End-to-end PERFORMANCE

Figure 1. ShawCor's simulated service vessel (SSV) facility simulates deepwater service conditions for pipes.

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In the world of pipe coating, an ongoing challenge for the industry is the field joint – the area at which the factory-applied coating is 'cutback' to allow for the welding of the pipe joints together to form the pipeline. While the joint cutback is necessary, it leaves points of potential vulnerability in the anti-corrosion protection of the pipeline. Traditionally, the field joint coating has not been considered as important as the factory-applied mainline anti-corrosion system. Over the last decade, the construction schedule, cost, and awareness of field joint coating performance and its impact on pipeline design has taken on new importance as offshore oil and gas projects are becoming increasingly complex, located in more remote fields and operating in deeper waters with higher fluid temperatures.

Wherever possible, full simulation of operating conditions should be carried out to confirm suitability of the coatings being considered for the intended application. During simulation testing, the typical parameters to be considered for offshore installation include: operating temperature, water depth, mechanical

forces associated with pipelay processes, and water immersion at service conditions. For insulated pipelines this also includes measurement of thermal performance characteristics and long-term compressive creep properties.

Considering the capital commitments, environmental risks, and overall complexity of offshore projects, there is an increasing demand within the industry to ensure that the field-applied joint coating provides equivalent anti-corrosion performance as the factory-applied mainline coating. Complete validation during the qualification phase is necessary.

Canusa-CPS and its parent company ShawCor, provide a full range of automated field joint coating solutions that directly addresses the need to provide a consistent high performance anti-corrosion coating along the full length of the pipeline. Using ShawCor's advanced testing facilities, these field joint coatings can undergo complete validation through simulated service vessel (SSV) testing under the anticipated service conditions.

Figure 2. Canusa-CPS's Factory Grade PP field joint coating system on 3LPP coated pipeline.

Figure 3. Canusa-CPS' IntelliCOAT provides automated application for field joint coatings.

Basic field joint background

All subsea pipelines require a mainline coating system for anti-corrosion protection, either independently or as a base prior to thermal insulation, negative buoyancy, or mechanical protection. Typically, this coating is factory-applied to 12 m (40 ft) or 24 m (80 ft) pipe joints.

The factory-applied mainline coating is selected to match offshore construction methods, pipeline design parameters and service conditions. Generally, three main anti-corrosion coating systems dominate the market for both onshore and offshore applications:

- Fusion bonded epoxy (FBE) – FBE is the foundation for the three primary anti-corrosion coating systems and provides excellent protection for pipelines with moderate operating temperatures (recommended maximum operating temperature of 110°C).
- Three layer polyethylene (3LPE) – 3LPE systems provide protection for pipelines with moderate operating temperatures, and consist of a high performance FBE layer, a copolymer adhesive, and an outer layer of polyethylene. The PE outer layer protects pipelines during transportation and installation, thereby reducing costly repairs while also providing added in-ground protection against shear forces, chemicals, and abrasive soil conditions. The maximum recommended operating temperature for 3LPE is 80°C.
- Three layer polypropylene (3LPP) – 3LPP systems are similar to the 3LPE systems and offer the same mechanical advantages of 3LPE, but can typically tolerate operating temperatures of up to 110°C onshore and 140°C offshore. The 3LPP system consists of a high performance FBE layer followed by a copolymer adhesive and an outer layer of polypropylene, which provides the toughest, most durable thin-film pipe coating solution available.

Once applied in the factory, these coatings are 'cutback' at either end of each pipe to allow for welding in the field. After welding, the cutback portion of the pipeline requires anti-corrosion protection similar to the mainline coating in order to provide complete and consistent corrosion protection for the entire length of the pipeline.

Field joint coating specifications

The specifications for factory-applied mainline coatings differ from the specifications for field joint coatings, with factory-applications being more stringent. This leaves a gap in the coating standards that are critical to the overall integrity of the pipeline. This discrepancy exists as it has been historically assumed that field joint products and application methods could not achieve the same standard required for the mainline coating; however, proven factory grade systems have been available to the market for more than 10 years. Industry coating specifications have been slow to recognise and update requirements.

