Corrosion Under Insulation

Understanding Issues Surrounding Corrosion Under Insulation

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Corrosion Under Insulation

CUI is a recent branch of corrosion control
Developed in the 1980’s and early 1990’s
Primarily in Petrochemical and Refining
Response to ban of lead, chromium, asbestos
Changes in piping, vessel and tank design
Development of better CUI coatings

Summarized from
Three-day
NACE New Orleans Section
CUI Mitigation Course

Corrosion Under Insulation

What's Really Under There ?

Corrosion Under Insulation

The Challenge:

A typical major refinery or chemical plant may contain a thousand insulated vessels and tanks and a thousand miles of insulated or coated and wrapped pipe.

Current corrosion condition (CUI), inspection intervals, scheduled maintenance and record keeping may vary widely.

Current maintenance budgeting is rarely enough to keep up with corrosion failures, much less to get ahead.

Current specifications and new construction practices do not always provide long-term assurance.

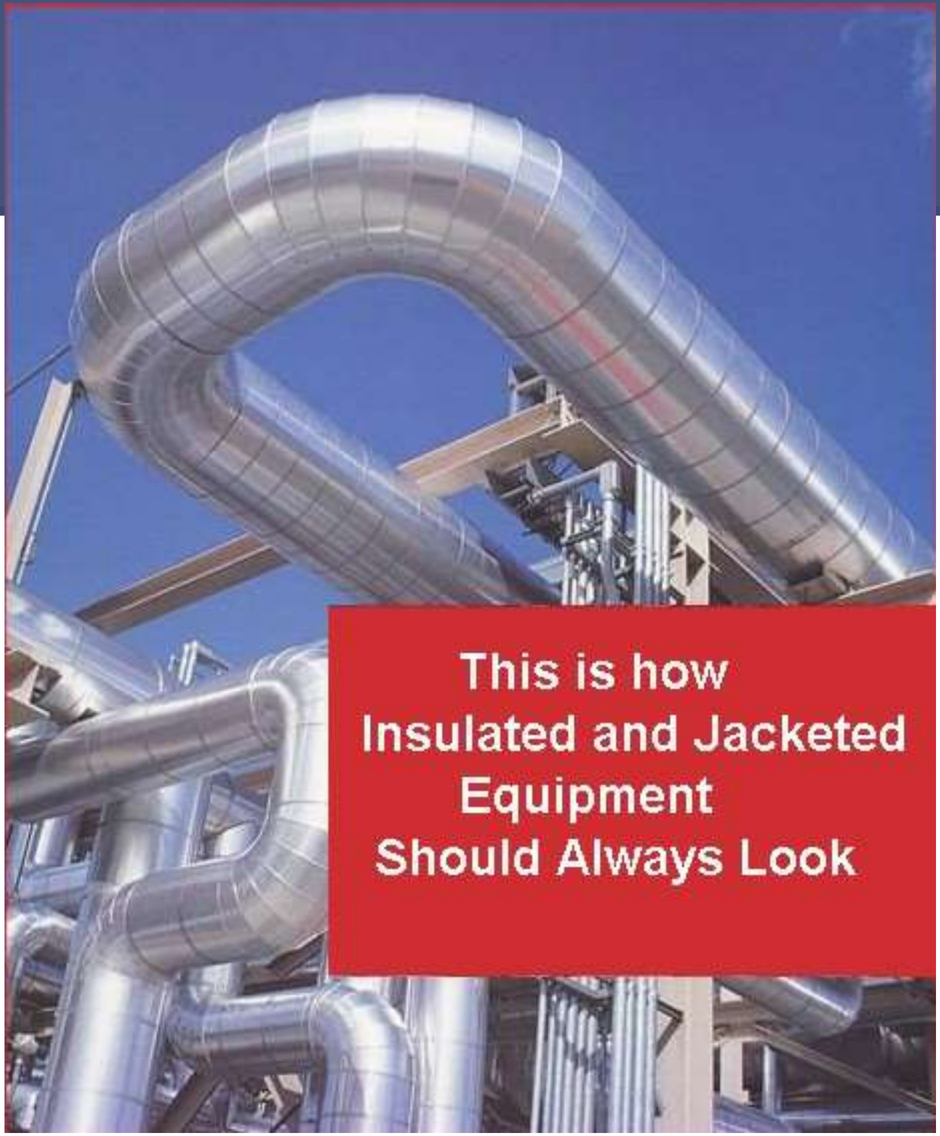
Corrosion Under Insulation

The Reality:

Jacketed and Insulated Equipment in a well-run refinery or chemical plant with an active RBI (Risk Based Inspection) program is inspected once every 3 years or less often, based on the severity rating of the vessel or pipe run.

The 3-year inspection is typically 99% (area) exterior visual and about 1% full removal and observation of the substrate.

CUI Coatings, insulation and jacketing are typically replaced on an 8-15 year cycle for liquid applied coatings and on a 15 to 30 year cycle for Thermal Spray Aluminum (TSA).


This is how
Insulated and Jacketed
Equipment
Should Always Look

Corrosion Under Insulation

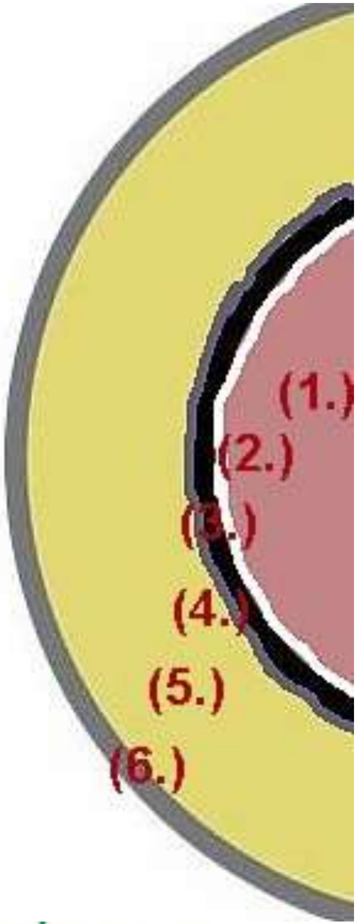
And this is what we see in real life.

