

Selecting the best Corrosion under Insulation (CUI) solutions

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2. How to approach CUI?
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- 1. Corrosion under insulation

Pictures say more than words



- 1. Corrosion under insulation

Pictures say more than words



•1. Corrosion under insulation

•CUI is defined as the external corrosion of piping and vessels that occurs when water gets trapped beneath insulation. CUI damage takes the form of localized corrosion in carbon and low alloy steels. Factors that affect CUI include

- Duration, frequency of exposure to moisture
- Corrosivity of the aqueous environment
- Condition of protective barriers (cladding, coating,...)
- Design
- Temperatures (-4°C to $+175^{\circ}\text{C}$ // also outside this zone!)
- Cyclic temperatures??
- Insulation type
- Climate
- Site maintenance practice
- Tracing systems
- General environment (proximity of saltwater, cooling towers,.....)

•Above definition copied from API 583

•1. Corrosion under insulation



Gaps exist in cladding

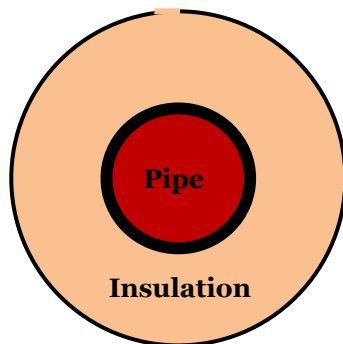
- Damage
- Poor sealing
- Improper fit
- All cladding leaks eventually



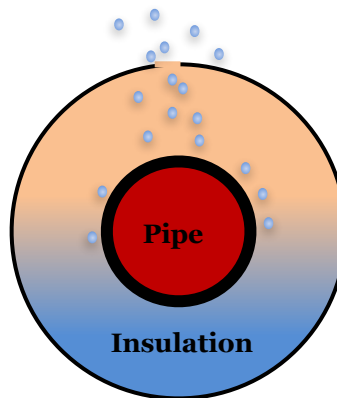
Rain dumps huge water against hot steel and flows throughout insulation



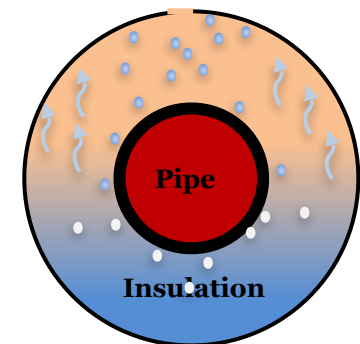
- Water boils at the pipe
- Electrolytes in the water concentrate
- Steam condenses when it reaches the cladding



Cladding



Cladding



Cladding

• 1. Corrosion under insulation

- Nothing stays hot forever
- Water under cladding is never completely expelled
- Additional water can enter damaged cladding
- Electrolytes in the water may concentrate
- Eventually the insulation becomes saturated or will hold water (depending on insulation)
- **The substrate will corrode if not properly protected**



•2. How to approach CUI?

It is important to take all aspects of the application into account as they all are equally important to reduce the problem of corrosion under insulation. The most important aspects are

a. Sheeting

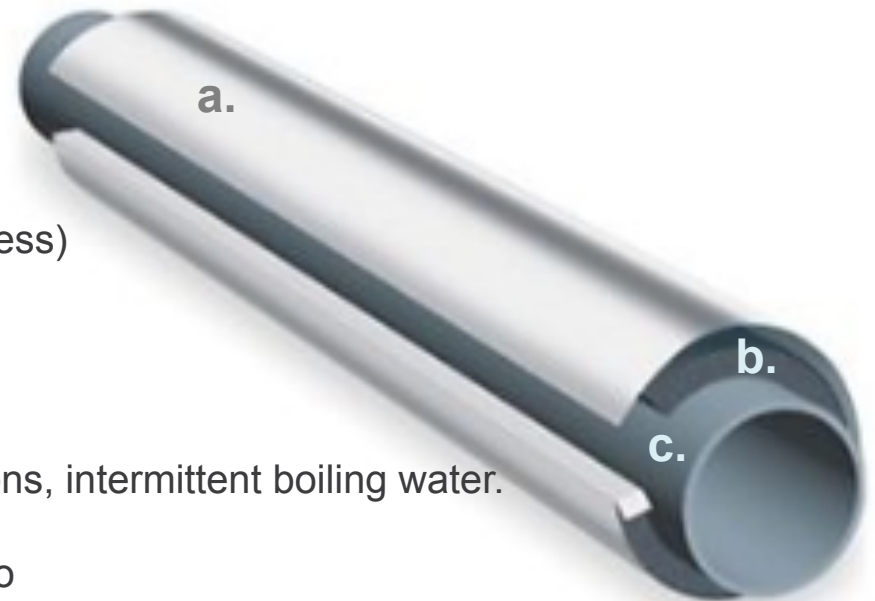
- correct sheeting selected
- correct application
- correctly sealed

