AkzoNobel

Alkylated Amine Epoxy: Maximise productivity, Minimise cost

February 2019

Agenda

- CUI Introduction and the Challenges
- Alkylated Amine Epoxy – Performance from -196ºC to +230ºC
- Performance Analysis - Benchmarking
- Conclusion

CUI – The Problem

Latest figure – Globally £4 trillion (OGTC site)

CUI – Corrosion Under Insulation

Electrochemical reaction
Problem recognised ~ 60 years ago
Still causing concern today
>80% CUI occurrences in piping

NACE SP0198 now states CUI can occur up to 175˚C

Insulation characteristics

Insulation system theoretically dry and barrier to water

In reality impossible to prevent water ingress

- Mechanical damage
- Degradation of mastic sealing cladding
- Complex geometries

Results of CUI

AkzoNobel

Typical results of CUI

- Metal Loss
- Failure of metal substrate resulting in catastrophic explosions

International

The Challenge

- Oil & Gas projects can involve thousands of pipe spools, valves and vessels
- All require different coating schemes depending on
  - Carbon steel or stainless steel
  - Insulated or un-insulated requirements
  - Service temperature range

The Challenge

Pipe Spool Coater, Louisiana, USA: “In a single month, I will use 40 different coatings from 6 different manufacturers…it’s a nightmare!”

The Challenge

AkzoNobel

SP0108-2008

Table 3B. Typical Atmospheric Zone Maintenance Coating Systems on Carbon Steels

Service Category	Coat	Coating System	DFT, µm (mil)	Target DFT, µm (mil)
CM-1 Water condensing pipes	1	Underwater-curable epoxy[A]	375-750 (15-30)	500 (20)
CM-2 Atmospheric zone -50 to 120°C (-58 to 248°F) with/without insulation	1 2 3	Epoxy primer High-solids epoxy Polyurethane	125-175 (5-7) 125-175 (5-7) 50-75 (2-3)	125 (5) 125 (5) 75 (3)
	1 2 3	Organic zinc-rich primer Epoxy Polyurethane	50-75 (2-3) 125-175 (5-7) 50-75 (2-3)	75 (3) 125 (5) 75 (3)
	1 2 3	Moisture-cured urethane primer Moisture-cured urethane Moisture-cured urethane	75-125 (3-5)[B] 75-125 (3-5)[B] 75-125 (3-5)[B]	100 (4) 100 (4) 100 (4)
CM-3 Atmospheric zone 120 to 150°C (248 to 302°F) with/without insulation	1 2	Epoxy phenolic Epoxy phenolic	100-125 (4-5) 100-125 (4-5)	125 (5) 125 (5)
	1 2	Silicon-based HB coating[C] Silicon-based HB coating[C]	100-200 (4-8) 100-200 (4-8)	150 (6) 150 (6)

