NACE JUBAIL

TECHNICAL WORKSHOP

CORROSION UNDER INSULATION

Corrosion Under Insulation (CUI) and the Insulation System

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ROCKWOOL Technical Insulation, Jubail, 10 December 2015

The issue

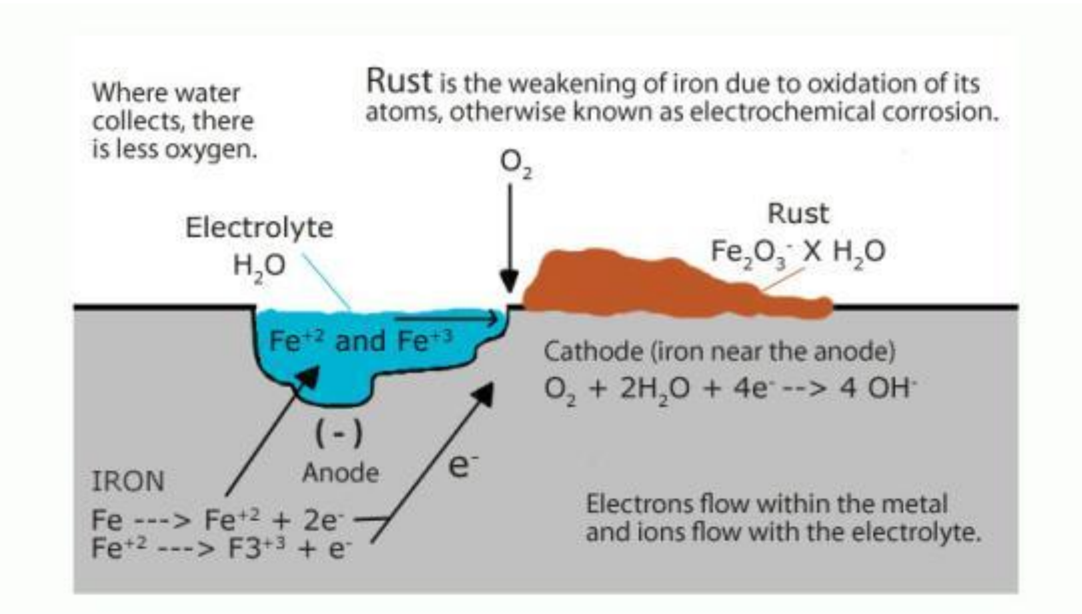
Corrosion of steel occurs in the presence of water and oxygen

- So, obviously, if the steelwork under insulation remains **dry there is no corrosion problem**
- But, **keeping the insulation dry can be difficult** which can lead to steel work corrosion
- Commonly referred to as corrosion under insulation (CUI)
- **CUI is found** under all types of insulation **when you have installation issues or damages**

Insulation does NOT protect against corrosion. Corrosion prevention requires a suitable coating, insulation, cladding and installation under dry conditions.

General corrosion process

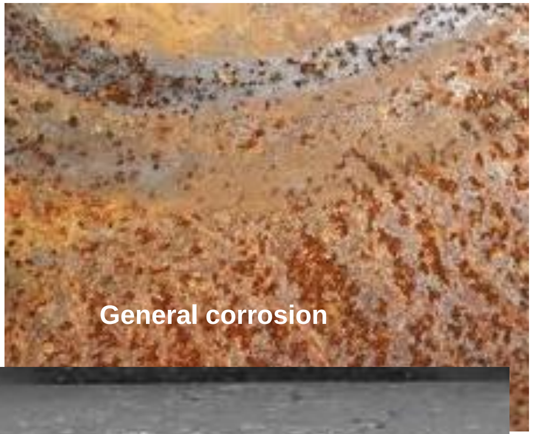
- Metal + Water + Oxygen => Corrosion



Accelerating factors:
- Time of wetness (access to water)
- Temperature (until the water has evaporated)
- Soluble salts (expecially chloride)
- Acidic impurities

Types of corrosion

- Steel is in general susceptible to **CUI** in the temperature range of **0ºC to 175ºC**. The most frequently occuring types of CUI are:
- **General and pitting corrosion of carbon steel**, which may occur if wet insulation comes in contact with carbon steel
- **External Stress Corrosion Cracking (ESCC) of austenitic stainless steel**, which is a specific type of corrosion mainly caused by the action of **water-soluble chloride** from rainwater or if the insulation is not meeting the appropiate requirements


General corrosion


External stress corrosion cracking


Typical example corrosion under insulation

The corroded surface is mostly **hidden by the insulation system** and will not be observed until the insulation is removed for inspection or in the event of metal failure leading to incidents.

