Element Materials Technology
Wilbury Way
Hitchin
Hertfordshire
SG4 0TW UK
info.hitchin@element.com
element.com

P: +44 (0) 1462 427850
F: +44 (0) 1462 427851
Bank HSBC
Acct 44462335
Sort Code 40-38-04
V.A.T. No 174376290
Company Reg. No. 08149114

Date: 18th March 2015
Author: Dr Nickie Smith
Report Number: C3810-2

HiTACC – Characterisation of Anti-corrosion Coatings

Prepared by:
Dr Nickie Smith
Senior Scientist
+44 (0) 1462 427850

Reviewed by:
Glyn Morgan CEng CSci FIMMM
Technical Lead Oil and Gas
+44 (0) 1462 427866

© 2015 by Element Materials Technology. All rights reserved. This document has been prepared by Element Materials Technology (Element) and all intellectual property rights associated with all or part of its contents remain the exclusive property of Element. It has been prepared exclusively for the organisation named above and is not for distribution or disclosure to any other third party without the express written permission of Element.

Element makes no representations or warranties with respect to the contents hereof and accepts no liability for any use to which the information may be put although every effort has been made to ensure the accuracy and reliability of the information contained.

TABLE OF CONTENTS

1. LIST OF ABBREVIATIONS

ACRONYM	DESCRIPTION
HiTACC	High Temperature Anti Corrosion Coating
NDT	Non Destructive Testing
PTS	Pipe Test Specimen
SST	Simulated Service Test
ASTM	American Society for Testing and Materials
ISO	International Organization for Standardization
NaCl	Sodium Chloride

2. SYNOPSIS

A study has been conducted 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. This report provides the results for one of the coatings as detailed in Table 2.1

Table 2.1: Anti-corrosion coating material

Grade	Colour	Supplier
Resichem 530 HA 100	Red	Resimac Ltd

Element performed an initial hot/wet exposure but the lack of insulation on the sections of pipe with anti-corrosion coating meant that an internal temperature of 200°C could not be achieved. A second hot/dry exposure was conducted with an internal pipe temperature of 200°C for 16 hours.

The integrity of the coating was investigated by measuring key performance properties relating to the durability, bond strength and cathodic disbondment resistance.

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.

3. OBJECTIVES

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.

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°C and an external environment of potable water at 4°C and 40 bar pressure.

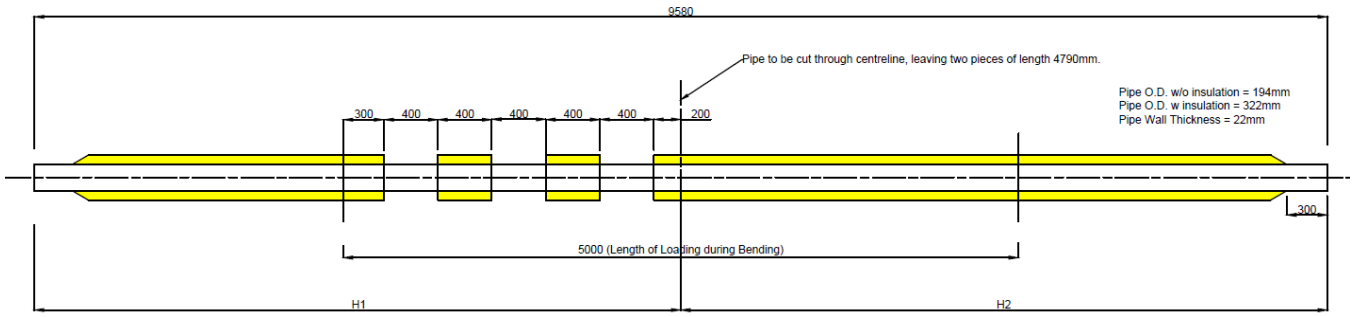

Figure 3.1 PTS drawing

Figure 3.2 PTS photograph

4. METHOD

4.1 SST Exposure

The first approach for the SST exposure involved housing the PTS in a specialist SST vessel equipped to provide an external water environment at 4°C and 40 bar pressure. However, it was observed that the internal heaters could not sufficiently heat the PTS in the regions where the insulation had been removed. The data log of internal pipe temperature, external water temperature and water flow rate are presented graphically in Figure 4.1. The heaters were started and within five hours the insulated sections of pipe had achieved the required test temperature of 200°C. By comparison, the anti-corrosion coated sections had only achieved an internal temperature of approximately 50 to 75°C. The set up was allowed to stabilize for 48 hours before reducing the water flow rate from 1.8 to 1.2 L/min. After a further 24 hours there was no discernible increase in the internal pipe temperature and the water flow rate was reduced to zero. The internal temperature of the pipe (anti-corrosion coated regions) is observed to rise but insufficiently so. The next step was to drain the water from the vessel at approx 120 hours. From this point on, the ‘average water temperature’ in reality is recording the air temperature in the vessel. From this point there is a sharp increase in the internal pipe temperature (anti-corrosion coated regions), however, the coated regions equilibrated at approximately 180 to 195°C. At this time the test was terminated.

A second exposure using hot/dry conditions was defined. The PTS was removed from the SST vessel and the anti-corrosion sections loosely wrapped with fibreglass insulation. The internal pipe temperature of 200°C was achieved in both the insulated and anti-corrosion coated regions. The temperature was maintained for 16.7 hours as illustrated in Figure 4.2. The heating was terminated and the PTS allowed to cool to room temperature.