International

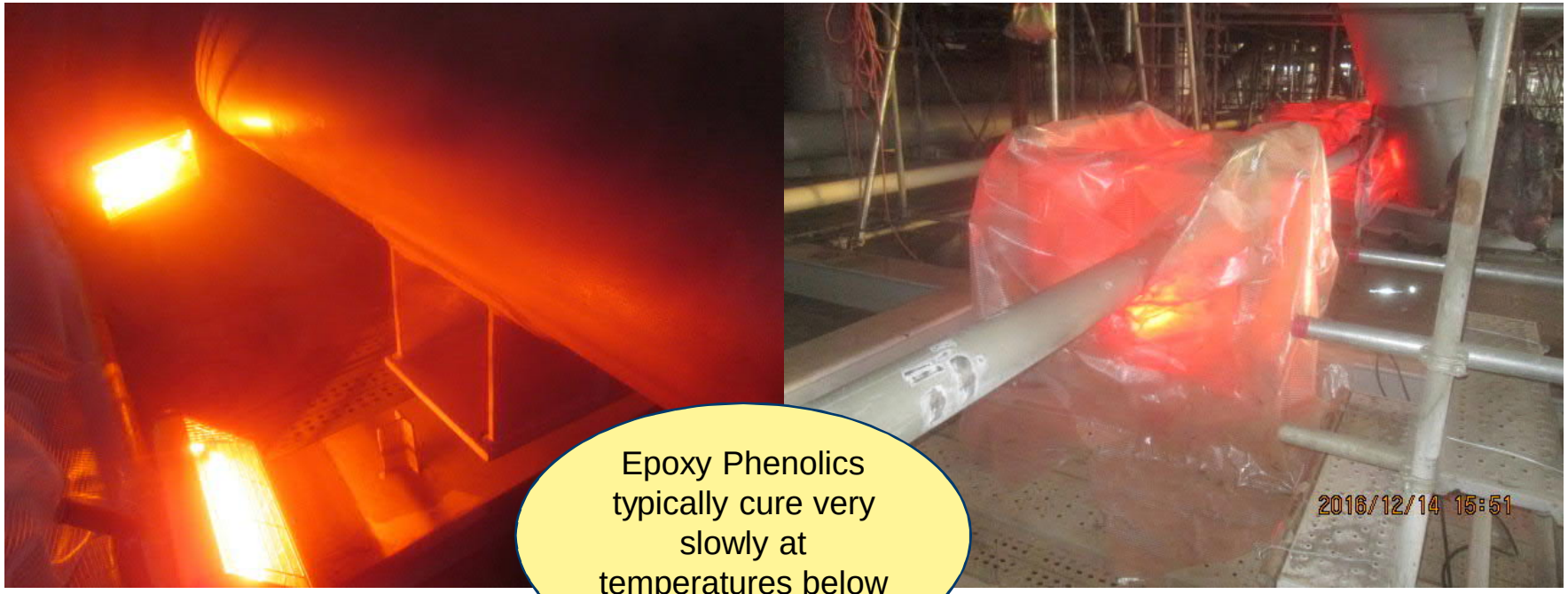
The Challenge
Epoxy Phenolics

In -196°C to 230°C (-320°F to 446°F) temperature range the epoxy phenolic currently dominates conventional specifications, but presents challenges for large, complex projects.

Epoxy Phenolic	Aluminium Silicone	Zinc Silicate
Epoxy Tie-Coat	Zinc Epoxy	High Build Epoxy Mid-Coat

The Challenge
Epoxy Phenolics

AkzoNobel



Epoxy Phenolics typically cure very slowly at temperatures below 10°C (50°F)

