ADVANCEMENTS IN ANTI-CORROSIVE LIQUID POLYURETHANE COATINGS

Mr. Rainer Kuprion
Diplom-Kaufmann (Business Administration)
Director Business Unit Coating Systems

Mrs. Maja Hornig
Diplom-Kauffrau (Business Administration),
NACE Coating Inspector Level 2 - Certified
Key Account Manager International

TIB Chemicals AG
- Business Unit Coating Systems -
Muelheimer Strasse 16-22
68219 Mannheim/Germany

Abstract

Each year more and more pipelines are being constructed for the supply and transmission of gas and oil and, in addition, many existing pipelines are approaching an age where inspection reveals the necessity to consider complete refurbishment. Protective coating systems hereby are one of the major defence mechanisms against corrosion on buried transmission pipelines and pipes within a refinery or a petrochemical processing facility.

A crucial point to be considered profoundly for each job is the treatment of the welded field joints. Application discontinuities between shop and field applied coatings have to be very much avoided as these may be one of the most delicate points in any coating project potentially leading to premature failure. In this affair, liquid polyurethane coatings during the past years have gained their market share.

The authors demonstrate the advantages of easy-to-apply liquid polyurethane permitting to optimize application and obtaining a better result and consequently enhanced life time of the pipe.

Résumé

Chaque année de plus en plus de pipelines sont construits pour l'approvisionnement et le transport de gaz et de pétrole et, de plus, beaucoup de pipelines existants s'approchent d'un âge où l'inspection révèle la nécessité de reconsidérer une éventuelle réhabilitation complète. Les systèmes de revêtement protecteurs sont un des mécanismes de défense des plus importants contre la corrosion des pipelines enterrés et des tuyaux dans une raffinerie ou une usine de traitement pétrochimique.

Un point important à considérer dans chaque projet est le traitement des joints de soudure in-situ. Les discontinuités d'application entre les revêtements appliqués en usine et ceux sur chantier doivent être traités comme un des points les plus délicats des projets de revêtement du fait d'être, potentiellement, responsable des défaillances précoces. Dans cette affaire, les revêtements de polyuréthane liquide ont gagné leur part de marché ces dernières années.

Les auteurs pointent les avantages du polyuréthane liquide et sa facilité d'application qui permettent d'obtenir un meilleur résultat de longévité des pipelines.

Zusammenfassung

Von Jahr zu Jahr steigt die Anzahl der neu in Betrieb genommenen Gas- und Öl-Leitungen. Zusätzlich nähern sich viele bestehende Rohrleitungen einem Alter, in dem Inspektion die Notwendigkeit offenbart, eine Komplettsanierung in Betracht zu ziehen. Die Beschichtung ist einer der Hauptmechanismen zum Schutz gegen Korrosion von Pipelines und Leitungen innerhalb einer Raffinerie oder einer petrochemischen Anlage.

Ein entscheidender und in jedem Projekt eingehend zu betrachtender Faktor ist die Behandlung der Schweißnähte im Feld. Applikationsunterschiede zwischen Fabrik- und Feldbeschichtung müssen als einer der schwierigsten Punkte in jedem Beschichtungs-Projekt behandelt werden, da sie möglicherweise zu vorzeitigem Ver-

sagen führen können. In diesem Zusammenhang ist in den letzten Jahren eine stetige Zunahme des Marktanteils der flüssigen Polyurethan-Beschichtungen zu beobachten.

Die Autoren zeigen die Vorteile eines flüssigen Polyurethans und seiner guten Applizierbarkeit auf. Durch den Einsatz des Materials können ein besseres Ergebnis und somit eine längere Lebenszeit der Rohrleitung erreicht werden.

Key words

MCL, multi component liquid polyurethanes, rigid polyurethanes, 100% solids, single layer, fast-curing, field joint coating, pipelines, rehabilitation, refurbishment, girth welds, 1:1 mixing ratio, ISO 21809-3:2008, DIN EN 10290, PROTEGOL®

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Mr. Rainer Kuprion[1] & Mrs. Maja Hornig[2]

TIB Chemicals AG
Business Unit Coating Systems
Muelheimer Strasse 16-22
68219 Mannheim/Germany

Advancements in Anti-corrosive Liquid Polyurethane Coatings

1. Today's Pipelines

Each year more and more pipelines are being constructed for the supply and transmission of gas, oil and water and, in addition, many existing pipelines around the world are approaching an age where inspection reveals the necessity to consider complete refurbishment.