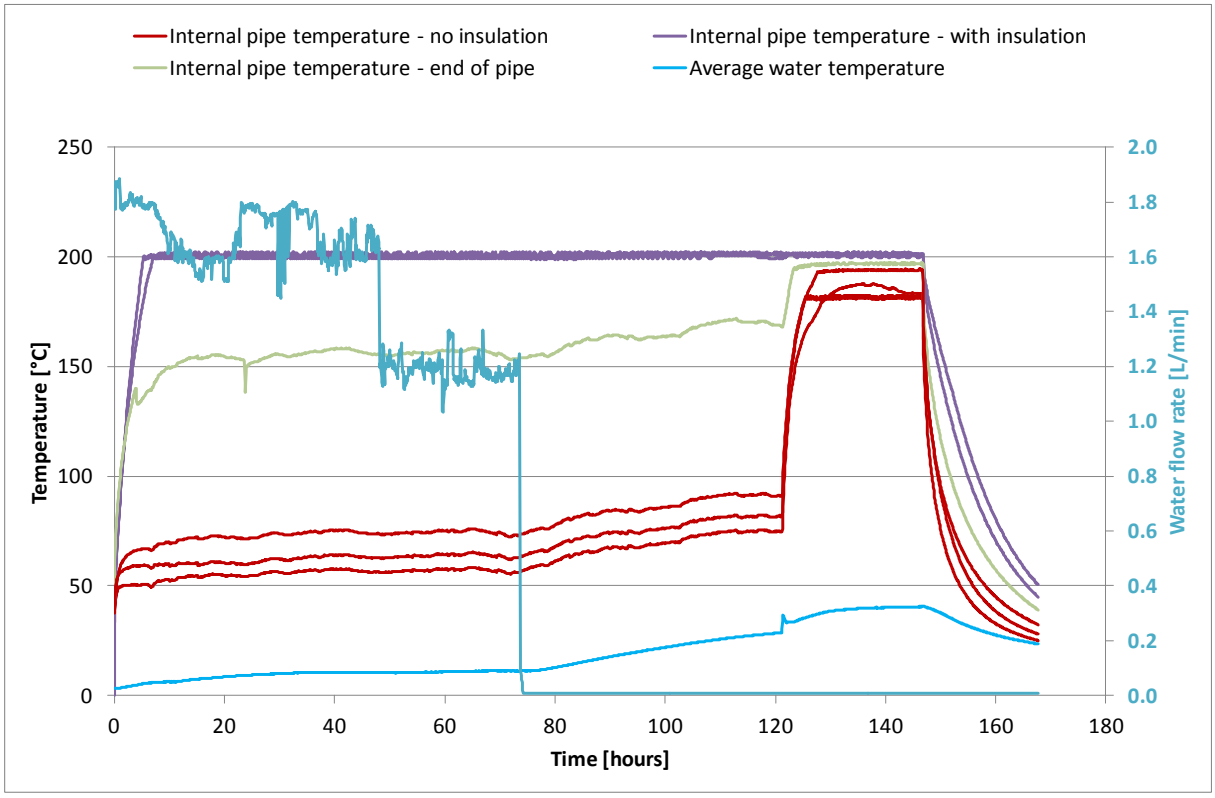

Figure 4.1 SST Exposure #1 (hot/wet): Internal pipe temperature, water temperature and water flow rate

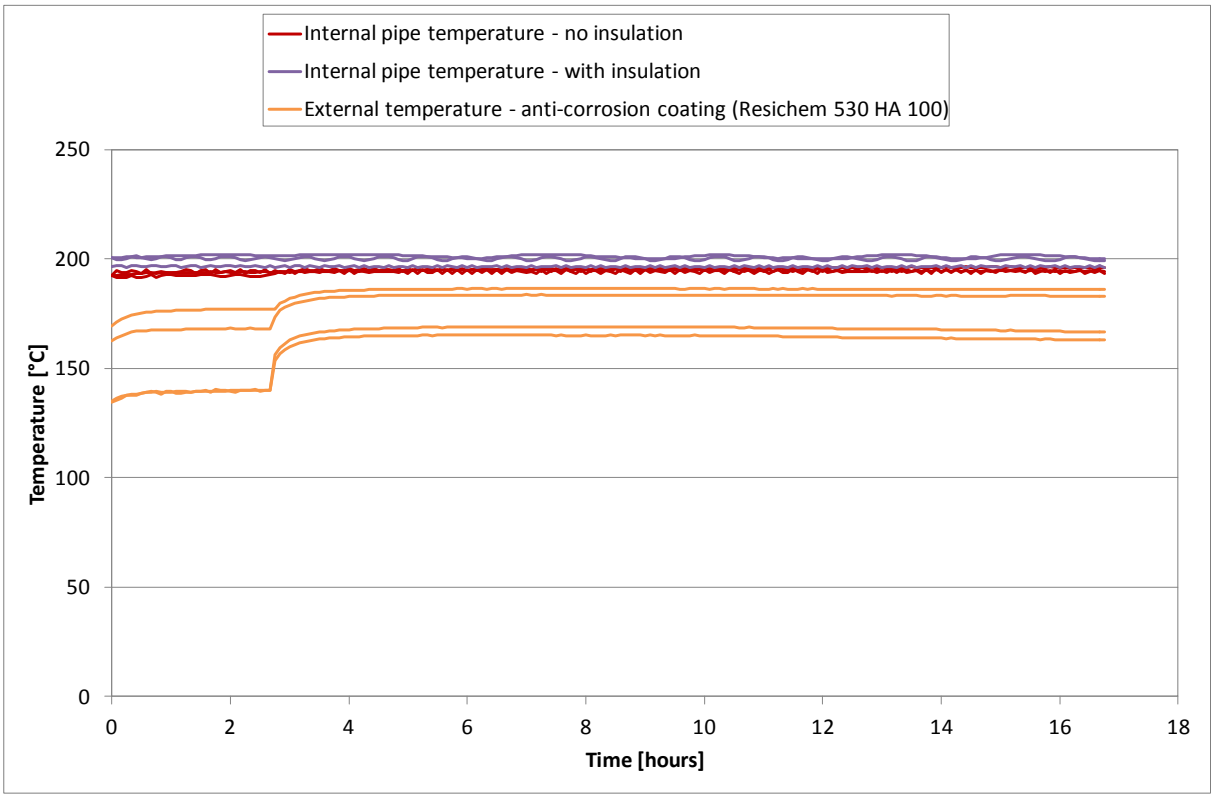

Figure 4.2 SST Exposure #2 (hot/dry): Internal and external pipe temperatures

4.2 NDT Inspection

Prior to exposure, each candidate coating was marked with a grid format as illustrated in Figure 4.3 showing the 13 sectors along the length of the coating and the 0 to 360° angles marked on the left hand insulation. Each coating was photographed prior to and after exposure for visual inspection purposes.