b. Insulation

- reduced or no water uptake (water repellant)
- very limited chloride content
- designed to serve the purpose (not more, not less)

c. Coating

- Suited for the temperature range
- immersion resistant
- able to serve under cyclic temperature conditions, intermittent boiling water.
- easy to repair if damaged
- Must be able to withstand a worst case scenario



•2. How to approach CUI?

- Protective coating
- Select the correct coating: This is the LAST barrier to the steel!
- Define temperature range,
- Define possible surface preparation
- Define maintenance intervals/ inspection intervals
- Select coating which serves the goal!
- Weigh coating cost up to expected service life!



ALL OPERATING CONDITIONS SHOULD BE CONSIDERED, INCLUDING OUT OF SERVICE STATE WHEN SELECTING THE CORRECT PROTECTIVE SYSTEM

3. Testing of coatings that serve under insulation

- **No specific test standard yet**
- **Several guidelines addressing the subject of CUI**
 - API 583 & EFC WP13 and WP14
 - These are very detailed documents addressing all aspects in mitigating CUI starting from the design phase.
 - All “last barriers” towards the steel are addressed (wrapping, TSA, coating)
 - general approach towards coatings (“conventional coating”)
 - NACE 0198-2010
 - Standard practice document (control of corrosion under thermal insulation and fireproofing materials)
 - Defines typical recommended generic coating systems based on different temperature zones

3. Testing of coatings that serve under insulation

•NACE 0198-2010

Typical Protective Coating Systems for Carbon Steels Under Thermal Insulation and Fireproofing					
System Number	Temperature Range (A)(B)	Surface Preparation	Surface Profile, μm (mil) (C)	Prime Coat, μm (mil) (D)	Finish Coat, μm (mil) (D)
CS-1, CS-2, CS-3	Epoxy, Fusion Bonded Epoxy, Epoxy Phenolic minus 110° to 302°F [minus 45° to 150°C]				
CS-4	-45° to 205°C [- 50 to 400°F]	NACE No. 2 / SSPC-SF 10	50-75 (2-3)	Epoxy novolac or silicone hybrid, 100- 200 (4-8)	Epoxy novolac or silicone hybrid, 100-200 (4-8)
CS-5	-45° to 595°C (-50 to 1100°F)	NACE No. 1 / SSPC-SP 5 ¹⁵	50-100 (2-4)	TSA, 250-375 (10-15) with minimum of 99% aluminum	Optional: Sealer with either a thinned epoxy-based or silicone coating (depending on maximum service temperature) at approximately 40 (1.5) thickness
CS-6	-45° to 650°C (-50 to 1200°F)	NACE No. 2 / SSPC-SF 10	40-65 (1.5-2.5)	Inorganic copolymer or coatings with an inert multipolymeric matrix, 100-150 (4-6)	Inorganic copolymer or coatings with an inert multipolymeric matrix, 100-150 (4-6)
CS-7	Petroleum wax primer; ambient to 140°F [60°C]				
CS-8	Shop primers and topcoats for inorganic zinc (IOZ) minus 110° to 750°F [minus 45° to 400°C] Novolac, phenolic, inorganic copolymer and inert polymeric matrix				

3. Testing of coatings that serve under insulation

- Test standard under development with committee ISO TC 67 WG 11 named ISO19277
- Standard will define:
- CUI environments