Corrosion Under Insulation

Major perforations caused by CUI

Corrosion Under Insulation

The CUI System

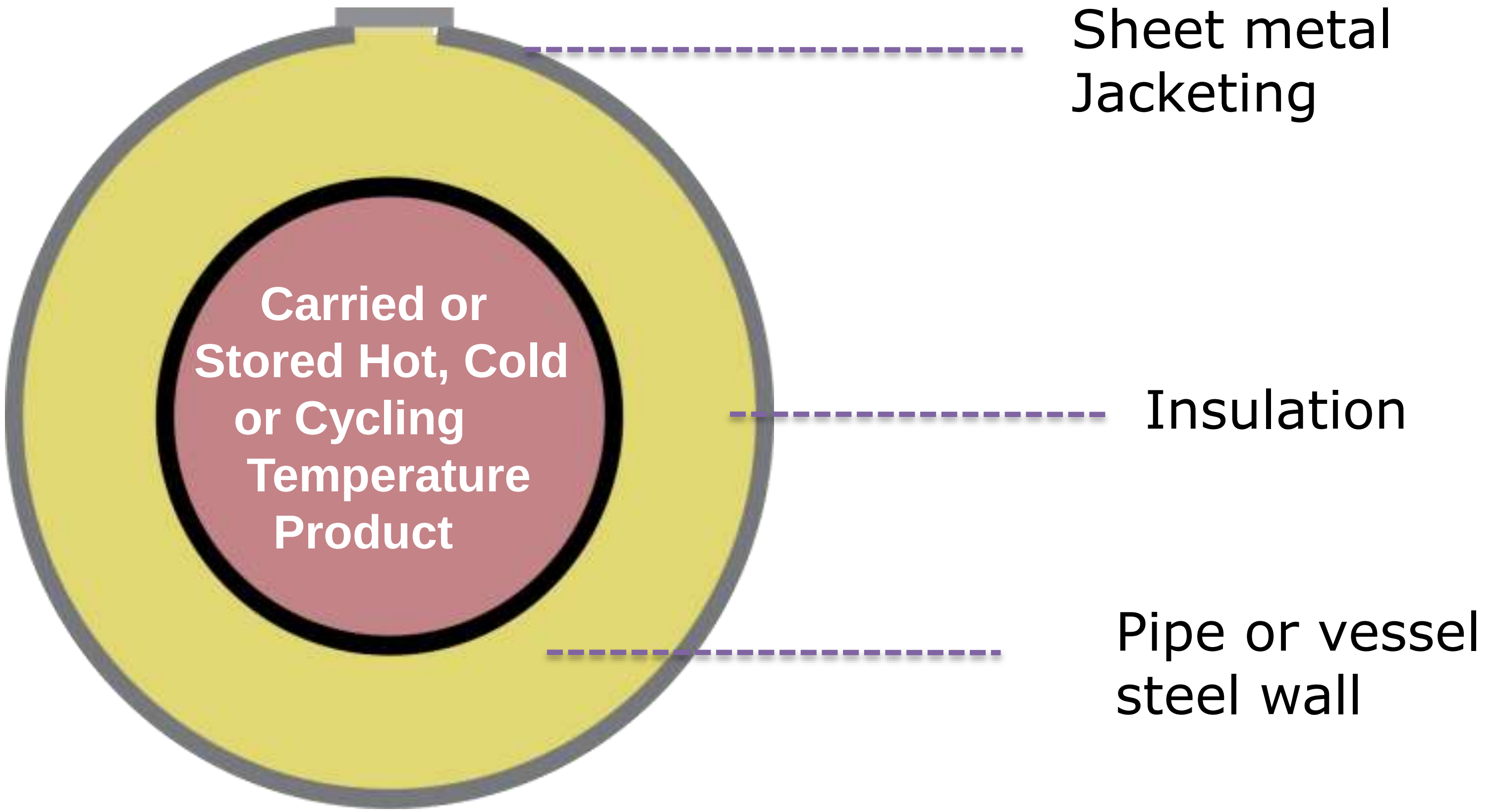


Like a good sandwich,
All the parts of a CUI System
Must be compatible and effective

(1.) Red – Stored or Carried Product
(2.) White – Product-Compatible Lining
(3.) Black -- Vessel or Pipe wall
(4.) Gray – CUI Coating
(5.) Yellow – Insulation
(6.) Gray – External jacketing

Corrosion Under Insulation

The CUI Cycle (1.)



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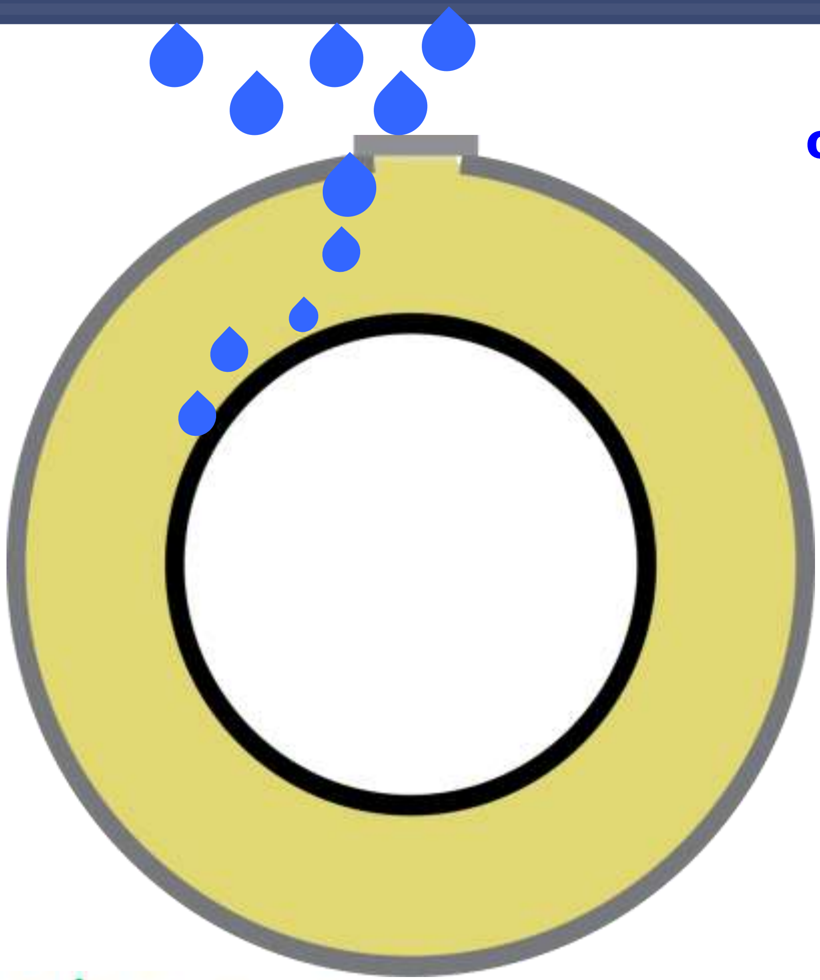
The CUI Cycle (2.)