Risk of CUI

Carbon/mild steel – risk of corrosion

Operating temperature	CUI risk
< -5 °C (25 °F)	Low
> 175 °C (347 °F)	Low
-5 to 49 °C (25 to 121 °F)	Medium
50 to 175 °C (122 to 347 °F)	High
Cycling temperatures between -20 and 320 °C (-4 and 608 °F)	Extreme

Stainless steel – risk of ESCC

Operating temperature	ESCC risk
< 50 °C (122 °F)	Low
50 to 175 °C (122 to 347 °F)	High
>175 °C (347 °F)	Low

Reference: Shell DEP 30.46.00.31-Gen. September 2011

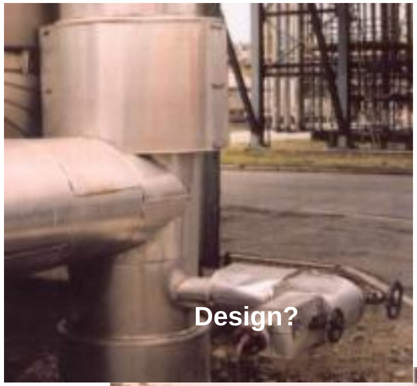
Preventing corrosion

(Risk mitigation)

Critical factors

Numerous factors are involved in causing or preventing corrosion under insulation

- **Surrounding environment**
  - Indoor/outdoor
  - Land / oceanic climate
  - Acidic environment
- **Operation of the plant**
  - Cyclic or continous operation
  - Temperatures
- **Choise and installation of coating system**
- **Design, choice and installation of the insulation system**
- **Actual operation**
  - Prompt, promptly maintenance
  - Foot traffic
  - Risk based inspection procedures

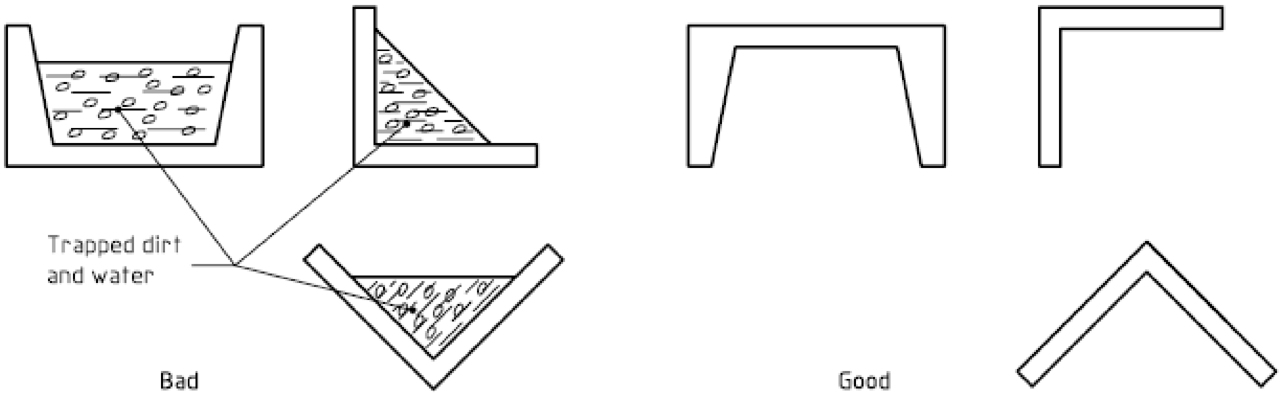


Design phase:

Design pipes, vessels etc. with corrosion protection in mind:

Consider:

- Avoidance of water traps, unintended bimetallic corrosion etc.
- Smooth surfaces, access for surface preparation and coating application
- Prevention of water ingress



Ref.: ISO 12944-3

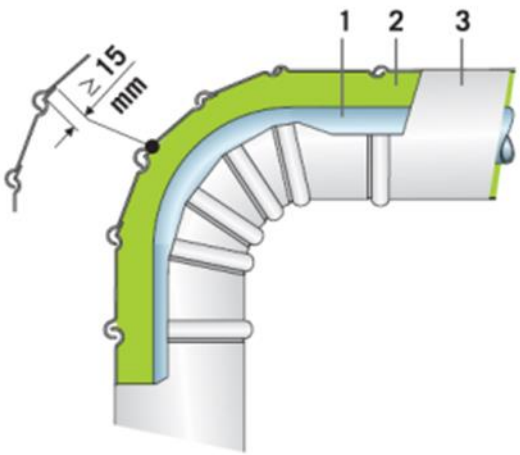
Choice and installation of coating system

- Coating system should be suitable for the operational temperatures (also when wet)
- Surface preparation and application is critical for performance and suppliers guidelines must be followed.
- Avoid damage of coating system after application.

