Corrosion technologies for under insulation

What you can’t see can hurt you!
Contents

- Problems faced by users
- 3 target areas
- Importance of cycling
- SP0198 and what it tells us
- Introduction of Inert Polymer Matrix category
- Heat versus immersion – how to have it all?
- Things to consider
- Category CS-8 approach to bulk items
- Conclusions
Physical problems facing users

- Amount of insulated surfaces
- Moisture & wet insulation
- Coating breakdown
  - Incorrect surface preparation
  - Incorrect coating specification (heat)
  - Insufficient coating resistance (immersion)
- Limited alternatives
Real problems facing users

- Budgetary pressures
- Increasingly complex production processes
- Reduced turnaround opportunities and durations
- Better understanding of coatings limits (adds complexity)
- Numerous coating options (more recent years)
- Lack of definitive guidance
  - Recommendation
  - Testing
- It’s a complex issue!
Three target areas

▪ Insulated equipment and pipework

▪ Operating temperature below Dew point (‘sweating’)

▪ Lower temperature reduced corrosion rate
Three target areas

- Insulated equipment and pipework
- Operating temperature in CUI range
- Increased corrosion rates

Silicones - 650° C (1202° F)
Epoxy phenolic - 205° C (400° F)
Epoxies - 120°C (248° F)
Three target areas

▪ Insulated equipment and pipework

▪ Operating temperature above CUI range

▪ Reduced corrosion rates
However, conditions are rarely constant

- Insulated equipment and pipework

- Loss of heat on process equipment
Example 2

- Insulated equipment and pipework

- Process regeneration (absorbers, driers etc.)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Fahrenheit</th>
</tr>
</thead>
<tbody>
<tr>
<td>-196°C</td>
<td>-321°F</td>
</tr>
<tr>
<td>50°C</td>
<td>122°F</td>
</tr>
<tr>
<td>175°C</td>
<td>350°F</td>
</tr>
<tr>
<td>650°C</td>
<td>1202°F</td>
</tr>
</tbody>
</table>

Silicones - 650°C (1202°F)

Epoxy phenolic - 205°C (400°F)

Epoxies - 120°C (248°F)
Example 3

- **Insulated equipment and pipework**

- **Outage on cryogenic equipment (e.g. BOG compressors)**
Example 4

- Insulated equipment and pipework

- Shutdowns

- Unexpected outages

Coatings must have the ability to withstand these cycles
What matters most?

Immersion linings - lack of heat resistance

Epoxy Novolac versus epoxy
What matters most?

High temperature coatings – lack of corrosion resistance

- Silicones at high temperature
- Micro-cracking issue
- Subsequent corrosion

- Incomplete cure
- Lack of corrosion resistance
- Handleability

Historic thin – film Silicones
Summarise coatings types

- Insulated equipment and pipework

Cycling
- Limited to narrow temperature range
- Effects permanent change in coating
### Stainless steel

<table>
<thead>
<tr>
<th>System</th>
<th>Temperature range</th>
<th>Surface preparation</th>
<th>Coating type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS-1</td>
<td>-45 to 60°C</td>
<td>SSPC-SP-1 / abrasive blast</td>
<td>Epoxy</td>
</tr>
<tr>
<td>SS-2</td>
<td>-45 to 150°C</td>
<td>SSPC-SP-1 / abrasive blast</td>
<td>Epoxy phenolic</td>
</tr>
<tr>
<td>SS-3</td>
<td>-45 to 205°C</td>
<td>SSPC-SP-1 / abrasive blast</td>
<td>Epoxy Novolac</td>
</tr>
<tr>
<td>SS-4</td>
<td>-45 to 540°C</td>
<td>SSPC-SP-1 / abrasive blast</td>
<td>Silicone or modified silicone</td>
</tr>
<tr>
<td>SS-5</td>
<td>-45 to 650°C</td>
<td>SSPC-SP-1 / abrasive blast</td>
<td>Inorganic copolymer / Inert multi-polymer matrix</td>
</tr>
</tbody>
</table>

### Carbon steel

<table>
<thead>
<tr>
<th>System</th>
<th>Temperature range</th>
<th>Surface preparation</th>
<th>Coating type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS-1</td>
<td>-45 to 60°C</td>
<td>NACE No. 2 / SSPC-SP-10</td>
<td>Epoxy</td>
</tr>
<tr>
<td>CS-2</td>
<td>-45 to 60°C</td>
<td>NACE No. 2 / SSPC-SP-10</td>
<td>Fusion bonded epoxy (FBE)</td>
</tr>
<tr>
<td>CS-3</td>
<td>-45 to 150°C</td>
<td>NACE No. 2 / SSPC-SP-10</td>
<td>Epoxy phenolic</td>
</tr>
<tr>
<td>CS-4</td>
<td>-45 to 205°C</td>
<td>NACE No. 2 / SSPC-SP-10</td>
<td>Epoxy Novolac or silicone hybrid</td>
</tr>
<tr>
<td>CS-5</td>
<td>-45 to 595°C</td>
<td>NACE No. 2 / SSPC-SP-5</td>
<td>Thermally sprayed aluminium (TSA)</td>
</tr>
<tr>
<td>CS-6</td>
<td>-45 to 650°C</td>
<td>NACE No. 2 / SSPC-SP-10</td>
<td>Inorganic copolymer / Inert multi-polymer matrix</td>
</tr>
<tr>
<td>CS-7</td>
<td>To 60°C</td>
<td>SSPC-SP2 or SSPC-SP3</td>
<td>Petrolatum / petroleum wax tape</td>
</tr>
<tr>
<td>CS-8</td>
<td>-45 to 150°C</td>
<td>Low pressure water cleaning</td>
<td>As CS-3/4/6</td>
</tr>
<tr>
<td>CS-8 (bulk or shop primed pipe coated with inorganic zinc)</td>
<td>-45 to 150°C</td>
<td>Low pressure water cleaning</td>
<td>As CS-3/4/6</td>
</tr>
</tbody>
</table>
Do we need to choose?

