.	Adhesive: BB127E	300 µm	Adhesive: BB127E	300 µm
3.	Solid PP: BB108E-1199	8.4 mm	Solid PP: BB108E-1199	8.8 mm
4.	Solid PP: BA202E	30 / 40 mm	Syntactic PP (SPP): BB700E	16/19/23 mm
5.	PP shield: BA202E	4.0 / 5.0 mm	PP shield: BA202E	5.0 mm
6.	PP Foam (TDF): BA212E + TR0103PP+Daploy WB 130 HMS	25 / 27 / 43 / 30 mm	PP Foam (TDF): BA212E + TR0103PP+Daploy WB 130 HMS	16 / 23 mm
7.	PP Outer Shield: BA202E	5.0 mm	PP Outer Shield: BA202E	5.0 mm

5. Summary

This paper reviews several unique advanced and proven pipeline coating technologies and services which are designed to protect pipelines for onshore and offshore applications, including the High Performance Composite Coating system (HPCC), low temperature application technology for powder coating on high strength steels and Thermotite flow assurance technology.

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