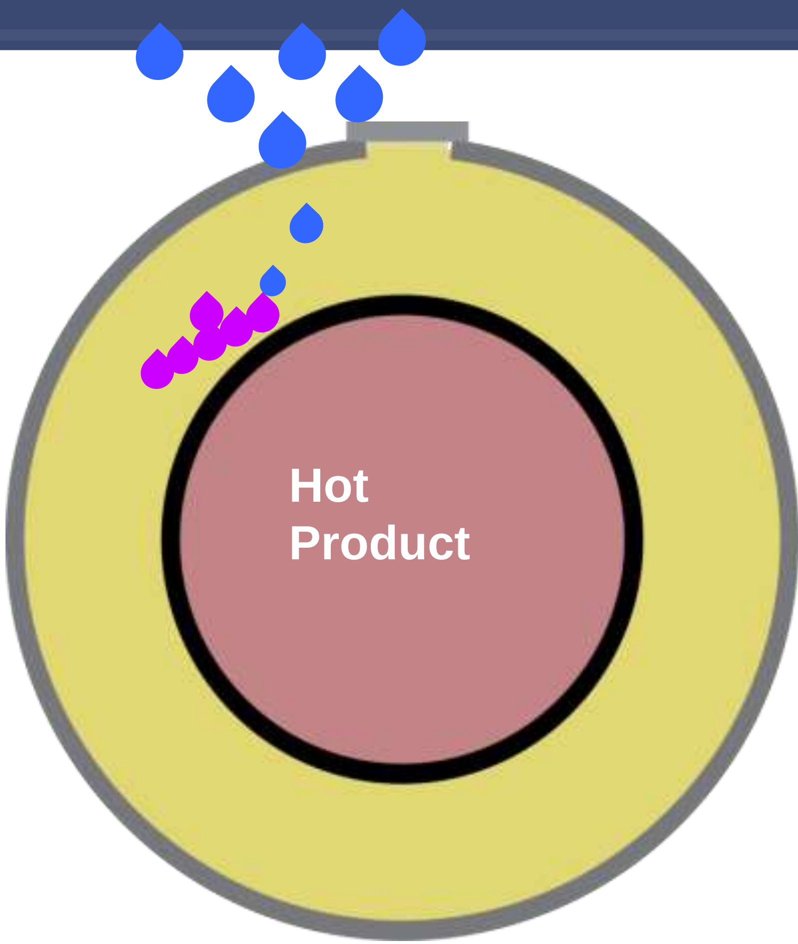


During rain, dew or fog or whenever water is present

when the stored/carried product temperature is low and rain, dew or fog occur, or water from some other source is on the outside of the jacketing, over extended time periods (years), water may penetrate the jacketing, displace air in the insulation, and may eventually reach the substrate.

Corrosion Under Insulation

The CUI Cycle (3.)



When carried/stored product temperature rises, it heats the vessel or pipe wall and water trapped in the insulation boils, steams away from the hot steel and travels through the insulation toward the jacketing, where it condenses, but is still trapped beneath the jacketing.

Corrosion Under Insulation

The CUI Cycle (4.)

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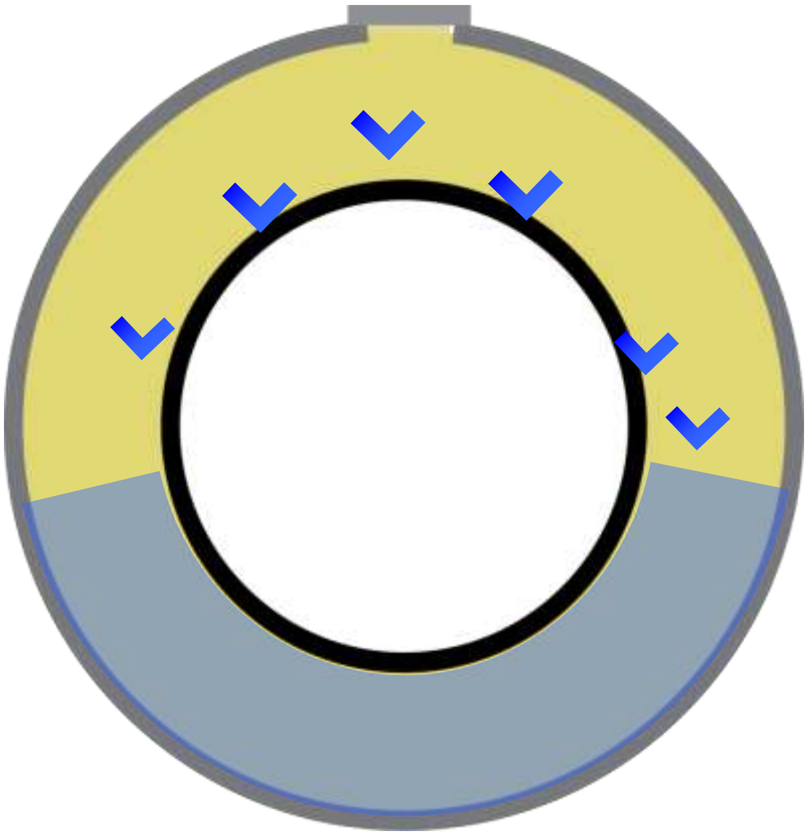
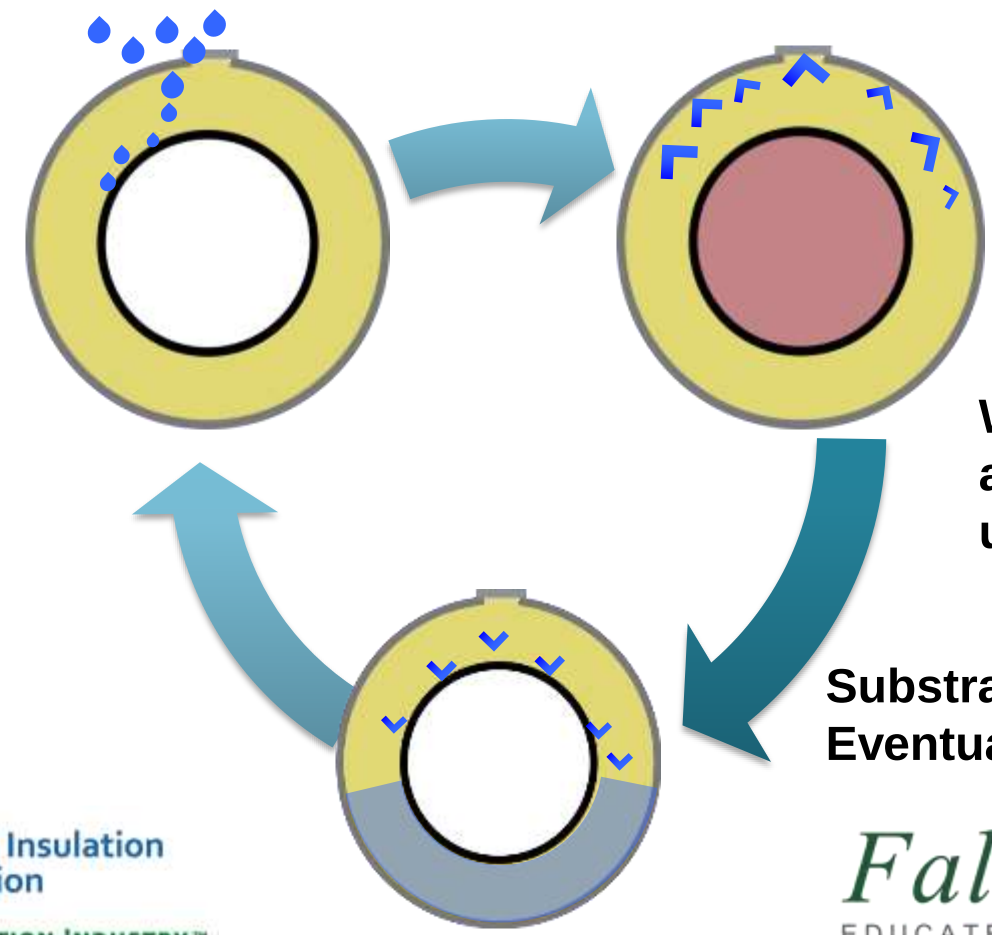


When the temperature is lower again, water in the insulation migrates back toward the substrate and corrosion can occur if there is not a good corrosion resistant CUI coating.