4.2.1 Coating Thickness and Disbondment Evaluation

An eddy current technique and an ultrasonic technique were employed to measure the thickness of each candidate coating, prior to, and after exposure. Any areas of disbondment were also identified with the same techniques. A measurement was made at each grid location, so covering the entire area.

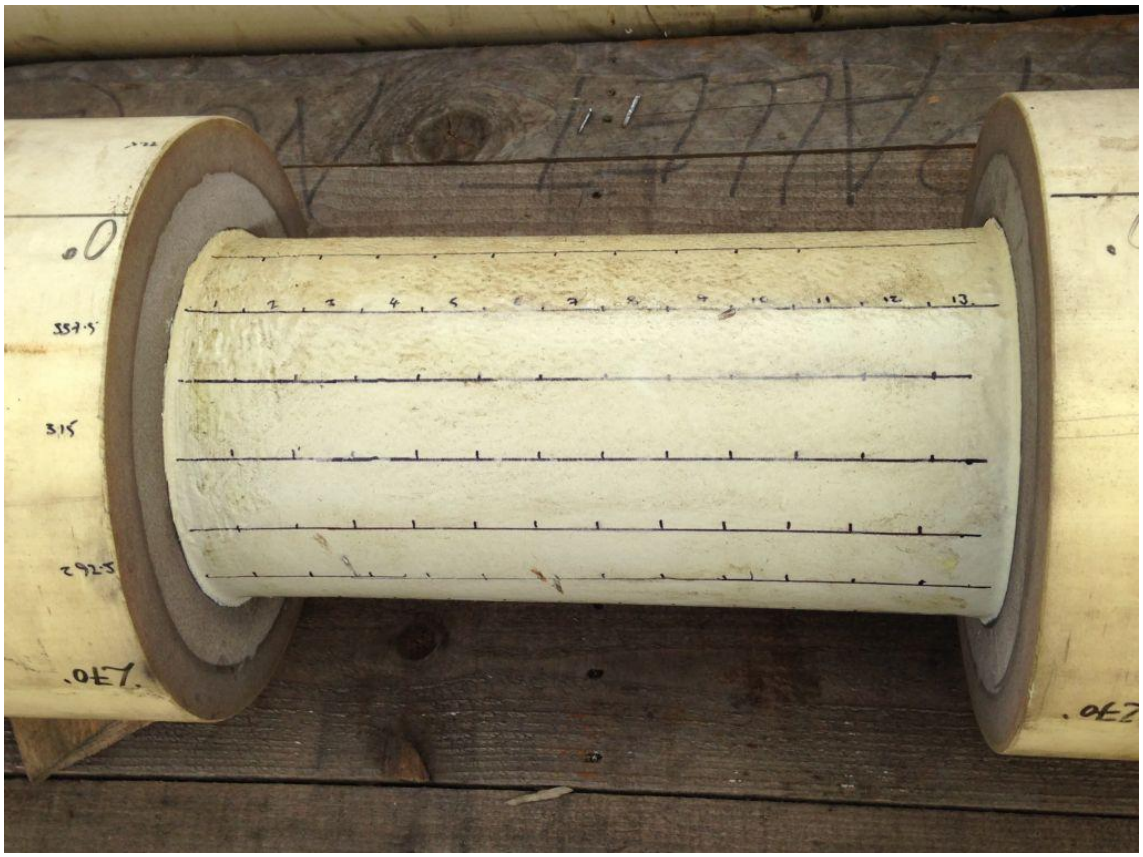

Figure 4.3: Mapping grid applied to coating

4.3 Adhesive Pull – Off Tests

Adhesive pull of testing has been conducted using ASTM D4541 as guidance. After all NDT testing had been completed, the pipe was cut into sections. Four replicate test samples were taken at a spacing of 90° around the circumference of the pipe at three locations along the length of the coated area giving a total of 12 replicates per coating.

A 20mm hole saw was employed to cut down through the coating and through the steel pipe. Aluminium pull-off dollies were shot blasted with aluminium oxide grit and cleaned with acetone. The surface of the coating was cleaned with acetone, abraded with 100 grade abrasive paper then cleaned again with acetone prior to the application of the dollies. The dollies were bonded to the

insulation using 3M Scotchweld DP460 adhesive and left to cure at ambient laboratory conditions for a minimum of 72 hours.

A Zwick-Roell material testing machine was used to pull the dollies from the substrate at a rate of less than 1MPa/sec, as stated in the standard. The displacement applied to the sample has been taken as the cross-head displacement. The test set up is shown in Figure 4.4.

Figure 4.4: Adhesive pull-off test set up

4.4 Cathodic Disbondment

Cathodic disbondment tests were conducted in accordance with ISO 21809-3 annex F using a Voltcraft PS-1152A power supply, Hewlett-Packard 34401A multimeter and Schott B2810 0117 Kalomel reference electrode.

An artificial defect was made in the coating to expose the steel substrate. A plastic cylinder was attached around the hole and filled with a NaCl solution. The test setup was placed in a controlled environment at a specified temperature for a defined period of time. An electric potential was applied between the steel substrate and the reference electrode. The voltage was checked with a reference electrode twice a week.

To measure the disbondment, radial cuts were made and the point of a utility knife was inserted under the coating. A levering action was manually applied on the coating, until strong resistance occurred. All disbondment lengths were measured and an average value calculated. The test parameters are provided in Table 3.1.