Classification	Minimum	Peak Temperature Range		Description
CUI-1	-45 ⁰ C	-45 ⁰ C	60 ⁰ C	Wet
CUI-2	-45 ⁰ C	60 ⁰ C	150 ⁰ C	Warm
CUI-3	-45 ⁰ C	150 ⁰ C	204 ⁰ C	Hot
CUI-4	-45 ⁰ C	204 ⁰ C	450 ⁰ C	Very Hot

PPG HI-TEMP™ heat-resistant coatings

3. Testing of coatings that serve under insulation

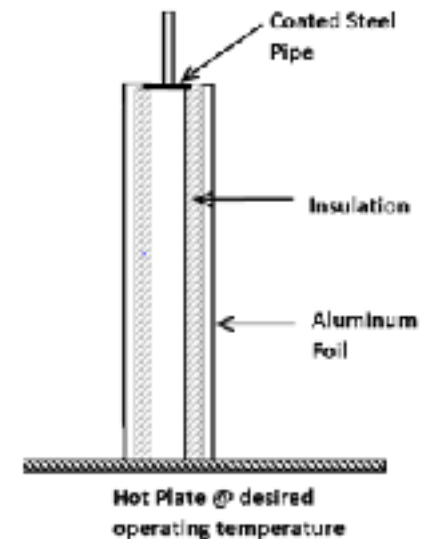
Specific CUI test methods

- Shell Test; Cyclic Wet / Dry Immersion Testing 16 weeks
- Steam Bypass Test 90 days
- Modified Houston Pipe Test 21-30 days
- ASTM G189
- PPG HTC CUI Chamber Test (1008 hours, 252 cycles)

Most manufactures of CUI protective coatings have developed a company specific test method

•These originate from

- ASTM G189 basic method
- Houston pipe test (see picture aside)
- Other test methods are a variance of these methods with modifications in the test cycles.



3. Testing of coatings that serve under insulation

- **PPG CUI Chamber Test 2008**

- **Uses ASTM G189 as a model**

- For simplicity the insulation is omitted
- Temperature control: ambient to 250°C
- Consistent and repeatable results.
- The chamber environment can be totally controlled

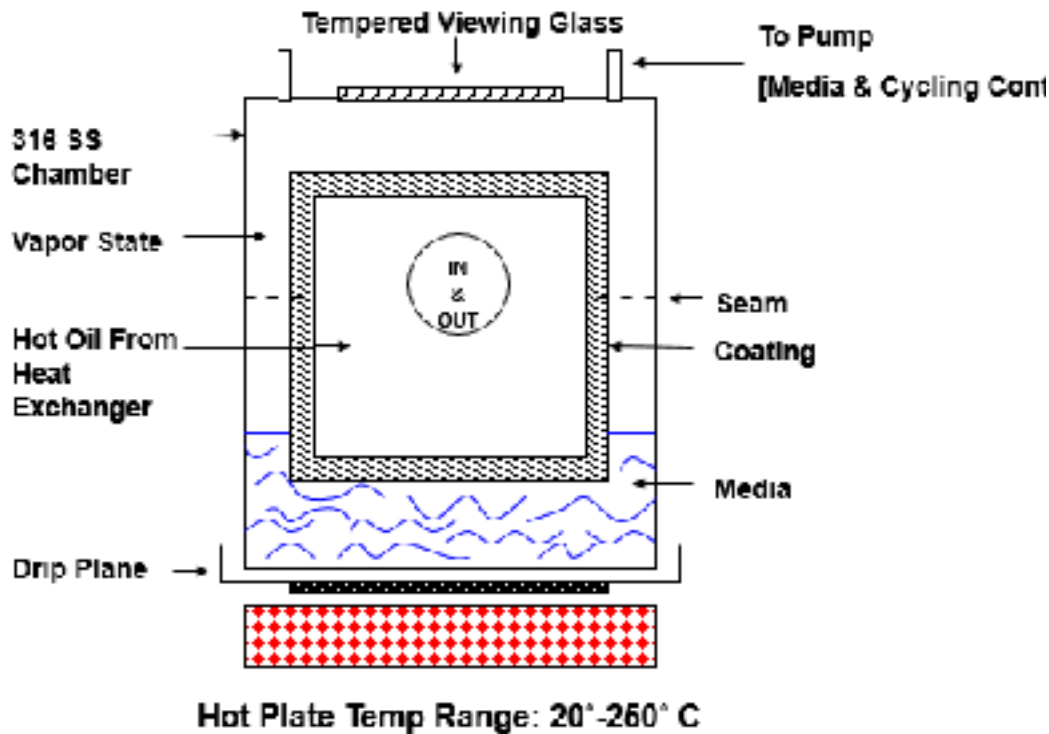
- **Approvals: Shell Oil 2008, Aramco 2010**