The discrepancy can be clearly seen in several commonly accepted industry standards. Consider the ISO standards for 3LPE and 3LPP mainline coating (ISO 21809-1) and 3LPE and 3LPP field joint coating (ISO 21809-3), as detailed in Tables 1 and 2. The adhesion, impact resistance, and hardness requirements are

all significantly reduced for the field joint coating performance compared to the requirements for the mainline coating.

This is an excellent example of an industry-wide practice of setting lower standards for field-applied coatings. This leaves the linepipe vulnerable, with potentially insufficient coverage, at every weld point along the pipeline.

High performance automated field joint coatings

To promote enhanced performance and long-term integrity, automated technologies can be incorporated throughout key phases of the coating application process:

- Surface preparation through use of automated closed-cycle blasting equipment to ensure proper surface profile and joint cleanliness.
- Pre-heating of the field joint area through use of induction heating technology to ensure sufficient and uniform temperature is applied to the substrate.
- Automated coating application technologies to deliver high performance factory grade coating materials to the field joint.

Automated coating application provides significant benefits to offshore lay contractors and pipeline owners as it relates to the quality, consistency and overall application productivity.

- Quality: automation allows the finished pipeline asset to benefit from a seamless anti-corrosion system with factory grade quality for the entire length of the pipeline, with no compromise on the field joints. Programmable control systems allow project-specific instructions to be developed for each and every unique project – qualified in advance of construction and then put into practice.
- Consistency: automation offers contractors and clients the unique opportunity to have each and every field joint coating applied in an identical manner – with heating intensity, time and sequence all tightly controlled.
- Productivity: the use of automation allows the contractor to precisely forecast the daily production of field joints, without relying on operators to conduct labour intensive work steps. This can result in significant reduction in overall project labour, which is relevant in high operating cost regions such as Canada, Gulf of Mexico (GOM), Europe, the North Sea and Australia.

With the development of efficient automated processes noted above and novel coating materials, the field joint no longer needs to be regarded as a vulnerability in the pipeline. The need for different field joint coating standards and mainline coating standards becomes unnecessary.

High performance automated field joint systems, such as Canusa CPS's IntelliCOAT™ PE and IntelliCOAT™ PP solutions, are raising the standard for field-applied coating systems. These systems provide Factory Grade™ materials that meet mainline coating specifications – a significant advantage over traditional field joint coatings.

The IntelliCOAT PE and IntelliCOAT PP solutions are automated 3-layer hot-applied sheet systems that are composed of the same base materials as the mainline coating:

- High temperature epoxy – the initial layer provides resistance to corrosion and cathodic disbondment equivalent to that of the FBE layer of the factory-applied coating.
- Copolymer adhesive – the intermediate layer bonds the top coat to the epoxy layer and fuses to the factory-applied 3LPE or 3LPP mainline coating.
- Top coat – the polyethylene or polypropylene top coat provides mechanical protection for the field joint area.

The installation process of the IntelliCOAT system is straight forward: following surface preparation and application of the epoxy anti-corrosion layer, the patented IntelliCOAT coil is lowered onto a pre-positioned proprietary PE or PP sheet material, which is then heat-activated and fused directly to the field joint area. The criteria for IntelliCOAT application is established and programmed specific to each individual project, and qualified in advance of construction.

Typical IntelliCOAT installation time for standard 3 mm thickness field joint coating is in the 2 min. 30 sec. range – independent of pipe diameter. Based on project requirements, coating thickness of up to 8 mm can be applied using the automated IntelliCOAT technology. This proven technology is currently being employed on the largest and most complex global onshore and offshore projects.

By using the same materials as the mainline coating and fully automated processes, Canusa-CPS is able to deliver a factory grade coating at the field joint. This provides a seamless, high-performance, three-layer anti-corrosion coating systems for the entire length of the pipeline – without compromise.