Table 4.1: Cathodic disbondment test parameters

Parameter	Value
Test start date	13.02.15
Test end date	13.03.15
Defect diameter	6mm
Internal cylinder diameter	75 ± 3mm
Solution	3% NaCl
Temperature	6 tests at 23 ± 2°C and 6 tests at 65 ± 2°C
Voltage	-1500 ± 10mV
Duration	28 days
Radial cuts	12

5. RESULTS

5.1 NDT Inspection

5.1.1 Visual inspection

The before and after exposure photographs of the Resichem 530 HA 100 coated pipe sections are presented in Figure 5.1 and Figure 5.2 respectively. The main observations from the visual inspection are:

- Resichem 530 HA 100 coating: There is a distinct colour change from a deep red to a dull brown red. The brown patches and yellow residue are from the yellow fibreglass insulation used to help maintain the required internal pipe temperature during the second hot/dry test.
- The adhesive (red and green material) from the bulk insulation section has leaked on to the anti-corrosion coating.

Figure 5.1 Resichem 530 HA 100 coating before exposure

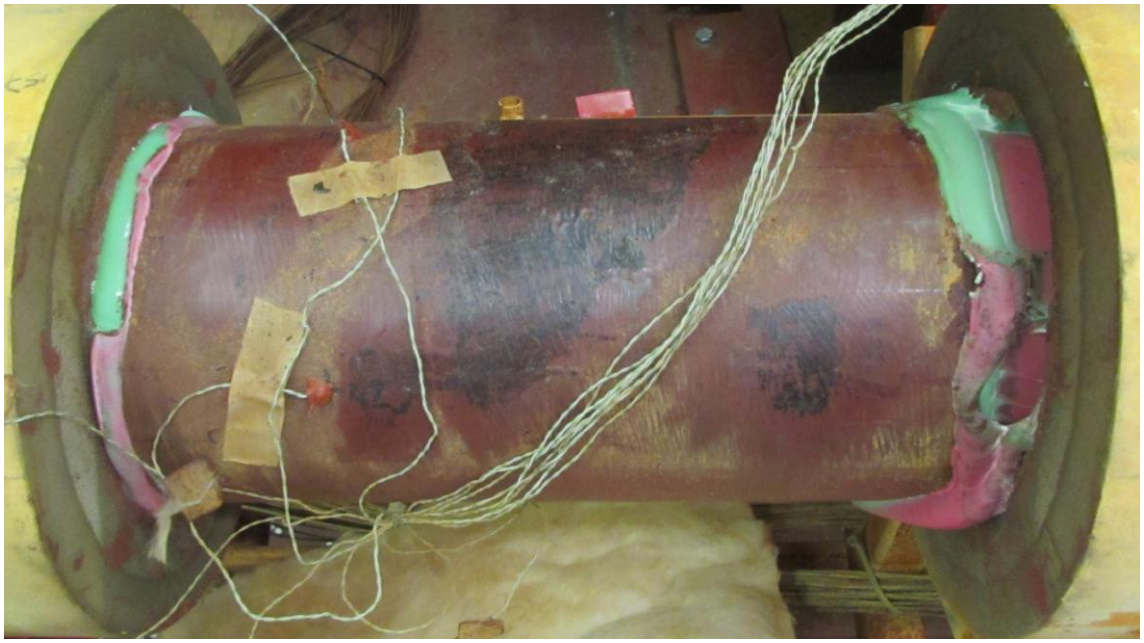

Figure 5.2 Resichem 530 HA 100 coating after exposure

5.1.2 Coating thickness and disbondment

The full NDT inspection reports are included in Appendix A. The coating thickness and disbondment results are reproduced in Table 5.1 and Table 5.2 below. The main observations are:

- Due to the leakage of adhesive on to the anti-corrosion coatings some regions could not be tested. These areas are marked with an X in the tables below.
- The Resichem 530 HA 100 coating had 4 locations where there is a dis-bond between the coating and the pipe surface prior to exposure. This disbondment does not increase after the exposure test. The coating thickness is unaffected by the exposure.

Table 5.1: Resichem 530 HA 100 coating thickness (mm); pre exposure; D indicates dis-bond

Angle°	Sector												
	1	2	3	4	5	6	7	8	9	10	11	12	13
0	0.96	0.76	0.74	0.74	0.54	0.78	0.54	0.76	0.98	0.98	0.83	1.02	0.74
22.5	0.50	0.46	0.46	0.85	0.76	0.87	0.94	0.85	0.96	0.54	0.68	0.87	0.98
45	0.52	0.48	0.63	0.54	0.67	0.78	0.76	0.85	0.92	0.98	0.85	1.02	1.02
67.5	0.46	0.46	0.46	0.54	0.84	0.84	0.94	0.86	0.94	0.92	0.76	0.76	0.94
90	0.74	0.56	0.54	0.75	0.82	0.85	0.94	0.96	0.96	0.96	1.00	0.94	0.76
112.5	0.74	0.46	0.76	0.92	0.84	0.87	0.92	D	D	0.98	1.02	0.74	0.74
135	0.76	0.74	0.88	0.83	0.61	0.61	D	D	0.89	0.87	0.81	0.98	0.94
157.5	0.48	0.48	0.76	0.96	0.96	0.74	0.86	0.88	0.92	0.82	0.98	0.98	0.98
180	0.52	0.81	0.96	1.07	1.09	0.87	0.87	1.13	1.13	0.98	0.76	0.52	0.76
202.5	0.52	0.81	0.56	0.81	1.09	0.92	1.02	0.76	0.92	0.76	0.76	0.76	0.76
225	0.76	0.74	0.73	0.76	0.72	0.52	0.67	0.87	0.81	0.63	0.76	0.80	0.81
247.5	0.76	0.67	0.92	0.98	1.02	0.81	1.09	1.05	0.84	0.54	0.56	0.76	0.56
270	0.56	0.56	0.78	0.58	0.67	0.92	0.59	0.92	0.92	0.98	0.83	0.89	0.98
292.5	0.51	0.81	0.81	0.61	0.98	1.05	0.89	0.89	0.70	0.85	0.89	0.81	0.79
315	0.50	0.54	0.83	0.70	1.09	0.87	0.76	0.86	0.84	0.85	0.83	0.81	0.56
337.5	0.48	0.81	0.76	0.94	0.76	0.58	0.54	0.87	0.59	0.87	0.87	0.85	0.85

Table 5.2: Resichem 530 HA 100 coating thickness (mm): post exposure; D indicates dis-bond

