Alkylated Amine Epoxy: Maximise productivity, Minimise cost

February 2019
CUI Introduction and the Challenges

Alkylated Amine Epoxy – Performance from -196°C to +230°C

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

Typical results of CUI

- Metal Loss
- Failure of metal substrate resulting in catastrophic explosions
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!”
### Table 3B. Typical Atmospheric Zone Maintenance Coating Systems on Carbon Steels

<table>
<thead>
<tr>
<th>Service Category</th>
<th>Coat</th>
<th>Coating System</th>
<th>DFT, µm (mil)</th>
<th>Target DFT, µm (mil)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CM-1 Water condensing pipes</strong></td>
<td>1</td>
<td>Underwater-curable epoxy&lt;sup&gt;(A)&lt;/sup&gt;</td>
<td>375-750 (15-30)</td>
<td>500 (20)</td>
</tr>
<tr>
<td><strong>CM-2 Atmospheric zone</strong></td>
<td>1</td>
<td>Epoxy primer</td>
<td>125-175 (5-7)</td>
<td>125 (5)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>High-solids epoxy</td>
<td>125-175 (5-7)</td>
<td>125 (5)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Polyurethane</td>
<td>50-75 (2-3)</td>
<td>75 (3)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Organic zinc-rich primer</td>
<td>60-75 (2-3)</td>
<td>75 (3)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Epoxy</td>
<td>125-175 (5-7)</td>
<td>125 (5)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Polyurethane</td>
<td>50-75 (2-3)</td>
<td>75 (3)</td>
</tr>
<tr>
<td><strong>CM-3 Atmospheric zone</strong></td>
<td>1</td>
<td>Moisture-cured urethane primer</td>
<td>75-125 (3-5)&lt;sup&gt;(B)&lt;/sup&gt;</td>
<td>100 (4)</td>
</tr>
<tr>
<td><strong>CM-3 Atmospheric zone</strong></td>
<td>2</td>
<td>Moisture-cured urethane</td>
<td>75-125 (3-5)&lt;sup&gt;(B)&lt;/sup&gt;</td>
<td>100 (4)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Moisture-cured urethane</td>
<td>75-125 (3-5)&lt;sup&gt;(B)&lt;/sup&gt;</td>
<td>100 (4)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Epoxy phenolic</td>
<td>100-125 (4-5)</td>
<td>125 (5)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Epoxy phenolic</td>
<td>100-125 (4-5)</td>
<td>125 (5)</td>
</tr>
<tr>
<td><strong>CM-3 Atmospheric zone</strong></td>
<td>1</td>
<td>Silicon-based HB coating&lt;sup&gt;(C)&lt;/sup&gt;</td>
<td>100-200 (4-8)</td>
<td>150 (6)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Silicon-based HB coating&lt;sup&gt;(C)&lt;/sup&gt;</td>
<td>100-200 (4-8)</td>
<td>150 (6)</td>
</tr>
</tbody>
</table>

<sup>(A)</sup> Underwater-curable epoxy coating systems are recommended for use in underwater environments. 

<sup>(B)</sup> Moisture-cured urethane primers and topcoats are recommended for use in atmospheric conditions with high moisture exposure.

<sup>(C)</sup> Silicon-based HB coatings offer high resistance to weathering and chemical attack.
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.
The Challenge
Epoxy Phenolics

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

Can be slow drying and sensitive to over-application
The Challenge
Epoxy Phenolics

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

Answer – with difficulty!
The Challenge
Complexity

Lots of coating systems
Some are difficult to apply easily
Complexity and slow curing can slow down productivity

Is there a better way?
Alkylated Amine Epoxy Coating
Performance from -196°C to +230°C
What is Alkylated Amine Epoxy Technology?

**Typical Epoxy Phenolic**
- Rigid network restricts DFT tolerance

**Alkylated Amine Epoxy**
- Hardener flexibility increases film DFT tolerance
- Low Temp Cure
The Benefits
Tolerance to over application

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

Standard Epoxy Phenolic
2 x 175µm (7mils)

Standard Epoxy Phenolic
2 x 225µm (9mils)

Alkylated amine epoxy
2 x 350µm (14 mils)
The Benefits
Fast and Low Temperature Curing = Productivity Increase

