Appendix 1

List of participants

Participants EFC WP15 meeting 12th September 2012 Istanbul (Turkey)

Name	Company	Country
Ridha Yahyaoui	AXENS - IFP Technology Group	FRANCE
Martin Hofmeister	Bayernoil Raffineriegesellschaft mbH	GERMANY
Hermenegildo Ruiz	CEPSA	SPAIN
Pedro Rangel	CEPSA	SPAIN
Stefan Winnik	Exxon Mobil Chemical	SINGAPORE
Alessandro Demma	Guided Ultrasonics Ltd	UK
Michael MeLampy	Hi-Temp Coatings Technology	USA
Brian Chambers	Honeywell	USA
Francois Ropital	IFP Energies nouvelles	FRANCE
Adam Ovington	International Paint Ldt	UK
Neil Wilds	International Paint Ldt	UK
Hennie de Bruyn	Johnson Matthey Catalysts	UK
Antal Krójer	MOL Hungarian Oil & Gas Co	HUNGARY
Attila Veres	MOL Hungarian Oil & Gas Co	HUNGARY
Baldy Laszlo	MOL Hungarian Oil & Gas Co	HUNGARY
Linda Goldberg	NACE	USA
Chris J Claesen	Nalco	BELGIUM
Valerie Bour Beucler	Nalco Energy Services	FRANCE
Alec Groysman	Oil Refineries Ltd	ISRAEL
Christoph Scharsching	OMV Refining & Marketing GmbH	AUSTRIA
Rachel Pettersson	Outokumpu	SWEDEN
Jian-Zhong Zhang	SABIC	UK
Josefin Eidhagen	Sandvik	SWEDEN
Jamal Al-Muailu	Saudi Aramco	SAUDI ARABIA
Mohammad Bokhari	Saudi Aramco	SAUDI ARABIA
Johan van Roij	Shell Global Solutions International B.V.	NETHERLANDS
Ole Knudsen	SINTEF	NORWAY
Andres Rivero	Statoil ASA	NORWAY
Stephen Brennom	Sulzer Chemtech USA	USA
Fred Van Rodijnene	Sulzer Metco Europe GmbH	GERMANY
Jurgen Heinemann	Technische Universtat	GERMANY
Christel Augustin	Total Raffinage Chimie	FRANCE

Appendix 2

EFC WP15 Activities

(Francois Ropital)

Presentation of the activities of WP15

European Federation of Corrosion (EFC)

- Federation of 31 National Associations
- 20 Working Parties (WP)
- Annual Corrosion congress « Eurocorr »
- Thematic workshops and symposiums
- Working Party meetings (for WP15 twice a year)
- Publications
- EFC - NACE agreement (20% discount on books price)
- for more information http://www.efcweb.org

EFC Working Party 15 « Corrosion in Refinery » Activities

Who is an EFC member

To be an EFC member you (individually or your company, university) has to be member of one of 31 national EFC "member societies" or member of a affiliate member. Your company or university can now also an affiliate member.

For example:
in Norway: Norsk Korrojonstekniske Forening
in France: Cefracor or Federation Française de Chimie
in Germany: Dechema or GfKORR
in UK: Institute of Corrosion or IOM or NACE Europe
in Israel: CAMPI or Israel Corrosion Forum
in Poland: Polish Corrosion Society
....
You will find all these information on www.efcweb.org or in the EFC Newsletter

Benefits to be an EFC member:
- 20% discount on EFC Publications and NACE Publications
-reduction at the Eurocorr conference
-access the new EFC web restricted pages (papers of the previous Eurocorr Conference) via your national corrosion society web pages

EFC Working Parties

http://www.efcweb.org

- WP 1: Corrosion Inhibition
- WP 3: High Temperature
- WP 4: Nuclear Corrosion
- WP 5: Environmental Sensitive Fracture
- WP 6: Surface Science and Mechanisms of corrosion and protection
- WP 7: Education
- WP 8: Testing
- WP 9: Marine Corrosion
- WP 10: Microbial Corrosion
- WP 11: Corrosion of reinforcement in concrete
- WP 12: Computer based information systems
- WP 13: Corrosion in oil and gas production
- WP 14: Coatings
- **WP 15: Corrosion in the refinery industry**
  (created in sept. 96 with John Harston as first chairman)
- WP 16: Cathodic protection
- WP 17: Automotive
- WP 18: Tribocorrosion
- WP 19: Corrosion of polymer materials
- WP 20: Corrosion by drinking waters
- WP 21: Corrosion of archaeological and historical artefacts

- A task force on CO2 Capture and Sequestration (CCS)

EFC Working Party 15 « Corrosion in Refinery » Activities

http://www.efcweb.org/Working+Parties-p-104085/WP%2B15-p-104111.html

Chairman: Francois Ropital Vice Chairman: Hennie de Bruyn

The following are the main areas being pursued by the Working Party:

Information Exchange
Sharing of refinery materials /corrosion experiences by operating company representatives.
Possibility to have a restricted web page on the EFC-WP15 page

Forum for Technology
Sharing materials/ corrosion/ protection/ monitoring information by providers

Eurocorr Conferences

WP Meetings
One WP 15 working party meeting in Spring,
One meeting at Eurocorr in September in conjunction with the conference,

Publications - Guidelines

Publications from WP15

- EFC Guideline n°40 « Prevention of corrosion by cooling waters » available from http://www.woodheadpublishing.com/en/book.aspx?bookID=1193

Update in relation with Nace document 11106 "Monitoring and adjustment of cooling water treatment operating parameters" Task Group 152 on cooling water systems

- EFC Guideline n° 46 on corrosion in amine units http://www.woodheadpublishing.com/en/book.aspx?bookID=1299

- EFC Guideline n° 42 Collection of selected papers http://www.woodheadpublishing.com/en/book.aspx?bookID=1295

- EFC Guideline n° 55 Corrosion Under Insulation http://www.woodheadpublishing.com/en/book.aspx?bookID=1486

- Future publications : suggestions ?
  - best practice guideline to avoid and characterize stress relaxation cracking ?

EFC Working Party 15 plan work 2011-2013

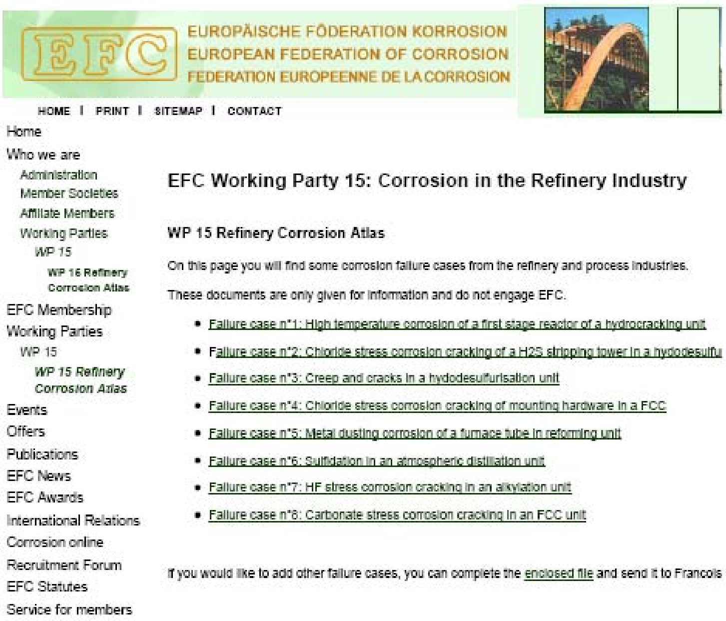
. Collaboration with Nace : exchange of minutes of meetings
"NACE TEG 205X information exchange -corrosion in refineries "

. Sessions with other EFC WP at Eurocorr (2013 in Estoril-Portugal, 2014 Pisa-Italy) on which topics?

