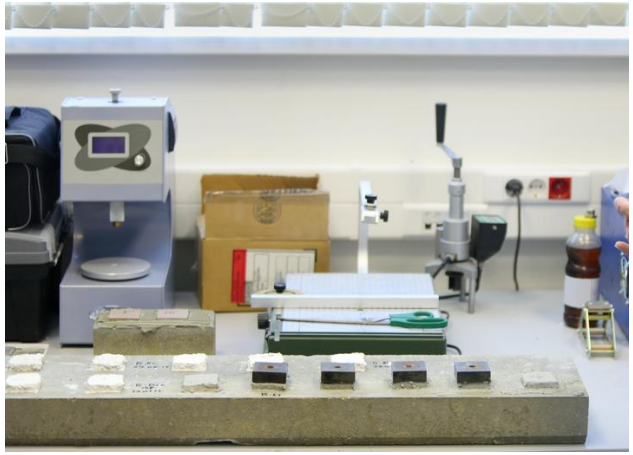
Corrosion Under Insulation In Service Coating

Resimac SA UK Based Manufacturer Formed in 2009

Dedicated Research & Development Chemists

Dr Paul Battey	**- Resimac since 2010**
	- Belzona for 37 years
Ian Robinson	**- Resimac since 2016**
	- Copon/ Thortex for 31 years
Norman Kershaw	**- Resimac since 2017**
	- Copon/ Thortex for 26 years



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Understanding and Mitigating Corrosion Under Insulation Using Novel Heat Activated Coating Technology

Equipment Suffering from CUI can now be Repaired and Coated Online

Corrosion Under Insulation Mechanisms

Carbon Steel

Carbon steel corrodes, not because it is insulated, but because it is contacted by aerated water.

The role of insulation in the CUI problem is threefold.

Insulation provides:

(a) An annular space or crevice for the retention of water and other corrosive media;
(b) A material that may wick or absorb water; and
(c) A material that may contribute contaminants that increase or accelerate the corrosion rate.

The corrosion rate of carbon steel may vary because the rate is controlled largely by the metal temperature of the steel surface and contaminants present in the water.

CUI Further Exacerbated By:

1. Poor choice of insulation

2. Poor design or installation of the insulation especially at problem areas

3. Mechanical damage to insulation

4. Degradation of sealants by natural weathering, thermal oxidation or UV degradation.

5. Water condensation, particularly on refrigerated or chilled water systems

6. Presence of salts

7. Chemical attack

8. Limitations of Metallic Cladding to prevent moisture ingress – Next Slide

LIMITATIONS OF METALLIC CLADDING TO PREVENT MOISTURE INGRESS

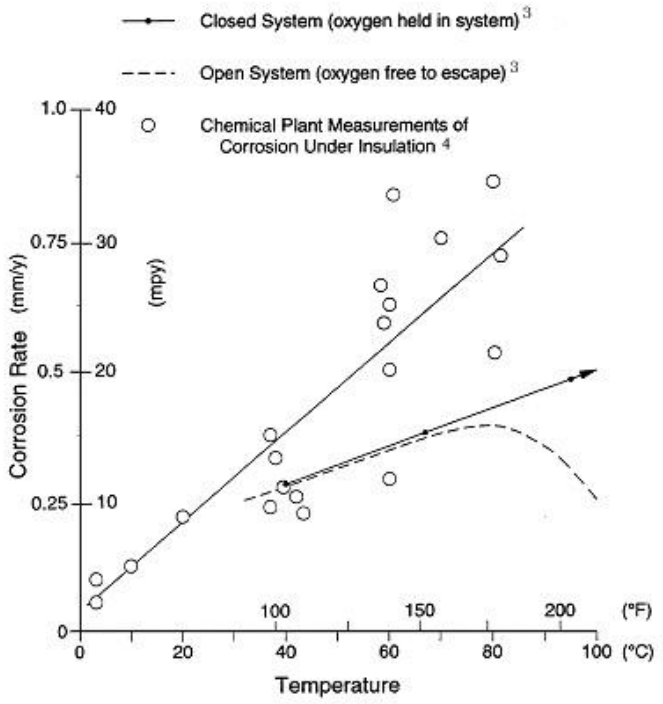
- Cladding is Unable to prevent moisture penetration
- Cladding and Insulation Subject to impact damage
- Cladding Not Seamless
- Limited Life expectancy of cladding
- Constantly Wet or Contaminated Insulation causes Energy Losses
- Inspections of system are costly and required frequently