System no	Temperature range	Surface preparation[1]	Surface profile µm (mil)	First coat µm (mil)	Finishing co µm (mil)
CS-1	-45°C/50°F to 60°C/140°F	ISO 8501-2: Sa 2½/ SSPC SP 10	50-75 (2-3)	High build epoxy 125 – 175 (5-7)	High build epoxy 125 – 175 (5-7)
CS-2	-45°C/50°F to 150°C/300°F	ISO 8501-2: Sa 2½/ SSPC SP 10	50-75 (2-3)	Epoxy phenolic/ novolac 100-200 (4-8)	Epoxy phenolic/ novolac 100-200 (4-8)
CS-3	-45°C/50°F to 595°C/1100°F	ISO 8501-2: Sa 3/ SSPC SP 5	50-75 (0.5-1)	Thermal sprayed Aluminium 250-375 (10-15)	Optional: Sealer: Type acc. to service temp. 40
CS-4[2]	-45°C/50°F to 650°C/1200°F	ISO 8501-2: Sa 2½/ SSPC SP 10	40-65 (1.5 – 2.5)	Inorganic copolymer[3] 100-150 (4-8)	Inorganic copolymer[3] 100-150 (4-8)

Watertight insulation protection /cladding is the first line of defence against CUI

- The cladding should shed water
- Sealing of joints
- Inspection points



Quality control in all phases:

- Steel quality, Steel work, Surface preparation, Coating application, Insulation installation, Cladding installation ....

Actual operation

- Prompt, promptly maintenance
- Avoid foot traffic, and other unnecessary activities that may damage the system
- Risk based inspection procedures

Where is CUI a risk factor – where should the inspection be more frequent?

- RISK = Probability X Consequence

Probability of CUI is affected by: Age, condition of cladding, location (corrosivity of environment), operational temperatures, insulation material, quality/age of primary corrosion protection etc. (where does the water go?)

Consequence of CUI is: Cost of shut-down for replacement, Environmental and safety hazards in case of leak etc.

Probability/ Consequence	High	Medium	Low
High			
Medium			
Low			

How does the insulation material affect corrosion?

Insulation selection

NACE SP0198-2010 (2.1.2):

CUI of carbon steel is possible under **all types of insulation**. The insulation type may only be a contributing factor. The insulation characteristics with the most influence on CUI are:

- Water-leachable salt content in insulation, such as chloride, sulphate and acidic materials that may contribute to corrosion;
- Water retention, permeability, and wettability of the insulation; and
- Foams containing residual compounds that react with water to form hydrochloric or other acids.

Because CUI is a product of wet metal exposure duration, the insulation system that **holds the least amount of water and dries most quickly** should result in the least amount of corrosion damage to equipment.

Corrosion can be reduced by careful selection of insulation materials.

Corrosion happen under all types of insulation but there are differences

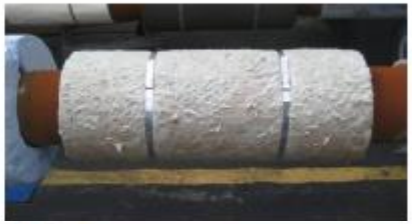
- **Go beyond the obvious (λ, MST, …):** To minimize the risk of CUI, it is also important that **the insulation does not affect the steel, does not absorb water and is open to vapour** so that moisture can easily egress the insulation
- Essential properties and test methods

Water absorption should be less than 1kg/m2	EN1609
Water vapour resistance (μ) is close to 1,0	EN12086
pH is neutral to slightly alkaline	
Conforms to the stainless steel corrosion specification as per ASTM test methods C692 and C871	ASTM C795
Water leachable chloride content < 10mg/kg [AS-Quality]	EN13468
Mass Loss Corrosion Rate < reference test	ASTM C1617

The amount of corrosion testing related to insulation products is limited

Results from natural weathering testing:

Massachusetts, US in 2009, 12 weeks outdoor testing. Insulation installed over bare mild steel with no cladding.