If the pipeline is known to have external corrosion, then safe and economic operation should be assured. Rehabilitation should be done before it is too late in order to ensure its future integrity and operational life. Rehabilitation of pipelines has been both the economic solution and, more significantly, the ecological solution and in many of those cases the coating selected for the external protection has been multi component liquids based on 100% solids polyurethanes.

Without doubt, the conclusion in respect to the estimated economic appreciation and problems derived from the corrosion within the pipeline sector (mainly water, gas and oil) is of enormous preoccupation

Therefore, a permanently updated technological knowledge on the best possible coatings, with or without cathodic protection (CP), has to be one of the fundamental occupations and preoccupations of specification-developing engineers, of contractors, applicators and particularly of the final clients as protective coating systems are one of the major defence mechanisms against corrosion on buried transmission pipelines and pipes.

2. Challenges for Pipe Coatings

The pipeline sector since many years is in need of an efficient corrosion protection system with excellent properties concerning application, efficiency and capacity to support corrosive environment and including the ability to rehabilitate seriously damaged pipes directly in the field.

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[1] Director Business Unit Coating Systems, E-Mail: rainer.kuprion@tib-chemicals.com
[2] Key Account Manager International, Business Line Corrosion Protection, NACE Coating Inspector Level 2 – Certified, E-Mail: maja.hornig@tib-chemicals.com

In order to accomplish all these challenges, a coating system has to be in a position to comply with five fundamental challenges which are highly recognized in the sector:

- Respect all legislation according to safety, security and the environment
- Provide cost-effectiveness
- Be suitable for application in the field
- Offer effectiveness in its intrinsic purpose of corrosion protection
- Feature high efficiency in durability terms

The core properties of these coating systems are documented in NACE SP0169-2007 “Control of External Corrosion on Underground or Submerged Metallic Piping Systems” and RP0285-2002 “Corrosion Control of Underground Storage Tank Systems by Cathodic Protection”.

In the continuing some of the most outstanding will be cited, not without insisting in the fact that the responsible specification-writing engineers have to break with the preservative “that’s the way we have always done it”, as technological evolution is directly related to the best protection of our assets, and on the other side these technical decisions do have a fundamental consideration in the invest these sort of projects assume.

3. Generic Types of Pipe Coating Systems

In order to identify the best, for a specific project most suitable, coating material, a close evaluation of available technologies has to be conducted. The following table 1 lists some of the mayor systems comparing core properties, advantages and disadvantages.

System	HDPE	FBE	100% solids epoxies	HSS	100% solids PU
Average coating dft	4,000µm	400µm	700µm	2,600µm	1,000µm
Layers	Multiple	1	1	Multiple	1
Water vapour permeability ASTM D1653	0.5g/m²/24hrs	7.5g/m²/24hrs	3.8g/m²/24hrs	0.2g/m²/24hrs	12g/m²/24hrs
Mechanical properties to resist damage during handling, etc	Fair	Poor	Poor	Fair	Good
Adhesion to steel ASTM D4541	n/a	11.4MPa	12.7MPa	n/a	13.8MPa
Impact resistance ASTM G14	20 J	6.J	3.J	10 J	10 J
Flexibility ASTM D522 (1’’ mandrel)	Pass at 180°	Fail at 180°	Fail at 180°	Pass at 180°	Pass at 180°
Elongation ASTM D638	300%	4.8%	2.8%	400%	8%
Cathodic disbonding CSA245.20M (-3.5V, 48hrs)	n/a	8.0mm radius	6.0mm radius	<8.0mm radius (ASTM G8)	4.0mm radius
Dielectric strength ASTM D149	56kV@ 3,175µm, 17.7V/µm	20.7kV@ 457µm, 45.3V/µm	7.1kV@ 659µm, 10.3V/µm	35kV@ 1,000µm, 25V/µm	22.4kV@ 1,016µm, 22.4V/µm
Reparation with itself	No, only glue sticks	2-part epoxy/ hot melt sticks	Yes	No, shrink patches	Yes

Pre-heating required	Yes	Yes	No	Yes	Usually not
Priming required	Yes, FBE primer	No	No	Yes, epoxy primer	No
Solvent-containing	No	No	No	No	No
Application	Extrusion	Flocking gun, electrostatic spray	Airless/air-assisted spray, brush, trowel	Wrapping and heat to shrink	Airless/air-assisted spray, brush, trowel
Fit for field application	No	No	Yes	Yes	Yes
Hardness ASTM D2240 (24℃)	60 Shore D	85 Shore D	82 Shore D	65 Shore D	72 Shore D
Abrasion resistance ASTM D4060, CS17, 1kg, 1,000 cycles	n/a	120mg loss	135mg loss	n/a	50mg loss
Soil stress resistance	Fair	Fair	Good	Poor	Very good