- **Method B:**

- 5% NaCl solution
- Set wet/dry cycle time [4 hours]
- 42 day duration [252 cycles] 1008 hours
- Internal temp 350°F [179°C]
- Steam-out immersion temp 212°F [100°C]



3. Testing of coatings that serve under insulation



Before Test

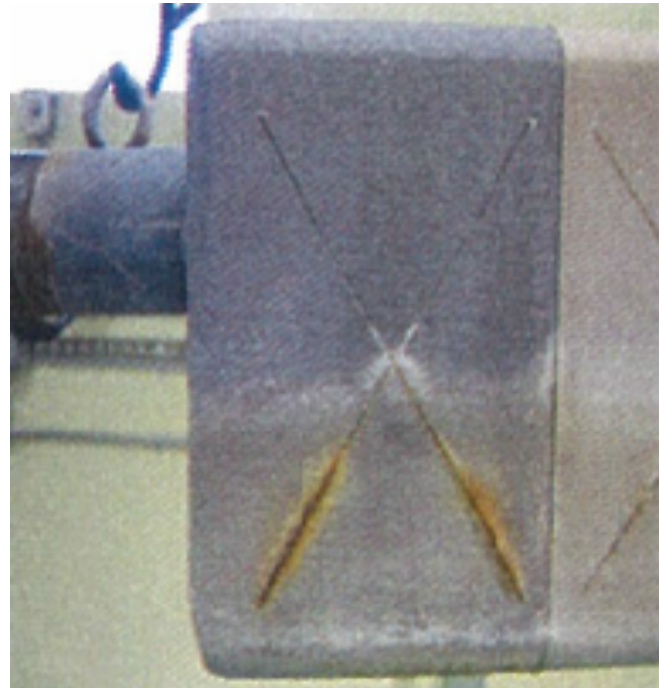


After 6 Weeks Front View



After 6 Weeks Bottom View

- Results from PPG CUI Chamber test



•4. Typical systems

CUI protection preferably through barrier effect. Why?

- Blasting profile of 50µm: Peaks covered?
- Barrier against moisture, impact and abrasion?
- Active galvanic protection.

Silicone (acrylic)

- 2 coats of 25µm
- Total DFT = 50µm
- Barely covers peaks
- Suitable under insulation?
- OK for galv and SS?

Zinc & Silicone (acrylic)

- 75µm zinc primer
- 2 coats of 25µm
- Total DFT = 125µm
- Galvanic protection (sacrificial, sealed)
- Covers peaks
- Suitable under insulation?
- NOK for galv and SS!

Phenolic or multipolymeric matrix

- 2 coats of 125µm = 250µm
- Covers peaks + 200µm
- Extra barrier in 3 coats possible
- OK under insulation.
- OK for galv and SS!



•4. Typical systems

- Temperature
- Maintenance or newbuild?
- Surface preparation

PPG CUI Newbuild, Maintenance & Repair Systems

Legend	Best Solution For In service and Peak Temperatures
	Good Solution
	Do Not Use
	Application Temperatures from 10°C + (50°F+) to>>>>

	-184°C (-300°F)	-101°C (-150°F)	-73°C (-100°F)	-46°C (-50°F)	-18°C (0°F)	10°C (50°F)	121°C (250°F)	149°C (300°F)	177°C (350°F)	204°C (400°F)	232°C (450°F)	260°C (500°F)	288°C (550°F)	316°C (600°F)	650°C (1200°F)
Epoxy and epoxy phenolic	Good Solution	Good Solution	Best Solution	Best Solution	Best Solution	Best Solution	Best Solution	Good Solution	Good Solution	Good Solution	Do Not Use	Do Not Use	Do Not Use	Do Not Use	Do Not Use
MP composite	Best Solution	Best Solution	Best Solution	Best Solution	Good Solution	Good Solution	Best Solution	Best Solution	Best Solution	Best Solution	Good Solution	Do Not Use	Do Not Use	Do Not Use	Do Not Use
Inert MP matrix	Best Solution	Best Solution	Best Solution	Best Solution	Good Solution	Good Solution	Good Solution	Best Solution	Best Solution	Best Solution	Best Solution	Best Solution	Best Solution	Best Solution	Best Solution

•4. Typical systems

•Inorganic zinc under insulation??

