

An innovative thermoplastic coating for CUI applications

Hindrik Harm Broesder
Seal For Life Industries – Stopaq B.V.
Gasselterstraat 20
9503JB Stadskanaal
The Netherlands

Dinko Cudic
Seal For Life Industries – Stopaq B.V.
Gasselterstraat 20
9503JB Stadskanaal
The Netherlands

Somaieh Salehpour
Seal For Life Industries Canusa Canada Ltd.,
455 West Airport Road
Huntsville, ON, P1H 1Y7
Canada

ABSTRACT

Corrosion Under Insulation (CUI) typically occurs on thermally insulated pipes. A systematic approach is needed to minimize the risk of CUI, and part of this approach is to choose coatings that protect the pipe from corrosion and can resist the often aggressive environment with insulated pipes. Presented is an innovative thermoplastic type of coating material for CUI purposes that can be used for both newly constructed pipes and coating repair. Presented are the technical assessments that were carried out to evaluate performance under CUI conditions, including tests as specified in various industry standards like ISO 21809-3 ¹ (e.g. accelerated ageing tests), ISO 12944-9 ² (corrosion at scribe), and additional customized tests including resistance to hot dry/wet cycling including thermal shock, and freeze/thaw cycling. Furthermore, a study was conducted to determine the capabilities of arresting pit growth in stainless steel. From these test it was concluded that these type of coatings are potentially suited for use in CUI service conditions up to temperatures of 120 °C.

Key words: Coating (process); Protective Coatings; Self-healing; Corrosion Control (USE FOR: Corrosion protection); Corrosion under insulation

INTRODUCTION

An innovative thermoplastic type of coating material based on pure isobutene homopolymer was investigated to determine whether it would be fit for purpose in CUI services at low and moderate temperatures up to 120 °C. This polymer is commonly called Polyisobutene (PIB) and has a unique set of properties that are beneficial for protecting metallic structures from corrosion. Polyisobutene is a polyolefin with a chemical structure similar to Polyethylene (PE) and Polypropylene (PP). One of the major differences is that PE and PP are solid materials with a high degree of crystallinity, whereas PIB does not have a crystallization or melting temperature. PIB has a glass transition temperature (T_g) below – 60 °C which indicates that the polymer is a liquid above this temperature. Due to this liquid nature,

mechanical stresses that for example occur with expansion and contraction upon temperature fluctuations will not accumulate in the coating. Adhesion of coatings based on PIB are solely based on van der Waals intermolecular forces. To obtain good adhesion the surface preparation of the substrates is not as critical as with many other types of coatings. They have good adhesion to various substrates like carbon steel, stainless steel, and existing coatings like liquid epoxies. PIB also has a low permeability for water vapor and oxygen, which is favorable for protection against corrosion.

Coatings based on PIB are commonly used for protection of pipelines in buried and submerged conditions against corrosion. For these purposes the coating is further foreseen with a polymeric outer wrap tape that provides mechanical protection to the complete coating and supports self-healing of small defects. It meets the minimum requirements of standards common in the Oil & Gas industry like ISO 21809-3 ¹. This standard includes requirements for properties like glass transition temperature, drip resistance, adhesion to various substrates before and after accelerated thermal ageing and hot water immersion, specific electrical insulation resistance, impact resistance, indentation resistance, and cathodic disbondment resistance.

Coatings based on PIB are also used to protect metallic structures from corrosion in atmospheric services. They meet the requirements of ISO 12944-9 ² cat. Cx for harsh conditions (formerly included in withdrawn standard ISO 20340 ³ cat. C5-M). Testing consisted of cyclic ageing for 25 weeks including exposure to UV and condensation, exposure to salt spray, and freezing at – 20 °C. The specimens were then inspected for corrosion at scribe, blistering, rusting, cracking and flaking.

Based on its current use it was speculated that PIB-based coating could be used in CUI services at low and moderate temperatures up to 120 °C. Various standards for CUI coatings applied to carbon steel and austenitic stainless steels are available. For example, NACE SP0198 ⁴ contains a systematic approach for corrosion control, and ISO 19277 ⁵ specifies test methods and acceptance criteria for the following properties:

- Adhesion testing before artificial ageing
- Artificial ageing by neutral salt spray test and water immersion
- Thermal cycling test (thermal shock)
- Multi-phase CUI cyclic corrosion test
- Optional cryogenic cyclic test
- Optional vertical pipe test

After the tests, the coated specimens are inspected for various parameters like adhesion, degree of blistering, rusting, cracking, flaking, and degree of delamination and corrosion around scribe.

