For the best protection against corrosion:

The key questions and answers on pipeline coatings

Expectations are high: Long-lasting corrosion protection, easy installation and compliance with high standards. Pipeline coatings and restorations must satisfy the highest EN and ISO standards to guarantee lasting protection.

The right choice, the specific conditions as well as the professional application of the coatings are absolutely essential. Subsequent, further damage due to failure with additional renovations are time-consuming and, above all, expensive. And yet, the requirements of the applicable standards and the integrity of the pipeline can be ensured for decades.

Our corrosion protection experts Michael Schad and Luc Perrad discuss the current developments and important prerequisites for a long pipeline life in an interview with World Pipelines (04/2020).

COATINGS Q & A

World Pipelines asked several companies to answer some questions in relation to coatings.

MICHAEL SCHAD, Director of Sales, International
LUC PERRAD, Area Sales Manager, DENSO Group Germany

Michael joined DENSO Group Germany in 1984, after finishing his studies at the universities of Freiburg and Tübingen. Through all his years of service with DENSO in different positions, his work has always been closely associated with product development and support for customers' needs on sites across the world. Michael is co-ordinator of the German International Pipeline Forum (GIPF), an association of German pipeline companies operating worldwide. He is a member of NACE and part of the advisory committee and chair of the Coating sessions at the Pipeline Technology Conference (PTC) in Berlin.

Luc has a Masters Degree in Civil Engineering, with a specialisation in Electronics and Mechanics. Luc has over 12 years of experience in sales and marketing of field-applied pipeline coatings in Western Europe, Africa, Asia and the Middle East. His functional experience includes marketing, strategy appraisal, due diligence, and business management in sales of cold-applied PE-butyl rubber tapes, heat shrinkable sleeves, liquid epoxy coatings, visco-elastic tapes and petrolatum tapes. Luc has been certified as a NACE Coating Inspector Level 2 since February 2014.

BOB BUCHANAN, Marketing Consultant, Seal For Life Industries

Bob has over 35 years of international sales, marketing, product management, and technical experience in the energy and construction products industries. He has been involved in ISO, NACE, AWWA and CSA technical activities and has written many articles and presented technical papers relating to pipeline corrosion prevention.

SCOTT AVERY, QC Supervisor and NACE CIP Level 1 Inspector L.B. Foster

Scott earned a Bachelor of Science in Business Management from Troy University, and has been working in oil and gas industry for more than 30 years. Prior to joining L.B. Foster in 2017, Scott worked in several roles such as Inspection Supervisor, Production Supervisor, QA/QC Co-ordinator and Quality Manager, gaining valuable experience through the years. Scott uses this experience to continuously improve productivity, efficiency and increase higher quality outputs at the Willis, Texas, US, Protective Coatings facility.

COATINGS Q&A

Q How can cutting-edge coatings achieve corrosion resistance?

A MICHAEL SCHAD & LUC PERRAD, DENSO Group Germany

By definition, cutting-edge means that the subject is the latest and newest development in the market. Related to coatings for large oil and gas pipelines, the latest and newest coatings include the following:

- Factory applied coatings: three-layer polyethylene (3LPE); three-layer polypropylene (3LPP); fusion-bond epoxy (FBE).
- Field applied coatings for field joints: three-layer heat shrinkable sleeves; three-ply polyethylene-butyl rubber tapes; liquid coatings (e.g. epoxies or polyurethanes).
- Field applied coatings for rehabilitation: liquid coatings (e.g. epoxies or polyurethanes); three-ply polyethylene-butyl rubber tapes.

In general, each coating has to provide the best possible prevention against corrosion and has to guarantee a high level of mechanical protection to prevent the coating from damage.

For field-applied coatings, the ease of application also needs to be considered, even under severe on-site conditions (ambient temperatures, sand, surface contamination, etc.).

Provided that coating systems meet the highest international standards, the best proof for coating systems is their ability to achieve corrosion resistance through long-term experience. Their performance has been confirmed from the field after decades in operation, with good results regarding adhesion, water and oxygen-resistance, electrical insulation, cathodic disbondment resistance, and mechanical strengths.