Table 1. Characteristics of pipeline coatings

The specific requirements of each project not only depend on methods of installation but also on operating and environmental conditions. An exhaustive specification of a project must thereby not limit to the mainline, whether coated in shop or in the field, but also give clear advice for difficult environmental approaches such as road or river crossings, and for special parts as welded field joints and valves, elbows and fittings, as requirements may vary substantially for these sections of the scope of work. It must give clear advice not only on preparation and application but also on inspection of all components of the job. It cannot be overemphasized that the entire project can only be a good as its weakest point which typically are the connections and that a perfect treatment of the main line cannot correct a poor treatment of the joints or other complicated pieces.

As the coating material costs of a project do hardly reach more than 0.04% of the overall cost of the project, it would be an even bigger fault to disregard this imperative point to select a high quality corrosion prevention system for each and every of the parts. The coating selection process therefore should include a Procedure Qualification Trial (PQT) including the job personnel and equipment, possibly at the contractor's site and the verification in the field at start-up of the project through a Pre-Production Trial (PPT). Tests could, according to the specification, include such as pull-off acc. to ASTM D4541, cross cut (ASTM D 4542), abrasion (e.g. ASTM D4060) and thermal aging tests (ASTM D3045), some have been indicated in table 1.

Having seen the core properties of certain coating systems, it is true that each and every system has its pro and cons and each one has its imperfections. That is why decisions can still vary according to project requirements. Nevertheless, some critical arguments have to be alluded referring to generic types of coating systems.

This is the case for the application of fusion bonded epoxy (FBE) powder as, for preheating up to 240℃, an energy-intense induction coil must be employed. Its necessity to be symmetrically-balanced makes its employment difficult for larger diameters, especially in the field, as the failure factor increases substantially. Variations in substrate heating can cause unequal application of the FBE, from foaming in overheated to undercure in low-heated areas. Especially in thin wall pipes it can come to blistering due to an excessive heating process (275℃ should not be exceeded), but a lower heating temperature on the other hand might decrease protec-

tive properties of the field joint coating. FBE is usually applied in stationary coating facilities.

Similarly, heat shrink sleeves (HSS) do cause the more problems the bigger the diameter is. The again upcoming problem of homogeneous heating on the whole sleeve can once again be eased by the employment of energy and cost intense induction heat instead of a manual gas flame, however therewith jeopardizing the possible initial cost advantage of the application of HSS. The manual gas flame treatment is even more susceptible to uneven heat allocation. Overheating though could result not only in destroying the sleeve itself but also the overlapping zone's subjacent parent coating, leading to huge imperfections in the anti-corrosive protection.

With HSS under the influence of soil stress it may additionally, even employing before mentioned induction heat, come to wrinkling and accelerated and elevated numbers of disbonding causing active corrosion cells and hence much accelerated corrosion rates. HSS are very sensitive to soil stress and disbonding spots difficult to repair. Heat shrink patches may be classified as a fault-prone repair method once more often causing failure due to adhesion problems. Consequently the whole sleeve for security reasons better has to be ripped off and replaced. This intense process might once again overcome the presumably economic use of HSS.

The same problem of vulnerability concerning soil stress affects multi-layer tape systems as can be seen in picture 1 illustrating wrinkling. Therefore, tapes must be employed with an overlapping of 50% and under severe construction or soil conditions the possibility of complete overwrapping might be considered.

Picture 1. Wrinkling of multi-layer tape system

The performance properties or the general nature of epoxy coating systems show their limitation in long reaction time to cure and elongated cure periods between coats. A higher coating thickness can only be achieved in multiple passes after certain waiting periods. These factors result in increased application costs and therefore a less economic process, especially under consideration of cold ambient temperatures. That is why epoxy coatings sometimes are not considered for rehabilitation projects.

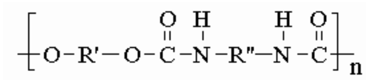
Polyurethanes, the last system to be analysed here, show the difficulty of proper mixing ratios which nevertheless can easily be overcome by the employment of modern variable automatic mixing equipment working with common airless machines, manufactured for example by Graco/USA or WIWA/Germany. It has to be stressed that the widely used method of visual judgement (trivialized also as glug-glug method) has to be avoided as it undoubtedly increases mismeasurement and subsequent curing or blistering inconveniences.