International

The Challenge
Epoxy Phenolics

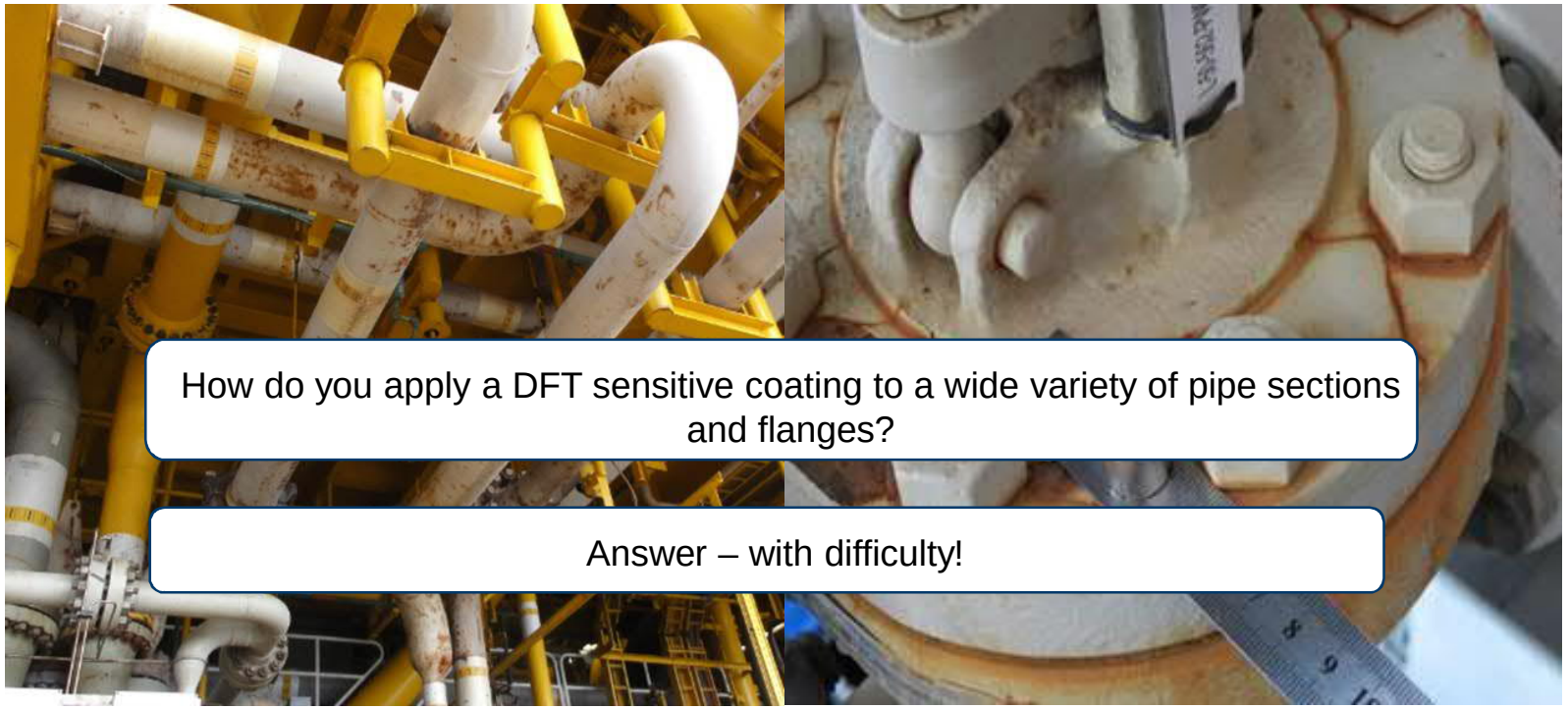
AkzoNobel

Can be slow drying and sensitive to over-application

International

The Challenge
Epoxy Phenolics

AkzoNobel



How do you apply a DFT sensitive coating to a wide variety of pipe sections and flanges?

Answer – with difficulty!

International

The Challenge
Complexity

AkzoNobel

Lots of coating systems

Some are difficult to apply easily

Complexity and slow curing can slow down productivity

Is there a better way?

International

AkzoNobel

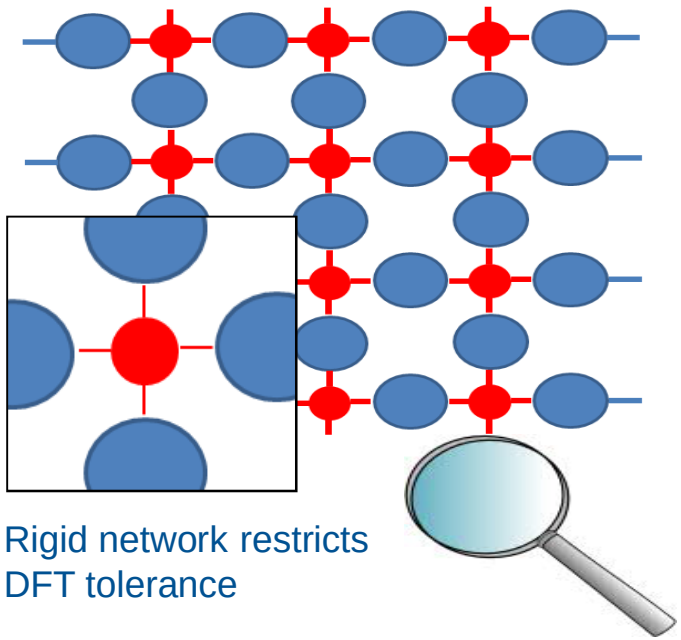
Alkylated Amine Epoxy Coating

Performance from -196ºC to +230ºC

What is Alkylated Amine Epoxy Technology?