Cost to Industry runs into $Billions Annually

Temperature range in which risk of CUI is present

- Carbon Steel:(highest risk) between:+50^{0}C to +120^{0}C
- Stainless Steel: +50^{0}C to + 175^{0}C

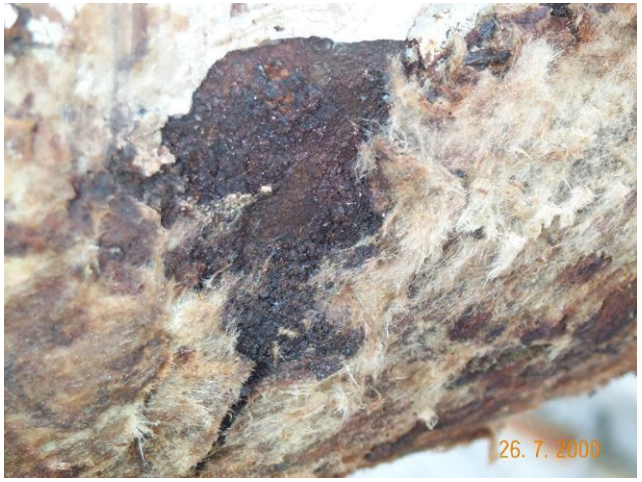
- Corrosion Rates Unpredictable
- Simulates Closed System
- CUI rates of 1.5 to 3mm per year may occur (20 times greater than atmospheric rates)



Corrosion Rates Unpredictable and not Linear

R& D Considerations

- Applied In Service – No need to Shutdown
- Application to Hot Surfaces
- Safe to Apply on Hot Surfaces– No solvents
- Surface Tolerant
- High Adhesion on Manual Prepared Steel
- Proven Immersion Resistance
- Quick Curing
- Tested to CUI International Standards
- Excellent CD Capability
- Quick Curing
- Long Life Expectancy
- Cost Effective



Resimac 530 HA 100

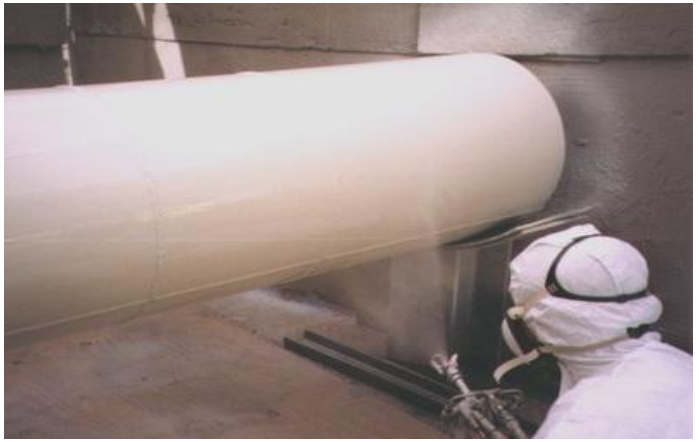
Resichem 530 HA 100 is a unique Single component epoxy novolac for application directly onto hot steel surfaces operating between 100^0C to 240^0C