One might also raise concerns over the difficulties in overlapping zones to 3-Layer PE/PP line pipe coating. In order to overcome this adversity, the factory coating is required to be sweep blasted and treated as basically every other substrate, meaning freedom from dust, debris and other contaminating material or chemical agent. This should not mean a problem as all cleaning equipment is already in place in order to pre-treat the complete field joint area. Additionally, and in order to obtain a better adhesion result, a flame treatment of the parent coat can be recommended.

4. Polyurethanes: Properties and Advantages

Polyurethanes, first developed in the late 1930s by Dr. Otto Bayer and his team and widely used in the industry since more than 50 years, are made by reacting diisocyanates (MDI and/or TDI) with a range of polyols. Isocyanates are esters of isocyanic acid (HNCO) and are by polyaddition amongst others used to produce detergents, bleaching agents, pharmaceutics and colorants. In the past, the coating industry due to missing or wrong information had the impression that PU coating systems were not as secure as epoxy based systems due to the toxic nature of its resins. Actually, completely cured polyurethanes no longer containing monomers usually do not possess any harmful properties. According to extensive research, they have been classified as secure and inert.

Picture 2 illustrates the generic chemical structure of polyurethanes. The linking occurs through the reaction of an isocyanate group (-N=C=O) of a molecule with a hydroxyl group (-OH) of another molecule, under formation of a urethane group (-NH-CO-O-).



Picture 2. Generic structure of polyurethane

The chemical formulations of polyurethanes, depending on the end product may contain catalysts, surfactants, blowing agents and fire retardants. By these means a range of product types can be made – rigid and flexible foams, rigid and flexible integral skin foams, elastomers, adhesives, sealants and finally the coatings treated herein.

The various polyurethane chemicals are used in a range of continuous or discontinuous processes and often combined with other materials to manufacture, for example, insulated building panels, mattresses, car seats, domestic refrigerators, truck bodies, footwear and coatings. Although there are many different types of PU available the following refers to two-component 100% solids PU cured with polyols and applied on pipes.

There are many reasons why 100% solids polyurethane coatings have provoked the attention of the pipe manufacturing industry and the final clients. Three of them will be mentioned in present work.

First of all, latest 100% solids polyurethanes have excellent attributes regarding handling and safety. They are much more secure and less harmful for the environment than traditional anticorrosive coatings and do no longer contain VOC, styrene, amine, coal tar or other carcinogenic agents. These mostly have been replaced, e.g. coal tar by long-chain polyols. This use of new raw materials can result in the employment of modern PU coatings even in potable water projects, one of the most regulated environments. 100% solids, i.e. 0% VOC, implicates they do not con-

tain any solvent to dissolve, carry or reduce the coating base. Such polyurethane systems are forming a durable protective coating film on the steel substrate.

Second, the MCL (multi-component liquids) polyurethane is the preferred system due to the advantage of being a single-layer system, not requiring primer, and no other products involved within, which eliminates the risk of interlayer failure. Most of the polyurethane-based coatings used in the pipeline industry are available as two-component products. They build a homogeneous coat ensuring there is no threat of incorrect overlapping or tension on bended areas, as observed when employing tapes. As it can be overcoated with itself or its repair material, this homogeneous coat is also maintained in case of repair of imperfections or mechanical damages,

Last, 100% solids PU has no need neither for pre-heating of the pipe as for other systems which require induction heaters, a cost-intensive and time-consuming treatment, or for post-heating, where excess temperature can destroy the protective system and too low temperatures result in adhesion failure. PU does not need external surface heating and can be applied in the desired film thickness, on pipes of all diameters and length and pieces of which geometry ever.

5. Employment of Polyurethanes in the Field

In most cases, pipes are joined in the field by welding. The challenge for the pipeline owners and constructors is to find the adequate protective coating system, which is fit for application in the field, by means to reduce the risk of failures resulting in corrosion. It shall be mentioned, that in practice for all coating systems the application circumstances are not ideal, therefore a solution must be found to reduce the sensitivity.

As basic guidance for works with PU as pipe coating, there are different norms on the requirements. The first widely referential one, DIN EN 10290:2002 “Steels tubes and fittings for onshore and offshore pipelines – External liquid applied polyurethane and polyurethane-modified coatings” refers to the overall line, the second, more recent one, ISO 21809-3:2008 “Petroleum and natural gas industries - External coatings for buried or submerged pipelines used in pipeline transportation systems - Part 3: Field joint coatings” essentially deals with field joints.

For works in the field, short cycle times and a reduced need of workmanship are essential. Furthermore, good tolerance to the backfill process including impact and damage through rough environment has to be kept in mind. Especially when conducting rehabilitation works, high alternative costs emerge for the time the installations are not in service, in short “time is money”.