Some of these tests were already conducted on PIB-based coatings in a modified form in accordance with standards other than ISO 19277 ⁵. Adhesion before ageing and after artificial ageing by long-term hot water immersion was tested in accordance with ISO 21809-3 ¹, and salt spray resistance was tested in accordance with ISO 20340 ³ cat. C5-M. The results from this tests provided a good indication of its potential performance in CUI services, but the need for additional test specific to CUI services was identified as outlined below.

EXPERIMENTAL PROCEDURE

The investigation on PIB-based coatings for CUI services consisted of 3 major parts. Hot dry/wet cycling and immersed freeze/thaw cycling was part of a technical assessment conducted by a major oil and gas company. Furthermore, a study into arresting of pit growth in stainless steel was conducted by a scientific institute.

Hot dry/wet cycling test

Hot dry/wet cycling tests were carried out in-house to get an impression of the performance of the coating at its specified maximum service temperature and when exposed to thermal shock.

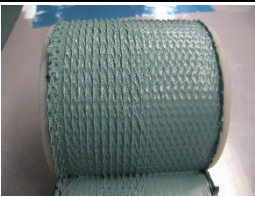
Pipe sections with diameter of 114.3 mm and length of 100 mm were used for the tests. Substrates types and surface preparation were as follows:

- CS Sa 2½: New carbon steel, surface cleanliness Sa 2½ (ISO 8501-1 ⁶)
- CS St 3: De-rusted carbon steel, surface cleanliness St 3 (ISO 8501-1 ⁶)
- SS 304: Stainless steel type 304, solvent cleaned with isopropyl alcohol
- Existing coating on carbon steel, coated with amine adduct cured modified epoxy phenolic

For each type of substrate, three specimens were prepared by application of one layer of PIB-based coating and two layers of complementary radiation cross-linked Polyethylene outer wrap tape. A scribe of 50 mm x 2 mm was made all the way to bare steel in the complete coating in accordance with the method as described in ISO 12944-9 ². The specimens were then exposed to 80 cycles that included the following steps:

- 1) 16 hours exposure in an oven to dry heat at 120 °C
- 2) Cold thermal shock: Quenching in tap water of approx. 10 °C for 5 minutes
- 3) Hot thermal shock: Immersion in boiling tap water for 8 hours

During non-working days, the specimens were stored at 120 °C as described in step 1. After cycling the specimens were inspected for corrosion at scribe in accordance with the method as described in ISO 12944-9 ² with the use of a Mitutoyo CD-15DAX caliper with resolution of 0.01 mm. Adhesion by peel test was carried out at 23 °C in accordance with the method as described in ISO 21809-3 ¹ Annex H method H.1, with a Zwick Z020 tensile testing machine equipped with a load cell of 2 kN and resolution of 0.01 N. The acceptance criteria as specified in ISO 21809-3 ¹ coating type 13 A were used to evaluate the performance of the coating. To compare the adhesion with non-aged specimens, additional sets of test specimens were also prepared and tested for adhesion. The results were as follows:

Substrate	CS Sa 2½	CS St 3	SS 304	Existing Coating
Peel test of non-aged specimens (ISO 21809-3 ¹ Annex H)				
Peel strength (P ₀)	0.64 N/mm	0.68 N/mm	0.63 N/mm	0.65 N/mm
Separation mode	Cohesive	Cohesive	Cohesive	Cohesive
Coverage	≥ 99%	≥ 99%	≥ 99%	≥ 99%
Typical picture of non-aged specimen after peel test				
Peel test of specimens after hot dry/wet cycling (ISO 21809-3 ¹ Annex H)				
Peel strength (P _x)	0.66 N/mm	0.68 N/mm	0.65 N/mm	0.86 N/mm
Separation mode	Cohesive	Cohesive	Cohesive	Cohesive
Coverage	≥ 99%	≥ 99%	≥ 99%	≥ 99%
Typical picture of cycled specimen after peel test				
Ratio P _x / P ₀	1.02	1.00	1.03	1.32