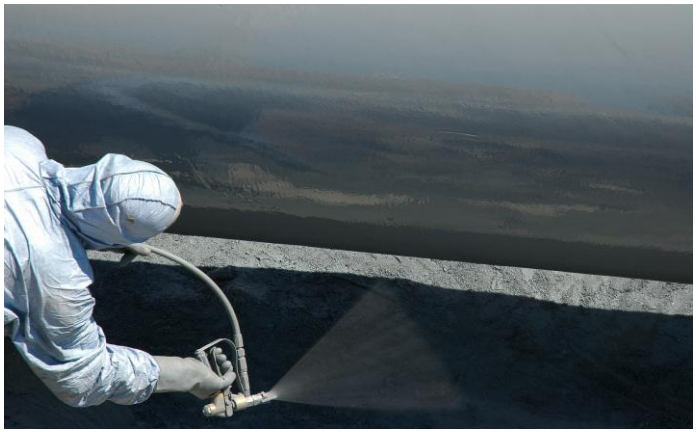
- Designed for protecting surfaces where CUI is Prevalent
- Single Component No Mixing required
- Innovative heat activated curing system
- Applied at temperatures ranging from 100^0C to 200^0C
- Independently tested by Oil and Gas major
- Can be applied by brush or by standard airless spray
- Exceptionally High bond strength to metals and 3LPP coatings, with the top coat being either polyethylene & polypropylene

Application Procedures

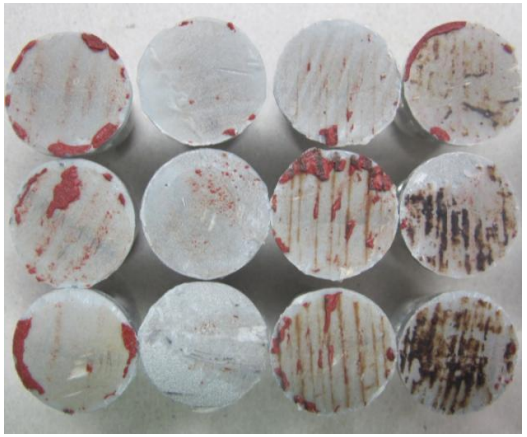
Brush & Roller

Airless Spray





530 Ha 100product Performance Testing In House



Aluminum Dollies after Pull Off Test
Demonstrating Cohesive Failure

Adhesion

Tensile Shear to ASTM D1002 on abrasive blasted mild steel with 75 micron profile and cured at 120^{0}C.
197 kg/cm² /2800 psi

Adhesion

Pull Off Adhesion to ASTM 4541abrasive blasted mild steel with 75 micron profile and cured at 200^{0}C. For 120hrs
>21 MPa /3045 psi

Manual Adhesion

Rusty steel panel (ISO 8501-1 grade C) wire brushed, further abraded with P36 abrasive paper to ISO 8501-1 St 3 surface.
2550 psi