- Update of publications
  - CUI guideline
  - Amine acid gas treatment plants

- New Publications: best practice guideline to avoid and characterize stress relaxation cracking ?

- Education – qualification – certification
  List of "corrosion refinery" related courses on EFC website ?



EUROPÄISCHE FÖDERATION KORROSION
EUROPEAN FEDERATION OF CORROSION
FEDERATION EUROPEENNE DE LA CORROSION

EFC Working Party 15: Corrosion in the Refinery Industry

WP 15 Refinery Corrosion Atlas

On this page you will find some corrosion failure cases from the refinery and process industries.

These documents are only given for information and do not engage EFC.

- Failure case n°1: High temperature corrosion of a first stage reactor of a hydrocracking unit
- Failure case n°2: Chloride stress corrosion cracking of a H2S stripping tower in a hydodesulfu
- Failure case n°3: Creep and cracks in a hydodesulfurisation unit
- Failure case n°4: Chloride stress corrosion cracking of mounting hardware in a FCC
- Failure case n°5: Metal dusting corrosion of a furnace tube in reforming unit
- Failure case n°6: Sulfidation in an atmospheric distillation unit
- Failure case n°7: HF stress corrosion cracking in an alkylation unit
- Failure case n°8: Carbonate stress corrosion cracking in an FCC unit

If you would like to add other failure cases, you can complete the enclosed file and send it to Francois

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Information :
Future conferences related to refinery corrosion

•17-21 March 2013 http://www.nace.org
Nace Conference 2013 Orlando USA

•1-5 September 2013 http://www.eurocorr2013.org
EUROCORR 2013 Estoril Portugal

•8-10 October 2013 http://www.esope-paris.com/spip.php?lang=en
ESOPE Paris France
(construction technologies, Codes, Standards and European Directives for stationary and transportable Pressure Equipment)

EFC WP15 spring meeting during 2 or 3rd week April ? (between 8 -19 April) in Paris to be confirmed – an email of information will be soon sent to the EFC members?

Appendix 3

CUI- Honeywell JIP Proposal

(B. Chambers - Honeywell)

Characterization and Quantification of Corrosion Under Insulation (CUI) for Process Plant Applications

Review of Joint Industry Program Proposal

Presentation by:
Brian Chambers, Ph.D.
Vishal Lagad
Sridhar Srinivasan
Honeywell

Corrosion Under Insulation - An Introduction

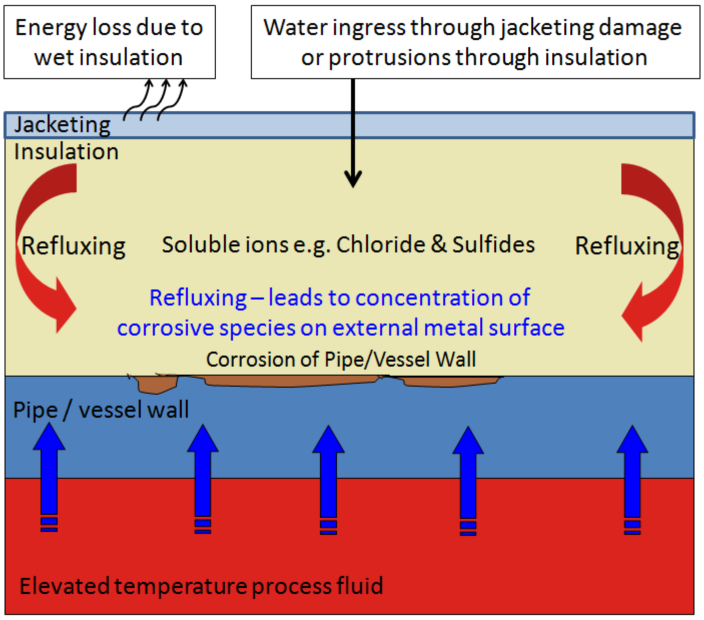
- Occurs under coverings, e.g. thermal insulation, fireproofing and jacketed vessels and piping

- Occurs in process equipment operating over a wide range of conditions:
  - Carbon and low alloy steels
  - Stainless steels (PREN $\leq$ 40)
  - Temperature range: -4C to 150 C
  - Refineries, petrochemical & power plants, industrial facilities (both onshore and offshore).

- Actual metal loss rates are dependent on a number of factors
  - Amount, duration, orientation and frequency of wetness
  - Chloride or other chemical contamination, presence of industrial pollutants, leachability of corrodents from the insulation
  - Operating temperature and
  - Wet-dry cyclic operation

Despite existing standards (NACE/EFC), the incidences of CUI appears to be occurring at an increasing rate. Mainly in existing construction.

Schematic View of CUI



Energy loss due to wet insulation

Water ingress through jacketing damage or protrusions through insulation

Jacketing

Insulation

Refluxing

Soluble ions e.g. Chloride & Sulfides

Refluxing

Refluxing – leads to concentration of corrosive species on external metal surface

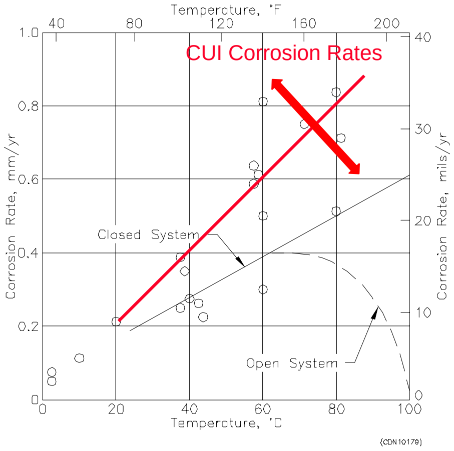
Corrosion of Pipe/Vessel Wall

Pipe / vessel wall

Elevated temperature process fluid

Why is Wet Insulation So Damaging?

