

100% SOLID POLYURETHANE THE INNOVATIVE TECHNOLOGY FOR CORROSION PROTECTION

V. N. Varma

Director, Macmet India Limited

ABSTRACT

100% solid polyurethane is the latest innovation in the field of anti corrosive coatings. It is internationally recognised for providing highest degree of protection to vital installations such as oil & gas pipelines, tanks, LPG mounded bullets and structures exposed to aggressively corrosive environment encountered in buried underground conditions or exposed to seawater such as drilling platforms, coastal installations or plant and equipment in sewage / waste water treatment services.

100% solid polyurethane is a two component, solvent free, elastomeric, thermosetting coating compound, which is expected to preserve the integrity of structures over their design life. It is preferred over other traditional coating systems because of its outstanding life expectancy, resistance to aggressively corrosive environment, very high abrasion and impact resistance, strong adhesion to steel substrate, extremely fast curing capability, high film build characteristic and most importantly, compliance with rigorous regulations on volatile organic compound (VOC) emissions.

In India, the concept of 100% solid polyurethane coating has come in only recently. Major oil and gas companies and reputed engineering consultants are now recommending its use to protect critical installations such as LPG mounded bullets, rehabilitation of old pipelines where conventional coating have failed, field joint of cross country pipelines, internal linings of intake water pipelines in power plants, equipment employed in waste water treatment plants etc.

This paper discusses in depth the chemistry of 100% solid polyurethane, its properties & physical characteristics, equipment and application techniques as also its various advantages.

What is Polyurethane?

In terms of simple chemistry, it is a product of reaction between two components viz. a polyol & an isocyanate. There are literally hundreds of different grades of polyols and thousands of isocyanates available to a polyurethane formulator to choose from, resulting in numerous permutations and combinations. Accordingly, properties of polyurethane vary from very soft and rubbery elastomers to tough and hard ceramic like systems. Polyurethanes also come in a wide variety of shapes and forms, such as:

- Flexible polyurethane in the form of foams used in mattresses, cushions, sofas, carpet-backing etc.
- Rigid polyurethane as insulators used in freezers, refrigerators, sandwich panels, roofs, etc.
- Tough elastomeric polyurethane as soles by shoe industries
- The auto components such as dashboards, bumper covers mouldings, fenders, door-panels etc.
- Paints and coatings for industrial floors, wood, floor-sealers, concrete linings etc.
- High gloss top coats for automobiles

For protection of corrosion in buried steel structures and pipelines etc., however, 100% solid, two component, elastomeric polyurethane has been found to be the most effective system.

The Chemistry of 100% Solid Polyurethane (PUR)

The chemistry of PUR is the key to its unique all round performance. Here, when the specially selected grades of two components (polyol & isocyanate) are mixed together, a rapid exothermic polymerisation reaction takes place, resulting in formation of a hard tough coating film. The molecular structure of this film is intensely cross-linked which makes the coating highly resistant to penetration of water vapours as also to a wide range of chemicals which explains its excellent corrosion preventive properties.

Most PUR coatings are fast setting and cure rather rapidly. After the two components are mixed together, the pot life ranges from a few seconds to several minutes (typically 30 – 40 seconds). After the mixed compound is sprayed on to a steel substrate, the touch dry time ranges from a few minutes to a few hours (typically 10 minutes at ambient 20°C).

Extremely short reaction time combined with high reactivity and thixotropy of PUR makes it easy to achieve high build film thicknesses (upto 2mm) in a single coat, without running or sagging even on vertical surfaces. In special formulations, a coating thickness upto 5mm can be achieved in a single coat without sagging on vertical surfaces. This is possible because the components react so quickly that it gels even before it can flow out.

Moisture is poison to the two components of PUR. The isocyanate is highly sensitive to moisture and if exposed, it will generate carbon di-oxide gas, leaving behind a hard gelatinous mass. Traces of moisture can also reduce the reactivity of isocyanate with polyol, thereby affecting the quality of coating. The polyol component on the other hand, is soluble in water without any chemical reaction. However, when moisture contaminated polyol meets with isocyanate, the water will immediately react with the latter and the resultant carbon-di-oxide gas will try to scape through the coating in the form of bubbles. The failure of coating is manifested by appearance of blisters on the surface of the coating. Therefore, utmost care has to be taken to prevent moisture coming in contact with either of the two components at any time.

Therefore, the chemistry of PUR on one hand, plays a crucial role in imparting in the coating, its unique properties that makes it such an outstanding corrosion protective coating, but on the other hand, it places special demands of sophistication in dispensing equipment and high degree of skill and quality assurance in its handling and application technique.

Outstanding Properties

PUR coatings are carefully engineered to provide a strong di-electric barrier between the external surface of steel and the surrounding soil. The coating gives all round performance in terms of its outstanding life expectancy, excellent protection from corrosion, fast & simple application procedure and compliance with most rigorous regulations on VOC emissions. Some of the special properties of PUR are described below:

- **Weather Resistant** - PUR is as effective in above ground applications as underground because of its exceptional resistance to ultra violet radiation, which prevents degradation due to exposure to weather under most severe climatic conditions. It passes the accelerated weathering test as per ASTM G-53 Standards.