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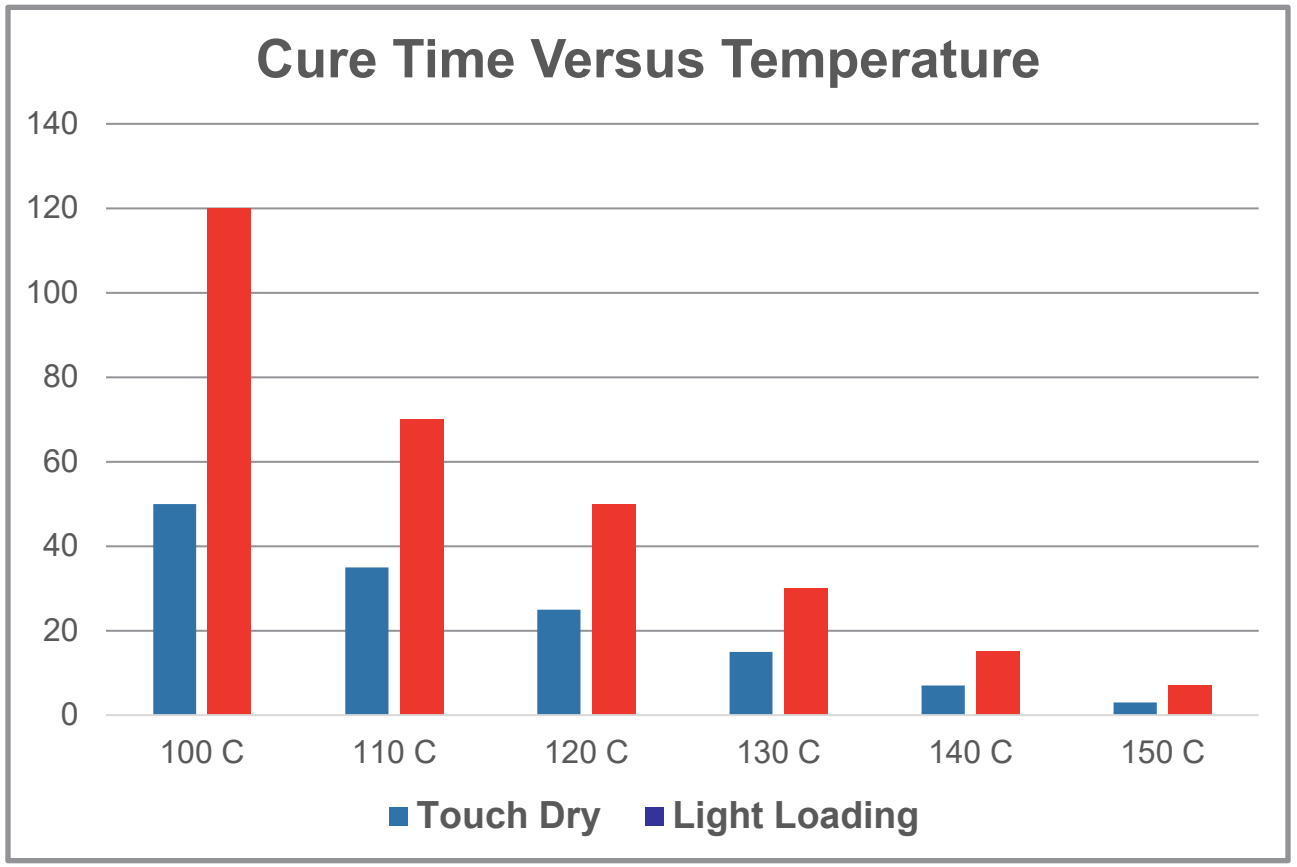
530 Ha 100 Product Performance Testing In House



Corrosion Resistance – Salt Spray Testing

Generates a very corrosive fog of warm salt water Coated panels are exposed to the salt water fog, with a scribed “X” cut through the coating
Tested in accordance with ASTM B117
Test not ideally representative of CUI but industry standard test for corrosion resistance

Salt Spray Results

Steel test panels prepared by abrading manually (no profile)
HA Coating applied onto hot panels and oven cured
Panels exposed for 1000 hours at 35ºC (95ºF) in saturated salt fog atmosphere

No field blistering or corrosion Minimal corrosion creep under the scribe mark

Cathodic Disbondment Testing

The ASTM/ISO standards for Cathodic Disbondment testing are accelerated procedures for determining a coating's ability to provide protection to a steel substrate under applied cathodic protection potentials and provide accelerated conditions for loosening to occur

Results

Tested to ISO 21809-3 Annex F in 3% NaCl at 1500mV at **23˚C** for 28 days.

Average 4 mm (pass)

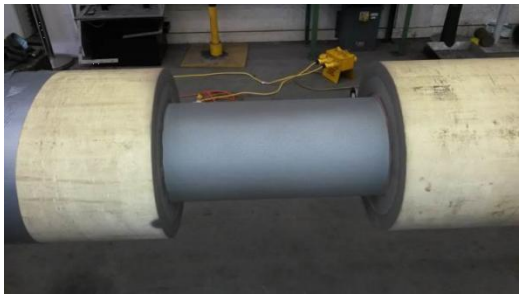
Tested to ISO 21809-3 Annex F in 3% NaCl at 1500mV at **65˚C** for 28 days.