- Out of site/out of mind???
  - Under covering & can’t see damage
- Local geometry is conductive to moisture trapping
- Corrosion rates are higher than expected based on simple exposure tests under comparable, non-CUI conditions.
- Corrosion can be localized or initiate SCC in stainless alloys
- Energy losses due to wet insulation can be very high!
- Ineffective temperature control can also lead to process upsets, off-spec product and internal dew point corrosion



Wet Insulation causes two major problems:
Corrosion Under Insulation & Significant Energy Loss

CUI JIP

Typical Approach to CUI Prevention

- Insulation selection and weather barriers
  - Key parameter is selection of insulation material – mostly neglected
  - Not enough research or information in selection insulation materials, often most “cost-effective” material is selected
  - Significant resources spent in keeping water out of the system
- Equipment design
  - Use of good design practices to minimize water ingress / retention
  - Often water ingress is inevitable in spite of efforts
- Protective coatings
  - Significant resources spent on coatings with acceptance of the fact that water will eventually get into the insulation system
  - Area of good understanding and wealth of information on coating system performance
- Inspection and maintenance practices
  - Laborious, time intensive
  - Relied on heavily and often struggling with resources to keep up

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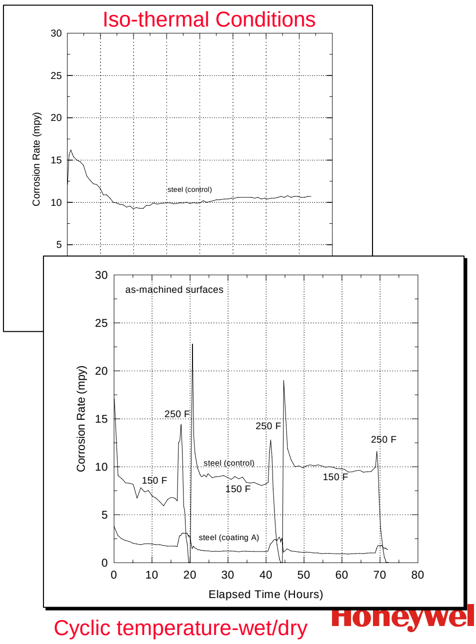
Methods for CUI Detection

- Initially manual / visual methods are commonly used:
  - Involve assessment of condition of insulation
  - Presence of rust staining
  - Age of equipment
  - Number of penetrations in covering
- Serve as the basis for more involved assessment methods
  - Some focused on detecting water or wet insulation (Thermography, Neutron backscatter etc.) and need a good baseline
  - Others focused on measuring wall/thickness loss(UT, etc.)
- Inspection techniques are limited to areas that are actually inspected
  - CUI occurs only in discrete locations unlike internal corrosion
  - Miles of pipes or areas of vessels could go un-inspected for years
- Real Time Monitoring with Sensors for Corrosion
- The problem of CUI is largely hidden and difficult/costly to access and quantitatively inspect

Corrosion Monitoring with SmartCET

- Corrosion rates for CUI are highly variable, but need to be assessed in critical (worst-case areas).
- Rates can be integrated with time for quantitative cumulative damage assessments.
- Rates depend on temperature conditions, insulation types, materials, coatings and impurities.
- Electrochemical methods are a natural for this type of assessment, but:
  - They need to be quantitative and differentiate between general and localized corrosion.
  - Can be accomplished using a sensor array under covering
  - Integrated with plant process control system for ease of implementation and automation with fault models.

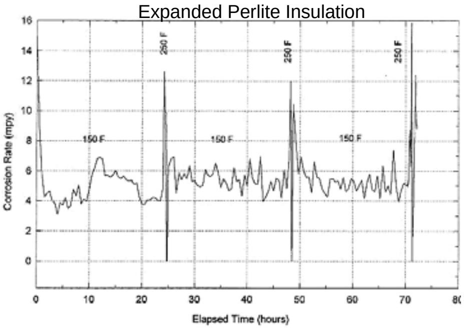


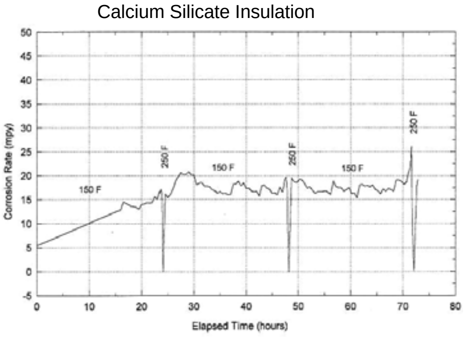
Cyclic temperature-wet/dry

CUI JIP

Corrosion Monitoring with SmartCET - 2

Calcium silicate insulation had 3 times the corrosion rate of expanded perlite

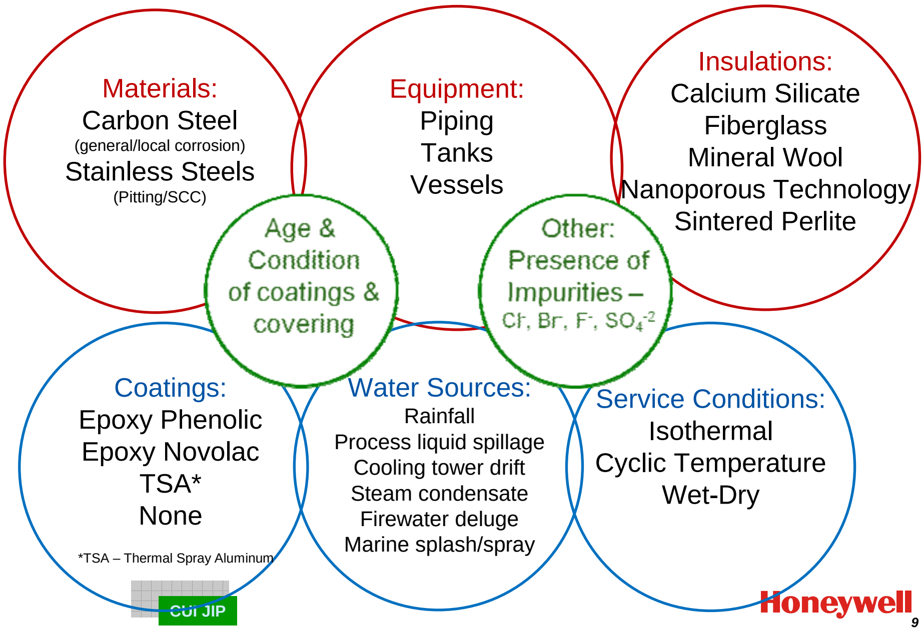




- Value of monitoring is to track actual rates that depend on:
  - Material of construction – carbon steel / stainless steel
  - Covering materials
  - Exposure conditions
  - Thermal Spray Aluminum and polymeric coatings
  - Local environment – chlorides, sulfur and other species from ambient environment or contained within the covering.

CUI JIP

Variables in the CUI Process



Materials:
Carbon Steel
(general/local corrosion)
Stainless Steels
(Pitting/SCC)

Equipment:
Piping
Tanks
Vessels

Insulations:
Calcium Silicate
Fiberglass
Mineral Wool
Nanoporous Technology
Sintered Perlite

Age & Condition of coatings & covering

Other: Presence of Impurities – Cl^-, Br^-, F^-, SO_4^{-2}

Coatings:
Epoxy Phenolic
Epoxy Novolac
TSA*
None

*TSA – Thermal Spray Aluminum

Water Sources:
Rainfall
Process liquid spillage
Cooling tower drift
Steam condensate
Firewater deluge
Marine splash/spray

Service Conditions:
Isothermal
Cyclic Temperature
Wet-Dry

Path Forward – CUI JIP

- Honeywell has a record of successful completion of joint industry programs
- CUI is a key issue in many petrochemical plant applications with significant concerns
- Industry currently relies on EFC and NACE guidelines for risk based approach but relies heavily on:
  - Weather barriers, sealants etc. for preventing water ingress into insulation systems
  - Coatings, TSA etc. for protection due to the inevitability of water ingress
  - Inspections that include in many cases insulation removal etc.
  - ASTM standards for insulation assessment and selection

