FACTORY OR FIELD?

SEEKING THE SAME STANDARDS

Pascal Laferriere and Bob Buchanan, Canusa-CPS, a division of ShawCor, Canada, analyse factory grade joint coating systems for multi-layer polyolefin coated pipelines.

A properly specified and applied pipeline anti-corrosion coating is critical to ensure that the chosen coating is capable of delivering the required performance over the life time of a buried or submerged pipeline. Given that the factory-applied (mainline) pipe coating must be 'cutback' from the pipe's edges in order to allow for the steel pipe to be welded to the next pipe in the field during pipelay, the field-applied coating that is applied over this welded area forms an integral part of a pipeline's continuous corrosion protection coating system. A high quality effective end-to-end coating is of paramount importance to the life of a steel pipeline and if performance and compatibility are sacrificed at the joint area, overall pipeline integrity can be significantly reduced.

This article summarises the performance of some of the leading 'factory grade' joint coating systems for multi-layer polyolefin coated pipelines, as well as some

of the best practices that have been employed on key pipeline projects that have utilised these advanced coating systems in recent years. The article is also intended to dispel the belief among some that field-applied joint coating performance requirements must be significantly reduced from those of the factory-applied coating and is based on a presentation that was given at the recent Middle East Pipelines/NACE UAE Conference that was held in Abu Dhabi.

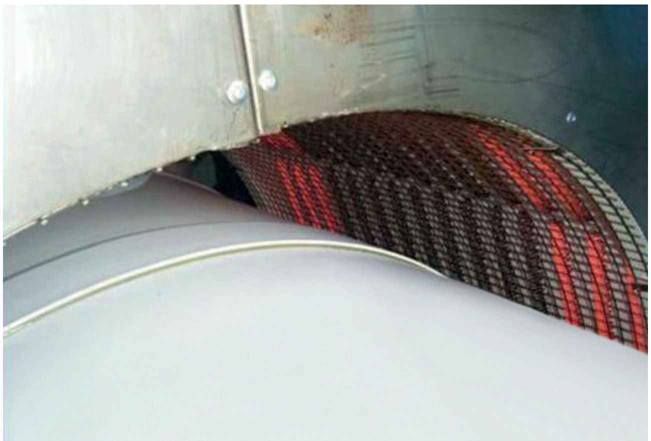

Figure 1. Pre-extruded heat shrinkable 3LPP.

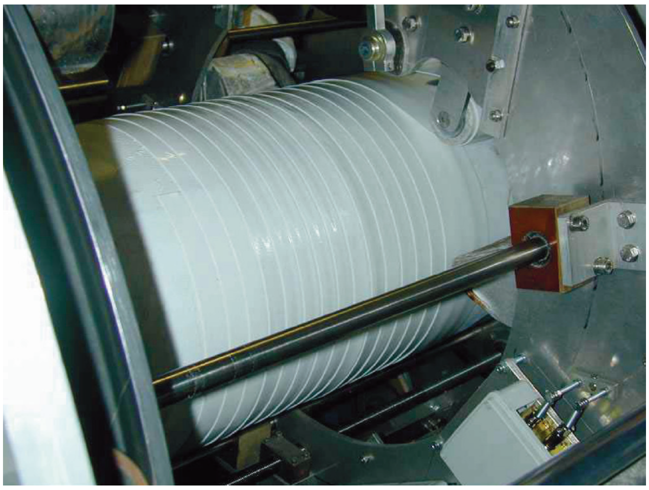

Figure 2. Pre-extruded hot applied 3LPP tape.

Figure 3. Preparation of injection mould field joint.

Clearly, ensuring consistent coating performance over the entire pipeline is very important. The factory-applied coating is typically chosen to meet the operating demands of a particular pipeline and if this same level of performance is not replicated at the joint areas, the integrity of the entire pipeline can be reduced. Further, higher temperatures, remote locations, deeper water and longer design life requirements mean that expectations for pipe coatings continue to increase in order to mitigate risk on these critical pipelines. The goal must always be to avoid having any weak link within the coating system and the field joint coating should be specified to provide the same level of protection as the factory-applied coating, especially given that there are systems available from numerous suppliers.