The CUI Cycle

Typically 8 to 10 years before Repair/Replacement

Water gets under jacketing



Most water cannot escape

Water accumulates under jacketing

Substrate stays wet Eventually causing corrosion

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Corrosion Under Insulation

The CUI Cycle (5.)

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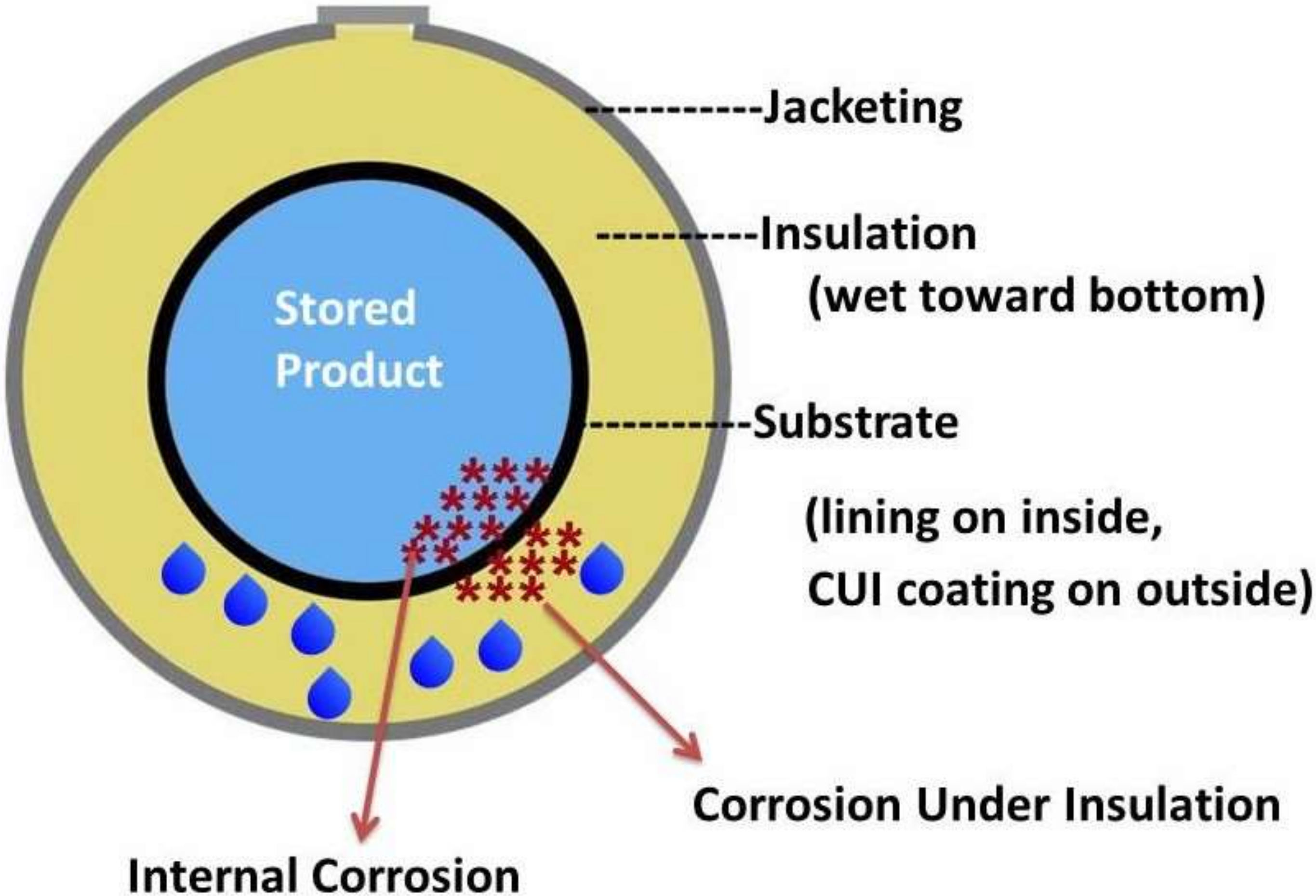

Corrosion Under Insulation

Industry Standards


Corrosion Under Insulation
and Fireproofing

API RECOMMENDED PRACTICE 583
FIRST EDITION, MAY 2014

API
AMERICAN PETROLEUM INSTITUTE

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API RP 583
First Edition
May 2014

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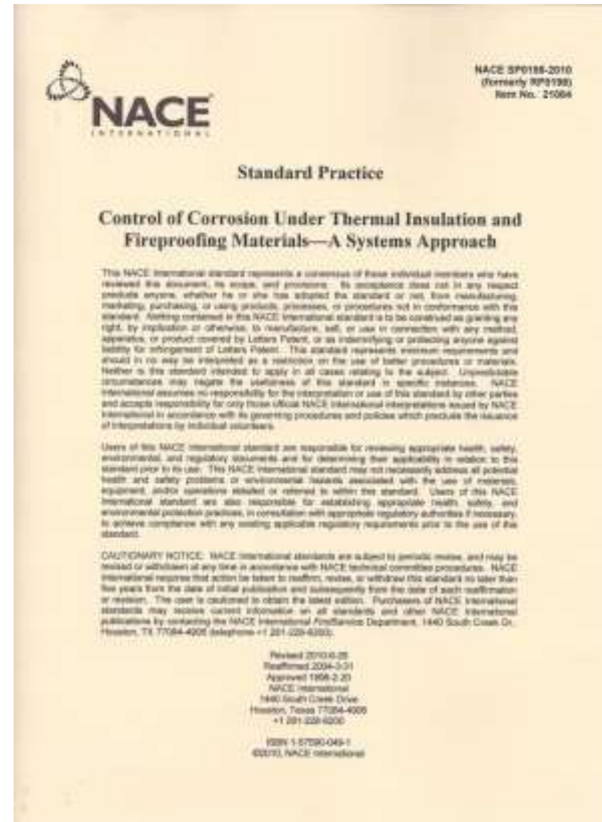
NACE SP0198-2010
June 2010
Originally Issued
February 1998


NACE SP0198-2010
(formerly RP0198)
Item No. 21084

NACE INTERNATIONAL

Standard Practice

Control of Corrosion Under Thermal Insulation and
Fireproofing Materials—A Systems Approach

Both Documents stress a "systems" approach

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Corrosion Under Insulation

2.1.3 Relevant guidelines & standards for the industrial/mechanical insulation industry in North America

In North America there are no regulations or codes governing the design and installation of industrial/mechanical insulation. Best practices is generally adopted following a variety of different standards & guidelines published by bodies such as ASTM, NACE, MICA & PIP.
Many ownership groups in North America have developed their own internal standards and guidelines which are used throughout various projects. The intention of the PIP guidelines is to consolidate these internal standards from ownership groups to create a uniform approach.