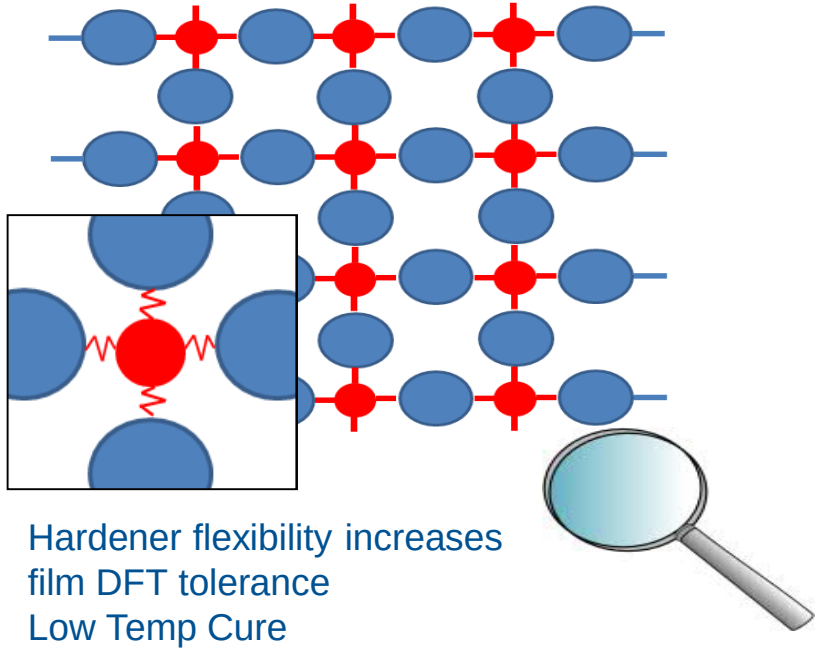
AkzoNobel

Typical Epoxy Phenolic



Rigid network restricts
DFT tolerance

Alkylated Amine Epoxy



Hardener flexibility increases
film DFT tolerance
Low Temp Cure

International

The Benefits
Tolerance to over application

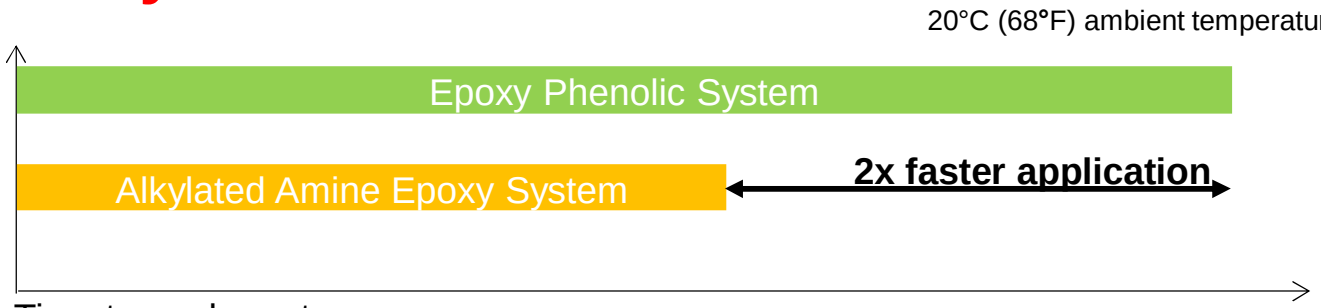
Standard Epoxy Phenolic
2 x 175µm (7mils)

Standard Epoxy Phenolic
2 x 225µm (9mils)

Alkylated amine epoxy
2 x 350µm (14 mils)