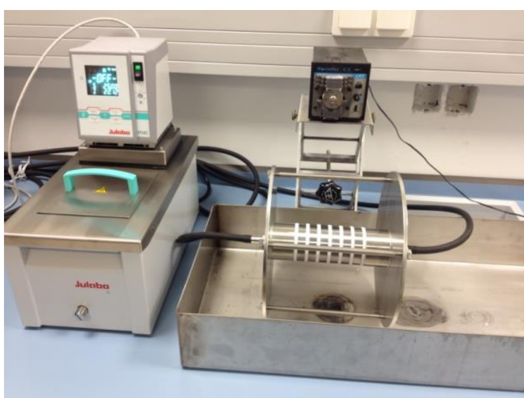
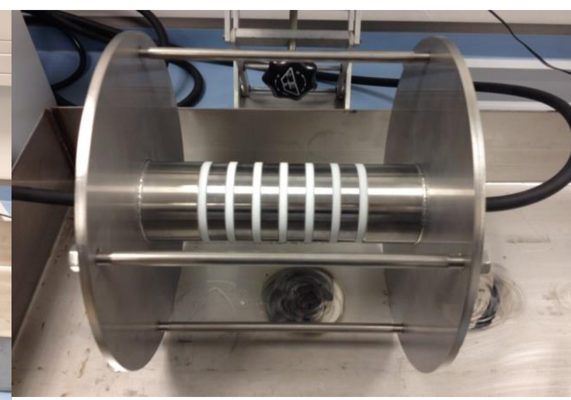
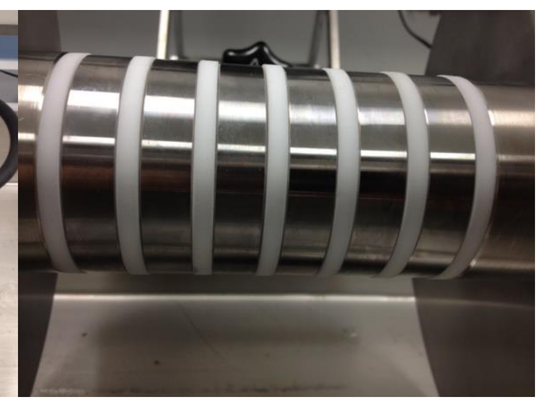
Observations	Day 1	Day 85	Day 85, insulation removed
Cellular Glass *Heavy general corrosion, concentrated at the top of the pipe*			
Mineral Wool *Moderate corrosion over top one-third. Material was damp to the touch upon removal.*			
WRG Mineral Wool *Some corrosion on top of pipe. Material was discolored after several weeks' exposure.*			

Ref.: Williams, J. Evans, O., "THE INFLUENCE OF INSULATION MATERIALS ON CORROSION UNDER INSULATION," NACE, Calgary Canada, February 2010.

CUI Simulation Measurements – ASTM G189-07

The test apparatus is constructed such that it contains six separate test samples in one test. Test samples are carbon steel.
The insulation is wetted and dried in set cycles of cold (60°) and hot (150°C).
The liquid used is recycled so that leaching products of the specific insulation influence the corrosion.

Cyclic test	One cycle		No of cycles
Duration	20 hours	4 hours	21 (21 days)
Temperature	60°C	150°C	
Wet/dry	Wet	Dry	

CUI Simulation Measurements – ASTM G189-07

CUI Test set-up
"Water on the pipe"

Stone wool PS (ASTM C547)

Aerogel (ASTM C 1728)

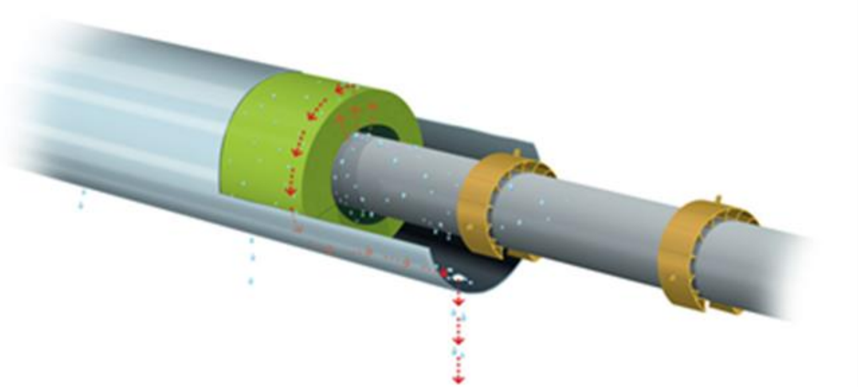
Cellular glass (ASTM C 552)