- Honeywell CUI JIP aims to provide a focus on the wet insulation problem
  - Focus on selection and rating of insulation materials

Honeywell CUI JIP – Key Points

- Hot insulation in outdoor plants
  - Inevitability of water getting into the insulation system
- Focus on insulation material and not coatings
  - Knowledge base on coatings is extensive
  - Primary concern with coatings is field application
    - Routinely ill afforded the scrutiny that is necessary
  - Develop performance data for commonly used insulation systems
- Provide sponsoring companies the ability to:
  - Evaluate insulation materials based on performance when wet
    - Severity of CUI
    - Thermal performance
  - Select appropriate insulation material using a software tool
  - Evaluate extent of damage from existing insulation material
  - Estimate energy losses from wet insulation
  - Evaluate any new insulation material or variant

Honeywell CUI JIP – Details

- Materials of construction to be investigated:
  - Carbon Steel (AISI 1018), Austenitic Stainless Steel (316L/304L) and Duplex Stainless Steel (Alloy 2205)
- Task 1: Screening Tests and Preliminary Ranking of Insulation Materials
  - Choose 72 insulation products for testing for six types of insulations
  - Perform ASTM standard test + other tests to collect data about insulation products
    - Water retention characteristics, leachable contaminants, corrosion response of leachate, heat transfer properties etc.
  - Create preliminary ranking

Insulation Type	Maximum Number of Products
Mineral Fiber	18
Calcium Silicate	12
Expanded Perlite	9
Nanoporous technology	15
Cellular Glass	6
Fiberglass	12

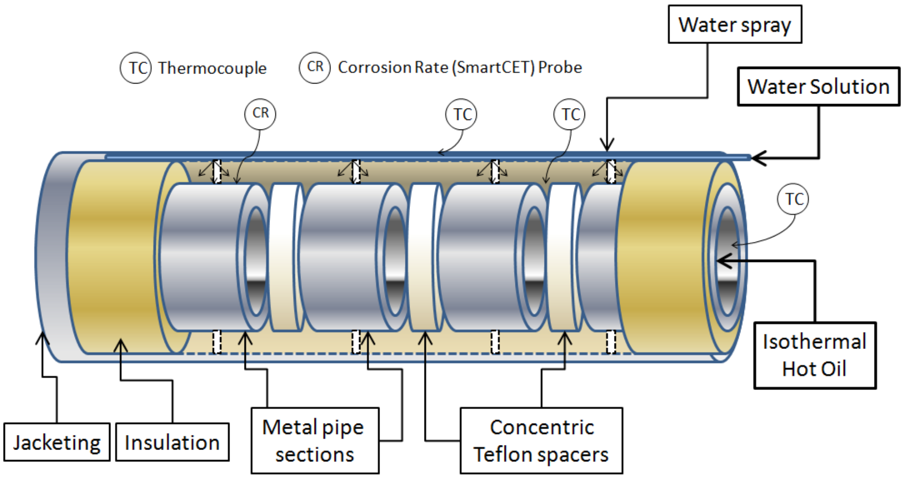
Honeywell CUI JIP – Details

- Task 2: Testing for CUI & Thermal performance
  - (2.1) Full scale pipe tests for 9 insulation products
    - Simulate the CUI problem in a lab in a controlled environment
    - Simulate wet, wet-dry cyclic and wet to dry conditions
    - Measure corrosion response (mass loss) and thermal performance
    - 108 total tests

Temperature (F)	Wet (Steady State)	Wet Dry (Cyclic)	Wet to Dry (Dynamic)
180	Continuous water supply to maintain water wet conditions for duration of test	Water supply will be cycled on and off to allow for dry-out at the steel surface (when measured corrosion less than 0.1 mpy), simulating Wet/Dry conditions	Water supply will be started till insulation is saturated or given opportunity for saturation, and then turned off for the duration of the test (or till dry-out)
250			
400			
700			

  - (2.2) SCC tests using leachate
    - Evaluate cracking resistance of U Bend coupons exposed to leachate
    - 18 tests
  - (2.3) Wild card tests
    - Additional 11 tests

Task 2 – Full scale pipe test schematic



Test Setup: 6 inch pipe sections electrochemically isolated

Honeywell CUI JIP – Details

- Task 3: Correlation of key properties to CUI and Thermal performance
  - Corrosion and Thermal performance Data from Task 2 will be correlated to property data collected in Task 1
  - Identify key parameters and relationships from Task 1 and Task 2 data
  - Development of ranking of insulation materials tested
  - Development of framework to evaluate insulation materials not tested based on “properties” collected in Task 1
  - Validation using wild card tests

- Task 4: Development of Insulation Selection Tool
  - Easy to use software will be developed that provides capability to
    - Evaluate insulation materials tested
    - Evaluate New insulation products using properties information
    - Estimate energy losses
    - Assess corrosion damage in existing insulation systems

Summary / Path Forward

- CUI represents a significant cost for Industry
- Resources currently focused on inspection, keeping water out, coating systems etc.
- Coating systems are limited by the degree of effectiveness of field applications
- Minimal effort and resources spent on identifying the right insulation for the job – often the most “cost effective” material is chosen (rather than the ‘most effective’)
- Thermal losses due to wet insulation not captured or identified

Summary / Path Forward - 2

- Utilize JIP approach to develop necessary data to support development of a CUI software tool for
  - Ranking available insulation products based on corrosion and thermal performance
  - Assessment of CUI damage in plant piping
  - Demonstrate efficacy of real time monitoring technology as a basis for field installation
  - Evaluation of energy losses due to wet insulation
  - Evaluation of any insulation materials and compare with others
- Develop an unbiased set of data to rank and select insulation materials and assess corrosion damage and thermal losses due to existing wet insulation

Appendix 4

CUI – SINTEF JIP Proposal

(O. Knudsen – SINTEF)

Scope and objectives

- Select or develop a test method that can be used for evaluation and pre-qualification of coatings for use under thermal insulation.
- The method shall be applicable as a pre-qualification test in NORSOK m-501 or any other recognized international standards.
- Effect of parameters on degradation.
- Interaction and information exchange with other organizations:
  - CEPE – European paint manufacturing organization (IPPIC also)
  - NACE

Principal parameters

- Exposure temperature
- Electrolyte
- Cycling:
  - Dry/wet
  - High/low temperature
- Coating:
  - Generic type
  - Dry film thickness and barrier properties
  - Surface cleaning and pre-treatment
- Insulation
  - Wicking/non-wicking
  - Contact/non-contact
- Test duration

Work description

- **WP1: State of art**
  - State of art concerning Coatings Under Insulation and test methods
  - Agree on a range of conditions that represent the problem

- **WP2: Test and apparatus development**
  - Agree on methodology
  - Build apparatus

- **WP3: Evaluation of the test method and investigate parameters**
  - Test a limited set of coatings under different conditions. References: TSA, uncoated steel, zinc silicate.
  - Evaluate and correlate
  - Modify apparatus and methodology