Test consists of heating to 200ºC (392°F) for 8hrs and leaving to cool to ambient for 16hrs; test is repeated 5 times

The Benefits
Fast and Low Temperature Curing = Productivity Increase



Temperature	Hard dry	Min Overcoating
-5°C	**10 hrs (N/A)**	**14 hrs (N/A)**
10°C	8 hrs (16 hrs)	10 hrs (36 hrs)
20°C	6 hrs (10 hrs)	7 hrs (20 hrs)
35°C	4 hrs (7 hrs)	4hrs (16 hrs)

Alkylated Amine Epoxy in Black. Typical Epoxy Phenolic values in red

Performance Analysis
Benchmarking

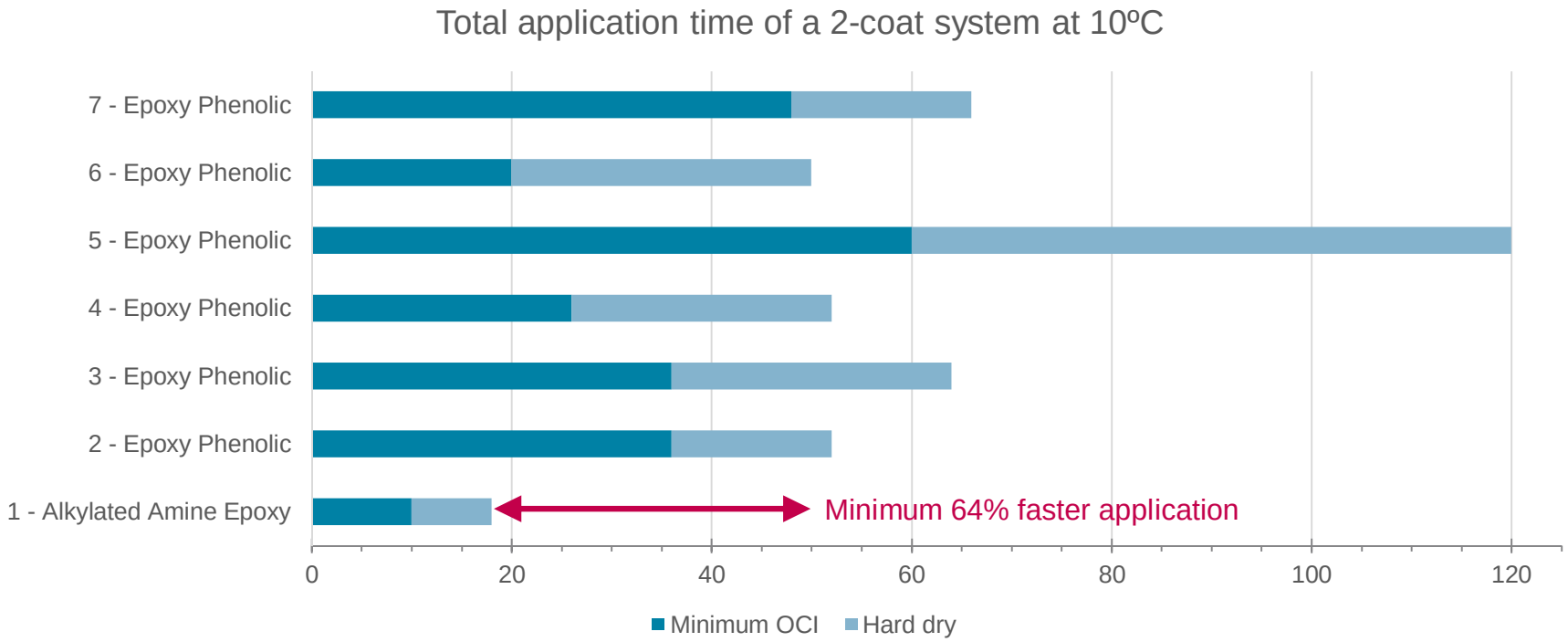
AkzoNobel

Coating	Coating Chemistry
1	Alkylated Amine Epoxy
2	Epoxy Phenolic
3	Epoxy Phenolic
4	Epoxy Phenolic
5	Epoxy Phenolic
6	Epoxy Phenolic
7	Epoxy Phenolic

