The 10th Tank & Refinery Conference

CUI, practical approach from a coating perspective

December 2017

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- Testing of coatings serving under insultation
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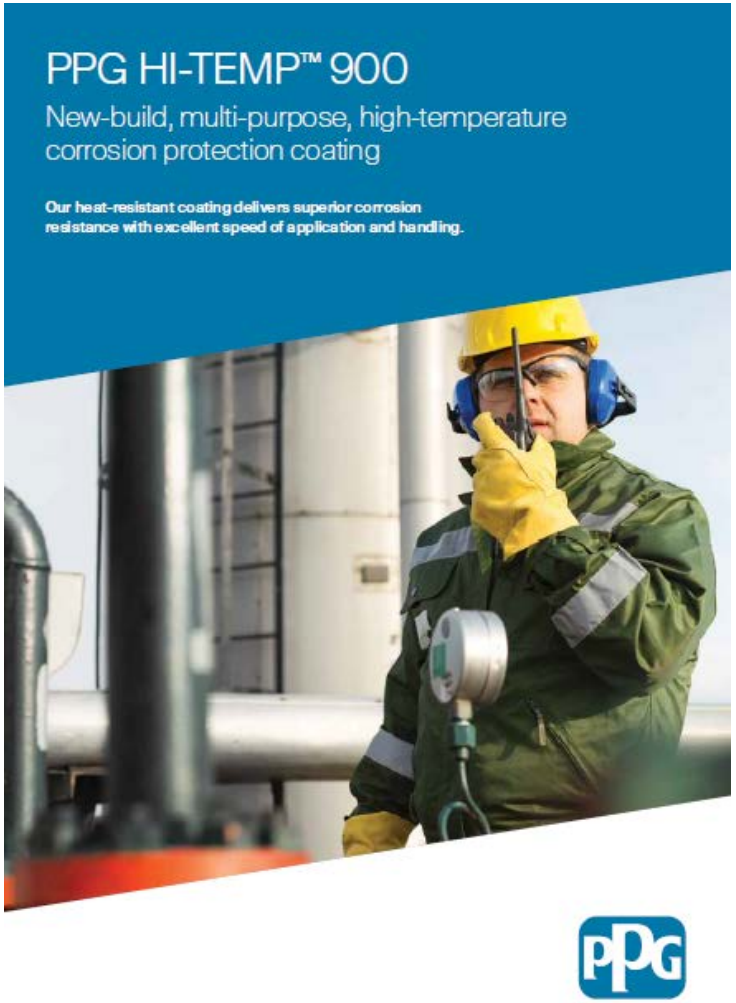


Corrosion under insulation

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°C // also outside this zone!)
- Cyclic temperatures??
- Insulation type
- Climate
- Site maintenance practice
- Tracing systems
- General environment (proximity of saltwater, cooling towers,…

API 583

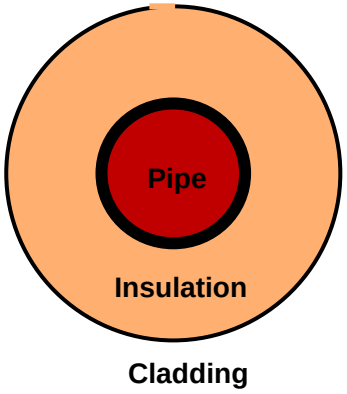
Corrosion under insulation

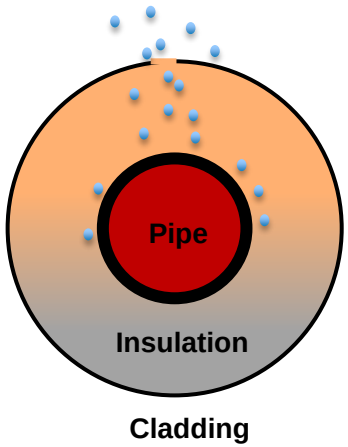
Gaps exist in cladding

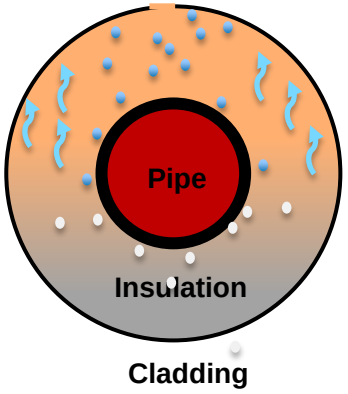
- Damage
- Poor sealing
- Improper fit
- All cladding leaks eventually

Via rain, water enters the system down to the insulation and steel.