Angle°	Sector												
	1	2	3	4	5	6	7	8	9	10	11	12	13
0	0.96	0.76	0.74	0.74	0.54	0.78	0.54	0.76	0.98	0.98	0.83	1.02	0.74
22.5	0.50	0.46	0.46	0.85	0.76	0.87	0.94	0.85	0.96	0.54	0.68	X	X
45	0.52	0.48	0.63	0.54	0.67	0.78	0.76	0.85	0.92	0.98	0.85	X	X
67.5	0.46	0.46	0.46	0.54	0.84	0.84	0.94	0.86	0.94	0.92	0.76	0.76	0.94
90	0.74	0.56	0.54	0.75	0.82	0.85	0.94	0.96	0.96	0.96	1.00	0.94	0.76
112.5	0.74	0.46	0.76	0.92	0.84	0.87	0.92	**D**	**D**	0.98	1.02	0.74	0.74
135	0.76	0.74	0.88	0.83	0.61	0.61	**D**	**D**	0.89	0.87	0.81	0.98	0.94
157.5	0.48	0.48	0.76	0.96	0.96	0.74	0.86	0.88	0.92	0.82	0.98	0.98	0.98
180	0.52	0.81	0.96	1.07	1.09	0.87	0.87	1.13	1.13	0.98	0.76	0.52	0.76
202.5	0.52	0.81	0.56	0.81	1.09	0.92	1.02	0.76	0.92	0.76	0.76	0.76	X
225	0.76	0.74	0.73	0.76	0.72	0.52	0.67	0.87	0.81	0.63	0.76	0.80	X
247.5	0.76	0.67	0.92	0.98	1.02	0.81	1.09	1.05	0.84	0.54	0.56	X	X
270	0.56	0.56	0.78	0.58	0.67	0.92	0.59	0.92	0.92	0.98	0.83	X	X
292.5	0.51	0.81	0.81	0.61	0.98	1.05	0.89	0.89	0.70	0.85	0.89	X	X
315	0.50	0.54	0.83	0.70	1.09	0.87	0.76	0.86	0.84	0.85	0.83	X	X
337.5	0.48	0.81	0.76	0.94	0.76	0.58	0.54	0.87	0.59	0.87	0.87	X	X

5.2 Adhesive Pull – Off Tests

The coated pipe section with dollies attached is shown in Figure 5.3 with the test sample identification provided in Table 5.3. The individual results are included in Appendix B. The surface of the aluminum dollies were photographed after the pull-off test and are presented in Figure 5.4. The average maximum stress and error range for each coating is presented in Figure 5.5.

As illustrated in Figure 5.4 the Resichem 530 HA 100 coating exhibits failure mainly at the adhesive / coating interface with small amounts of coating visible on the surface of the dollies – most of the coating remains attached to the pipe. Therefore, in these cases the maximum stress is not a true measure of the bond strength of the coating to the pipe. That is, the anti-corrosion coating is bonded more strongly to the pipe than to the aluminum dollies.

Figure 5.3: Section coated pipe with dollies attached

Table 5.3: Sample identification

Coating	Ring	Sample number
Resichem 530 HA 100	1	1-1, 1-2, 1-3, 1-4
	2	1-5, 1-6, 1-7, 1-8
	3	1-9, 1-10, 1-11, 1-12

Figure 5.4: Aluminium dollies after pull of test from Resichem 530 HA 100 coating

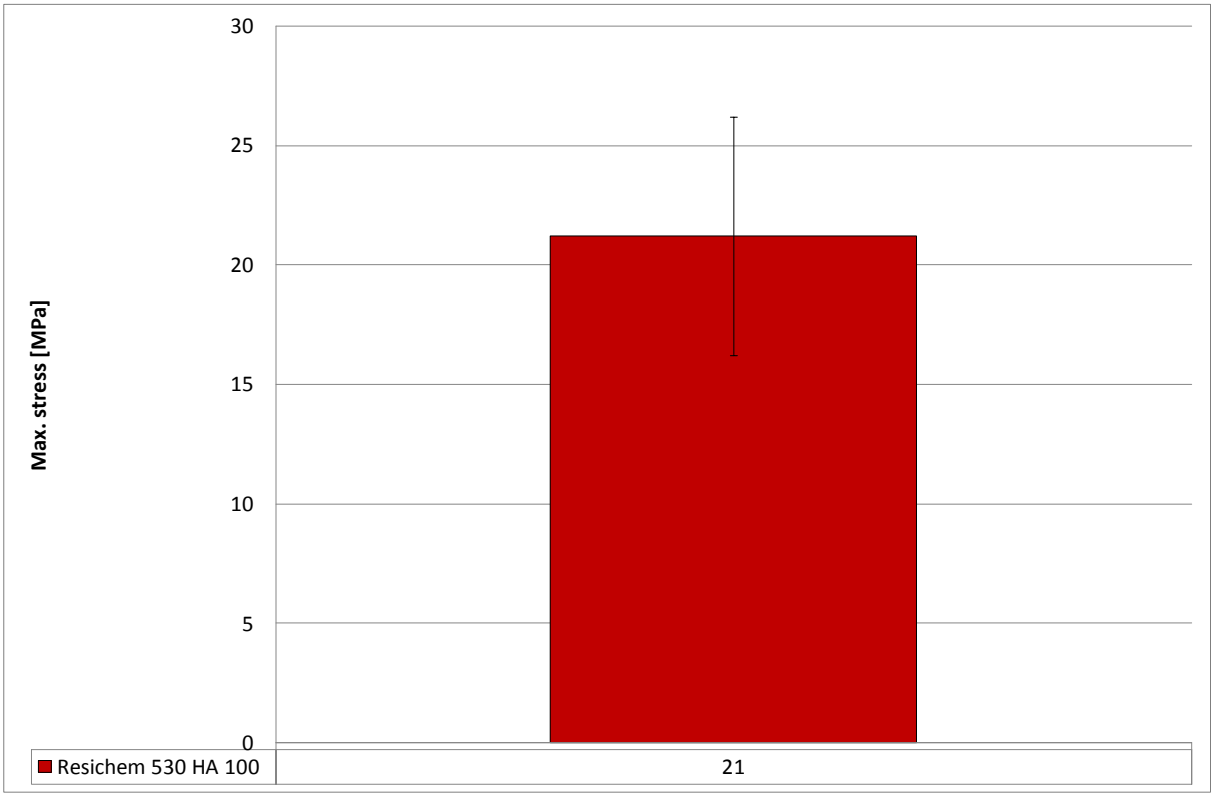

Figure 5.5: Adhesive pull-of tests: Average max. stress of the coating

5.3 Cathodic Disbondment Testing

The results of the cathodic disbondment testing are presented in Table 5.4 as the average disbondment distance from the artificial defect at the centre of the test piece. The coating was not influenced by the elevated temperature. Resichem 530 HA 100 coating exhibited an average disbondment of 4mm.