Multi-layer (3LPE and 3LPP) coatings, factory- or field-applied

As it relates to multi-layer polyolefin coated pipelines, typically three-layer polyethylene (3LPE) and three-layer polypropylene (3LPP), field joint coating systems are available today that use 'factory grade' materials, and that are capable of delivering the same, or similar, performance and thickness as the factory-applied coating. In some cases, these coatings have been used successfully for many years with proven and extensive track records.

While many multi-layer coating types and configurations exist, 3LPE and 3LPP coatings are the most common and typically consist of the following three components:

Epoxy layer applied directly to the steel

This provides excellent resistance to corrosion but without protection can be susceptible to damage from external forces exerted on the pipeline and also to moisture absorption at elevated temperatures.

Outer polyethylene (PE) or polypropylene (PP) layer

This layer provides protection of the epoxy from external forces exerted on the pipeline and resistance to moisture absorption or transmission. PE provides effective performance in this regard, typically at pipeline operating temperatures up to approximately 80 °C, while PP provides effective performance at operating temperatures up to 110 °C, or higher depending on project specific conditions and requirements.

PE or PP copolymer mid-layer

The mid-layer bonds to both the epoxy (1) and to the outer PE or PP layer (2) due to the fact that the PE or PP outer layer will not typically bond to the epoxy due to their opposing chemical compositions.

Categorising 'factory grade' field-applied coatings

The above design overview applies both to the factory-applied versions of these coatings and also to the advanced 'factory grade' field-applied versions that are the subject of this article.

The 'factory grade' field-applied coatings that have been well established in the industry can generally be categorised as follows:

- Pre-extruded PE or PP systems:
- Hot applied spiral wrapped tape systems, using PE or PP outer layer and copolymer mid-layer.

- Heat shrinkable hot applied wrappable sheet systems, using PE or PP outer layer and copolymer mid-layer.
- Field-extruded PE or PP systems.
- Injection moulded PE or PP.
- Flame sprayed PE or PP.

Figure 4. Abrasive blasting to Sa 2.5, near white metal.

Figure 5. Induction heating coil for pre-heating cutback.

Figure 6. Automated onshore 'factory grade' field joint coating using IntelliCOAT™.

Although specific configuration may vary depending on supplier, user preference and intended application, each of these coating types is essentially using similar polymer/resin grades and providing similar, or equivalent, performance to the factory-applied coating. The systems are also generally fully compatible with the adjacent factory-applied coating to eliminate this area as a weak point. In fact, at the area of overlap with the factory-applied coating, these coatings typically cannot be separated (they become fused). Moreover, the systems are generally only applied by certified applicators or with full automation to ensure consistent and uniform application on each and every joint.

Industry accepted coating standards for 3LPE and 3LPP coatings

For a variety of reasons, industry standards for factory-applied coatings have typically been more consistent and requiring higher levels of performance than those developed for field joint coatings. Widely accepted and used factory-applied coating standards for 3LPE and 3LPP coated pipelines include: ISO 21809-1 (3LPE and 3LPP), NFA 49 711 (3LPP), DIN 30670 (3LPE) and DIN 30678 (3LPP).

Canusa-CPS, and its sister divisions within ShawCor Ltd, provides factory-applied, as well as a range of field-applied versions (pre-extruded heat shrinkable, injection moulded and flame sprayed) of these multi-layer coatings, all using similar 'factory grade' materials. This perspective and experience has demonstrated that 3LPE and 3LPP field joint coatings should be required to provide similar or equivalent performance to the factory-applied mainline coating. Many projects have followed this practice very successfully, as is highlighted briefly later in this article. However, field joint coating industry standards have varied greatly in this regard, and typically have required much lower levels of performance due to a variety of influences.