Epoxy Phenolic System

Alkylated Amine Epoxy System

2x faster application

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)  | 4 hrs (16 hrs)  |

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

Benchmarking

<table>
<thead>
<tr>
<th>Coating</th>
<th>Coating Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alkylated Amine Epoxy</td>
</tr>
<tr>
<td>2</td>
<td>Epoxy Phenolic</td>
</tr>
<tr>
<td>3</td>
<td>Epoxy Phenolic</td>
</tr>
<tr>
<td>4</td>
<td>Epoxy Phenolic</td>
</tr>
<tr>
<td>5</td>
<td>Epoxy Phenolic</td>
</tr>
<tr>
<td>6</td>
<td>Epoxy Phenolic</td>
</tr>
<tr>
<td>7</td>
<td>Epoxy Phenolic</td>
</tr>
</tbody>
</table>

- All coatings typically specified for service at least up to 200°C
- Applied at 2 x 125 µm
- All coatings cured at ambient (20°C) for a minimum of 7 days before testing
Based on technical datasheets of each product

Productivity

Total application time of a 2-coat system at 10°C

- 7 - Epoxy Phenolic
- 6 - Epoxy Phenolic
- 5 - Epoxy Phenolic
- 4 - Epoxy Phenolic
- 3 - Epoxy Phenolic
- 2 - Epoxy Phenolic
- 1 - Alkylated Amine Epoxy

Minimum 64% faster application

Minimum OCI  Hard dry
Performance of the 7 coatings was tested under the following conditions:

- **Anti-corrosive performance at ambient temperature (-20°C to +60°C)**
  - Cyclic ageing test (ISO 12944-9:2018) – 25 week cyclic accelerated test

- **Heat resistance**
  - Exposure to +205°C for up to 6 months

- **Durability without topcoat or insulation**
  - Erosion resistance
## Anti-corrosion performance

<table>
<thead>
<tr>
<th>System</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photos</td>
<td><img src="..." alt="Image" /></td>
<td><img src="..." alt="Image" /></td>
<td><img src="..." alt="Image" /></td>
<td><img src="..." alt="Image" /></td>
<td><img src="..." alt="Image" /></td>
<td><img src="..." alt="Image" /></td>
<td><img src="..." alt="Image" /></td>
</tr>
<tr>
<td>Rust creep</td>
<td>5.3 mm</td>
<td>7.7 mm</td>
<td>7.7 mm</td>
<td>8.1 mm</td>
<td>8.8 mm</td>
<td>8.1 mm</td>
<td>3.3 mm</td>
</tr>
<tr>
<td>Defects</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Ri5</td>
</tr>
</tbody>
</table>

**25 weeks – Cyclic ageing test according to ISO 12944-9:2018 (performance testing for CX environments)**
**Dry Heat resistance – 6 months at 205°C**

<table>
<thead>
<tr>
<th>System</th>
<th>1 – Alkylated Amine Epoxy</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photos (and close-up where defects were observed)</td>
<td><img src="image1" alt="No visible defects" /></td>
<td><img src="image2" alt="No visible defects" /></td>
<td><img src="image3" alt="Significant cracking after 6 weeks" /></td>
</tr>
<tr>
<td>Results after 6 months exposure</td>
<td><img src="image4" alt="No visible defects" /></td>
<td><img src="image5" alt="No visible defects" /></td>
<td><img src="image6" alt="Significant cracking after 6 weeks" /></td>
</tr>
<tr>
<td><img src="image7" alt="Significant cracking after 12 weeks" /></td>
<td><img src="image8" alt="No visible defects" /></td>
<td><img src="image9" alt="No visible defects" /></td>
<td><img src="image10" alt="Minor cracking after 3 weeks" /></td>
</tr>
</tbody>
</table>

*Images show the results of different systems exposed to dry heat resistance for 6 months at 205°C. System 1 shows no visible defects throughout the exposure. Systems 2 and 3 show varying degrees of cracking after different periods.*
Performance under insulation (ISO19277-2018)- Appendix

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

- Houston Pipe test
  Tested up to ~400°C, although organic coatings are expected to degrade above 250-300°C

- Alkylated Amine Epoxy coating offers comparable performance to industry standard epoxy phenolic in terms of protection against Corrosion Under Insulation
### Alkylated Amine– Track Record 2016

<table>
<thead>
<tr>
<th>Customer</th>
<th>Clavon Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Information</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Project</strong></td>
<td>Rapid RGT2 Project.</td>
</tr>
<tr>
<td>Customer</td>
<td>Chevron</td>
</tr>
<tr>
<td>------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Information</td>
<td>Alkylated Amine has been applied to flare release lines on the Gorgon Gas Project in Western Australia.</td>
</tr>
<tr>
<td>Project</td>
<td>Gorgon Gas Project</td>
</tr>
</tbody>
</table>
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
Questions?