Table 5.4: Cathodic disbondment results

Test temperature	Anti-corrosion coating	Average disbondment distance [mm]	
		Replicate #1	Replicate #2
23°C	Resichem 530 HA 100	4	4
65°C	Resichem 530 HA 100	3	5

6. CONCLUSIONS

A study to investigate the performance of three candidate anti-corrosion coatings has been conducted. A 5m pipe test specimen was supplied to Element which featured three 400mm sections with the insulation removed. Each of these sections had then been coated in one of the candidate anti-corrosion coatings. This report details the results for Resichem 530 HA 100.

Element performed an initial hot/wet exposure but the lack of insulation meant that an internal temperature of 200°C could not be achieved. A second hot/dry exposure was conducted which achieved an internal pipe temperature of 200°C for 16 hours.

The approach to evaluate the coatings comprised of visual inspection, NDT to evaluate the coating thickness and disbondment before and after exposure, pull off tests to determine the adhesive strength of the coating to the steel pipe and cathodic disbondment to assess the cathodic disbondment resistance of each coating.

The main outcomes of the testing are:

- The Resichem 530 HA 100 coating exhibited a minor discolouration from deep red to pale red/brown.
- The NDT results demonstrated that the Resichem 530 HA 100 was unaffected by the exposure with no change in disbondment or coating thickness.
- The adhesive pull off tests do not represent a true value for the adhesion of the Resichem 530 HA 100 coating as the failure occurred at the interface between coating and the adhesive on the aluminum dolly rather than within the bulk of the coating or between the coating and the steel pipe. That is, the bond between coating and the steel pipe is stronger than the value measured.
- The cathodic disbondment tests demonstrated that Resichem the 530 HA 100 exhibited good disbondment resistance.

7. APPENDIX A – NDT TEST REPORTS

7.1 NDT: Pre exposure test report

Element Hitchin Coated Pipe Simulated Service Pressure Vessel HiTACC Test
Pre Exposure Measurements

Specific Test Procedures Adopted For:

Ultrasonic and Eddy Current Testing Coating Thickness Measurements.

Commissioned by: Element Materials Technology (Hitchin Ltd),
Wilbury Way, Hitchin, Hertfordshire SG4 0TW, UK

Prepared by: D Chadwick Testsure Technology Ltd 7th August 2014

7.1.1 Ultrasonic Inspection Records: Resichem 530 HA 100 coating

Ultrasonic Inspection Report		
Customer: Element Materials Technology (Hitchin Ltd)	**Job No:**	**Test Date:** 31st July 2014
Address:	**Material:** Carbon Steel	**Location:** SG4 0TW
Wilbury Way, Hitchin, Hertfordshire SG4 0TW, UK	**Inspection** **Standard:** BS EN 1714	
Component: Coated Pipe	**Drawing** **Reference**:	
Manufacturing **Process:** Resichem 530 HA 100		

Test Equipment				
Flaw Detector Type: Panmaterics	**Model:** Epoch III 2300	**Serial Number:** 95061107	**Couplant:** Sonagel W 140315	**Test Temperature:** Ambient
Calibration Spec: BS EN 12668	**UKAS:** 7640	**Calibration Date:** 25/11/13	**Calibration Due:** 24/11/14	**Calibration Sample**: 5-35mm Stepped block

Transducers					
Type	WK CD 10	**Serial Number:**	21203		
Frequency	5 MHz				
Crystal Size	2x 5mm				
Angle	0º				
Report Level: 10% Above Noise		**Reject Level:** 25% of Backwall Echo amplitude.		**Defect Sizing Method:** 80% to 20% drop signal amplitude	

Table 7.1: Pre exposure: Resichem 530 HA 100 coating thickness (mm) D indicates dis-bond

RESULTS													
Sector/ Angle^{o}	1	2	3	4	5	6	7	8	9	10	11	12	13
0	0.96	0.76	0.74	0.74	0.54	0.78	0.54	0.76	0.98	0.98	0.83	1.02	0.74
22.5	0.50	0.46	0.46	0.85	0.76	0.87	0.94	0.85	0.96	0.54	0.68	0.87	0.98
45	0.52	0.48	0.63	0.54	0.67	0.78	0.76	0.85	0.92	0.98	0.85	1.02	1.02
67.5	0.46	0.46	0.46	0.54	0.84	0.84	0.94	0.86	0.94	0.92	0.76	0.76	0.94
90	0.74	0.56	0.54	0.75	0.82	0.85	0.94	0.96	0.96	0.96	1.00	0.94	0.76
112.5	0.74	0.46	0.76	0.92	0.84	0.87	0.92	**D**	**D**	0.98	1.02	0.74	0.74
135	0.76	0.74	0.88	0.83	0.61	0.61	**D**	**D**	0.89	0.87	0.81	0.98	0.94
157.5	0.48	0.48	0.76	0.96	0.96	0.74	0.86	0.88	0.92	0.82	0.98	0.98	0.98
180	0.52	0.81	0.96	1.07	1.09	0.87	0.87	1.13	1.13	0.98	0.76	0.52	0.76
202.5	0.52	0.81	0.56	0.81	1.09	0.92	1.02	0.76	0.92	0.76	0.76	0.76	0.76
225	0.76	0.74	0.73	0.76	0.72	0.52	0.67	0.87	0.81	0.63	0.76	0.80	0.81
247.5	0.76	0.67	0.92	0.98	1.02	0.81	1.09	1.05	0.84	0.54	0.56	0.76	0.56
270	0.56	0.56	0.78	0.58	0.67	0.92	0.59	0.92	0.92	0.98	0.83	0.89	0.98
292.5	0.51	0.81	0.81	0.61	0.98	1.05	0.89	0.89	0.70	0.85	0.89	0.81	0.79
315	0.50	0.54	0.83	0.70	1.09	0.87	0.76	0.86	0.84	0.85	0.83	0.81	0.56
337.5	0.48	0.81	0.76	0.94	0.76	0.58	0.54	0.87	0.59	0.87	0.87	0.85	0.85