Polyurethanes due to their properties are the perfect option for the application both in shop and in field. In the following, field application will closely be regarded as this is where they can best develop their advantages.

100% solids PU can meet time pressure exigencies through its short curing and reaction time, beginning immediately after mixing. Some PU systems provide a touch-dryness time of less than 5 minutes and a time to backfill, only of course after successful inspection, of less than one hour. Even in cold climates this benefit can be maintained outpacing for example epoxies which cure very poorly under these conditions. Fast-curing properties of PU also permit a film thickness of more than 1.5 mm achievable in one single operation. Virtually unlimited DFT is attainable with no need to respect elongated waiting periods.

The required mechanical properties of a pipe coating include:

- Resistance to impact and abrasion during handling and construction
- Resistance to impact/damage from stones and crushed rock during backfilling
- Long term resistance to penetration and creep

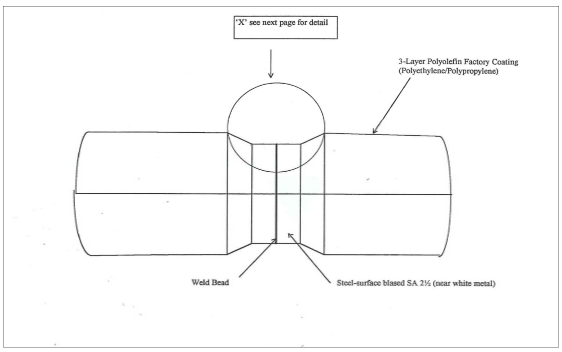
High built thickness creates very good indentation resistance as well as better tolerance to scratches and impact caused by rocks or other material when handling or backfilling the trench. It also constitutes its ability to horizontal directional drilling (HDD) works, e.g. for road or river crossings, being demonstrated as well in its positive abrasion resistance values as indicated before (table 1) and its advantageous flexibility characteristics. These have been some of the reasons why MCL, namely PROTEGOL® UR Coating, has been used on field joints in Northern German Bunde-Etzel-Pipeline (BEP) project, where one of the critical points has been the under-crossing of the river Ems.

6. Surface Preparation of Field Joints

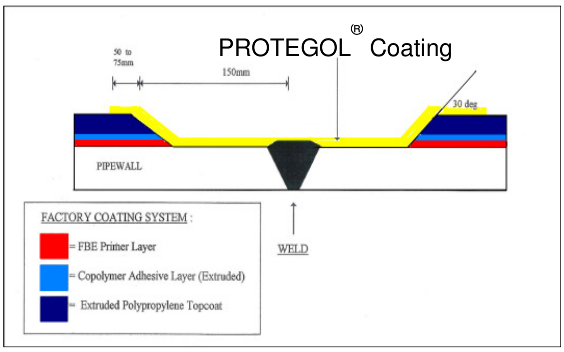
The treatment of the field joints is of extraordinary importance in every coating project. This is reflected, as mentioned before, in the development of the according norm ISO 21809-3:2008 "Petroleum and natural gas industries - External coatings for buried or submerged pipelines used in pipeline transportation systems - Part 3: Field joint coatings". Ideally and advantageously, the field joint coating has to be a continuation of the line coating without any discontinuities discernible between the morphology of the shop coating and the field-joint coating, in order to neither permit interruptions in the system's operation, nor lagging with existing cathodic protection (CP) that would provoke heavy anode sacrifice in these critical zones. Very favourable results have been achieved when treating an FBE line's field joints with MCL such as two-component polyurethanes dealt with herein. When applied correctly, very high production rates can be achieved.

The coating performance is directly affected by the surface preparation, and coating integrity and service life will be reduced by insufficient or poorly prepared steel substrate. Only the selection and implementation of the proper surface preparation can ensure the long lasting performance of the coating. This document especially cares for the field joint treatment, its previous surface preparation, testing etc. as one of the most crucial parts of a pipeline coating project.

The following pictures 3 and 4 show the application zone of polyurethane coating on a welded field joint on the example of a 3-layer polyethylene or polypropylene line coating.



Picture 3. Application area of PROTEGOL® to welded field joint



Picture 4. Application area of PROTEGOL® to welded field joint - detail

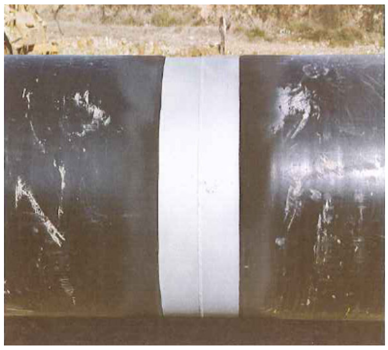
The line coating has to be cut off to bare steel in a range of approximately 15 cm on each side of the pipe ends and be feathered to an angle of 45° to 30° on approximately 5 cm in order to level the transition between the main coat and the field joint coat and thereby obtaining better adhesion in the transition area.