The commonly referred to standards and guidelines in North America include:
-ASTM C1696
-NACE SP0198
-MICA National Commercial & Industrial Insulation Standards

Before Publication of API RP 583

Corrosion Under Insulation

API 583 defines three generic types of insulation most commonly used in oil refineries and petrochemical plants:

Granular **Fibrous** **Cellular**

Major Generic types of Insulation listed in NACE SP 0198-2010,

NACE SP 0198 Listing		Type	ASTM
Par. 5.2.1	Pg. 27	Calcium Silicate	ASTM C533
Par. 5.2.2	Pg. 27	Expanded Perlite	ASTM C510
Par. 5.2.3	Pg. 28	Mineral Fiber/Wool	Various ASTM
Par. 5.2.4	Pg. 28	Cellular Glass	ASTM C552
Par. 5.2.5	Pg. 28-29	Organic Foams	Various ASTM
Not Listed		Aerogel Blanket	
Not Listed		Spray-On Acrylic	
Not Listed		Epoxy Syntactic Foam	

INSULATION

API RP583 chart of insulation types:

Table 6 Commonly Used Insulation Materials

	Insulation Material	Low Temperature Range		High Temperature Range	
		°F	°C	°F	°C
Granular	Calcium silicate	0	-18	1200	650
Granular	Expanded perlite			600	315
Cellular	Cellular glass	-450	-260	900	480
Fibrous	Mineral wool	32	0	1800	1000
Fibrous	Fiberglass	-20	-30	1000	540
Cellular	Polyurethane	-350	-210	250	120
Cellular	Polyisocyanate foam	-290	-180	300	150
Cellular	Elastomeric foam	-70	-55	250	120
Cellular	Polystyrene foam	-60	-50	165	75
Cellular	Phenolic foam			300	150
Aerogel	Silica Aerogel	-460	-270	1200	650

CALCIUM SILICATE (Granular)

Quoted direct from API RP 583:

Advantages:

- Low thermal conductivity
- Usable to 1000°F (538°C) cont./1200°F (650°C) intm.
- Available in a variety of shapes/sizes/thicknesses

Disadvantages:

- Can absorb and retain water
- Has pH of 9-10 when exposed to water
- Care needed to avoid breakage during installation

EXPANDED PERLITE (Granular)

Quoted direct from API RP 583:

Advantages:

- Water resistant up to 400°F (205°C)
- Good resistance to mechanical damage
- Available in a variety of shapes/sizes up to NPS 24

Disadvantages:

- More fragile than calcium silicate during installation
- Higher thermal conductivity than calcium silicate

CELLULAR GLASS (cellular)

Quoted direct from API RP 583:

Advantages:

- Does not absorb water
- High resistance to mechanical damage when jacketed
- Thermal conductivity does not deteriorate with aging

Disadvantages

- Fragile as glass
- Thermal shock at temp. gradient >300°F (>150°C)
- Abrades in vibrating service, fragile before application

(Not from API RP 583)

Low permeability and absorption make cellular glass an ideal system for cold and cryogenic service.

MINERAL WOOL (fibrous)

Quoted direct from API RP 583:

Advantages:

- Used in hot applications up to 1200°F (650°C)
- Lower conductivity than calcium silicate and perlite
- Low leachable chloride content (< 5ppm)

Disadvantages:

- Readily permeable to vapors and liquids.
- Subject to mechanical damage
- Low compressive strength and lack of resiliency

MINERAL WOOL (fibrous)

Not from API RP 583:

Most widely used insulation type in Petro CUI (and elsewhere)
Available from multiple manufacturers/vendors
Quality and performance may vary by manufacturer and grade
Binder used can affect performance characteristics
"Water Resistant" grades are available
Specifiers don't always specify required level of quality
Contractors buy the cheapest generic equal

MINERAL WOOL

DONE WRONG AT AN ASIAN PLASTICS PLANT

Stainless Steel Vessel
under insulation
with Carbon Steel parts
welded directly to it;
mineral wool insulation
(the only thing done right!)
Two-sides galvanized
sheet metal jacketing
with large cutouts at
penetrations allowing
water to enter
= instant electrolytic cell

Jacketing had been painted
Aluminum to hide the rust

SILICA AEROGEL BATTS

Quoted direct from API RP 583:

Silica Aerogel is synthetically produced amorphous silica gel, distinctly different from crystalline silica.

Aerogel is impregnated into a non-woven flexible fabric substrate (batts or blankets) for reinforcement.

AEROGEL INSULATION BATTS

Quoted direct from API RP 583:

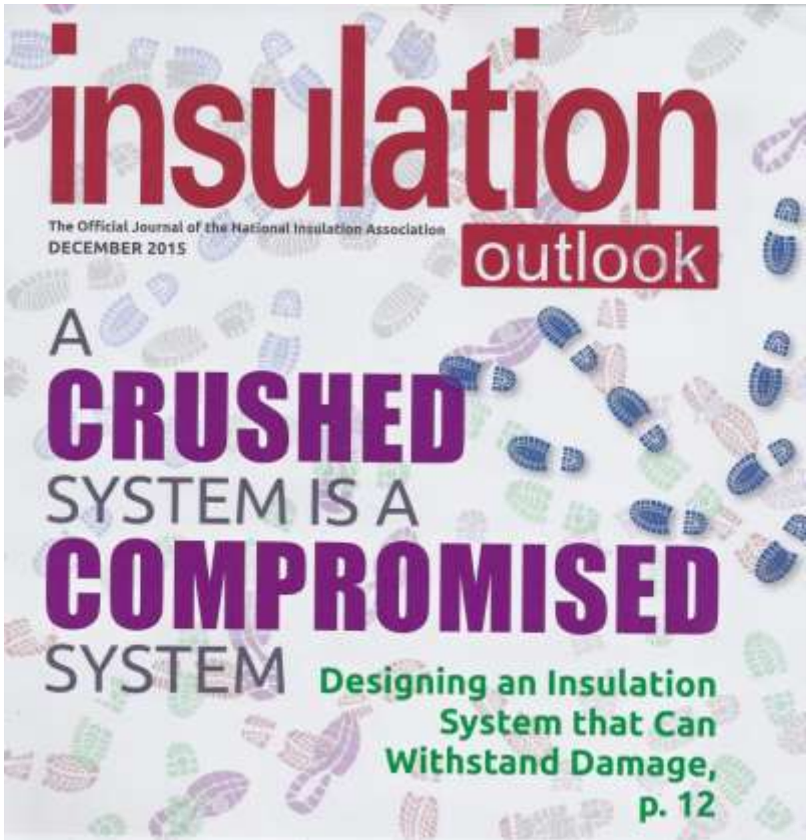
Advantages

- Highest thermal performance of any insulating material known
- Significantly reduced thickness for equivalent performance
- Wide range of temperature applications