7.2 NDT: Post exposure test report

Element Hitchin Coated Pipe Simulated Service Pressure Vessel HiTACC Test
Post Exposure Measurements

Specific Test Procedures Adopted For:

Ultrasonic and Eddy Current Testing Coating Thickness Measurements.

Commissioned by: Element Materials Technology (Hitchin Ltd),
Wilbury Way, Hitchin, Hertfordshire SG4 0TW, UK

Prepared by: D Chadwick Testsure Technology Ltd 4th December 2014

7.2.1 Ultrasonic Inspection Records: Resichem 530 HA 100 coating

Date: 4th Dec 2014

Location: Element Hitchin, SG4 0TW

Carried out by: D L Chadwick

ULTRASONIC INSPECTION REPORT		
Customer: Element Materials Technology (Hitchin Ltd)	**Job No:**	**Test Date:** 4th Dec2014
Address:	**Material:** Carbon Steel	**Location:** SG4 0TW
Wilbury Way, Hitchin, Hertfordshire SG4 0TW, UK	**Inspection** **Standard:** BS EN 1714	
Component: Coated Pipe	**Drawing** **Reference**:	
Manufacturing **Process:** Resichem 530 HA 100		

Test Equipment				
Flaw Detector Type: Panmaterics	**Model:** Epoch III 2300	**Serial Number:** SERC 0870	**Couplant:** Sonagel W 140315	**Test Temperature:** Ambient
Calibration Spec: BS EN 12668.1	**UKAS:** 0381	**Calibration Date:** 26/11/14	**Calibration Due:** 26/11/15	**Calibration Sample**: 5-35mm Stepped block

Transducers					
Type	WK CD 10	**Serial Number:**	21203		
Frequency	5 MHz				
Crystal Size	2x 5mm				
Angle	0º				
Report Level: 10% Above Noise		**Reject Level:** 25% of Backwall Echo amplitude.		**Defect Sizing Method:** 80% to 20% drop signal amplitude	

Table 7.2: Post exposure: Resichem 530 HA 100 coating thickness (mm) D indicates dis-bond

RESULTS													
Sector/ Angle^{o}	1	2	3	4	5	6	7	8	9	10	11	12	13
0	0.96	0.76	0.74	0.74	0.54	0.78	0.54	0.76	0.98	0.98	0.83	1.02	0.74
22.5	0.50	0.46	0.46	0.85	0.76	0.87	0.94	0.85	0.96	0.54	0.68	X	X
45	0.52	0.48	0.63	0.54	0.67	0.78	0.76	0.85	0.92	0.98	0.85	X	X
67.5	0.46	0.46	0.46	0.54	0.84	0.84	0.94	0.86	0.94	0.92	0.76	0.76	0.94
90	0.74	0.56	0.54	0.75	0.82	0.85	0.94	0.96	0.96	0.96	1.00	0.94	0.76
112.5	0.74	0.46	0.76	0.92	0.84	0.87	0.92	**D**	**D**	0.98	1.02	0.74	0.74
135	0.76	0.74	0.88	0.83	0.61	0.61	**D**	**D**	0.89	0.87	0.81	0.98	0.94
157.5	0.48	0.48	0.76	0.96	0.96	0.74	0.86	0.88	0.92	0.82	0.98	0.98	0.98
180	0.52	0.81	0.96	1.07	1.09	0.87	0.87	1.13	1.13	0.98	0.76	0.52	0.76
202.5	0.52	0.81	0.56	0.81	1.09	0.92	1.02	0.76	0.92	0.76	0.76	0.76	X
225	0.76	0.74	0.73	0.76	0.72	0.52	0.67	0.87	0.81	0.63	0.76	0.80	X
247.5	0.76	0.67	0.92	0.98	1.02	0.81	1.09	1.05	0.84	0.54	0.56	X	X
270	0.56	0.56	0.78	0.58	0.67	0.92	0.59	0.92	0.92	0.98	0.83	X	X
292.5	0.51	0.81	0.81	0.61	0.98	1.05	0.89	0.89	0.70	0.85	0.89	X	X
315	0.50	0.54	0.83	0.70	1.09	0.87	0.76	0.86	0.84	0.85	0.83	X	X
337.5	0.48	0.81	0.76	0.94	0.76	0.58	0.54	0.87	0.59	0.87	0.87	X	X

Additional Information: X Donates no measurement possible due to presence of insulation spew.

8. APPENDIX B – Adhesive pull-off tests

Table 8.1: Individual adhesive pull-off test data

Material	Sample ID	Diameter d0 mm	Max Force N	Max. Stress MPa	Stress rate MPa/s
Resichem 530 HA 100	1-1	20	8109	26	0.52
	1-2	20	5077	16	0.55
	1-3	20	6580	21	0.55
	1-4	20	5151	16	0.57
	1-5	20	9205	29	0.57
	1-6	20	6967	22	0.56
	1-7	20	6792	22	0.59
	1-8	20	5726	18	0.49
	1-9	20	8677	28	0.56
	1-10	20	6159	20	0.58
	1-11	20	7279	23	0.54
	1-12	20	4224	13	0.56
	AVERAGE			**21**	
	ST.DEV.			**5**	

9. APPENDIX C – MSDS

9.1 RESICHEM 530 HA 100

resimac Ltd.