A more recently introduced standard for field joint coatings has been ISO 21809-3, which was first introduced in 2008. While this standard provides good advice to users on various elements within the supply chain for field joint coating, it is essentially an impartial grouping of many field joint coating systems that exist in the market. The document does not directly contrast one system with another. Essentially, it sets minimum standards for each type of coating in isolation from the others and often the standards are set relatively low, in order to accommodate systems that may exist in the market already.

ISO 21809-3 does not attempt to set required levels of performance for a given pipeline and given operating conditions, and therefore requires those who use the standard to use it with this in mind. It requires that the purchaser, applicator and end user to act in unison to obtain the best results. It is not enough to simply state in a specification that field joint coatings must comply with ISO 21809-3. One must always consider expected operating conditions of the pipeline in question and also the factory-applied coating that has been selected to meet these demands. Where possible, the goal should always be to create a field joint coating with equivalent performance (and with full compatibility) to the factory-applied coating to avoid any compromise in pipeline integrity.

Table 1. 3LPE coating performance requirements summary

Property	Factory coating requirements	Joint coating requirements		Actual performance of factory grade 3LPE joint coatings
	ISO 21809-1	ISO 21809-3 3LPE heat shrink systems (Clause 11)	ISO 21809-3 other 3LPE joint systems (Clause 14)	
Ambient adhesion	≥ 150 N/cm	≥ 25 N/cm	Not required	≥ 150 N/cm
Adhesion at T_{max}	≥ 30 N/cm	≥ 2 N/cm	≥ 15 N/cm	≥ 30 N/cm
Impact resistance	≥ 7 J/mm	≥ 5 J/mm	≥ 5 J/mm	≥ 10 J/mm
Indentation resistance at T_{max}	≤ 0.4 mm penetrated	≥ 0.6 mm residual thickness (= 2.4 mm penetrated for a 3.0 mm coating)	≤ 1.0 mm	≤ 0.4 - 0.9 mm†

† Specific performance/requirement depends on test method and exact system configuration

Table 2. 3LPP coating performance requirements summary

Property	Factory coating requirements		Joint coating requirements		Actual performance of factory grade 3LPP joint coatings
	NFA 49 711	ISO 21809-1	ISO 21809-3 3LPP heat shrink systems (Clause 11)	ISO 21809-3 other 3LPP joint systems (Clause 14)	
Ambient adhesion	≥ 150 N/cm	≥ 250 N/cm	≥ 40 N/cm	Not required	≥ 250 N/cm
Adhesion at T_{max}	≥ 40 N/cm	≥ 40 N/cm	≥ 20 N/cm	≥ 15 N/cm	≥ 60 N/cm
Adhesion to 3LPP factory coating	n/a	n/a	≥ 20 N/cm	≥ 15 N/cm	Fused
Impact resistance	≥ 10 J/mm	≥ 10 J/mm	≥ 8 J/mm	≥ 7 J/mm	≥ 10 J/mm
Indentation resistance at T_{max}	≤ 0.4 mm penetrated	≤ 0.4 mm penetrated	≥ 0.6 mm residual thickness (= 2.4 mm penetrated for a 3.0 mm coating)	≤ 0.9 mm	≤ 0.4 - 0.9 mm†

† Specific performance/requirement depends on test method and exact system configuration

While a full definition of each can be found in the standard and elsewhere, these elements ultimately greatly improve consistency, uniformity and control of the field joint coating process and allow the document to be used as a tool to ensure proper and standardised procedures are used on all projects.