Average 4 mm (pass)

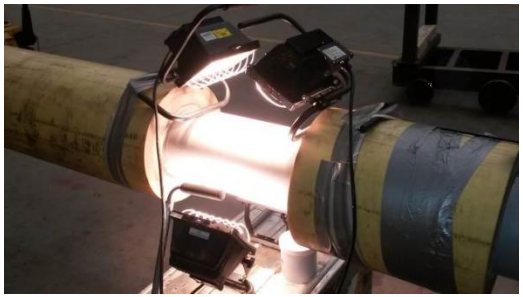
Independent Testing – Chevron Offshore

Test Data…. Doosan Babcock/ Chevron

- Chevron Texaco looking at HA100 for subsea pipeline, high temp riser protection
- Product applied on site at DOOSAN BABCOCK in prep for bend tests
- 2 x 350 microns applied, cured at 150° C

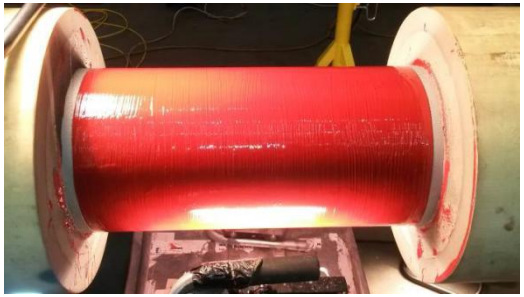


PREPARED SURFACE SA2.5



HEATED TO 100° C

APPLIED 1st COAT 300MIC



APPLIED 2nd COAT 300MIC

HEATED TO 100° C

JACKETED TO GET 150° C

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Independent Testing – Chevron Offshore