Material Safety Data Sheet

1. Identification of Substance/ Preparation and Company

Product Name:	**RESICHEM 530 HA100**
Company:	Units 10/ 11, Poplars Industrial Estate, Wetherby Road, Boroughbridge, North Yorkshire, YO51 9HS, UK
Chemical Name & Synonyms:	Modified Epoxy Novolac Resin
For Information:	Call on +44 (0) 1423 325073
In an Emergency:	As Above

2. Hazards Identification

Irritating to eyes and skin. May cause sensitization by skin contact. Dangerous for the environment

3. Composition/ Information on Ingredients

Hazardous Components	CAS Number	Percentage	Classification
Epoxy Phenol Novolac Resin	28064-14-4	60 – 80%	Xi;N, R36/38-43- 51/53

4. First Aid Measures *Summon immediate medical assistance after contact with skin, eyes, inhalation or ingestion*

Eye:	Immediately flush eyes with plenty of running water for at least 15 minutes. If irritation persists seek medical advice
Skin:	Remove contaminated clothing immediately. Wash affected area with soap and water. If irritation persists seek medical attention.
Ingestion:	Do not induce vomiting. Rinse mouth and drink plenty of water. Seek medical attention
Inhalation:	Remove person to fresh air.
	FIRST AIDERS SHOULD PROTECT THEMSELVES FROM EXPORSURE (Ref SECTION 8)

5. Fire Fighting Measures

Extinguishing Media:	Water spray, Dry powder, CO_2 and Foam.
Exposure Hazards:	In case of a fire, aside from the major combustion products Carbon Dioxide and Carbon Monoxide other harmful gases and vapours may be formed. Hazardous polymerisation can occur if material is heated above 70°C in bulk.
Fire Fighting Equipment:	Wear self contained breathing apparatus

6. Accidental Release Measures

Avoid skin and eye contact. Prevent from entering sewer system, surface water or soil. For large amounts dike spilled product with liquid absorbing material and pump off. For small spills soak up and transfer to a suitable container. Wash area with water/detergent.
Refer to section 5, 8 and 13 for Protective Measures and Disposal.

7. Handling and Storage

Store in a cool dry area between 10°C and 30°C, away from direct sunlight, heat and sources of ignition – no smoking. Use in well ventilated area. Wash hands after contact.

8. Exposure Controls/ Personal Protection

OCCUPATIONAL EXPOSURE LIMITS

Respiratory:	Not required during normal use
Ingestion:	Not during normal use
Skin Protection:	Protective clothing should be worn to avoid skin contact, PVC or Rubber gloves
Eye Protection:	Safety Goggles

Resimac Ltd
Units 10/11, Poplars Industrial Estate, Wetherby Road, Boroughbridge, North Yorkshire, United Kingdom
Tel: +44 (0) 1423 325073 Fax: +44 (0) 1423 325073 Email: info@resimac.co.uk Web: www.resimac.co.uk

resimac Ltd.

Material Safety Data Sheet

9. Physical/ Chemical Properties

Appearance:	Coloured fluid	**Odour:**	Weak
Viscosity:	Thixotropic	**Specific Gravity:**	1.40 g/ cm^3 at 20°C
Boiling Point/Range:	170ºC	**Melting Point/Melting Range:**	N/A
Flash Point:	> 150ºC	**Flammability:**	Will burn if involved in a fire
Auto-Flammability:	Above boiling point	**Explosive Properties:**	None
Oxidising Properties:	None	**Vapour Pressure:**	N/A
Evaporation Rate:	N/A	**Solubility:**	Insoluble in/with water
pH:	Neutral		Soluble in/with organic solvents
Partition Coefficient:	No data	**Di-Electric Strength:**	No data
Additional Information:			

10. Stability and Reactivity

Stability:	Stable until heated above 70°C.
Materials to Avoid:	May react with considerable heat build up with amines , mercaptans and acids.
Hazardous decomposition:	None
Hazardous polymerisation:	Bulk material should not be heated above 70°C due to the risk of hazardous polymerisation.

11. Toxicological Information

Oral:	LD_{50} (rat) (95% in Acetone) 11.4 g/kg.
Inhalation:	Not during normal use.
Eye:	Severe irritation.
Skin:	Irritant. Can cause sensitisation.

12. Ecological Information

Toxic to aquatic organisms, may cause long term adverse effects in the aquatic environment.

13. Disposal Considerations

Dispose of in accordance with local regulations

14. Transport Information

Environmentally hazardous substance, solid, N.O.S.,(epoxy resin) .U.N.No: 3077. Class: 9. Packing group: III

15. Regulatory Information

Labeling: Irritant (Xi), Dangerous for the environment.(N)

R-Phrases	(R36/.38)	Irritating to eyes and skin
	(R43)	May cause sensitisation by skin contact
	(R51/53)	Toxic to aquatic organisms, may cause long term adverse effects in the aquatic environment.
S-Phrases	(S2)	Keep out of reach of children
	(S24/25)	Avoid contact with skin and eyes.
	(S28)	After contact with skin wash immediately with plenty of soap and water
	(S36/37/39)	Wear suitable protective clothing, gloves and eye face protection.
	S46)	If swallowed seek medical advice immediately and show this container or label.
	(S61)	Avoid release to the environment. Refer to special instructions/safety data sheet.
Precautionary phrase	(P5)	Contains epoxy constituents. See information supplied by the manufacturer

16. Other Information

Risk phrases used in section 3 and not previously mentioned:
R38 - Irritating to skin

DATE OF PREPARATION: 3rd December 2013

The information contained within this document is furnished without warranty of any kind. Users should consider this data only as a supplement of other information gathered by them and make independent determinations of suitability and completeness of information from all sources to ensure proper use and disposal of these materials and the safety of employees and customers.

Resimac Ltd
Units 10/11, Poplars Industrial Estate, Wetherby Road, Boroughbridge, North Yorkshire, United Kingdom
Tel: +44 (0) 1423 325073 Fax: +44 (0) 1423 325073 Email: info@resimac.co.uk Web: www.resimac.co.uk