Corrosion under insulation (CUI) and Insulation systems

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Corrosion Under Insulation (CUI)

Presentation Outline

1. Critical factors influencing CUI
2. The issue
3. Evidence from CUI simulations
4. The Golden Guideline for mitigation of CUI
5. Three key rules to apply the Golden Guideline
6. Four principles for insulation selection
7. Analysis of six generic insulations
8. Questions
1. **Critical factors that influence CUI** (from design to decommissioning)

Factors that can combine to cause, accelerate and/or prevent CUI are:

- **Operating temperatures**
  - Cyclic temperature operation (-20°C to +320°C)
  - Static temperature operation (-5°C to +175°C)

- **Choice and installation of coating system**

- **Design, choice & installation of insulation system.**

- **Plant operation**

- **Surrounding environment**
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2. The issue

Corrosion of steel occurs in the presence of water and oxygen under **all** insulation.
3. Evidence from CUI simulation

Methodology: Test Method – ASTM G189-07

- Test apparatus constructed to contain six generic insulation material types in one test.

- Tested on carbon steel.
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3. Evidence from CUI simulation

Methodology (cont):

- The insulation is **wetted** and **dried** in set cycles of cold (60°C) and hot (150°C).

<table>
<thead>
<tr>
<th>Cyclic test</th>
<th>One cycle</th>
<th>No. of cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Duration</strong></td>
<td>20 hours</td>
<td>4 hours</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>60°C</td>
<td>150°C</td>
</tr>
<tr>
<td><strong>Wet / Dry</strong></td>
<td>Wet</td>
<td>Dry</td>
</tr>
</tbody>
</table>
3. Evidence from CUI simulation

Methodology (cont):

- The liquid (demi water) used is **recycled** so that **leaching products** of the specific insulation influence the corrosion.

<table>
<thead>
<tr>
<th>Insulation</th>
<th>Aerogel blanket</th>
<th>Calcium silicate</th>
<th>Cellular glass</th>
<th>Fibreglass</th>
<th>Polyisoc’té (PIR)</th>
<th>Stone wool</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Top side</strong></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
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<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Bottom side</strong></td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
<td><img src="image9.png" alt="Image" /></td>
<td><img src="image10.png" alt="Image" /></td>
<td><img src="image11.png" alt="Image" /></td>
<td><img src="image12.png" alt="Image" /></td>
</tr>
</tbody>
</table>
3. Evidence from CUI simulation

Observations (by METALOGIC)

- **Corrosion occurred under all tested insulations.**

- **With water introduced onto the steel surface:**
  - Insulation materials open to water vapour diffusion performed better than closed cell materials.
  - Insulation materials with a vapour open system performed better than those with a vapour closed system.

- **Material with higher concentrations of leached chloride gave higher corrosion rates (independent of insulation type).**
3. Evidence from CUI simulation

Conclusion (by METALOGIC)

The rate of CUI is driven by the DURATION OF WET METAL EXPOSURE to leached salts and other compounds reacting with water.
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3. Evidence from CUI simulation

Results & conclusions published at:

NACE Paper No. 8877
https://store.nace.org › Conference Papers

(Copies of this paper are available after today's presentation)
4. The Golden Guideline for mitigation of CUI

The insulation material that holds the least amount of contaminated water on the steel surface, for the shortest time, provides the lowest corrosion rates.
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5. Three key rules to apply the Golden Guideline

- Properly designed and installed jacketing/cladding system.
- Use of a suitable coating system for steel pipe and vessel surface protection.
- Choosing an insulation material and system with important ‘corrosion reduction’ characteristics.
6. Four principles for insulation selection relating to CUI

Water ingress cannot be avoided and will occur under all types of insulation. To mitigate the harmful effects of CUI, choose an insulation with:

- The **least** water absorption.
- The **fastest** moisture dissipation.
- The **most durable** performance over the entire CUI temperature range.
- The **lowest amount** of leachable chlorides or residual compounds that react with water.
Corrosion Under Insulation (CUI)

6. Four principles for insulation selection relating to CUI

Principle 1: Least water absorption

Achieved by:

• Foam insulation – with a closed cell structure that is \textit{not} affected by water (in liquid or vapour form).

or

• Fibrous insulation – with a \textit{high level} of water repellency.
Corrosion Under Insulation (CUI)

6. Four principles for insulation selection relating to CUI

Principle 1: Least water absorption (cont)