It is important to distinguish the application of a protective system on a new pipe from the rehabilitation of a corroded pipeline in the field. For instance, according to DIN EN ISO 12944-4:1998-07, “Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 4: Types of surface and surface preparation”, it may be sufficient to dry abrasive blast clean all surfaces to be coated to a “near white” metal finish Sa 2½ according to Swedish Standard SIS055900 (SSPC-SP10/Nace no. 2). According to ISO 8501:2007, “Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings”, this will produce a surface finish where “when viewed without magnification, the surface shall be free from visible oil, grease and dirt and from most of the mill scale, rust, paint coatings or foreign matter. Any remaining traces of contamination shall show only as slight stains in the form of spots or stripes.” Grit abrasive usually has to be employed, as contrasted to shot blasting it will create a better anchor pattern the coating can adhere to. The recommended anchor pattern for 100% solids PU figures between 70µm and 100µm (i.e. approximately 3 to 4 mils).

Pictures 5 to 7 very well illustrate the process of field joint coating preparation by grit blasting bare steel to Sa 2 ½ (picture 5 and 6) (blast sweeping only for the line coat material) and achieving the specified surface profile.

Picture 5. Untreated field joint

Picture 6. Blasting of field joint



Picture 7. Field joint blast-cleaned to Sa 2 ½, parent coat sweep-blasted

A topic often neglected in the past, is the relevance of non-visible contamination of the steel substrate with soluble salts, particularly chlorides, sulphates and nitrates, with regard to coating service life and their involvement with premature coating failures. Many specifications still do not capture the essence of testing and decontamination that would effectively provide for maximum coating performance and even has the industry not concluded acceptable soluble salts levels yet.

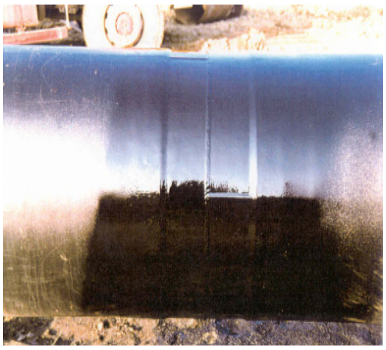
Although soluble salt removal methods will not be widely discussed herein it has to be mentioned that particularly pipe substrates to be rehabilitated, with possible corrosion and higher soluble salts contamination levels, will need additional pretreatment, e.g. wet abrasive blast and high pressure water jetting followed by dry abrasive blast, in order to prevent the formation of active corrosion cells under new coating. Various analyses, such as the Bresle (DIN EN ISO 8502-6) and the CSN

(DIN EN ISO 8502:5) test can be used to detect soluble salts on ferrous substrates. An example demonstrates the importance of the removal of soluble salts: at a provision of NaCl of 31µg/cm² flush rust appears within 30 minutes, this time is increased to 20 hours (!) for a NaCl provision of 5.3µm/cm².

7. The Coating Process in the Field

The coating of the welded field joint is mostly executed by an airless hot spray system, in the pictured case using a manual spray gun (picture 8). Picture 9 clearly shows the feathered borders of the subjacent parent coat and the newly applied PROTEGOL® field joint coat. A big advantage is that, when coated within reasonable time after blast-cleaning, no temporary protection with varnish/primer on the cut back section of the bare steel is necessary. As mentioned before an accurate mixing process and the observation of the correct ratio are essential as e.g. the curing process might be affected.

Picture 8. Field joint coating with PROTEGOL® by airless hot spraying



Picture 9. Field joint coated with 2-component 100% solids PU PROTEGOL®

The full potential of a protective system nevertheless can only be taped with optimum technical equipment. In the case of multi component liquid polyurethane, the necessary two-component airless hot spray equipment can be completed with a fast-working automatic oscillating spray ring as shown in picture 10. This is the best way to constantly ensure highly controlled application according to the specification, meaning precise bandwidth and thickness monitoring. The automatic spray ring is equipped with usually one or two oscillating nozzles altogether covering a 360° rotation, set up for the correct bandwidth and coating thickness, e.g. between 1,000µm and 2,500µm for PROTEGOL® coatings.