In order to highlight the above comments on coating performance levels, Tables 1 and 2 compare the requirements for factory-applied coatings and field joint coatings covered under ISO 21809-1 and ISO 21809-3 for three-layer polyethylene and three-layer polypropylene coatings respectively. For 3LPP, key performance properties for the predominant standard (NFA 49 711) that has been used for many years for factory-applied, and also for field joint coatings on many projects, is summarised for comparison. It should be noted that any system that is using true PP materials can easily meet these performance levels. Also included in these tables is actual typical performance data for the above-mentioned 3LPE and 3LPP 'factory grade' joint coating technologies.

It is clear that these 'factory grade' 3LPE and 3LPP joint coating technologies can far exceed the performance of ISO 21809-3 and that they can meet the performance levels required for the factory-applied versions of these coatings.

The tables also point out the fact that even within the ISO 21809-3 document, the performance levels vary greatly for the alternate configurations of 3LPE and 3LPP joint coating systems, even though often, these coatings are considered alongside one another for use on projects, due to their equivalent, or similar, performance.

Other industry standards organisation are considering adoption, or have already adopted ISO 21809-3 and therefore it will become even more important for end users to take responsibility to define specifically what is required for their pipeline, rather than just stating that coatings must comply with a particular standard.

With the above in mind, if proper performance requirements are set that consider the operating conditions and parent coating in question, documents such as ISO 21809-3 can be used as effective tools. As mentioned, this document provides effective guidance with regards to the various elements of the supply chain and does define the following elements that are key to any properly planned and designed pipe coating system:

- Application procedure specification (APS).
- Pre-qualification trial (PQT).
- Pre-production trial (PPT).
- Inspection and testing plan (ITP).
- Quality assurance (QA) versus quality control (QC).

Project specifications – best practice

While many pipeline projects have not followed this best practice, many major multi-layer polyolefin coated pipelines over the past 15 years have employed technologies and practices that have resulted in consistent end-to-end coating performance. The approaches used on these pipelines have typically benefited from a few key common practices as follows:

- An understanding that pipeline planning and design must commence well in advance of pipeline construction (the length of time required can depend on the complexity of the project but in many cases, can take many years).
- A philosophy that factory and field-applied coatings to be used on the project would be equivalent and fully compatible with a fused interface between the two.

Figure 7. Soil stress testing in soil box.

Figure 8. Full-scale pipe bend testing.

- A philosophy that additional investment in planning and risk prevention is worthwhile when considering the potentially very high costs and negative consequences that can be associated with pipeline failures. Typically the upfront investment required is quite minimal when considering the risks and potential negative consequences ("an ounce of prevention is worth a pound of cure").
- A commitment that proper planning would take place in terms of the required certified personnel, equipment and inspection controls to ensure that leading coatings would be applied in a consistent and uniform manner, both in the factory and in the field.

In order to eliminate any question in terms of the performance desired for the field joint coating, end users and/or engineers have often simply referenced the factory-applied coating standard within the project specification for the field joint coating. This has been especially true for many projects that have used/required 3LPP coated pipelines. Given that many of these pipelines are operating under more extreme conditions (the reason that 3LPP would have been chosen in the first place), there has typically been a desire to mitigate risk and to adopt a philosophy that the field joint coating should have the same, or similar, performance to the factory-applied coating, to avoid any weak link.

Table 3 provides a summary of some of the key coating requirements of a field joint coating specification from one leading user of 3LPP globally, which is typical of the approach that has been employed by many others who are using this coating regularly, and which would be considered best practice in the industry.

As mentioned, this specification is based largely on the performance levels that are typically required for the factory-applied coating and is typical of the practice that has been employed within the 3LPP coating segment of the market in order to better control the field joint coating and to ensure consistent end-to-end performance on these critical pipelines. More recently,

Table 3. Sampling of key requirements from actual 3LPP joint coating specification from a leading user of 3LPP coatings†