- **WP4: Finalizing the method**
  - Determine the parameters
  - Testing a set of coatings with the final procedure

State of art

- CUI – a short summary of some facts
- NACE SP198-2010: Control of Corrosion Under Thermal Insulation and Fireproofing Materials—A Systems Approach
- EFC 55 "Corrosion-under-insulation (CUI) guidelines"
- ASTM G189 - Standard Guide for Laboratory Simulation of Corrosion Under Insulation
- ASTM D2485 – Standard Test Method for Evaluating Coatings For High Temperature Service
- Previous projects with focus on test method
  - Hydro 1995-1997 (Jan Ivar Skar)
  - Statoil 2010 (Kristian Haraldsen)
  - International Paint 2005-2012

CUI – summary of some facts

- Materials
  - C-steel (general corrosion)
  - Austenitic and duplex Stainless steels (stress corrosion cracking)
- Water – wet insulation
  - External water sources: Rain, washing, spill, ground water …
  - Internal water source: Condensation
- Contaminants frequently found in the water
  - Cl^-, SO_4^{2-}
- Type of insulation
  - Water retention, permeability, and wettability of the insulation
  - Substances in the insulation that may increase corrosivity, e.g. chloride and acidic components

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CUI - Temperature range

- -4 to +175 °C
- Above 175 °C the surfaces are generally dry and corrosion does not occur
- Still, corrosion may occur when the system is idle
- In closed systems there are no upper temperature limit

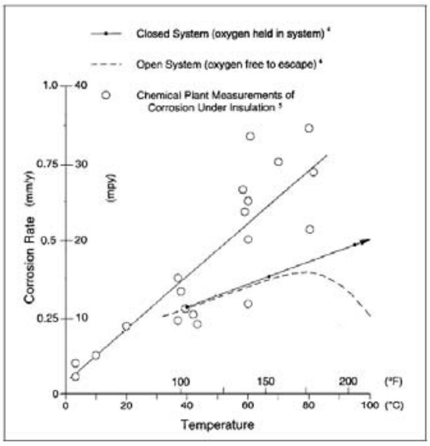

Figure 1: Effect of Temperature on Steel Corrosion in Water

Weather and water barriers

- Mantling
- Mastics and sealants

- Will often be damaged so that water leaks inn anyway
- Will slow down evaporation of water and may therefore enhance CUI

NACE SP-0198: Control of Corrosion Under Thermal Insulation and Fireproofing Materials—A Systems Approach

1. General
2. Corrosion Mechanisms
3. Mechanical Design
4. Protective Coatings
5. Insulation, Fireproofing, and Accessory Materials
6. Inspection and Maintenance

NACE SP-0198 and coatings

- Scope: Information about coating selection
- Generic description of coatings and recommended temperature range
- Based on practical experiences
- Suitability of a specific product for a specific case is based on supplier recommendation

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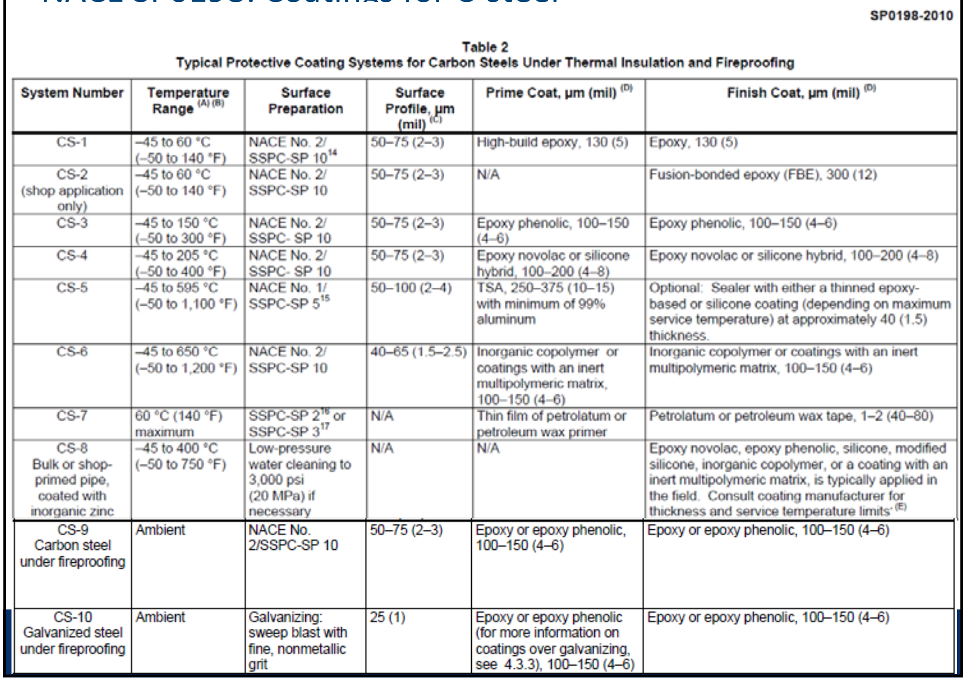
NACE SP0198: Coatings for C-steel