A BOB BUCHANAN, Seal For Life Industries

A classic coating that is designed to prevent corrosion on steel pipelines acts as a barrier to corrosion species but must also survive getting out of the box, onto the pipe, and into the ditch ready for service. Corrosion is an electro-chemical process, so by interfering with that process, the coating can achieve its goal. This means preventing electrolytes (water, moisture) or microbes from getting to the steel, by breaking the electrical circuit.

Different manufacturers of coatings take their own approaches, but there is not one that fits all since pipelines have so many variables from the point the project is conceived, to being put into service. A cutting-edge coating therefore must be easy to apply in a plant or in the field, survive the transportation of pipe from the coating plant to right-of-way, be damage free throughout the pipelaying process, and then perform in service under specific conditions.

Other attributes such as the ability to self-heal or be incredibly tough yet ductile, are being seen in some technologies such as visco-elastics, polyurethanes and next-generation epoxies.

A SCOTT AVERY, L.B. Foster

The corrosion cell consists of an anode, a cathode, a metallic pathway, and an electrolyte. All four elements must be present for corrosion to occur. To achieve corrosion resistance, some coatings act as a barrier to the corrosive environment and other coatings sacrifice themselves and corrode instead of the substrate that they are applied to.

Barrier coatings simply slow down the corrosion process by getting between the protected material and the electrolyte (ground, saltwater, etc.). Metals corrode according to the galvanic series – with more easily corroded materials at the top and less corrosive, often referred to as noble, materials at the bottom. When using a sacrificial coating, the coating that is applied is much higher in the galvanic series than the metal that it is chosen to protect and will corrode first or sacrifice itself. In acting as one of these protections, coatings provide corrosion resistance.

DENSO Group Germany: Peeling test of a 40-year old pipe.

Q How does pipeline surface preperation and coatings application determine the success of coatings?

A MICHAEL SCHAD & LUC PERRAD, DENSO Group Germany

This question is related to field-applied coatings where application conditions are not fully controlled.

Surface preparation includes cleanliness (from dust, grease, etc.), surface profile (anchor pattern), and moisture (rain, fog or condensation). Cleanliness and moisture affect adhesion, whilst the surface profile affects cathodic disbondment.

Coatings application conditions depend on the coating type:

- Heat shrinkable sleeves need enough heat, including pre-heat and post-heat, as well as avoiding trapped air under the sleeve.

- Liquid coatings need the correct mixing ratio, proper application thickness, and enough curing between the different passes.
- Three-ply polyethylene-butyl rubber tapes need enough tension and constant overlap, both of which are generally easily secured by a manual or motorised wrapping machine, e.g. DENSOMAT®-11.

The majority of coating failures that occur on-site are not caused by intrinsic failure of material properties, but by improper surface preparation and inappropriate application of the coating. Therefore, the human impact on coating failures must be minimised by developing easy-to-apply and failure-tolerant coatings. A coating system which can be corrected or adjusted during application (also with a machine) is most likely to be successful.

A BOB BUCHANAN, Seal For Life Industries

This is of paramount importance and the reason that highly trained coating inspectors are required in the pipe coating plant and on the ROW. Some coatings, however, are more sensitive to degrees of surface preparation, which is why international standards have various levels identified.

The manufacturer of the coating will be able to identify and specify what level of surface preparation and what application process is required to provide sufficient long-term performance. A good coating on a well-prepared surface is not enough. The coating must also be properly applied, meaning that the process from coating storage, product handling, and pipe surface heating to ultimate application are critical.

A SCOTT AVERY, L.B. Foster

Surface preparation is possibly the most important step taken during the coating process to ensure the success of the coating system. Improper or poor surface preparation can be immediately detrimental to a coating system, or it can be the reason that the coating fails over time. Blast cleanliness and anchor profile are key to the actual surface preparation. They are both performed to a standard

DENSO Group Germany: Efficient application with DENSOMAT®-11.

or criteria that was determined by a corrosion engineer before the work begins.