- All coatings typically specified for service at least up to 200ºC
- Applied at 2 x 125 µm
- All coatings cured at ambient (20ºC) for a minimum of 7 days before testing

International

Productivity



Based on technical datasheets of each product

Performance Analysis
Benchmarking

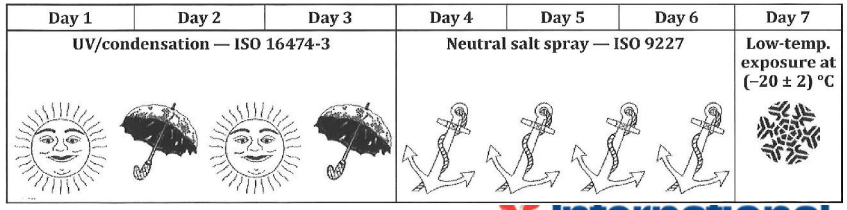
Performance of the 7 coatings was tested under the following conditions:

- **Anti-corrosive performance at ambient temperature (-20ºC to +60ºC)**
  - Cyclic ageing test (ISO 12944-9:2018) – 25 week cyclic accelerated test
- **Heat resistance**
  - Exposure to +205ºC for up to 6 months
- **Durability without topcoat or insulation**
  - Erosion resistance

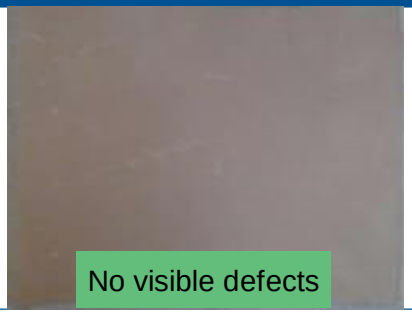
Anti-corrosion performance

System	1 AAE	2	3	4	5	6	7
Photos							
Rust creep	5.3 mm	7.7 mm	7.7 mm	8.1 mm	8.8 mm	8.1 mm	3.3 mm
Defects	None	None	None	None	None	None	Ri5

25 weeks – Cyclic ageing test according to ISO 12944-9:2018 (performance testing for CX environments)



Dry Heat resistance – 6 months at 205ºC

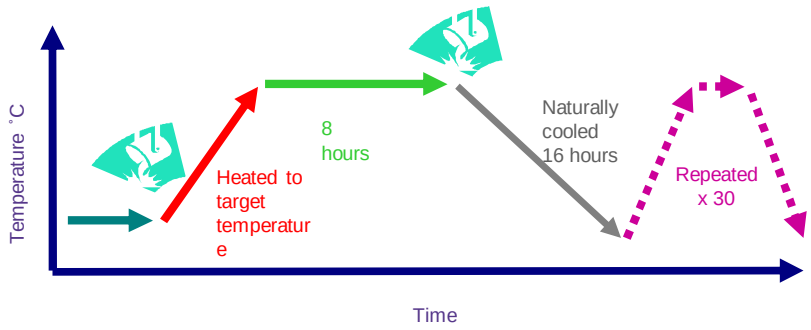
System	1 – Alkylated Amine Epoxy	2	3
Photos (and close-up where defects were observed) Results after 6 months exposure	 No visible defects	 No visible defects	 Lens x30 Significant cracking after 6 weeks
4	**5**	**6**	**7**
 Significant cracking after 12 weeks	 No visible defects	 No visible defects	 Lens x30 Minor cracking after 3 weeks

Performance under insulation (ISO19277-2018)- Appendix

AkzoNobel

Test Method

- Carbon steel pipe insulated with Calcium Silicate insulation
- Add 1 litre water (1% NaCl Solution)
- Hotplate applies heat for 8 hours to produce a thermal gradient
- Add one more litre of salt water
- Allow to cool to ambient for 16 hours