**Effective heat resistance**
- Wide range
- Change in temperatures (Cycling)
- No micro-cracking
- Cryogenic capability

**Corrosion resistance**
- Before exposure
- After heat exposure
- CUI environment

**Practical**
- Physically durable
- M & R friendly
Things to consider

▪ Heat resistance
▪ Corrosion resistance after heat exposure
▪ Effect of thermal cycling
▪ Corrosion under insulation resistance
▪ Cryogenic resistance
▪ Resistance to damage (CS-8)
## Heat resistance

<table>
<thead>
<tr>
<th>DFT</th>
<th>Temperature</th>
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</thead>
<tbody>
<tr>
<td>1 x 150 µ (6 mils)</td>
<td>650° C (1202° F)</td>
</tr>
<tr>
<td>2 x 150 µ (6 mils)</td>
<td>625° C (1157° F)</td>
</tr>
<tr>
<td>3 x 150 µ (6 mils)</td>
<td>600° C (1112° F)</td>
</tr>
<tr>
<td>2 x 300 µ (12 mils)</td>
<td>450° C (842° F)</td>
</tr>
</tbody>
</table>

- **Modified ASTM D2485 – Method B**
- **Exposure 300 - 650° C (572 - 1202° F)**
- **50° C (122° F) steps**
- **Can be noticeable at 450° C (842° F)**
Heat resistance

Before heat exposure (650°C)

After heat exposure (650°C)
Corrosion resistance

<table>
<thead>
<tr>
<th>Heat exposure limit</th>
<th>Candidate scheme</th>
<th>ISO 7253 / ASTM B117</th>
<th>Heat exposure limit</th>
<th>Micro cracks form active sites for corrosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>650° C (1202 °F)</td>
<td>1 x 150µ</td>
<td>2 x 150µ</td>
<td>3 x 150 µ</td>
<td>650° C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>450° C</td>
</tr>
<tr>
<td>450° C (842° F)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Cyclic CUI corrosion test

- 210°C dry heat for 16 hours
- Quench in cold water
- Immersion in boiling water for 8 hours

- Results are scheme dependent
- Emphasises barrier effect of pigments

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Cycles achieved</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 x 150 µ</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 x 150 µ</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 x 150 µ</td>
<td>80</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

18th May 2014
CUI resistance

- Houston pipe test
- Multi-temperature evaluation
- Mineral wool insulation
- Repeated cycles
  - Soak-heat-hold-soak-cool

Immersion in salt water to identify presence of micro-cracks
Cryogenic exposure

NACE SP0198 - 2010

- No account for cryogenic conditions
- Minimum temperature - 45°C
- Typically epoxy phenolics

+ 200°C - 196°C

- No cracking or delamination
- Irrespective of substrate
Physically durable

Conventional silicones
- Soft prior to heat exposure
- Easily damaged
- Particularly aluminium variants
- Not ideal for off-site fabrication

SS-5 / CS-6
- Hardness can vary significantly
- Impact resistance / damage resistance should be considered

<table>
<thead>
<tr>
<th>Candidate</th>
<th>Average impact resistance (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>49</td>
</tr>
<tr>
<td>#2</td>
<td>37</td>
</tr>
<tr>
<td>#3</td>
<td>27</td>
</tr>
<tr>
<td>#4</td>
<td>25</td>
</tr>
</tbody>
</table>
Use of Zinc silicate on bulk items
- Conventional schemes
  - If degraded, zinc is exposed
  - Not ideal
- Limits top temperature limit / substrate
- Assists with specification simplification
- Eliminating zinc primer may increase scheme thickness in C5M

No heat exposure
Heat exposure (400°C)
Conclusions

▪ Improved materials category ➔ improved durability ➔ reduced lifecycle costs
▪ No micro-cracking ➔ improved CUI resistance
▪ Scheme thickness can have significant impact
▪ Pigment type will affect barrier properties
▪ Inert multipolymer matrix type materials
  ▪ Improves on current options across ‘High temperatures’
  ▪ Provides resistance to CUI / atmospheric corrosion after high temperature exposure
Thank you
SIDA@hempel.com