Test Data…. Doosan Babcock/Chevron

- Product tested on test rig, PASSED bend test set at 20%

Independent Testing – Chevron Offshore

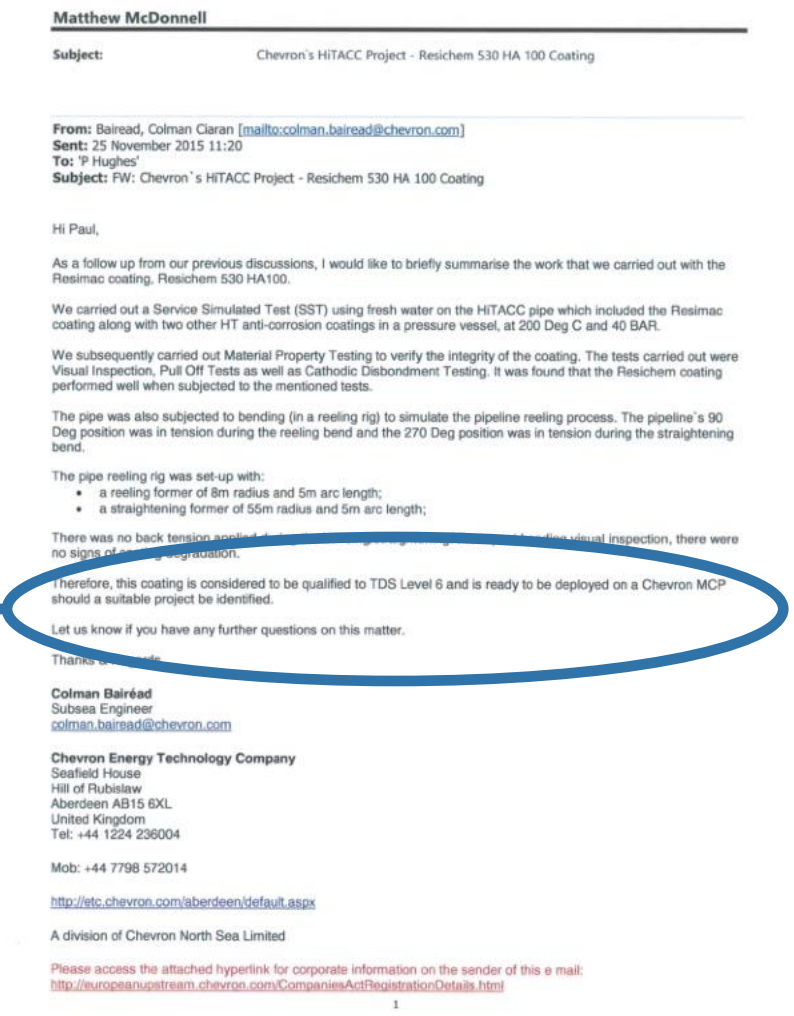
Test Data…. Doosan Babcock/Chevron

- Follow on testing approved by Chevron
- Samples at ELEMENT – product passed all tests
- Cathodic disbondment testing 28 days - 20^0C, ISO 21809
- Peel test ISO 21809, Water Immersion Test

Independent Testing – Chevron Offshore

Outcome of Chevron Testing
Chevron Energy Technology Centre

Following Testing this coating is considered to be qualified to TDS level 6 and is ready to be deployed on a Chevron MCP



Matthew McDonnell

Subject: Chevron`s HiTACC Project - Resichem 530 HA 100 Coating

From: Bairead, Colman Ciaran [mailto:colman.bairead@chevron.com]
Sent: 25 November 2015 11:20
To: 'P Hughes'
Subject: FW: Chevron`s HiTACC Project - Resichem 530 HA 100 Coating

Hi Paul,

As a follow up from our previous discussions, I would like to briefly summarise the work that we carried out with the Resimac coating, Resichem 530 HA100.

We carried out a Service Simulated Test (SST) using fresh water on the HiTACC pipe which included the Resimac coating along with two other HT anti-corrosion coatings in a pressure vessel, at 200 Deg C and 40 BAR.

We subsequently carried out Material Property Testing to verify the integrity of the coating. The tests carried out were Visual Inspection, Pull Off Tests as well as Cathodic Disbondment Testing. It was found that the Resichem coating performed well when subjected to the mentioned tests.

The pipe was also subjected to bending (in a reeling rig) to simulate the pipeline reeling process. The pipeline`s 90 Deg position was in tension during the reeling bend and the 270 Deg position was in tension during the straightening bend.

The pipe reeling rig was set-up with:

- a reeling former of 8m radius and 5m arc length;
- a straightening former of 55m radius and 5m arc length;

There was no back tension applied [illegible] visual inspection, there were no signs of [illegible] degradation.

Therefore, this coating is considered to be qualified to TDS Level 6 and is ready to be deployed on a Chevron MCP should a suitable project be identified.

Let us know if you have any further questions on this matter.

Thanks [illegible]

Colman Bairéad
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HiTACC – Characterisation of Anti-Corrosion Coatings

A study has been conducted by Element to assess a range of high temperature anti-corrosion coatings (HiTACC) which are being developed for high temperature service environments. As part of the project three candidate coatings, were exposed to a realistic service environment which represents a worst case scenario, that is, a hot/wet environment at pressure.

The aim of the project is to evaluate the performance of the candidate coatings after being exposed to an extreme operating environment. The techniques employed to assess the coatings are:

- Non destructive techniques (NDT) pre and post exposure to determine coating thickness and evidence of disbondment
- Visual inspection pre and post exposure
- Mechanical testing – adhesive pull off tests
- Cathodic disbondment.

Independent Testing – Element

The pipe test specimen (PTS) is 5m in length and features three 400mm sections with the insulation removed as shown in Figure 3.1. Each of these sections has then been coated in a candidate anti- corrosion coating as illustrated in Figure 3.2. The PTS has been subjected to a short term simulated service test (SST) with an internal temperature of 200^{0}C and an external environment of potable water at 4^{0}C and 40 bar pressure.