New tools in the CUI battle

Non contact insulation

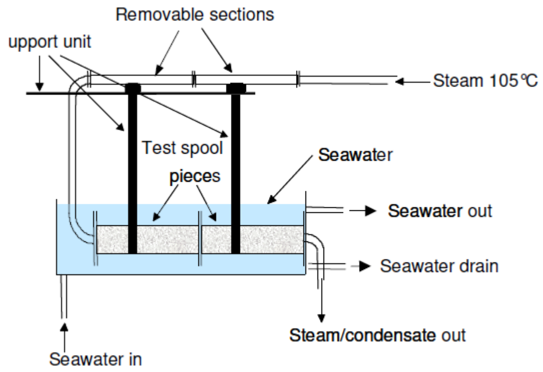
- Spacers ensure an air gap between the steel pipe and the insulation.
  - **Reduced time of ”Wetness” = lower corrosion rates**
  - **Hot water immersion like situations are avoided/limited = extended lifetime of the protective coating system**

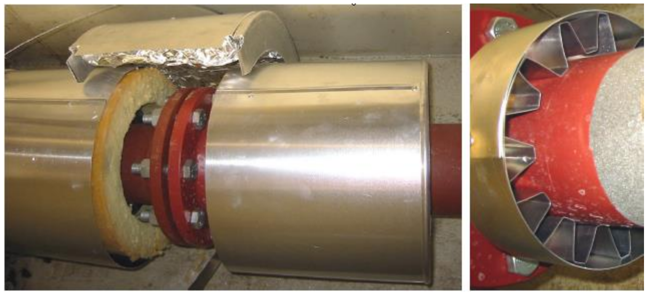
Combining a spacer with an insulation material with a high water vapour permeability allow the water to move to the cladding where it can condense, run to a lower point and be tapped out.



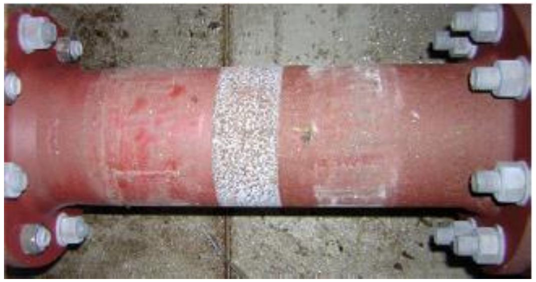
Results of corrosion testing with spacers Norway 1:

Results from accelerated testing in Norway, 2005: Comparing mineral wool and spacer with cellular glass directly on the pipe.

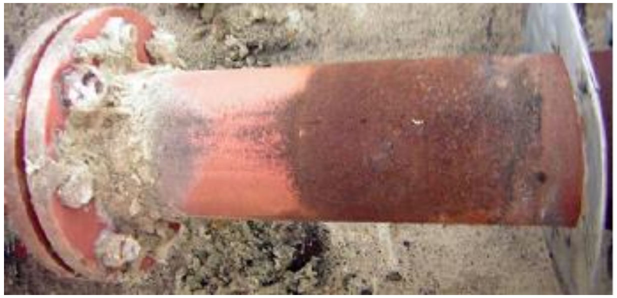




Operational temperature: 105°C, with biweekly 30 minutes immersion in Seawater. Test duration 3 months.



Mineral wool and spacer: Limited corrosion and coating intact.



Cellular glass: Severe corrosion and coating damage.

ASTM G189-07 testing of non-contact insulation

- CUI simulation tests carried out by METALogic on behalf of ROCKWOOL Technical Insulation in accordance with ASTM G189-07.

- Comparing ASTM C547 pipe sections direct on pipe and via use of spacer rings

  - Up to 21 cycles of 24 hours (20 hrs. 60ºC wet – 4 hrs 150ºC dry)
  - Use of demineralized water

Direct to metal

Coupon Code	Ini. weight (g)	Fin. weight (g)	# days (cycles)	Surface (mm²)	Affected surface (cm)	Estimated affected surface %	Max. measured pitting depth (µm)
79	73.5967	73.5776	21	2262	4	21%	30
80	72.7350	72.7075	21	2262	5	27%	25
81	72.6888	72.6480	21	2262	6	32%	20
82	72.6463	72.5726	21	2262	7	37%	30
83	72.8088	72.7524	21	2262	7	37%	40
84	72.6530	72.6000	21	2262	7	37%	20