- **High Film Build - Fast Setting** - PUR is a high build coating which is applied directly on prepared steel substrate without any primer, in a single coat with dft varying from 0.6mm to 2.0mm, without sagging or running even on vertical surfaces. It is a fast curing coating which in some well established brands, has a pot life of 40 seconds at dispensing temperature (50 – 60°C) and becomes touch dry in 10 minutes (at ambient 20°C) and can be holiday tested within 2 hours. Mechanical handling/ back filling can start after 6 – 8 hours.
- **Strong Adhesion** - The ability of a coating to resist disbondment due to soil stresses is dependent upon its adhesion to steel substrate and a good indicator of its longevity – the greater the adhesion to substrate, the longer it will last. PUR has exceptionally strong adhesion properties as reflected by tests as per ASTM 4541. PUR virtually fuses with the steel substrate. It has equally good adhesion with factory applied line pipe coatings such as 3 layer PE / PP or fusion bonded coatings.
- **Hard and Tough** - PUR gives a hard, tough and smooth surface finish (like ceramics) with outstanding value of hardness, abrasion resistance and high impact resistance. This prevents coated surfaces from getting damaged during transportation, handling or back filling unlike other conventional coatings which often get damaged during transit and are prone to accelerated corrosion and increased cost of cathodic protection by consuming more current from the CP system.
- **Flexible** - PUR is at the same time flexible enough to withstand flexing movements or breathing of steel substrate that happens in pipelines, tanks and bullets due to thermal expansion and contraction. This is reflected in high percentage of recoverable elongation as per ASTM D-638 tests. Also, PUR passes the stringent 180° bend test as per ASTM - 1737 Standard.
- **Electrical Resistivity and Cathodic Disbondment** - PUR has a very high electrical resistivity which effectively insulates the steel surface and reduces current density required for achieving the protective potential. Further, it is fully compatible with cathodic protection system and has outstanding resistance to cathodic disbondment as reflected by tests as per ASTM G-8 / G-95 Standards. PUR provides such excellent protection to coated surfaces that the current consumption in the CP system is drastically reduced to mere 'traces'. Accordingly the cost of the CP system, both in terms of initial design and long term consumption of current comes down substantially.
- **Pinhole Free** - On account of high-pressure airless hot spray application and high film build, PUR coating is virtually free from pinholes and holidays. This is reflected by nil or extremely low consumption of current in the CP system.
- **Water Vapour Permeability** - All coatings, without exception, allow the passage of some water through the film – depending upon its thickness, natural permeability and integrity of the applied film. PUR is highly resistant to water vapour permeability as reflected by tests as per ASTM E-96 Standard.
- **Chemical Resistance** - PUR has exceptional corrosion protective properties due to its resistance to a wide range of chemicals, acids, bases and salt solutions including seawater exposure. It passes the 6000 hours salt spray test as per ASTM B 117-100 and withstands 1000 hr exposure to Sulphuric acid 10 – 50%, Hydrochloric acid 10 – 32%, Nitric acid 10 – 25%, Phosphoric acid 10 – 70%, Sodium Carbonate 20%, Sodium Chloride 20%, Sodium Hydroxide 10 – 50%, Sea water, and a number of other chemicals. It is therefore strongly recommended for use in chemical immersion and splash zone environment. It is ideal for internal linings and corrosive applications such as sewage and effluent treatment industries apart from marine and petroleum industries.

PHYSICAL PARAMETERS

The data given below is based on a well-established brand of PUR and may vary to some extent with other brands. Typical value at ambient temperatures (20°C) except otherwise mentioned:

Pot-life		40 seconds
Touch dry		<10 minutes
Holiday test		<2 hours
Mechanical handling & back filling		<8 hours
Operating temp limit		-30 to +80 ° C
Application temp	Comp A	50-80 ° C
	Comp B	40-60 ° C
Recommended dft applied in single coat		600–2000 micron (without sagging on vertical surface)
Coverage (theoretical)		1.6 kg / sq.m / mm dft
Shelf life		12 months

THE COATING PROCEDURE

The application of PUR is basically a very simple, two step procedure involving just the surface preparation by abrasive blasting followed by spray of the coating directly on blasted surface without any primer. However the performance of PUR coating is very much dependent upon use of proper equipment and strict adherence to quality assurance guidelines. Yet another important factor is the weather, since PUR is very sensitive to moisture. It is therefore imperative to follow the laid down procedure to the letter. Details of coating procedure are described below:

- **Weather Conditions**

Ensure substrate temperature is atleast 3°C above the dew point. The dew point is computed from a psychrometric chart after determining the relative humidity and substrate temperature. The basic concept is that there should be no chance of water vapour condensing on the surface after the blasting or during coating operation

- **Surface Preparation**

Surface preparation of the steel substrate must conform to SSPC – SP10 specifications - giving Sa2½ degree of cleanliness with an anchor profile of 50 – 70 microns. Before blasting, ensure substrate is absolutely dry and free from oil, grease, water or other contaminants.