Table 1. 3LPE specification standards comparison: factory vs field coatings

	Factory coating performance requirement ISO 21809-1	Field joint coating performance requirements ISO 21809-3 (Clause 11: Heat Shrink Systems)
Adhesion at 23°C	≥150 N/cm	≥25 N/cm
Adhesion at 80°C	≥30 N/cm	≥2 N/cm
Impact resistance	>7 J/mm	≥5 J/mm
Hardness (Shore D)	≥55	Not specified

Table 2. 3LPP specification standards comparison: factory vs field coatings

	Factory coating performance requirement ISO 21809-1	Field joint coating performance requirements ISO 21809-3 (Clause 11: Heat Shrink Systems)
Adhesion at 23°C	≥250 N/cm	≥40 N/cm
Adhesion at 110°C	≥40 N/cm	≥20 N/cm
Impact resistance	>10 J/mm	≥8 J/mm
Hardness (Shore D)	≥60	Not specified

Figure 4. Pipeline bending rig used for simulating reel-lay application conditions.

Based on the available technology, reduced requirements for field-applied 3LPE and 3LPP coatings are unwarranted, and unnecessarily puts the pipeline at risk. Ensuring the factory and field-applied coatings have the same high standards is particularly relevant for offshore applications, since the stakes are high and the risks are greater. The integrity of the end-to-end coating system is vital for these technically challenging and demanding projects.

Simulated testing of field-applied coatings

To ensure long-term performance and integrity, a full simulation of operating conditions should be carried out to confirm suitability of the coatings at the qualification stage.

At a minimum, this qualification process should include four validation steps:

- Application of the nominated field joint coating onto project coated pipe using production grade equipment according to a defined installation procedure.
- Application of the appropriate mechanical loading to the coated sample to replicate stress caused by the specific offshore pipelay method. For instance, roller box testing for S-lay installation and bending/straightening trials for reel-lay using purpose built equipment to closely simulate installation conditions.
- Completion of Simulated Service Vessel (SSV) testing to replicate service conditions experienced by subsea coatings. This can be completed by placing the coated pipe sample into a specialised pressure vessel that controls the internal temperature of the pipe sample, while pressurising the external coating surface with water. During the standard 28 day test, information such as compressive creep and heat-flux should be recorded for evaluation of the coating's thermal performance (U-value).
- Completion of post-SSV small-scale laboratory tests such as sectioning of the field joint, DSC analysis of the epoxy, adhesion strength of the top coat and cathodic disbondment to determine overall performance.

Canusa-CPS has a wealth of experience in managing and executing qualification test programs as outlined above. For instance, in 2014, Canusa-CPS's high performance factory grade high temperature PP solution was fully qualified and utilised on a 1300 m deepwater project in the Gulf of Mexico.

As part of the in-depth qualification process, a sample field joint was prepared by the lay contractor under direct guidance of Canusa-CPS. The sample pipe joint was subjected to a cyclic bending test (or reeling simulation) performed using a purpose-built bending rig. Visual inspection following the bending tests demonstrated no sign of disbondment between the Canusa-CPS high performance PP field joint coating and the factory coating.

Next, the coated sample underwent a 28 day SSV test to simulate the service conditions experienced by the pipeline. This was achieved by applying 140 bar pressure to the water surrounding the coating system while controlling the internal temperature of the pipe to 150°C. After completion of the reeling simulation and SSV test additional laboratory analysis was performed on the coating system under third party witness.

The field joint coating system exhibited excellent performance on all functional small-scale laboratory tests such as cathodic disbondment and hot water soak. A detailed visual inspection of cut-out sections illustrated excellent adhesion between the PP field joint coating and the parent coating, with zero disbondment.

Overall, the qualification program demonstrated that the field joint coating system was not adversely affected by the cyclic bending test or the SSV test. Consequently, the applied system was approved by the pipeline operator for use at 150°C in deepwater conditions.

The final word

The gap between material quality and reliability of application processes between mainline and field applied coatings has existed long enough. Consistency along the length of the pipeline to a single standard is now achievable with Canusa-CPS' IntelliCOAT PE and IntelliCOAT PP automated field joint coating systems. These high performance systems are applicable for all 3LPE & 3LPP coated pipelines, but are particularly useful in offshore applications, where technical reliability and schedule certainty are highly critical.