Disadvantages

- Aerogels are typically hygroscopic (absorb water from air)
- Aerogels need chemical treatment to be hydrophobic
- Typically higher material cost
  - (easier installation/better performance justify extra cost)

Corrosion Under Insulation


insulation outlook
The Official Journal of the National Insulation Association
DECEMBER 2015

A CRUSHED SYSTEM IS A COMPROMISED SYSTEM

Designing an Insulation System that Can Withstand Damage, p. 12

Crushed jacketing =
Crushed Insulation =
Water ingress =
Wet Insulation =
Loss of Efficiency

Corrosion Under Insulation
Wet Insulation

Wet Insulation

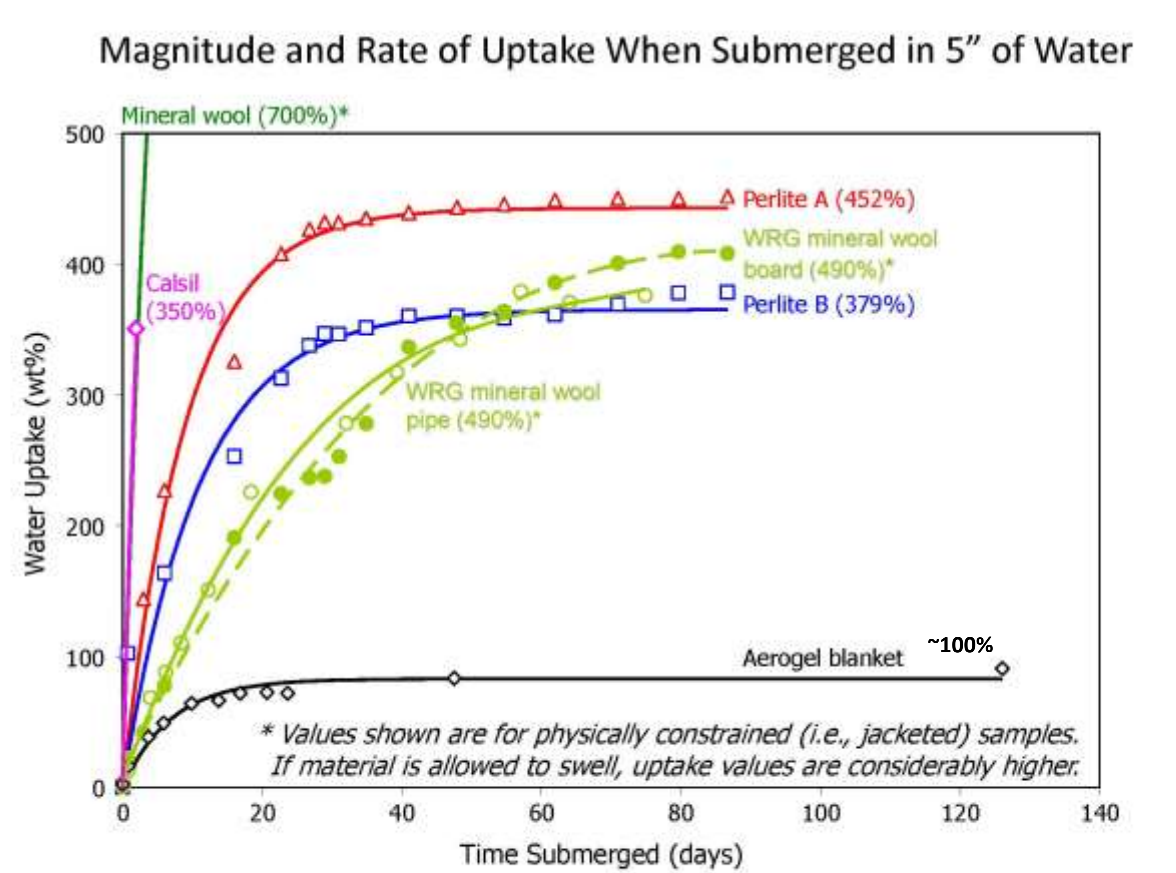
(Regardless of what kind

or what original, dry k value)

Doesn't Insulate.

Wet insulation is also a primary cause of CUI.

Wet Insulation



Possibly Biased Sales Presentation Information

The importance of the chart above is that even in a sales presentation, the "best" Insulation absorbs almost 100% of its weight in water in only 20 days exposure.

Corrosion Under Insulation

CUI Coatings

API RP 583 Makes no CUI Coating Recommendations

Refers all coatings decisions to NACE SP-0198-2010

NACE SP-0198-2010 rates CUI coatings

(1.) By Temperature Tolerance

(2.) By use on Stainless and/or Carbon Steel

CUI mitigation has emphasized “better” CUI coatings rather than preventing water ingress and wet insulation.

Corrosion Under Insulation

Wet Insulation

- A primary cause of corrosion under insulation is water ingress through the jacketing, into the insulation and to the substrate.

THE ENEMY*

*Note that we used Club Soda, which contains chemicals, just like the water that gets under jacketing.

Corrosion Under Insulation

NACE SP 0198-2010 Recommended CUI Coating Systems

High Build Epoxy (SS) (CS)	-50 to 140° F
Fusion Bond Epoxy (CS)	-50 to 140° F
Phenolic Epoxy (SS) (CS)	-50 to 300° F
Novolac Epoxy (SS) (CS)	-50 to 400° F
Silicone Hybrid (CS)	-50 to 400° F
Thin Film Silicone (SS)	-50 to 1000° F
Polysiloxane Hybrid (SS) (CS)	-50 to 1200° F
Thermal Spray Aluminum (SS) (CS)	-50 to 1100° F
Aluminum Foil Wrap (SS)	-50 to 1000° F
Wax Tape Wrap (CS)	140° F Maximum

Corrosion Under Insulation

Typical Application Times for Liquid Applied Coatings:

1st Coat:	**apply**	**1 hour**
	drying time	**8-12 hours**
	inspection	**1 hour**
2nd Coat:	**apply**	**1 hour**
	drying time	**8-12 hours**
	inspection	**1 hour**

Spot repair low film thickness (if needed)

	apply	**1 hour**
	drying time	**8-12 hours**
	inspection	**1 hour**

Total: 3 days

TSA for CUI

**See "Joint Standard,
NACE No. 12/AWS C2.23M/SSPC-CS 23.00
Specification for the Application of
Thermal Spray Coatings (Metallizing)
Of Aluminum, Zinc, and Their Alloys
And Composites for the Corrosion
Protection of Steel"**

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Corrosion Under Insulation

Typical Application Time for Thermal Spray Aluminum:

Single Coat:	**apply**	**1 hour**
	drying time	**Near Zero**
	inspection	**2 hours**
	repair any low DFT	**1 hour**

Total: Half Day
Time savings versus liquid coatings: 2 ½ days

Thermal Spray Aluminum (TSA) costs more to apply and inspect than liquid coatings but time savings during application and longer service life make TSA extremely competitive for new construction as well as for field maintenance.