- **Coating**

Apply PUR coating immediately after blast cleaning or within 3 – 4 hours on the same day ensuring no rusting has taken place on the substrate even in traces. If rusting occurs, it should be soft blasted again before commencing coating.

PUR is applied using a plural component airless hot spray equipment. The application temperature should normally be around 50 – 60°C and the pressure at the spray tip around 4000 – 5000 psi which is controlled by the equipment.

PUR coating is applied directly on the prepared steel substrate without any primer and in a single coat by multiple passes, wet over wet till the desired dft is achieved.

- **Inspection and Testing**

The coating is tested 'on line' for wet film thickness using a wet film gauge, dft with a mill gauge, holidays & pinholes using a holiday tester with applied voltage of 10,000 volts per mm dft, Shore D hardness after full cure and adhesion test as per ASTM 4541.

If the coating has been done on a contaminated surface or there is anything wrong with mixing ratio etc., the coating will fail within couple of hours and the defect

will be visible with the appearance of bubbles or blisters on the coated surface. Such spots must be thoroughly scrubbed clean and blasted before repairing with hand applied repair kit.

100% SOLID POLYURETHANE IS SAFE

PUR systems are completely safe and contrary to popular belief, the isocyanate used in the formulation is not carcinogenic. However, direct contact with skin causes irritation and should be avoided by wearing normal protective gears such as fresh air face mask, goggles, hand gloves and overalls. The coating being 100% solid is free from solvent-based health hazards and flammability concerns. It also contains none of the other dangerous ingredients that are common in many other coating systems such as 'amines', 'styrenes' or 'monomeric isocyanate'.

The tar modified PUR, however, does fall in the category of toxic products in as much as any other coal tar based coating such as CTE, which is still being widely used in India.

CRITICAL APPLICATIONS

PUR coatings have been effectively used to protect pipelines and structures exposed to corrosive and abrasive environment such as those encountered in buried and underground conditions or coastal installations and splash zones in contact with sea water, such as -

- Buried pipelines, valves, bends, tanks, vessels
- External coatings of LPG mounded bullets
- Internal linings of sea water intake pipelines in power plants
- Rehabilitation of old underground pipelines
- Coating of pipelines used for horizontal directional drilling
- Field joint coating on pipes coated with 3LPE/PP/FBE etc.
- Offshore drilling platforms and splash zones of coastal installations
- Internal linings for drinking water, sewage / waste water pipelines of municipalities

THE ADVANTAGES OF 100% SOLID POLYURETHANES (PUR) IN A 'NUT SHELL'

The biggest advantage of is its simple two stage application procedure which can accelerate the execution of projects as shown under:

- Stage 1 - Surface preparation by abrasive blasting to Sa2½ with an anchor profile of 50 – 70 micron. This is a standard procedure for most modern coating systems.
- Stage 2 - Direct application of PUR on the blasted surface without any primer in a single coat, through multiple passes, wet over wet, till the desired dft is achieved (600 – 2000 micron)
- Despite such a high build coating thickness applied in a single coat, the PUR coating is virtually pinhole free and there is no running or sagging even on vertical surfaces.
- The PUR coating is very fast setting – at ambient temperature (20°C) becomes touch dry within 10 minutes, holiday test in 2 hours and back filling can be started in 6 – 8 hours. It easily sets and cures even at lower temperatures, with only slightly longer time.

- As a result of its quick setting property, there is virtually no contamination on the coated surface due to flying sand, dust, insects etc. which are so common and difficult to control at a construction site.
- PUR comes in the category of non-dangerous goods, non-flammable, solvent free and completely safe for storage and transportation.
- PUR is environmentally safe and coatings have virtually none or near zero volatile organic compound (VOCs) emissions.
- PUR has outstanding adhesion and gets virtually fused to the steel substrate.
- PUR is highly resistant to water vapour permeability and wide range of chemicals and salty environment.
- PUR has very high electrical resistivity and highly resistant to cathodic disbondment.
- PUR has excellent mechanical strength with great resistance to impact & abrasion.
- PUR is hard and tough and at the same time, flexible and resilient and does not crack during flexing of steel substrate.

CONCLUSION

There is a growing realisation in the industries internationally that traditional coatings have failed to provide the required long-term performance, which can last the design life of structure. Failures have been reported for coating systems like coal tar enamel, polyethylene tapes, asphalt mastic tapes etc. due to their inherent weaknesses in mechanical strength and chemical resistance properties. The technological break through achieved by 100% solid polyurethane coatings therefore, offers a ray of hope for really critical applications.

References :

1. *Dr Shiwei Guan, Ph.D., Chief Chemist, Madison Chemical Industries Milton Canada
- Assuring quality when applying 100% solid polyurethane*
2. *Dr M B Mishra, Chief Engineer (NDTS) PDIL, Noida
- Corrosion Prevention in LPG Mounded Bullets*
3. *Ms Kate Hopton, Editor DGS Publishing Ltd., UK, The Curse of Corrosion*
4. *Christopher P Dorsey, Sales Manager, U.K., India, Middle and Far East,
Goldschmidt TIB GmbH, Germany Pipeline Protection*