After 30 cycles (6 weeks) the pipe is removed from test and the coating evaluated

International

CUI Resistance - Houston Pipe Test (ISO19277-2018)- Appendix

- Houston Pipe test

  Tested up to ~400ºC, although organic coatings are expected to degrade above 250-300ºC

- Alkylated Amine Epoxy coating offers comparable performance to industry standard epoxy phenolic in terms of protection against Corrosion Under Insulation

AkzoNobel

Pipe temperature (ºC)	Systems	
	Alkylated Amine Epoxy	Traditional Epoxy Phenolic
120		
140		
155		
170		
190		
220		
240		
270		
300		
340		
390		
420		

International

Alkylated Amine– Track Record 2016

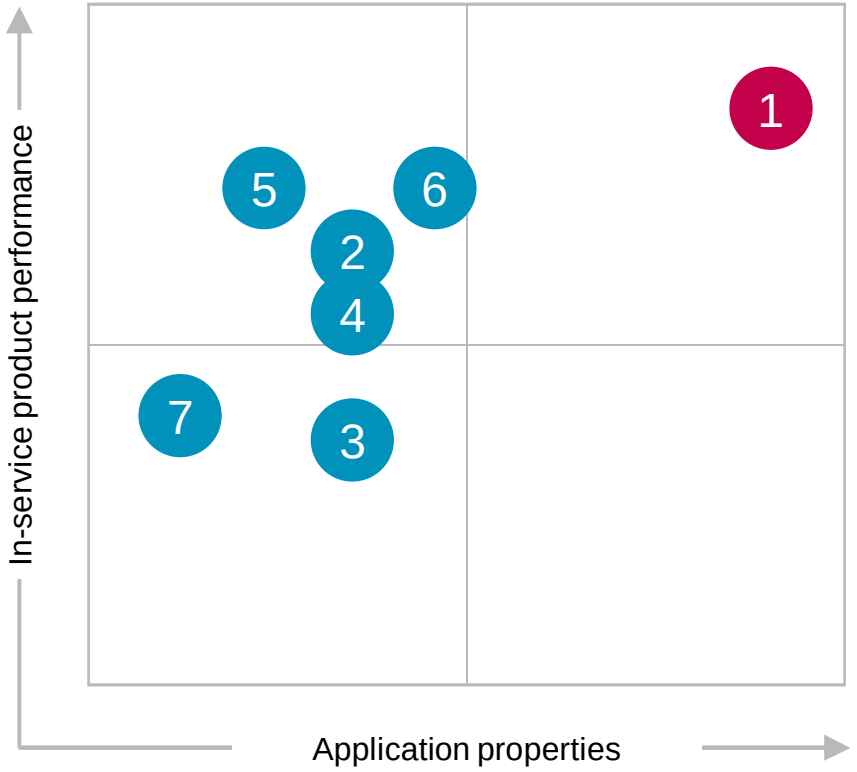
Customer	Clavon Engineering
Information	Alkylated Amine was applied in 2 x 100 micron coats to pressure vessels. These vessels will operate uninsulated and at high temperature as part of the Rapid RGT2 Project.
Project	Rapid RGT2 Project.

Alkylated Amine – Track Record 2016

Customer	Chevron
Information	Alkylated Amine has been applied to flare release lines on the Gorgon Gas Project in Western Australia.
Project	Gorgon Gas Project

Overall Performance – Conclusion

- Generic coating chemistry is not a guarantee of performance: heat resistance and anti-corrosion performance is not equal amongst “epoxy phenolics”.
- Alkylated Amine Epoxy coating offers equivalent high heat and CUI performance to industry standard epoxy phenolics. UV resistance is significantly improved.
- Alkylated Amine Epoxy coating offers major application advantages:
  - Improved DFT overapplication tolerance
  - Fast and low temperature curing



Overall Performance – Conclusion

All together mean that Alkylated Amine Epoxy technology offers

= reduced application costs and increased productivity

AkzoNobel

Questions?