The type of coating that will be applied and the desired coating thickness are elements in deciding necessary blast cleanliness and anchor profile. Other factors that influence surface preparation are the ambient conditions where the cleaning and coating will take place. Generally speaking, the relative humidity, or the amount of moisture in the air, must be lower than 85%. The dew point in the area is also important. If the surface temperature of the metal to be coated is less than 5°F above the dew point, moisture can form on the surface and will negatively affect coating performance.

L.B. Foster's coatings facility in Texas (US) aims to instill confidence in its customers that surface preparation and the entire coating process will be monitored and performed in accordance with the specifications that are agreed to during the quotation process. Always improving, a large CAPEX plan is in place for the facility for 2020 and beyond, to further aid in superior surface preparation and coating performance.

Q How do coatings influence flow efficiency?

A MICHAEL SCHAD & LUC PERRAD, DENSO Group Germany

Internal coatings (thin layer of liquid epoxy curing by evaporation of solvents) are able to reduce the friction between the internal wall of the pipeline and the transported gas. By using an internal lining of the pipe, flow efficiency can be raised by up to 20%. The internal lining will provide a smooth surface which will decrease turbulences and friction in the pipe significantly.

As a consequence, pressure drops (or losses) along the pipe are also reduced, which can lead to a reduction in the number of compression stations along the pipeline route. The financial benefit from the reduction of compression stations largely compensates for the costs of the internal coating, also called liner coating.

The primary function of liner coatings is to facilitate product (gas) flow, and not really to protect internal pipeline walls against corrosion. This is not the case for the transportation of crude oil, where bacterial attacks can happen inside the pipe and lead to corrosion. This is a phenomenon called microbiological influenced corrosion (MIC).

A BOB BUCHANAN, Seal For Life Industries

First of all, coatings that are designed for flow efficiency should not to be confused with corrosion preventative coatings. Second, a flow efficiency coating could be an internal coating designed to lower the roughness level of the inside of the pipe, or an external insulation coating designed to maintain temperature of the flowing product.

For the inside of a pipe, a flow efficiency coating is typically a very thin, high solids polyurethane or epoxy coating that can reduce the roughness level of the steel and has a smooth surface. If the internal coating is specified for corrosion prevention, then flow efficiency may be a side benefit, although the consideration must include how rough the applied coating ends up and whether it can resist erosion from the flowing media.

For an external insulated coating, there will generally be a corrosion coating applied first, followed by insulation and some sort of mechanical jacket. The approach for onshore pipelines will be very different from offshore pipelines.

A **SCOTT AVERY, L.B. Foster**

Internal liners and coatings can greatly reduce friction and therefore improve flow efficiency, by filling in and overcoating surface irregularities. L.B. Foster's facility can offer high quality, fast-turnaround internal flow efficiency coatings.

Q Detail some recent, innovative advancements being made in the pipeline coatings industry

A **MICHAEL SCHAD & LUC PERRAD, DENSO Group Germany**

Surface preparation is critical to ensure a coating's performance (mainly adhesion). Protecting the steel surface on the field from moisture can be easily achieved by using adequate enclosures.

However, removing the moisture coming from the condensation of air humidity (substrate temperature below dew point) is much more difficult, and can be very expensive. This typically happens on pipelines in operation when the temperature of the transported product is low. Many pipeline operators do not want to reduce or stop the transported product flow during coating application (loss of profit). They are also not ready to pay for completely sealing the jobsite in conditioned air.

The most efficient alternative is to consider a coating system which can be applied on wet surfaces while guaranteeing the level of performance requested to protect the substrate against corrosion. This type of coating has been recently developed by combining the application of two tapes: a petrolatum-tape and a polyethylene-butyl rubber tape, which strongly bond to each other and therefore show a cohesive failure during peel-test. Unlike epoxy coatings designed for wet surfaces, this new system does not need a grit blasting cleaning according to SA 2.5.