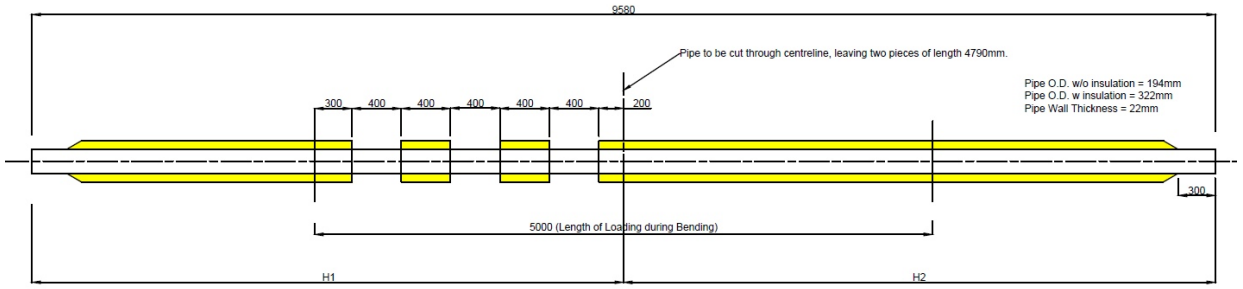


Figure 3.1 PTS drawing

Figure 3.2 PTS photograph

Overall, the Resichem 530 HA 100 coating exhibited excellent performance properties with no change in disbondment or coating thickness after exposure, excellent adhesion to the steel pipe and good cathodic disbondment resistance.

Independent Testing – Shell Corrib Pipeline

Test Data…. Plastcoat Systems

- On site trial performed by COATSOL
- System used is 530 HA100 with flame sprayed PP from PLASCOAT
- 530 HA100 used as the primer layer
- PP Flock sprayed onto wet film
- Heated to 150^0C to cure HA100 and to fuse the PP
- Cathodic Disbondment test performed at PLASCOAT Labs

Test Results

Test Sample	Required Performance	Test Result
Sample 1	≤7 mm	<1 mm
Sample 2	≤7 mm	<1 mm
Sample 3	≤7 mm	<1 mm

Conclusion

When tested in accordance with ISO21809 Part 1, Resimac HA100 has been found to have an average radius of Cathodic Disbondment of <1mm. This result exceeds the requirements for the standard.

Independent Testing – Shell Corrib Pipeline

Test Data…. Plastcoat Systems

- **Photos of CD Testing for Corrib Pipeline**

<1 mm

<1 mm

<1 mm

Independent Testing – Shell Corrib Pipeline

Test Data…. Plastcoat Systems

Cathodic Disbondment	28 days @ 90^{0}C CAN/CSA-Z245.20	<5mm radial
Adhesion after hot water soak	28 days @ 80^{0}C CAN/CSA-Z245.20	Class 1
Peel Strength @ 23^{0}C	ISO 2180-39: Annex D	>12 N/mm
Peel Strength @ 90^{0}C	ISO 21809-3: Annex D	>5 N/mm
Hardness @ 25^{0}C	ASTM D-2240 Shore D	>60
Flexibility @ 0C	CAN/CSA-Z245.20	No cracks @ 3^{0}C PDD
Impact Resistance @ 23^{0}C	DIN 30670	>20 Joules
Tensile Elongation of topcoat @ 25^{0}C (after flame spraying)	ASTM D-638	10%
Taber Abrasion topcoat	ASTM D-4060/84, H18 500Gm load 1000 cycles	55 mg weight loss

Independent Testing – Plastcoat/Coatsol

Field Qualification Plascoat Systems – Coatsol – South America

- On site trial performed by COATSOL
- System used is HA100 with flame sprayed PP from PLASCOAT
- HA100 used as the primer layer
- PP Flock sprayed onto wet film
- Heated to 150^0C to cure HA100 and to fuse the PP
- Cathodic Disbondment test being performed at PLASCOAT Labs






Petroleum, Petrochemical and Natural Gas Industries – Qualification Testing and Acceptance Criteria for Protective Coating Systems Under Insulation

Scope

This document describes various corrosion under insulation (CUI) environments in refineries and other related industries and environments, and establishes CUI environmental categories including operating temperature ranges from −45 °C to 204 °C for topside and aboveground service only. This document specifies both established and other test methods for the assessment of coatings used for prevention of CUI for each given environment. This document also provides acceptance criteria for each CUI environment.

