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SOLVENT-FREE RIGID 2K POLYURETHANES

FOR PROTECTIVE COATINGS

Head Office: 17A- Abdel Wahab Khalifa St. - off Abdel Aziz Fahmy St. - Heliopolis, Cairo.
Tel. : +2 02 26392604 Mob: 01016042932
Fax : +2 02 26392604
E-mail: info@corrocoategypt.com

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Solvent-free two-component Polyurethane (2-K-PUR) systems have been approved over decades as suitable protective coatings systems. Those products are being used for tanks, buried pipelines, steel constructions, fittings and tubes (steel & ductile iron). For renovation in the field, Polyurethanes are of growing importance because of their superior curing characteristic – also at low temperatures – and their outstanding mechanical properties. Cost/performance is clearly the key parameter for the success of this technology.

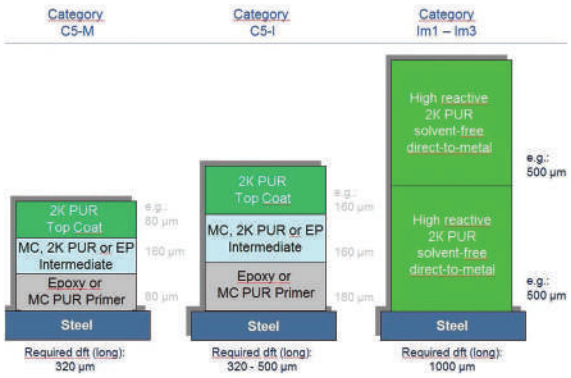
overlap. For C2 and C3 applications solvent-based coatings are being used but waterborne systems become stronger in that area. For C4 to C5 applications usually solvent-based systems are being used. Overlap in selecting coating systems lies in between C3 and C4. For immersed conditions – Im1 up to Im3 - usually solvent-free systems are being used. In this paper we concentrate on immersed conditions for tank and pipeline applications and solvent-free 2K Polyurethane systems.

International Nomenclature according ISO 12944

corrosion category	stress by corrosion	outdoor	indoor
C2	slight	Slight contamination, dry climate (rural)	Solvent-based & waterborne systems
C3	moderate	Urban and industrial atmosphere, moderate contamination with SO_2, coastal area with slight salt load	
C4	strong	Industrial area and coastal area with moderate salt load	solvent-based systems
C5-I	very strong	Industrial area with high humidity and aggressive atmosphere	
C5-M	very strong	Coastal and offshore areas with high salt load	
Im1	very strong	Sweet water, e.g. river works, hydroelectric power-plant	solvent-free systems
Im2	very strong	Salt water, brackish water, e.g. off-shore platforms, floodgates	
Im3	very strong	Sheet pile walls, tanks, pipelines	

Corrosion categories & type of coatings

Standard ISO 12944-5 also requires total dry film thicknesses (dft) for "long" (> 15 years) lifetime of the coating which indicates the figure. An exact term of the protection lifetime of the coating systems is not possible because this depends on many influencing variables like:
Type of the coating system, condition of the steel surface before pre-treatment, effectivity of the surface pre-treatment, geometry of the steel structure, execution of the application, conditions during and after application, and many more. The market reports that the lifetime of coatings in fact can be much longer than required by the standard. The maximum total dft for C5-I is 500 µm whereas the total dft for Im1 – Im3 is 1000 µm. This film thickness can either be achieved by applying several layers of solvent-based coatings or by applying one or two layers of solvent-free systems. As time (= money) is often a very important factor, solvent-free 2K Polyurethane systems deliver advantages.



Corrosion categories & type of coatings

Curing time and reactivity

Standard Polyurethane systems are touch-dry after approx. 60 minutes at 20°C or approx. 100 minutes at 5°C. The curing time through the coating can vary from approx. 50 minutes to approx. 4h at 20°C whereas pot life can last some m inutes. Adjusting curing time saves time / money for the contractor especially when the application takes place in the field because the entire rehabilitation process will be faster. Chemically speaking, the reactivity of a polyurethane system can easily be controlled by incorporating suitable catalysts. The chemical structure and the end-use properties remain nearly independent of the catalyst used.