Seal For Life Industries: Pipeline CAT coating.

Seal For Life Industries: Pipeline CAT rehabilitation.

A **BOB BUCHANAN, Seal For Life Industries**

Polyurethane coatings formulated from renewable feedstocks are taking the term 'green coatings' to a whole new level. Not only do the polyurethanes not contain any VOCs or solvents, rendering them 100% solids, they are also formulated using high levels of crop-based raw materials, which mitigates the dependency on oil and gas based raw materials. These coatings actually qualify under the USDA BioPreferred programme. Polyurethane coatings and linings offer the benefits of fast cure and handling times, allowing for high productivity levels for the coating applicators, while at the same time providing the requisite corrosion and durability properties in a thin coating system – no protective topcoat is required.

Visco-elastic coating systems have been developed and approved for repair and rehabilitation of coatings that protect pipelines from the phenomenon commonly known as corrosion under insulation (CUI). Such pipelines are exposed to conditions that are often far more aggressive than normally encountered with buried or submerged pipelines, and therefore the minimum requirements and acceptance criteria for such coatings are far more stringent.

Q Which international and national standards are important?

A MICHAEL SCHAD & LUC PERRAD, DENSO Group Germany

The answer is mainly dependent on the geographic location of the pipeline operators. In Europe, Africa, the Middle East and western parts of Asia, international standards from EN and ISO organisations are mainly used. For coatings, the most relevant international standards are ISO 21809-3 for field joint coatings and ISO 21809-1/2 for mill coating of pipes. The European Standard EN 12068 is still renowned and very popular for field joints executed with tapes or heat shrinkable sleeves because this standard considers the practical aspects of different stress loads on-site. In general, standards should all be stress-related and load case dependent, instead of a material-based selection only.

In North America, NACE standards for oil and gas pipelines and AWWA standards for water pipelines are the most important. In Russia and the former CIS countries, the GOST standards are the dominant ones. Overall, national standards are considered less and less.

A BOB BUCHANAN, Seal For Life Industries

Certainly, the ISO 21809 series of standards are comprehensive, cover a wide range of coating technologies, and have their roots in DIN and EN standards amongst others. This is why some national standardisation bodies have chosen to adopt those standards or are looking at ways to adopt them. The challenge with any standard is that, by being consensus standards, there are typically many people with their own interests at heart and the standards become the lowest common denominator.

There are obviously unique national standards that are widely recognised. From Canada, CSA Z662 and the coatings under the CSA Z 245 series are internationally recognised for fusion-bonded epoxy, multi-layer polyethylene, and field-applied coatings. The uniqueness in these standards is that they do not only cover coating performance but also put emphasis on application and, with the field-applied, put heavy emphasis on applicator qualification. There are many other national standards that have international following such as NACE and API in the US.

A SCOTT AVERY, L.B. Foster

ASTM, ISO, NACE, SSPC, and many other organisations publish standards that are globally accepted as instructions on how to perform operations, inspections and other tasks. While they are all important, to say that one is more important than the others would be incorrect. Standards are called out in specifications so that the individual writing the specification can be confident that a certain task or inspection will be carried out in a way that is consistent with the standard that is referenced. It also ensures that the contractor has a clear understanding about what the expected outcome is for that step in the specification. Therefore, a specific standard, regarding a coating project, is only important if it is referenced in the specification that has been agreed for that project.

Q How do you overcome coatings failures?

A MICHAEL SCHAD & LUC PERRAD, DENSO Group Germany

It is well-known and recognised in the pipeline coating industry that the majority of coating failures are the result of bad coating application conditions. Those conditions are generally related to surface preparation, weather conditions, condensation, salt contamination, and the application not being in line with the manufacturer's recommendations.

Another reason for coating failure is due to the wrong coating selection. Parameters like pipeline operating temperatures, pipe diameter, backfill materials, and mechanical impacts are critical in the selection of an appropriate coating system.

The best way to overcome coating failures is to consider all the parameters indicated above.