Relationship between artificial testing and natural exposure

The selection of a coating system for specific conditions should preferably be based on experience from the use of the system in similar cases. The reason is that the durability of a CUI coating system depends on many external factors, such as the environment, the design of the structure, the insulation material, the weather proofing (cladding), the surface preparation, the application, drying procedures, service temperature, thermal shock, thermal cycling, peak temperature, amount of moisture, contaminants and other variables.

Relationship between artificial testing and natural exposure

The following documents relating to test procedures are referred to in ISO 19277:2018 in such a way that some or all of their content constitutes requirements of this document.

ISO 554, Standard atmospheres for conditioning and/or testing — Specifications

ISO 1513, Coatings and varnishes — Examination and preparation of samples for testing

ISO 2409, Coatings and varnishes — Cross-cut test

ISO 2812-2, Coatings and varnishes — Determination of resistance to liquids — Part 2: Water immersion method

ISO 4624, Coatings and varnishes — Pull-off test for adhesion

ISO 4628-2, Coatings and varnishes — Evaluation of degradation of coating coatings — Designation of intensity, quantity and size of common types of defect — Part 2: Designation of degree of blistering

ISO 4628-3, Coatings and varnishes — Evaluation of degradation of coating coatings — Designation of intensity, quantity and size of common types of defect — Part 3: Designation of degree of rusting

Relationship between artificial testing and natural exposure

ISO 4628-4, Coatings and varnishes — Evaluation of degradation of coating coatings — Designation of intensity, quantity and size of common types of defect — Part 4: Designation of degree of cracking

ISO 4628-5, Coatings and varnishes — Evaluation of degradation of coating coatings — Designation of intensity, quantity and size of common types of defect — Part 5: Designation of degree of flaking

ISO 4628-8, Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 8: Assessment of degree of delamination and corrosion around a scribe

ISO 7384, Corrosion tests in artificial atmospheres — General requirements

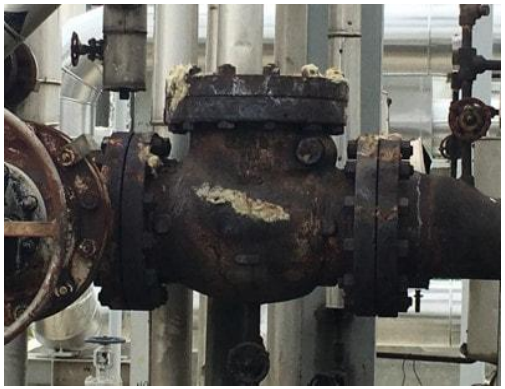
ISO 9227, Corrosion tests in artificial atmospheres — Salt spray tests

ISO 12944-6, Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 6: Laboratory performance test methods and associated assessment criteria

ISO 15528, Paints, varnishes and raw materials for paints and varnishes — Sampling

ISO 19840, Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Measurements of, and acceptance criteria for, the thickness of dry films on rough surfaces

Corrosion Under Insulation Typical Applications



RESIMAC 530 HA 100 IN SERVICE COATING FOR CUI PROTECTION

- Applied to Hot Surfaces Between 100^0C and 240^0C
- No Requirement for Costly Shutdown
- Minimal Surface Preparation
- High Adhesion
- Independently Tested for Resistance to Saturated Insluation
- High Corrosion and Chemical Resistance
- Ease of Use
- Reduce Life Cycle Costs

Resimac 530 Ha 100 in Service Coating for CUI Protection