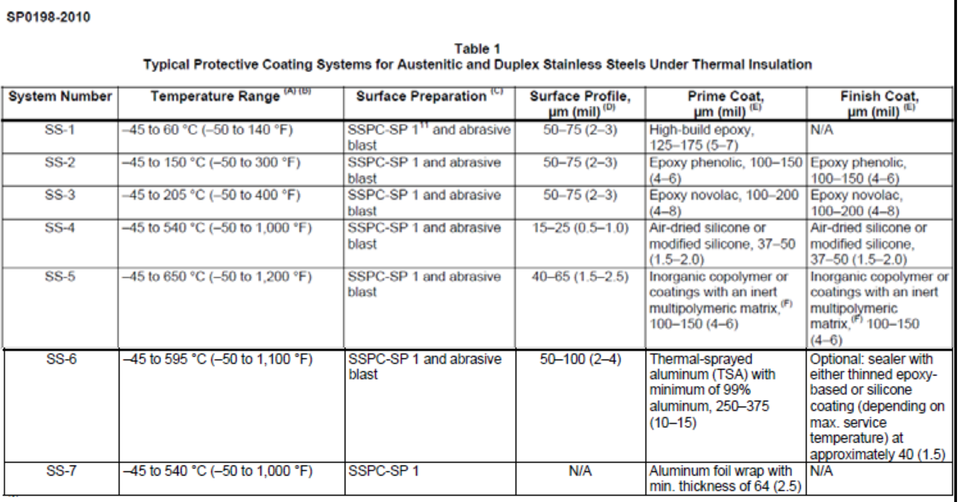


SP0198-2010

Table 2
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	–45 to 60 °C (–50 to 140 °F)	NACE No. 2/ SSPC-SP 10[14]	50–75 (2–3)	High-build epoxy, 130 (5)	Epoxy, 130 (5)
CS-2 (shop application only)	–45 to 60 °C (–50 to 140 °F)	NACE No. 2/ SSPC-SP 10	50–75 (2–3)	N/A	Fusion-bonded epoxy (FBE), 300 (12)
CS-3	–45 to 150 °C (–50 to 300 °F)	NACE No. 2/ SSPC- SP 10	50–75 (2–3)	Epoxy phenolic, 100–150 (4–6)	Epoxy phenolic, 100–150 (4–6)
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 1,100 °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 1,200 °F)	NACE No. 2/ SSPC-SP 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	60 °C (140 °F) maximum	SSPC-SP 2[16] or SSPC-SP 3[17]	N/A	Thin film of petrolatum or petroleum wax primer	Petrolatum or petroleum wax tape, 1–2 (40–80)
CS-8 Bulk or shop-primed pipe, coated with inorganic zinc	–45 to 400 °C (–50 to 750 °F)	Low-pressure water cleaning to 3,000 psi (20 MPa) if necessary	N/A	N/A	Epoxy novolac, epoxy phenolic, silicone, modified silicone, inorganic copolymer, or a coating with an inert multipolymeric matrix, is typically applied in the field. Consult coating manufacturer for thickness and service temperature limits. (E)
CS-9 Carbon steel under fireproofing	Ambient	NACE No. 2/SSPC-SP 10	50–75 (2–3)	Epoxy or epoxy phenolic, 100–150 (4–6)	Epoxy or epoxy phenolic, 100–150 (4–6)
CS-10 Galvanized steel under fireproofing	Ambient	Galvanizing: sweep blast with fine, nonmetallic grit	25 (1)	Epoxy or epoxy phenolic (for more information on coatings over galvanizing, see 4.3.3), 100–150 (4–6)	Epoxy or epoxy phenolic, 100–150 (4–6)

NACE SP0198: Coatings for duplex stainless steels



SP0198-2010

Table 1
Typical Protective Coating Systems for Austenitic and Duplex Stainless Steels Under Thermal Insulation

System Number	Temperature Range (A)(B)	Surface Preparation (C)	Surface Profile, µm (mil) (D)	Prime Coat, µm (mil) (E)	Finish Coat, µm (mil) (E)
SS-1	–45 to 60 °C (–50 to 140 °F)	SSPC-SP 1[11] and abrasive blast	50–75 (2–3)	High-build epoxy, 125–175 (5–7)	N/A
SS-2	–45 to 150 °C (–50 to 300 °F)	SSPC-SP 1 and abrasive blast	50–75 (2–3)	Epoxy phenolic, 100–150 (4–6)	Epoxy phenolic, 100–150 (4–6)
SS-3	–45 to 205 °C (–50 to 400 °F)	SSPC-SP 1 and abrasive blast	50–75 (2–3)	Epoxy novolac, 100–200 (4–8)	Epoxy novolac, 100–200 (4–8)
SS-4	–45 to 540 °C (–50 to 1,000 °F)	SSPC-SP 1 and abrasive blast	15–25 (0.5–1.0)	Air-dried silicone or modified silicone, 37–50 (1.5–2.0)	Air-dried silicone or modified silicone, 37–50 (1.5–2.0)
SS-5	–45 to 650 °C (–50 to 1,200 °F)	SSPC-SP 1 and abrasive blast	40–65 (1.5–2.5)	Inorganic copolymer or coatings with an inert multipolymeric matrix,(F) 100–150 (4–6)	Inorganic copolymer or coatings with an inert multipolymeric matrix,(F) 100–150 (4–6)
SS-6	–45 to 595 °C (–50 to 1,100 °F)	SSPC-SP 1 and abrasive blast	50–100 (2–4)	Thermal-sprayed aluminum (TSA) with minimum of 99% aluminum, 250–375 (10–15)	Optional: sealer with either thinned epoxy-based or silicone coating (depending on max. service temperature) at approximately 40 (1.5)
SS-7	–45 to 540 °C (–50 to 1,000 °F)	SSPC-SP 1	N/A	Aluminum foil wrap with min. thickness of 64 (2.5)	N/A

EFC 55 "Corrosion-under-insulation (CUI) guidelines"

1. Introduction
2. Economic consideration
3. Ownership and responsibility
4. The risk-based inspection (RBI) methodology for CUI
5. Inspection activities/strategy
6. NDE/NDT screening techniques for CUI
7. Recommended Best Practice to Mitigate CUI
8. Design for the prevention of CUI

- Appendix D: Coatings General; Protective coatings; Thermal spray aluminium; Surface/moisture tolerance - alternative coatings; Tape coatings.
    - Reference to NACE SP-0198 regarding selection of coatings
    - General comparison of TSA and conventional paint

TSA vs conventional paint

Feature	TSA	Paint
Durability	25+ years	5-13 years
Cyclic service	Yes	No
Upper temperature limit	480°C	175°C
Mechanical damage	Resistant Small damages ok	Susceptible Will result in corrosion

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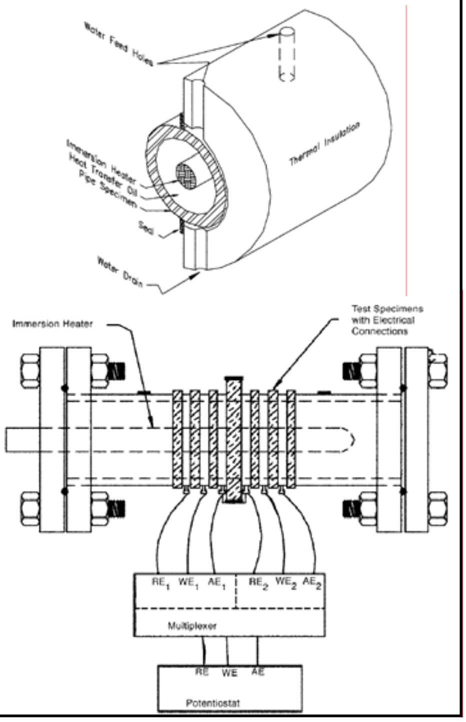
ASTM G189

Laboratory Simulation of Corrosion Under Insulation

- 6 steel ring samples mounted with PTFE rings between
- Mounted in a flanged pipe section
- Filled with oil
- Insulation with cavity to the samples
- Cavity filled with electrolyte
  - 0.5 g/l NaCl
  - pH 6
- Wet/dry cycling
- Hot/cold cycling
- 72 hours
- Weight loss measurement



ASTM G189

- Primarily a corrosion test for comparison of corrosion rate for different types of steel
- In my view the test is similar to a simple immersion test

- Has been used for testing of a coating (CORROSION/97, paper #266)
  - The coating quality was evaluated by steel corrosion rate
  - Will only be a measure of % surface area damaged
  - The ring samples are too small for testing of coatings
  - Not really suitable for coating evaluation as described

ASTM D2485 Evaluating Coatings For High Temperature Service

Method A

•Place **two panels** in a muffle furnace at the test temperature for 24 h

•Plunge one of the panels into water at 21 ± 2.5°C
•Examine the coating film for dulling, blistering, cracking, and loss of adhesion

•Allow the second panel to cool at a room temperature of 24 ± 2.5°C for 1 h
•Rapidly bend double over a 12.7-mm diameter steel mandrel
•Examine this panel for cracking and loss of adhesion