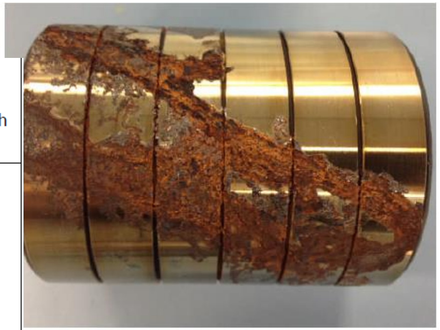


Figure 5: Top side coupons belonging to ProRox PS960

Figure 6: Bottom side coupons belonging to ProRox PS960

Non-Contact Insulation

Coupon Code	Ini. weight (g)	Fin. weight (g)	# days (cycles)	Surface (mm²)	Affected surface (cm)	Estimated affected surface %	Max. measured pitting depth (µm)
127	73.7689	73.7658	21	2262	0	0%	0
128	74.1598	74.1589	21	2262	0	0%	0
129	73.6376	73.5874	21	2262	3	13%	90
130	73.7003	73.5750	21	2262	7	37%	40
131	73.8016	73.7997	21	2262	0	0%	0
132	73.5828	73.5828	21	2262	0	0%	0

Figure 11: Top side coupons belonging to "non-contact"

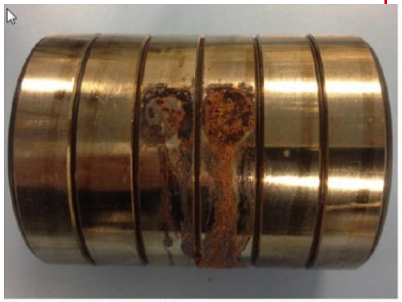
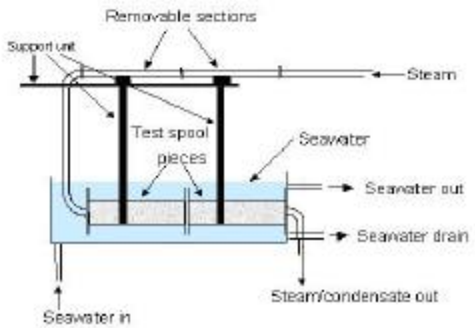


Figure 12: Bottom side coupons belonging to "non-contact"

Results of corrosion/coating testing with spacers Norway 2:

Results from accelerated testing in Norway (Statoil) 2009:
Comparing mineral wool with and without spacers.



Operational temperature: 140°C, with 20 minutes immersion in Seawater 3 times a week. Test duration 2 months.

Insulation system	Mineral wool	Mineral wool + Distance
Coating system A, UHPWJ, 15°C	Medium: 35-50%, B	Slight: 10%, B,
Coating system A, UHPWJ, 120°C	Heavy: 35-50%, B, poor top layer	Medium: 10%, B, poor top layer
TSA, Grit blasting, 15°C *	No: 0%, DFT = 170 □m	No: 0%, DFT = 260 □m
Coating system B, UHPWJ, 15°C	Heavy: 80-95%	No: 0%
Coating system B, UHPWJ, 120°C	Heavy: 95-98%	Slight: 0%, high DFT, b, loose top layer

Significant difference in coating performance – even for TSA

Ref.: NACE paper 10022, K. Haraldsen

Spacers – what is on the market?

- Metal solutions – available from main Insulation installers
- Polymer based solutions are becoming available offering added advantages.

Main advantage of **metal** solutions is higher temperature resistance

Main advantages of **polymer** based solutions are :

- No damage to heat tracing and coating
- No damage to coating
- Lower risk of injuries/damage due to sharp edges.
- More efficient installation

Seamless cladding

- Seamless cladding based on UV cured GRP is an alternative tool in
- the CUI fight.
  - **Eliminate/minimize water ingress**
  - **Cladding with higher mechanical and chemical resistance**

Wrap up

- **CUI is a system challenge and must be addressed and planned from design phase to service. Including steps as:**
  - steelwork quality and design (smooth surfaces, water shedding)
  - coating selection and application,
  - insulation selection and installation,
  - cladding selection and installation
  - Inspection and maintenance plans in service – possibly risk based
  - **Quality control important in all phases**.
- **The choice of insulation material do influence corrosion rates. Care should be given to the selection. Old assumptions may not hold-up.**
- **New tools in the CUI fight are becoming available – some are available and some being finalised in the laboratories.**

Thank you for your attention