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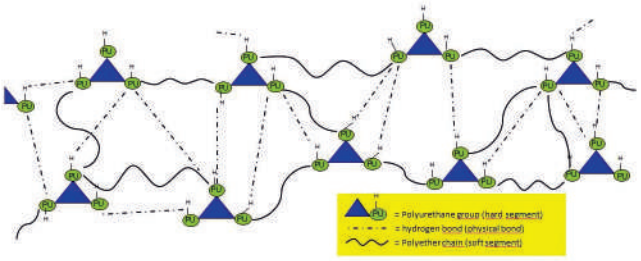
Mechanical Properties

Many relevant technical parameters for protective coatings are related to mechanical properties (film hardness and flexibility) along with adhesion and other chemical/physical properties (e.g. resistance against chemicals and solvents) in order to provide excellent protection against corrosion. When comparing 100% liquid Polyurethane with 100% liquid epoxy pipe coating systems, the following features can be observed: The impact resistance at a given Shore hardness, where values are typically in the range of approx. D75, is higher for Polyurethane. A good impact resistance is beneficial for the transport to the site. The elongation properties are relevant to compensate frost in "cold" regions. The good impact resistance and flexibility is generated by the special urethane functionality within the Polyurethane coatings: inter-polymer hard segments (formed by PUR- and urea-groups with resulting hydrogen bonding) and soft segments (formed by polyol chains) deliver excellent mechanical properties, indicated by the figure. This physical effect being inherent in Polyurethane systems leads to coatings being able to withstand for example longer permanent mechanical forces, described as "cold creep" problem.



Schematic illustration of crosslinking with chemical and physical bonds

Mechanical properties can be steered by varying ratio of hard and soft segments, molecular weight and the crosslinking density of the cured film. Therefore it is possible to create different PUR coatings with physical properties that can range from soft/plastic across elastic up to hard/rigid and even brittle.

Cathodic disbonding properties

Protective coatings must often fulfill certain cathodic disbonding properties. This de- lamination test is being used to check the behavior of the coating – once it has been damaged - under typical conditions: Continuous current (as active anti-corrosion protection system), temperature (representing the service temperature) and a salt solution (representing the ground water). Different test procedures exist within the industry with different requirements for voltage, temperature, salt solution and test period. A higher crosslinking density and a more hydrophobic character of a 2-K-PU coating lead to reduced water permeability and a higher temperature resistance under cathodic protection. Furthermore the surface pre-treatment – especially roughness profile after blasting - has an important influence on adhesion and cathodic disbonding test results.

Rigid Solvent-Free Polyurethane System No 1

The rigid 2K Polyurethane coating system No 1 was developed for tanks. Immersion tests were carried out in artificial sea water (3% NaCl, circulating water, RT) and in sweet water over longer periods (1 – 3 years). Picture 1 indicates the wet adhesion test after immersion in artificial sea water for three years.

Rigid Solvent-Free Polyurethane System No 2

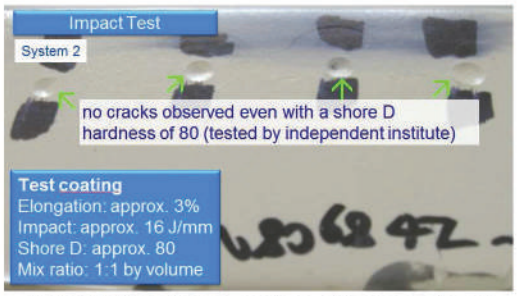
The rigid 2K Polyurethane coating system No 2 was developed for buried pipelines. Pre-tests in the lab were successfully done with very good test results.

Cathodic Disbonding Test

Several cathodic disbonding tests were carried out at higher temperatures and with different qualities of the surface profile of the steel plates

Impact Test

The elongation at break of that new system is less than 5% which means the resulting coating is very hard but not brittle which can be seen on the picture (the impact test was done at Exova)



Rigid Polyurethane coating after impact test

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Final inspection on site

- Overall impression was ok.
- Overall sag resistance was ok.
- Leveling was ok.
- Dry film thickness: 1650-1900 microns
- No blisters or failures were observed

As one aim was to speed up the maintenance process, we instructed to backfill the pipe in three hours after the application had been completed (usually backfill is done after 24h).

Application of rigid Polyurethane coating No 2

Inspection of the coating immersed in wet soil conditions
After 15 months in wet soil conditions with high salt content the pipeline was excavated and the rigid Polyurethane coating was inspected by the experts of the oil & gas company. The coating was in excellent condition and did not show any damages, bubbles, rust, de- lamination etc. The Pictures indicate in comparison the excellent coatings performance

Rigid 2K-Polyurethane test- coating 20 minutes after application was finished. Backfill was done 3h after application.

CONCLUSION

- PU is the most versatile product class, properties can be matched in a wide range
- Development of new building blocks for rigid 2-K-PU systems has been shown
- Rigid Polyurethane as an innovative binder class has proofed its capability under harsh, real conditions
- Rigid Polyurethanes deliver advantages where high performance & efficiency is very important

OUTLOOK

As the entire evaluation process of the rigid 2-K-Polyurethane technology at an oil & gas company was successfully done with confirmation of the excellent performance -especially under (real) wet soil conditions - the oil & gas company intend to implement this technology as an alternative coating system for pipelines.

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