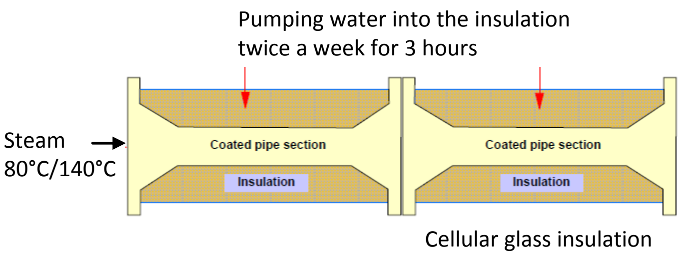
ASTM D2485 Evaluating Coatings For High Temperature Service

Method B

- Expose two panels at:
  - 205°C (400°F) for 8 h
  - 260°C (500°F) for 16 h
  - 315°C (600°F) for 8 h
  - 370°C (700°F) for 16 h
  - 425°C (800°F) for 8 h

- Remove the panels and inspect
- Allow to cool for 1 h at ambient conditions
- Panel 1: Salt spray test for 24 h
- Panel 2: Field test for 12 months

Hydro 1995-1997 (Jan Ivar Skar)



Pumping water into the insulation twice a week for 3 hours

Steam 80°C/140°C

Cellular glass insulation

+9 weeks test

Primer	Intermediate	Top coat	Thickness [µm]	Test - temp. [°C]
Phenolic epoxy	(Phenolic epoxy)	Phenolic epoxy	250 - 300	80 & 140
Thermal sprayed Al		Sealer	270 - 300	80 & 140
Thermal sprayed Al			270 - 330	80 & 140
One comp. inorganic zinc		Two comp. siloxane	200	140
One comp. inorganic zinc		One comp. inorganic silicate	200	140
Zn rich moisture cured urethane	Moisture cured urethane	Moisture cured urethane	160 - 200	140
One comp. modified silicone		One comp. modified silicone	100	140
Butyl rubber tape		Plastic polymer tape	>1000	80 & 140
Inorganic zinc		High temp. siloxane	ca. 350	140
Inorganic zinc			100	140
Two comp. epoxy with ceramic filler		Two comp. epoxy with ceramic filler	780 - 900	80 & 140

✓ Systems passed at 140°C

- Phenolic epoxy
- Thermal sprayed Al with sealer
- Epoxy with ceramic filler

✓ Systems failed at 140°C

- Inorganic zinc
- Inorganic zinc + siloxane (also with high temp. version)
- Inorganic zinc + inorganic silicate
- Moisture cure urethane
- Modified silicone
- Thermal sprayed Al without sealer
- Tape

Conclusions

- Phenolic epoxy works up to 140 °C
- Lack of good products 140 – 180°C

Comments

- Non-wicking insulation
- Mainly dry exposure?

Statoil 2010 (Kristian Haraldsen)

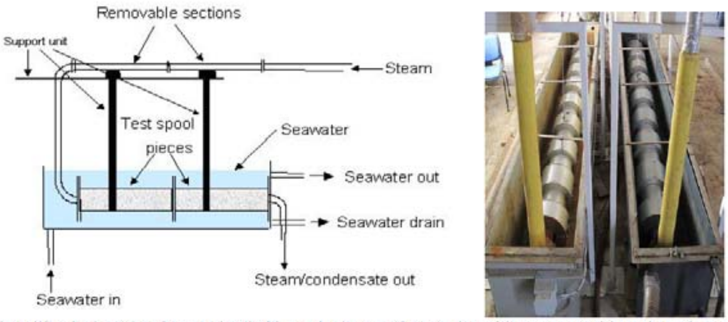
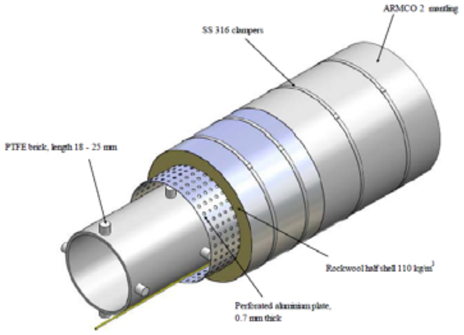


Figure 1 - *Simplified sketch of test-rig (left) and photo of test-rig with mounted insulated spools.*

Statoil 2010

- Insulation: Mineral wool
- 140°C
- The pipe was submerged 3 times a week
- 20 minutes submersion



Statoil 2010

Objectives:

- Comparing high temperature coatings to phenol epoxy and TSA
- Effect of application at normal surface temperatures and at surface temperatures of 120°C and 150°C
- Effect of different pre-treatment methods on the performance of the coating systems.
- Effect of using mineral wool insulation with and without distance from the steel

Coatings

	Type	Thickness
Coating A	Inorganic copolymer	1x200 µm
Coating B	One-component multi-polymeric	2x200 µm
Ref. 1	Phenol epoxy	2x150 µm
Ref. 2	TSA, AlMg5 with silicon sealer	200 µm?

Results

- The conditions were very aggressive – the coating was wet all the time
- Distance between insulation and coating surface improved coating performance
- The phenol epoxy performed better than coating A and B
- TSA performed well

International 2005 (Marie Halliday)

- Objective
  - Development of a single coat thick-film system for temperatures up to 400 °C
  - Development of an internal test method for product development and evaluation

- The testing consisted of several types of exposures:
  1. Cyclic heating and cooling with subsequent corrosion testing (ASTM G85 prohesion test) and field exposure (costal)
  2. Cyclic heating and cyclic wetting →
  3. Thermal cycling/quenching
  4. Cyclic heating and cooling with subsequent immersion

International 2006 (Marie Halliday)

- Continuation of the work from the 2005 paper

- Objective:
  - Application of coating on hot surfaces

- Testing:
- Field exposure and pilot tests
- Further lab testing
  - Thermal cycling (3 x 8 hours at target T) followed by EIS, i.e. barrier against ions

- Comparison between lab and pilot:
  - Too short service time to conclude at that time

Mike O’Donoghue et al. 2012 (JPCL)

Objective:

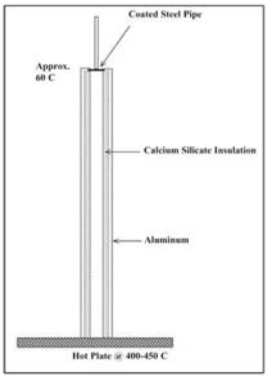
- Evaluation of coatings under insulation at very high temperatures (400°C)

Coatings:

- TSA: Thermal Spray Aluminum (1 coat @ 10 mils DFT).
- Modified Silicone Copolymer (2 coats @ 10 to 12 mils TDFT).
- Inorganic Polymer with MIO (2 coats @ 12 to 18 mils TDFT).
- TMIC: Titanium Modified Inorganic Copolymer (1 coat 7 to 8 mils DFT).

Test methods

- Cyclic heating and cyclic wetting →
- EIS after the cyclic heating
- Cyclic salt immersion and high heat dry out at 200 °C
- Evaluation for adhesion, porosity, cracking, and flaking



Cyclic heating and wetting test:

- A coated pipe is insulated and placed onto a hotplate where a thermal gradient (in general 450ºC – 60ºC)
- Cycled 8 hours heating with 16 hours natural cooling
- The insulation is soaked before and after the heating cycle (1 liter 1% NaCl solution)
- 30 cycles are performed.