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







Very Aggressive Corrosion

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

Corrosion under insulation

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

Corrosion under insulation

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

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 a 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

Testing of coatings that serve under insulation

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-SP 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-SP 10	40-65 (1.5-2.5)	Inorganic coplymer or coatings with an inert multipolymeric matrix, 100-150 (4-6)	Inorganic coplymer 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				

Testing of coatings that serve under insulation

Test standard under development with committee ISO TC 67 WG 11 (ISO19277

Standard will define:

- **CUI environments**
- **Temperature ranges**
- **Specific testing to be done depending on the environment like**
- Neutral salt spray
- Water condensation test
- Immersion test (if applicable)
- Thermal cycling test
- Specific CUI test (Houston pipe test/PPG CUI chamber test,…this is still to be defined

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

Testing of coatings that serve under insulation

Typical test methods for elevated temperature coatings

- **ASTM B-117:**
  - Salt Fog Chamber 3500–4500 hours
- **ASTM 2485:**
  - This test ensures adhesion based on CTE after severe thermal shock
- **ASTM 2402:**
  - Mass loss is critical in determining the porosity and longevity of a coating

Specific CUI test methods

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

Other tests only focus on dry exposure and/or thermal shock.

Testing of coatings that serve under insulation

PPG CUI Chamber Test 2008

Uses ASTM G189 as a model

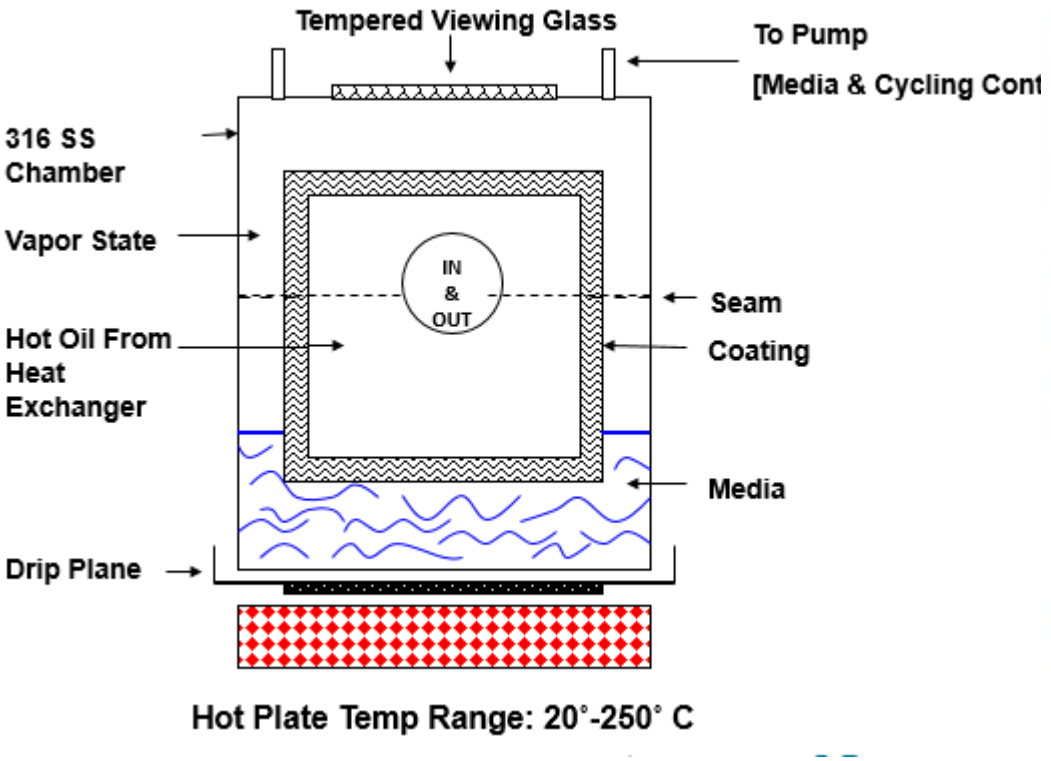
- For simplicity the insulation is omitted
- Temperature control: ambient to 250°C
- Consistent and repeatable results.
- The chamber environment can be totally controlled

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]

Testing of coatings that serve under insulation



Before Test

After 6 Weeks Front View

After 6 Weeks Bottom View

Testing of coatings that serve under insulation

Hi-Temp 1027

Competitor

Immersion - Bottom

Steam Interface - Front

Typical outcomes

Positioning of PPG CUI coating range

CUI protection preferably through barrier effect. Why?

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

<u>Silicone (acrylic)</u>
- 2 coats of 25µm
- Total DFT = 50µm
- Barely covers peaks
- Suitable under insulation?
- OK for galv and SS?