Verified by – Partial immersion testing to:

- **BS EN 1609** (Slab, mattress and blanket)
- **BS EN 13472** (Piping)

Verified by – Full immersion testing to:

- **ASTM C1763-16**
Corrosion Under Insulation (CUI)

6. Four principles for insulation selection relating to CUI

Principle 1: Least water absorption (cont)

Research paper and slide presentation:

• Mineral wool & water repellency
  NACE Paper No. 10929
  by Claudia Zwaag & Soren Nyborg Rasmussen
  (Copies of this paper available after today’s presentation)

• 16 slide presentation
  Based on NACE Paper No. 10929
  (Available from AIS on request)
Corrosion Under Insulation (CUI)

6. Four principles for insulation selection relating to CUI

Principle 2: Fastest moisture dissipation

Achieved by:

- **Vapour open fibrous structure** – allows water to evaporate from the surface and diffuse out through the insulation.

- **Lowest water absorption** – the drier the fibrous material the faster the dry-out time.
Principle 2: Fastest moisture dissipation (cont)

Achieved by:

- **Highest vapour flow** – material with a water vapour resistance factor closest to air ($\mu=1.0$).
- **Non-contact** – a system where the insulation has no contact with steel surface.
Corrosion Under Insulation (CUI)

6. Four principles for insulation selection relating to CUI

Principle 2: Fastest moisture dissipation (cont)

Example: **Non-contact systems** with spacer between insulation and piping
6. Four principles for insulation selection relating to CUI

Principle 2: Fastest moisture dissipation (cont)

Example: **Non-contact system** with spacer between insulation and piping

(Non-contact insulation system presentation available on request)
Corrosion Under Insulation (CUI)

6. Four principles for insulation selection relating to CUI

Principle 2: Fastest moisture dissipation (cont)

Determination of Water Vapour Transmission Properties by testing to:

- **EN 12086** for water vapour diffusion resistance factor (μ)

Product examples:

<table>
<thead>
<tr>
<th>Kingspan™ Tarec™pir</th>
<th>μ ~ 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROCKWOOL™ stone wool</td>
<td>μ = 1.3</td>
</tr>
</tbody>
</table>
6. Four principles for insulation selection relating to CUI

Principle 3: Most durable CUI temperature range

Achieved by:

• Insulation material that suitable for the maximum service temperature.

• If additives are used for insulation water repellency, they must maintain their properties up to 250°C.

(Separate presentation on binders and additives available from AIS on request)
Principle 4: Lowest leachable chlorides & others that accelerate CUI

Mitigated by:

- Using low leachable substance ($\leq 10$ mg/kg).
- Insulations with pH in neutral to slightly alkaline range.
- Conformity to the stainless steel corrosion specification ASTM C795.
6. Four principles for insulation selection relating to CUI

Principle 4: Lowest leachable chlorides & others that accelerate CUI (cont)

Compliance with:

- **ASTM C795** *(Acceptable Analysis Graph* for selection of insulation in contact with austenitic stainless steel)*

Testing based on:

- **ASTM C692** *(external stress corrosion cracking tendency of austenitic stainless steel)*
- **ASTM C871** *(chemical analysis of thermal insulation materials)*
## 7. Analysis of six generic insulations

<table>
<thead>
<tr>
<th>Generic material</th>
<th>Brand &amp; product example</th>
<th>Material structure</th>
<th>Product toughness</th>
<th>Dissipation of water ($\mu$)</th>
<th>Low water absorption</th>
<th>Low chloride</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone wool</td>
<td>ROCKWOOL™ ProRox®</td>
<td>Fibrous</td>
<td>Partial</td>
<td>Fast</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Aerogel</td>
<td>Armacell® Armagel HT</td>
<td>Semi-closed</td>
<td>No</td>
<td>Fast</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Glass wool</td>
<td>CSR Bradford™ Multitel</td>
<td>Fibrous</td>
<td>No</td>
<td>Fast</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Cellular glass</td>
<td>PCC Foamglas®</td>
<td>Cellular</td>
<td>Yes/No</td>
<td>Slow</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Calcium silicate</td>
<td>Calsilite®</td>
<td>Semi-closed</td>
<td>Partial</td>
<td>Slow</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Polyisocyanurate</td>
<td>Kingspan™ Tarec™pir</td>
<td>Cellular</td>
<td>Partial</td>
<td>Partial</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Questions?

Thank you