Picture 10. PROTEGOL® applied by an automatic oscillating spray ring in BEP Project in Northern Germany

After set-up of the spray ring, the coating of one joint for the a 48 inch pipe of Bunde-Etzel-Pipeline (BEP) Project in Northern Germany only took approximately 1.5 minutes which is extremely time-saving in relation to other systems and has the

additional benefit of reduced overspray. The spray ring can be taken off the pipe immediately after having finished spraying and be travelled to the next joint. Touch-dryness is achieved after a few minutes depending on the ambient conditions. A short curing time and an easy application method, together with good inspection, assure the coatings continuity and a short time to back-in-service.

The principle of the automatic spray ring thereby is not limited to field joints. It has for more than 20 years perfectly been employed to coat the whole line with MCL and similar to the use on the field joint area, with highly controlled application and consistent and uniform thickness. The ring is moving either in the ditch, even when the pipe is in service, or over the ditch, with a variable speed of 0.5 to 1.0 m/minute.

Supplementary to the spray-applicable material, small repair kits allowing manual application can be supplied. In case of any imperfection or damage, repair can be carried out easily by brush or spatula after roughening the affected area manually. This fast-curing repair material will always form one single homogeneous layer together with the before-applied spray material. The ability to be repaired quickly and efficiently is one of the core exigencies to all systems.

After the application and cure of the field joint coating, a high voltage electrical inspection (holiday testing) acc. to NACE RP0274-2004 using a spiral (picture 11) or rubber electrode is conducted. Holidays, as other imperfections, can be repaired using the hand application product in small pre-assembled packages.

Picture 11. High-voltage electrical inspection (holiday testing)
by spiral electrode

The molecules of shop and field applied coatings, including those of possible repairs, have to bond to a homogeneous barrier of similar protection levels. The electrical continuity in the whole line is fundamental in order to assure that the critical parts have the same treatment and therefore the same characteristics and expected service life as the rest of the line. The “weak element of the chain” has to be treated with the same rigorousness as the rest of the line.

8. A New Polyurethane Development

In order to even ameliorate the goods properties of polyurethane coatings, a new high-performance product has been developed. It is a solvent-free two-component liquid, 100% solids, pure polyurethane which fulfils the requirements of DIN EN 10290:2002 (2002) “Steel tubes and fittings for on- and offshore pipelines, external liquid applied polyurethane and polyurethane-modified coating“, class B, thickness of 1,500 µm, for a service temperature between -20℃ and +80℃.

Properties	Polyurethane	Epoxy	New polyurethane
Viscosity at 20℃: Comp. A	20,000 mPas	7,000 mPas	2,500 mPas
Comp. B	200 mPas	5,000 mPas	1,700 mPas
Density at 20℃: Comp. A	1.5 - 1.7 g/cm³	1.6 g/cm³	1.20 g/cm³
Comp. B	1.2 - 1.3 g/cm³	1.1 g/cm³	1.20 g/cm³
Mixing ratio comp. A:B by weight	From 3 : 1 to 4 : 1	2.5 : 1	1 : 1
Mixing ratio comp. A:B by volume	4 : 1	1.75 : 1	1 : 1
Touch dry at 23℃	After 10 min	After 90 min	After 5 min
Hardness Shore D	75	> 80	75 $\pm$ 5
Exposure to mechanical and chemical load (without pre- or post heating procedures)	After one week	After one week	After 30 min
Number of coats to thickness over 800 µm	1 (one)	2 (two)	1 (one)
Pot life at 60℃	40 sec	120 sec	10 – 15 sec
Pot life modified product			2-3 sec with fusion gun
Touch dry			After 1 min

Table 2. Product data in comparison (analysis by TIB Chemicals AG)

It features improved properties and is a very fast set coating which can be reliably applied onsite without the complex and time consuming application processes normally associated with alternative systems. Using a regular airless gun for the application of the product with a pot life of 10 to 15 seconds, or the fast-curing modification using a fusion gun, like the one from picture 12, with two mixing chambers and tip air-blast cleaning (instead of solvents), an advantage in reducing cleaning agents and waste of material - a more ecological solution.

Picture 12. Impingement mix spray or fusion gun
(picture by TIB Chemicals AG)

To formulate such a coating system it is important to choose and select the ideal raw materials in order to achieve a polyurethane system which produces a high

intensity/grade of polymerisation and capacity for resistance against chemical and mechanical influences.

The analysis with the test equipment “SubCASE pot life monitor”, proofs that the high performance product, PROTEGOL® UR Coating 32-60, has an extremely short curing time, as illustrated in table 3, compared to alternative systems and it is the reaction time which gives many reasons to choose it:

- The rapid curing speed protects the coated surface against contamination, such as wind carrying sand and dust.
- The coated pipes or pipe sections can be inspected short time after application, holiday tested and brought back into service
- Increase in efficiency, the major objective in rehabilitation work is to maintain a set schedule that minimises “out-of-service time”.