A BOB BUCHANAN, Seal For Life Industries

The elements required for a successful coating job start with proper specification. A good coating applied well can fail if it is in a service condition that it is not designed for. This might be a function of temperature, immersion

L.B. Foster: L.B. Foster Protective Coatings Willis, Texas facility is designed to provide versatility, speed, quality and experience to custom coating applications.

conditions, soil movement, etc. Therefore, the specifying engineer must be in tune with available coating technologies and their respective performance attributes.

Selection of an adequate type of coating for specific service conditions is of paramount importance. Therefore, specifying appropriate qualification tests and acceptance criteria plays an important role; for instance, the results of accelerated ageing tests may help in the coating selection process. Such tests should not only be conducted under laboratory conditions, but should also be conducted by the coating applicator under conditions that simulate practical situations, with the aim of demonstrating that the application procedure, and inspection and test protocol, are adequate for the applicator to produce coatings that comply with the specifications.

Once the suitable coating or coating technology is chosen, then it is a matter of making sure that it is applied correctly in the plant or field, with surface preparation being a primary consideration. The next step is to get the pipe transported and handled properly to get it laid and buried without damage.

The final element is service condition, since that may change over time. If the pipeline operator decides to make a change in the product that will flow through the line or the pipeline is operated beyond design conditions, such as a drastic change in operating temperature or pressure, then that will likely affect performance.

A SCOTT AVERY, L.B. Foster

As noted earlier, surface preparation is possibly the most important step taken during the coating process to ensure the success of the coating system. Coating application parameters and procedures follow in a close second to surface preparation. With this in mind, the employees at L.B. Foster's facility are always trying to improve these processes. Putting clear standard operating procedures, work instructions, quality forms, and training in place can ensure that each project goes through the facility with the highest quality outcome. Frequent quality checks are performed and documented throughout the entire process for each piece that is coated. L.B. Foster also performs destructive testing in the company's on-site laboratory, using test specimens cut from a test ring which is cut from one of the production pieces. These tests offer more certainty that the coating that the company applied will perform as expected and without failure in the field.

Q How and why do you carry out pipeline coating rehabilitation?

A MICHAEL SCHAD & LUC PERRAD, DENSO Group Germany

Pipeline coating rehabilitation is necessary and should be considered when the existing coating compromises the integrity of the pipeline.

There is no recognised rule or standard for defining coating conditions which might jeopardise the integrity of the pipeline. Each operator takes full responsibility for deciding whether or not to rehabilitate the coating.

This decision is influenced by economic and environmental factors – coating rehabilitation for a water pipeline is not based on the same criteria as for a high-pressure transportation gas pipeline.

The major steps for pipeline coating rehabilitation include: pipeline section excavation; existing coating removal; surface preparation – surface profile and cleaning (dust, grease, salt); new coating application and curing; new coating inspection and eventual repair; and backfilling.

Pipeline rehabilitation is necessary when the mill coating gets weak or brittles after 30 - 35 years in service. In particular, coal tar and bitumen coatings show a tendency to brittle and must be rehabilitated. After the old mill coating is removed by grit blasting or water jetting, the new coating can be applied in the field.

Preferably self-amalgamating three-ply polyethylene-butyl rubber tapes are used for this purpose, or liquid coatings based on epoxy or polyurethane. For the self-amalgamating tapes, there are proven track records available dating back for more than 40 years in service. These pipe sections have been excavated and tested in laboratories and showed excellent results after this long service period. Even after more than 40 years they exceed the requirements of the current guidelines, ISO 21809-3 and EN 12068 class C50.

A BOB BUCHANAN, Seal For Life Industries

The 'Why' is to extend the service life of a pipeline or replace a coating that has prematurely failed. The 'How' is the tricky, and potentially expensive part, and must consider the 'Why'. In different regions around the world, asset owners or specifiers will have their preferences based on why the existing coating is no longer useful, the types of existing coatings, regional soil or service conditions and experiences.