Corrosion Under Insulation

The corrosion engineer for the tower on the right estimated every day out of service cost the owner $1,000,000 in lost production. Use of TSA for the CUI coating provided seven-figure cost savings.

Corrosion Under Insulation

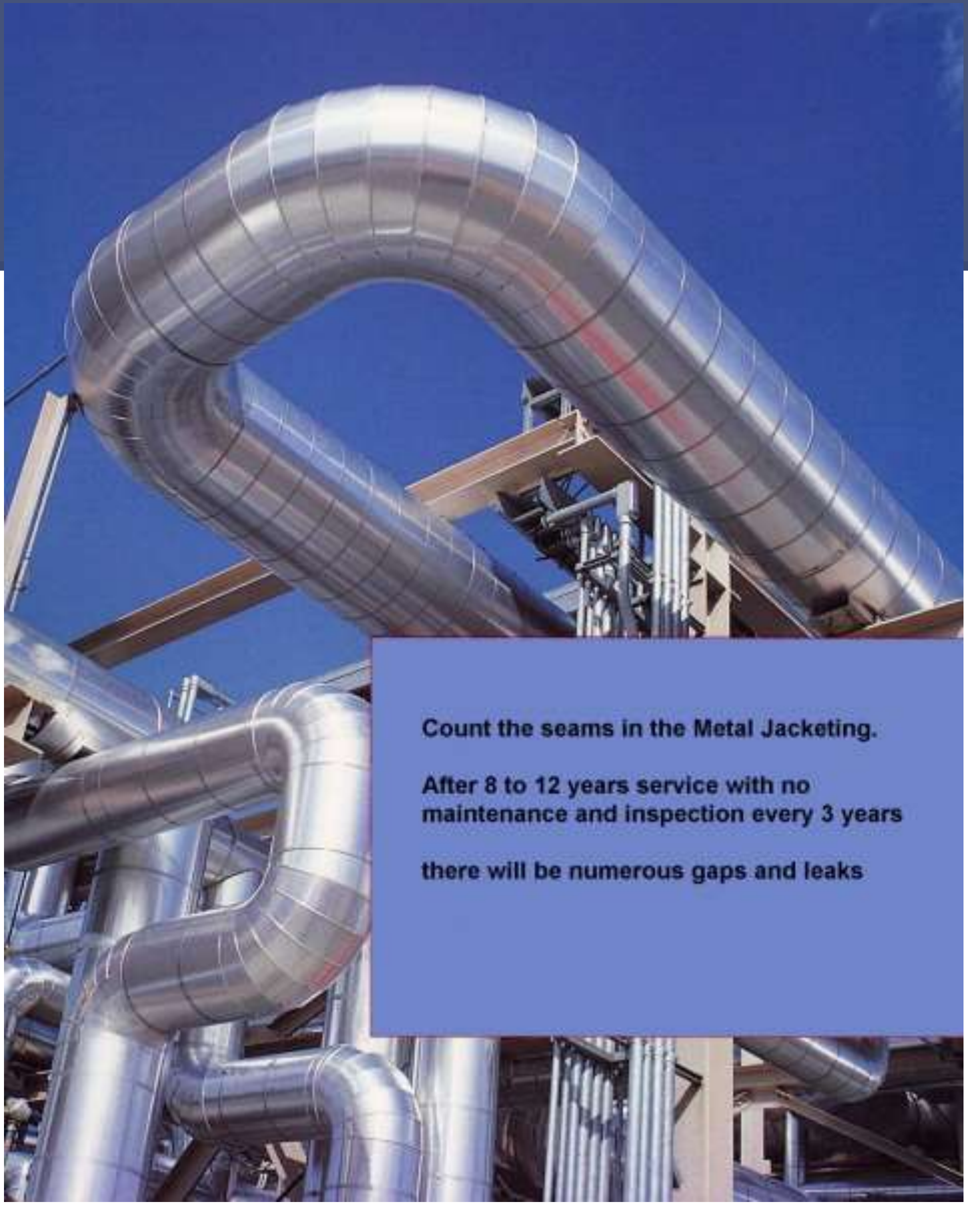
Jacketing

Both API RP 583 and NACE SP0198-2010 spend a lot of space discussing jacketing, specifically aluminum or stainless steel sheet metal jacketing.

- API RP 583 gives new construction structural design recommendations to minimize water ingress.
- NACE SP0198-2010 includes numerous diagrams of metal jacketing where water ingress is expected.

Both documents assume water ingress is inevitable.

Corrosion Under Insulation
Jacketing



Corrosion Under Insulation

Nonmetallic Jacketing

Jacketing doesn't need to be shiny (or metal) to be good.

Corrosion Under Insulation

NACE SP 0198-201 and API RP 583 both assume metal (Aluminum or Stainless Steel) Jacketing as "standard" Some overseas facilities use 2 sides galvanized jacketing.

Sheet Metal jacketing is pieced together from hundreds (? thousands ?) of pieces of sheet metal with joints between each piece.

Joints are supposed to be caulked and leakproof. Sheet metal jacketing is assumed to be damage resistant. It isn't.

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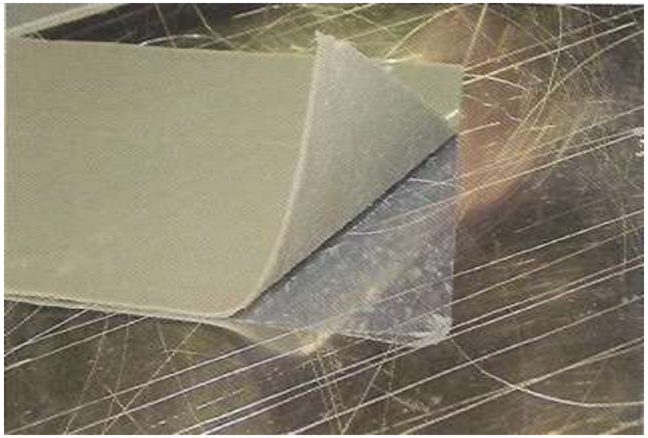
Corrosion Under Insulation

Nonmetallic Jacketing

FRP (Fiberglass Reinforced Plastic) jacketing:

Supplied as a preformed sheet in boxed 1 m x 10 m rolls
Sandwiched between two nonadhesive plastic sheets
Cut and installed at jobsite
Self-curing (sunlight or UV light)
No heat or catalyst is used
Self-adhesive at laps and joints
Forms a monolithic jacket
Cures to 1.5 – 2.0 mm thickness
No caulking of joints required
Can be double-layered at areas of expected damage



Corrosion Under Insulation

Nonmetallic Jacketing

Product properties

	Performance	Standard
Color	Grey	-
Handling / Application temperature	min. 5°C - max. 45°C	-
Service temperature	max. 90°C	-
Emissions (styrene)	< 20 ppm (MAC-value 25 ppm), safety data sheet upon request	-
Flashpoint (non-cured)	125°C	-
Reaction to fire	C_L-s1, d0 round	EN 13501-1
	C-s2, d0 flat	EN 13501-1
	Surface burning characteristics; Flame spread = passed. Smoke development=passed	ASTM E84
Density	1.8 g/cm^3	ISO 1183
Thickness (after curing)	1.5mm - 2.0 mm	-
Linear expansion coefficient	$25*10^{-6}$ K^{-1}	ISO 11359-2
Hardness	45 Barcol	ASTM D2583
Tensile strength	50 MPa	EN ISO 527-4
Tensile modulus	9 GPa	EN ISO 527-4
Tensile elongation at break	1.0%	EN ISO 527-4
Compressive strength	150 MPa	EN ISO 14126
Water vapour permeability	0.001 g/m^2.h.mmHg	ASTM E96
Chemical resistance	available upon request	-
Compliance	[redacted] conforms to CINI 3.2.11 "Weather resistant UV-curing fiberglass reinforced polyester (GRP)"	-

There are few US standards for nonmetallic (FRP) jacketing, since Petrochemical/Industrial CUI jacketing is assumed to be sheet metal.

Corrosion Under Insulation
INSPECTIONS AND SERVICE LIFE

Major Oil, Chemical and Petrochemical Company coating system specifications currently Rate CUI Liquid Applied Coating Systems as **8 to 15** years Service Life.

The same companies' specs rate CUI Thermal Spray Aluminum as high as **30** years Service Life.

Several specs require no intermediate inspections for CUI Thermal Spray Aluminum.

Can you trust anything for 30 years without looking at it occasionally?

Corrosion Under Insulation

Risk-Based Inspection Program

Hazard—Something that has potential to cause harm

Risk—Likelihood of a specified undesired event occurring within a specified time period or resulting from specified circumstances

Safety Critical Elements—What needs to be protected

Mitigation—Measures to prevent the hazard occurring

ALARP—As Low As Reasonably Practicable

Corrosion Under Insulation

RISK ASSESSMENT MATRIX

CONSEQUENCES					INCREASING LIKELIHOOD				
SEVERITY	PEOPLE	ASSETS	ENVIRONMENT	REPUTATION	A	B	C	D	E
					Never heard of in the industry	Heard of in the industry	Has happened in EPW or more than once per year in the industry	Has happened at the location or more than once per year in EPW	Has happened more than once per year at the location
0	No injury or health effect	No damage	No effect	No impact					
1	Slight injury or health effect	Slight damage	Slight effect	Slight impact					
2	Minor injury or health effect	Minor damage	Minor effect	Minor impact					
3	Major injury or health effect	Moderate damage	Moderate effect	Moderate impact					
4	PTD or up to 3 fatalities	Major damage	Major effect	Major impact					
5	More than 3 fatalities	Massive damage	Massive effect	Massive impact					

INCREASING RISK

Raising the Standard

Corrosion Under Insulation

Risk-Based Inspection Program

Plant Survey to evaluate relative risk of units or sections
- Units or sections are assigned severity levels
- Rating is by management and operators

Regular spot inspections are scheduled
- Inspected points are highest-risk units or sections
- If problems are found, additional inspection is done
- Lower risk areas are surveyed based on condition of high-risk units or sections

Maintenance funding is allocated based on inspection
- Maintenance is scheduled to lower event risk
- (High risk units with problems receive priority)

Inspection frequency is adjusted based on findings

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Risk-Based Inspection Program

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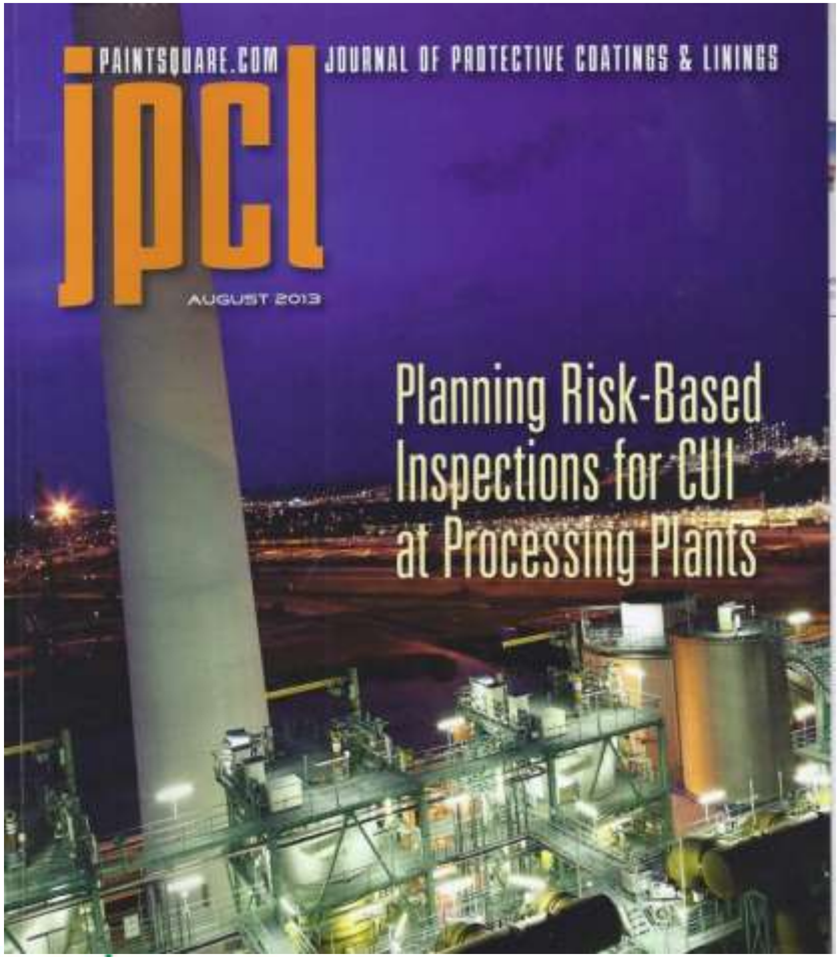
Risk-Based Inspection Program



This is a Good Basic Primer on Risk Based Inspection

JPCL Magazine August 2013 Available online

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Questions?

Please feel free to telephone or e-mail me With any questions or comments.

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