These are advantages over coatings with long pot life that shed perfume attracting insects which finally results in pores. The longer the pot life is the longer the coating is susceptible to insect damage. In addition, coatings with long curing time are sensitive to water or high humidity during the curing process.

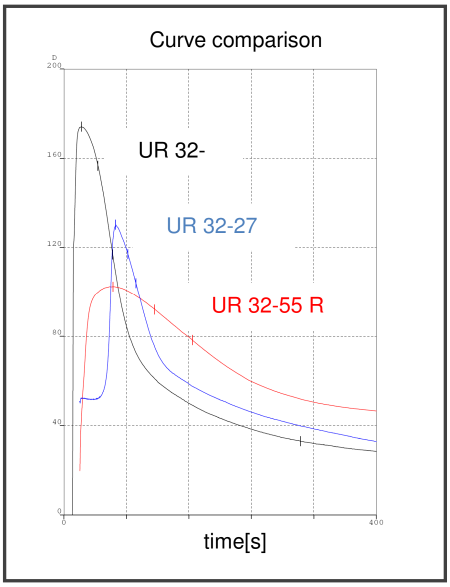


Table 3. Reaction performance D of three different 100% solids rigid polyurethanes
- Analysis carried out with SubCASE pot life monitor (data by TIB Chemicals AG)

Additionally, the field coating should perform, when the pipeline is in service, under field conditions in many different climates and any weather condition. Corrosion protection coatings are being challenged to perform and to be applied under very low temperatures, as pipelines are laid in regions like Alaska and Siberia. Under these climatically severe conditions pipeline rehabilitation is only possible by improving these conditions, especially by covering the excavated pipe sections with a heated tent. This is where the polyurethane coatings again are more suitable due to the short curing time, whereas epoxy coatings need the warm housing for up to 24 hours.

Experiences in the field reveal that the housing conditions have to be maintained at 25°C for approximately 6 hours for this polyurethane system providing the advantage of lower maintenance costs and of course the benefit of higher production rate for a crude-oil pipeline in service, rehabilitation being carried out in sections, bell

holes, of limited length of excavation, due to the high weight of the pipeline carrying oil. Pictures 13 and 14 illustrate the employment of the 1:1 mixing ratio polyurethane in Novopilymskaya/Russia under very harsh environment at very low temperatures below -40°C.


Picture 13 and 14. Pipes and parts in Novopilymskaya/Russia coated with 1:1 low temperature resistant 100% solids PU

9. Supplementary Application Options

In particular with the newly developed 1:1 mixing ratio product, the application of smaller areas, whether small joints or geometrically difficult or inaccessible parts, can be carried out by an air-assisted cartouche gun. Ready-to-use cartridges filled with 0.78kg of the product sufficient to coat an area of 0.4 m² in a DFT of 1,500µm make an erroneous mixing ratio virtually impossible. The cartridges will be supplied with two different static mixers, one straight and the other perpendicular.

Due to the ease of use of the packages and the gun, the average application time per joint will be around 5 minutes, only varying slightly upon pipe diameter. Advantageously, the cartouche spray application can be carried out by one single qualified person. Pictures 15 to 17 give a good view of the application process and the easy-to-handle equipment.



Picture 15, 16 and 17. Application with air-assisted hand spray cartouche gun

The variety of application methods of 100% liquids polyurethanes for different requirements adds to its physical and chemical advantages over other coating systems and emphasizes its position ahead of other systems available in the market.

10. Conclusion and Outlook

In the upcoming years, a rising need and necessity of either replacement of refurbishment of existing transmission pipelines, in service since many decades, can be expected, owners and operating companies having to face this complicated decision.

The election of the best suited anticorrosive coating system is a decision based on an analysis of different parameters of the medium to be transported under certain conditions, of the economic factors of the project and of the overall characteristics of the coating system.

The general trend for field joint coating onshore is to apply liquid polyurethanes or epoxies, instead of HSS. PUs' good adherence to tensile strength, resistance to cracking, abrasion and impact and its good flexibility and elongation values do offer to the decision maker a long-lasting coating system for aggressive environments.

Recent developments of 1:1 mixing ratio liquid polyurethanes are easy to use due to the often stressed avoidance of mixing failures. Diverse application technologies offer flexibility according to project and environmental requirements.

Material manufacturers, applicators and specification engineers need to continue the dialog to anticipate increased performance requirements and to develop trial and approve the use of new materials to meet these challenges.

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