Much like a new build pipeline, it starts with specification of what the new coating will be. It is important to choose a technology that can be efficiently applied under regional environmental conditions and which will perform in service. This may mean that, on the same overall project, different coating types could be specified based on service conditions, microclimates, soil conditions or available workforce.

It should be noted that with application of coatings in the field, the control of surface preparation is often far more complicated than with coatings applied in the factory – ISO 21809-11 has more information. Complicating issues are accessibility of the pipeline; transportation of equipment to often remote places; environmental restrictions (use of hazardous materials and collection of waste); surface temperature (especially with live pipelines); ambient temperature (curing conditions); humidity; salt residues, and more.

Q Discuss the current limitations of coatings technology

A MICHAEL SCHAD & LUC PERRAD, DENSO Group Germany

The ultimate coating system should be armed as a universal solution for all applications against all influencing factors – it should also be easy to apply, and at the same time exclude or at least significantly reduce the human error component. But is this even possible? So far at least, it is not because a wide variety of influencing factors require correspondingly co-ordinated material properties. The ideal property of a product for one requirement may not be ideally suited for another requirement or another application.

A coating's ageing or behaviour over time is also an important limitation for all coating systems. Even if the coating shows excellent performance in its youth, it might weaken after a number of years. It is therefore important to choose the right coating which does not only promise to last but provides the respective proven track record in the field for decades.

The selection of the right coating should be undertaken according to stressable, objective data to evaluate the best system for the specific demands on-site. Instead of focusing on (raw) material properties of the coating system, the expected loads such as temperature, corrosion, mechanical impact, onshore/offshore, etc. should determine the choice of the right coating system. These criteria should be surveyed by independent third parties. In addition, the applicators need regular training to freshen up on the newest application skills.

A chain is only as strong as its weakest link – this is also valid for the coating of a pipeline. The lifespan of a pipeline depends largely on the choice of the right field joint coating. For any new build pipeline, the field joint coating only makes up a fraction of the total costs. Even in a rehabilitation of an existing pipeline the costs are significantly lower than building a new pipeline – especially considering the fact that the pipeline can still be in operation during rehabilitation works.

If the price of the field joint coating is pushed so far that only cheap and poor quality is used, the weak link of the chain becomes even more weakened.

A BOB BUCHANAN, Seal For Life Industries

Every coating technology has limitations, which is why there are so many coating technologies available. One key challenge that is often overlooked is where the pipe comes from and who is applying the coating. If the coated pipe must travel a long way, and be handled multiple times during transportation, significant coating damage may occur. In that case, a thinner coating is more susceptible.

Another limitation is cost, or at least perceived cost. High performance, multi-layer coatings will cost more than a thin single layer coating but, in reality, the total installed cost difference on a project that must perform for many years is negligible.

In addition to this, a 'cheap' coating may prematurely fail and lead to high costs for maintenance and repair. Therefore, this should also be considered when estimating the total cost of ownership from a coating perspective.

Limitations must be considered separately for mainline and field-applied coatings. The challenges for field-applied coatings are significant, so limitations are a factor of security, available workforce, installation equipment, surface preparation, and environment, amongst others. The attributes of high performance coatings may be balanced by the fact that they are more challenging to apply. In that case, an alternate technology that is easier to apply with lower equipment and surface preparation requirements may be preferred.

A SCOTT AVERY, L.B. Foster

One of the main current limitations of coating technology is coating life. While protecting the substrate to which they are applied, the protective coatings are also wearing away. The service environment that the coating is placed in is usually the largest factor in the rate of degradation, with the more severe environments degrading the coating more aggressively than when in a less severe environment. Coating manufacturers are in constant pursuit of developing coatings with longer service life. Cost, application methods and environmental impact can all influence these developments.

L.B. Foster: The Texas facility can coat 1/4 in. up to 74 in. pipe, as well as induction bends, forged fittings, tees, pups and spool pieces, all on one site with numerous coating options.

L.B. Foster: The company's variety of coating solutions includes FBE, Specialty Polymer Coatings, Denso Protal, and Seal for Life Powercrete.