- STRENGTHS
- High temperature limits
- Good sacrificial corrosion protection
- SP0198 CS-8 as a bulk shop primer and when used - a top coat is recommended



PPG HI-TEMP™ heat-resistant coatings

- WEAKNESSES
- Thin film coating (75µm)
- Corrosion can occur with zinc consumption in corrosion cell
- Will not survive long in wet environments
- Thermal shock and cycling may reduce life expectancy
- May suffer “reverse galvanic” corrosion between 60 and 80°C
- SA2,5 absolute minimum



Not recommended

•TSA

- STRENGTHS

- Mechanical bond to substrate
- High durability
- High temperature limits
- Automated application possible

- WEAKNESSES

- SA2.5 absolute minimum
- Limited suitability for maintenance
- Coefficient of thermal expansion (CTE) not matched to substrate. Can lead to stress in thermal cyclic conditions
- costly



•Epoxy and Epoxy Phenolic Coatings

- STRENGTHS
 - Very good chemical resistance
 - High durability
 - Hard and durable coatings
 - Provides extremely good corrosion protection in immersion service
- WEAKNESSES
 - **SA2.5 absolute minimum**
 - **Limited suitability for maintenance**
 - **Coefficient of thermal expansion (CTE) not matched to substrate. Can lead to stress in thermal cyclic conditions**
 - **Temperature limitations**



• **MultiPolymeric copolymer and Inert Multipolymeric ceramic Matrix coatings**

- STRENGTHS
 - Large temperature range
 - Coefficient of thermal expansion (CTE) matches almost the substrate, so thermally durable
 - Can withstand thermal cycling
 - Can withstand thermal shock
 - Surface tolerant (ST2)
 - Easy to apply
 - Hot application possible!
- WEAKNESSES
 - Slightly higher initial cost
 - Moderate chemical resistance (PH5 to 10)
 - Good but not best solution below 120°C



•Summary of proposed CUI Coating range

•Epoxy:

- **Immersion resistant**
- **Glassflake reinforced**
- **Surface tolerant**
- **Up to 150°C in CUI service**
- **250µm dft (1 coat possible)**

Phenolic epoxy:

- **Immersion resistant**
- **High chemical resistance**
- **Up to 230°C dry heat exposure**
- **Up to 150°C in CUI service**
- **2 x 125µm dft**

Inorganic copolymer:

- **Designed for CUI service**
- **Resistant to thermal cycling**
- **Resistant to thermal shock**
- **-185°C to 204°C**
- **2 x 100µm dft or 1 x 200µm dft**

Inert Multipolymeric Matrix:

- **Designed for CUI service**
- **Surface tolerant**
- **Resistant to thermal cycling**
- **Resistant to thermal shock**
- **-185°C to 650°C (peak 760°C)**
- **2 x 125µm dft**

•5. Conclusion

•Coating must withstand:

- the process temperatures (design and operational range e.g. 200° to 500°C)
- the actual exposure scenario (cyclic, iso-thermal, wet/dry/immersion exposure, thermal shock, steam-out)
- the most corrosive temperature range of 150° to 180°C
- chlorides, halides and sulfides and intermittent pH in the range of 5 to 10
- accelerated CUI Test

•And must:

- be compatible with the specified substrate: carbon, duplex and austenitic stainless steels
- be suitable for insulated and non-insulated service
- Meet application requirements:
 - New construction
 - Maintenance

ALL OPERATING CONDITIONS SHOULD BE CONSIDERED, INCLUDING OUT OF SERVICE STATE WHEN SELECTING THE CORRECT PROTECTIVE SYSTEM