Property	Test standard	Requirement
Adhesion to steel at 23 °C	NFA 49 711	≥ 150 N/cm
Adhesion to steel at T_{max}	NFA 49 711	≥ 40 N/cm
Adhesion to factory-applied 3LPP at 23 °C	NFA 49 711	≥ 150 N/cm
Adhesion to factory-applied 3LPP at T_{max}	NFA 49 711	≥ 40 N/cm
Impact resistance	NFA 49 711	≥ 10 J/mm
Indentation resistance at T_{max}	DIN 30678	≤ 0.4 mm penetrated
Hardness	ASTM D2240	65 Shore D
Cathodic disbondment at 23 °C, 28 days	NFA 49 711	3 mm
Cathodic disbondment at 95 °C, 28 days	NFA 49 711	7 mm

† Although above is a sampling from one leading 3LPP user, it is reflective of approximate requirements for most major users of 3LPP coatings worldwide

Figure 9. Subsea simulation testing.

Figure 10. Offshore laybarge stinger.

similar 'factory grade' options exist for 3LPE coated pipelines and have been implemented successfully on many key projects.

Installation methods and automation

As it relates to application methods, the goal should always be to maximise process control and uniformity under the given practical conditions.

For 'factory grade' field-applied solutions, abrasive blasting, induction heating should be considered a given and are required by each of the suppliers/applicators of these systems to ensure a properly prepared and cleaned surface to which the coating will adhere and a uniform and consistent heat profile on each and every joint. Full consideration should also always be given to the ability of the chosen factory-applied coating to withstand the installation temperatures that will be associated with field joint coating later in the process.

If possible, automated installation of the coating system should be used in order to fully maximise process control and to replicate factory conditions and parameters as closely as possible. A variety of effective systems exist in the market and other innovative solutions continue to be introduced. A key in the determination as to whether full automation is possible, and to the selection of a specific type of technology is the consideration of practicality and whether or not conditions can be suitably controlled for the technology in question. Examples of such considerations include: offshore space limitations, desired lay rate, onshore terrain and climate/weather elements such as blowing desert sand, rain, moisture, snow, wind, etc. In many cases, equipment has been designed to control for most such elements, again, the key is early planning and consideration.

Simulating service conditions

As mentioned, standards are not completely definitive so there are other considerations that an end user must consider when considering and specifying field joint coatings.

For example, for offshore pipelines the operating parameters such as temperature, water depth and pressures, seawater effects, lay method, etc. need to be considered when selecting the optimum coating and application method. For onshore pipelines, soil type and stress exerted on the pipeline, backfill methods, thermal cycling and ambient environment can also be very important. The required design life is also another important consideration that can affect the coating required.

Where possible, full simulation of operating conditions should be considered. Onshore, examples of such simulation testing include: soil stress and thermo-cycling testing to assess long-term performance. Offshore, examples include: simulating pressure vessel and pipe heating testing to simulate the subsea and operating conditions that will be seen by the pipeline. Or, in the case of pipe that will be installed using the reel-lay method, full-scale bend testing, can provide valuable insight into the suitability of specific factory-applied and field-applied coatings.

Summary

In summary, although in many cases, standardisation is absolutely required and can help to better execute projects with more consistently implemented procedures and steps, if used blindly or without proper expertise and understanding, many standards can lead to diluted project specifications. Canusa-CPS and ShawCor have seen many such examples in recent years, where project specifications are simply and blindly referencing test standards, without consideration or understanding of what is needed for the pipeline in question.

Those responsible for designing pipelines and the coatings that will be used to protect them, must be aware of the actual requirements for the pipeline and when developing specifications for joint coatings, should consider the factory coating that has been selected and why that coating was selected. In all cases, the ultimate goal should be for the joint coating to match the performance and design of the given factory-applied coating and to have full compatibility with that coating to minimise risk.

If the objectives and requirements for coating performance are clearly set with an end-to-end vision in mind and installation parameters are properly controlled with appropriate upfront planning, the company's experience on hundreds of pipeline projects that have been executed in this manner demonstrates that the result will be a field joint coating that is an integral and strong part of the continuous corrosion protection system.