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

<u>Phenolic or multipolymeric matrix</u>
- 2 coats of 125µm = 250µm
- Covers peaks + 200µm
- Extra barrier in 3 coats possible
- OK under insulation.
- OK for galv and SS!

Positioning of PPG CUI coating range

CUI solutions can be classified by generic type, temperature or type of application

Generic Type	Temperature	Type of application
• Epoxy Glass Flake • Epoxy Phenolic • Multipolymeric Generic type discussions are usually held by asset owners and engineering companies. Depending on the assets, they specify technologies that will give the best protection and contribute to extending the life cycle of the assets	• Insulated assets can be exposed to extreme conditions ranging from -196°C to 650°C The operating temperature of the insulated asset will determine the type of technology needed for certain job	• New build (NB) • Maintenance & Repair (M&R) M&R scenarios might require from your solution to be surface tolerant, applicable by brush or roll, one-component material. NB scenarios will require blast cleaned surfaces and a coating less prone to mechanical damages

Positioning of PPG CUI coating range

NB / M&R	min SURFACE PREP	-196°C (-321°F)	-46°C (-50°F)	-18°C (0°F)	121°C (250°F)	149°C (300°F)	204°C (400°F)	232°C (450°F)	316°C (600°F)	482°C (900°F)	650°C (1200°F)	760°C (1400°F)
Epoxy Phenolic	SA2.5											
Epoxy (imm)	ST2											
MP copolymer	ST3											
MP hybrid	SA2.5											
IMPM	ST2											

- Below 120°C, Epoxy or Epoxy Phenolic is preferred
- For cyclic but <200°C exposure → use PPG HI-TEMP™ 222G
- For newbuild across the temp range, you can select PPG HI-TEMP 900
- Main repair solution on site → use PPG HI-TEMP 1027™

Typical systems

INORGANIC ZINK

STRENGTHS

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

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^{0}C**
- **SA2,5 absolute minimum**

Not recommended

Typical systems

TSA

STRENGTHS

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

WEAKNESSES

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

Typical systems

EPOXY AND EPOXY PHENOLIC

STRENGTHS

- Very good chemical resistance
- High durablity
- Hard and durable coatings
- Provides extremely good corrosion protection in immersion service

WEAKNESSES

- SA2.5 absolute mimimum
- Limited suitability for maintenance
- Coefficient of thermal expansion not matched to substrate. Can lead to stress in thermal cyclic conditions
- Temperature limitations

PPG HI-TEMP™ heat-resistant coatings

Typical systems

INORGANIC COPOLYMER – HYBRID COPOLYMER - IMPM

STRENGTHS

- **Large temperature range**
- **CTE matches almost the substrate, so thermally durable**
- **Can whithstand thermal cycling**
- **Can whithstand 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**

Typical systems

SIGMASHIELD 400/AMERLOCK 400 GF	• Epoxy glass flake • Immersion resistant • Surface tolerant	• Up to 200°C in CUI service • 250µm dft (1 coat possible
SIGMATHERM 230	• Epoxy phenolic • Immersion resistant • High chemical resistance • Up to 230°C dry heat exposure	• Up to 180°C in CUI service • 2 x 125µm dft
HI TEMP 222G	• Inorganic copolymer • Resistant to thermal cycling • Resistant to thermal shock	• -196°C to 204°C • 2 x 100µm dft or 1 x 200µm dft
HI TEMP 1027	• Inert multipolymeric matrix • Surface tolerant • Resistant to thermal cycling • Resistant to thermal shock	• -196°C to 650°C (peak 760°C) • 2 x 125µm dft
HI TEMP 900	• Hybrid Copolymer • NEW NEWBUILD PRODUCT • Resistant to thermal cycling • Resistant to thermal shock	• Up to 482°C in CUI service • 1 x 200µm dft

PPG HI-TEMP™ 900 value proposition

- Completes PPG CUI coating range
- ***Newbuild* 2K heat resistant multipolymeric primer coating**
- Designed to protect carbon and stainless steels under insulation
- Increased mechanical resistance (harder)
- Withstands cryogenic exposure (-196°C) up to +482°C
- High solid (75%VS)
- 1 coat application up to 375µm dft without cracking issues
- UV stable
- Compatible with zinc silicate primers and heat resistant topcoats
- Compatible when overcoated with HI-TEMP 1027™ (on site repair)
- Improved corrosion protection when comparing to current multipolymeric solutions

D: Exposure for 2000 hours
1) Panels which were air dried for 7 days

	Current HT 1027	900U
Measured D.F.T.	300-300µm	270-300µm
Pictures		
Creep (mm)	5.5mm	1.44mm
Blister x-out	N	N
Blister, field	N	N
Field rust	Ri1, Spot rust	N

We protect and beautify the world™