Correlation with in service performance

- The paper focus mainly on coating performance and less on test correlation
- There seems to be a certain correlation: TSA and TMIC performed better than the inorganic polymers both in lab and field

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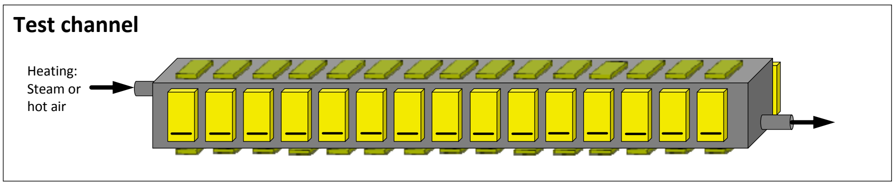
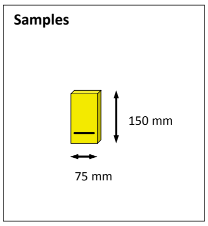
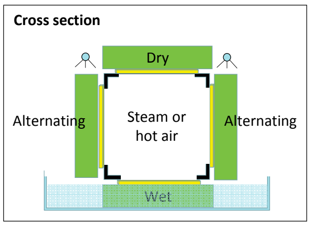
Initial thoughts about test method

Alternative 1







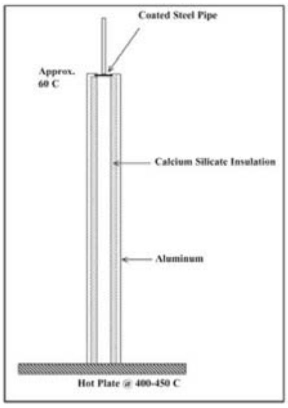
- Temperature will depend on wetting
- Test temperature defined as dry T
- Duration: 1-3 months?
- Electrolyte:
  - 3.5% NaCl?
  - pH ca 7
- Wet dry cycling on side panels: 24/24h
- 8 samples per coating system

Initial thoughts about test method

Alternative 2

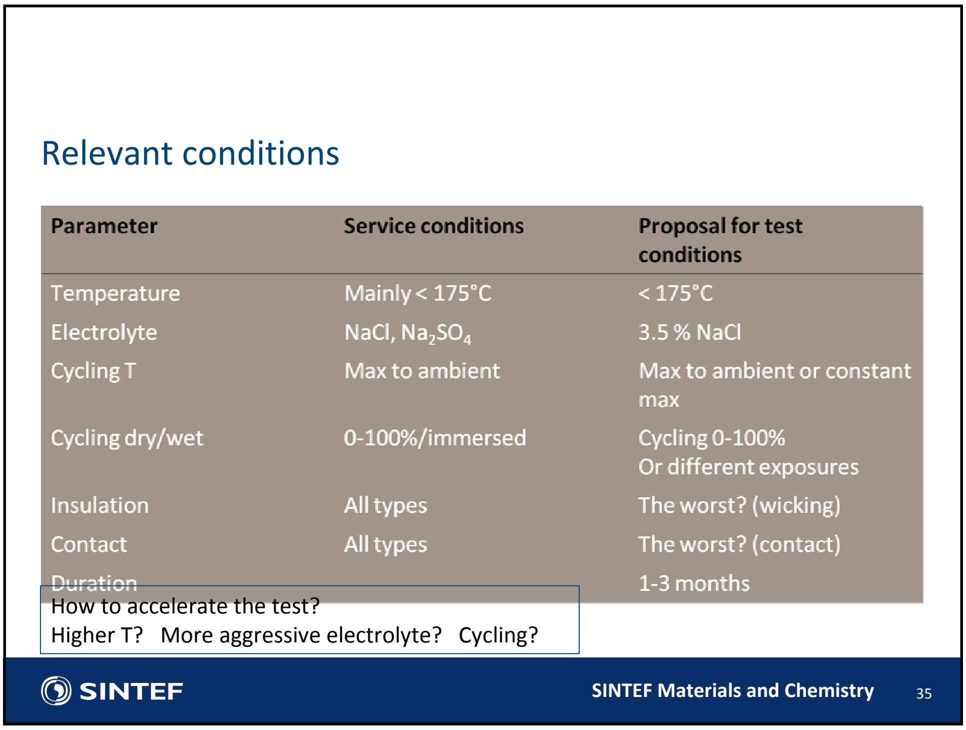
Cyclic heating and wetting test:

- A coated pipe is insulated and placed onto a hotplate where a thermal gradient is formed (in general 450ºC – 60ºC)
- Cycled 8 hours heating with 16 hours natural cooling
- The insulation is soaked before and after the heating cycle (1 liter 1% NaCl solution)
- 30 cycles are performed
- The pipe samples should have a somewhat challenging geometry, e.g. a piece of steel welded to it



Principal parameters

- Exposure temperature: Talk with the OC's
- Electrolyte: 3.5% NaCl
- Cycling:
  - Dry/wet
  - High/low temperature : Has to be cycling
- Coating:
  - Generic type
  - Dry film thickness and barrier properties
  - Surface cleaning and pre-treatment
- Insulation – go for the worst
  - Wicking/non-wicking
  - Contact/non-contact
- Test duration



Relevant conditions

Parameter	Service conditions	Proposal for test conditions
Temperature	Mainly < 175°C	< 175°C
Electrolyte	NaCl, Na_2SO_4	3.5 % NaCl
Cycling T	Max to ambient	Max to ambient or constant max
Cycling dry/wet	0-100%/immersed	Cycling 0-100% Or different exposures
Insulation	All types	The worst? (wicking)
Contact	All types	The worst? (contact)
Duration		1-3 months

How to accelerate the test?
Higher T? More aggressive electrolyte? Cycling?

Appendix 5

Crude units overhead systems

(B. Chambers - Honeywell)

Corrosion Characterization in Crude Distillation Unit Overhead Systems – Phase I

Review of Joint Industry Program Proposal

Presentation by:
Brian Chambers, Ph.D.

Honeywell

Crude Distillation Unit (CDU) Overhead Systems

- The top of the atmospheric distillation unit and CDU overhead systems are exposed to different corrosion problems than those in the higher temperature regions of the atmospheric / vacuum distillation units
- The conditions in the CDU overhead contributing to corrosion include:
  - Presence of significant amounts of water vapor / condensed water
  - Presence of HCl, NH_3, amine neutralizers, H_2S and reaction products
  - Temperatures relevant to salt formation and water condensation
- Modeling and simulation can aid users in identifying areas of concern for corrosion in the CDU overhead system
- Corrosion monitoring can be difficult and misleading as the conditions may change upstream of the monitoring

Crude Distillation Unit (CDU) Overhead Systems

- While operating guidelines and case studies exist, there is a need to quantify corrosion rates and associated risks in the CDU Overhead
- The industry trend towards processing of more opportunity crudes renders the need to understand the effects of corrosion in refinery units critical
- Changes in crude feedstock may result in unexpected corrosion challenges outside of traditional refinery “rules-of-thumb”
- Maintaining a safe and efficient operation is necessary if opportunity crudes can help maximize refinery profitability

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Proposed Honeywell JIP – CDU Overhead Corrosion

- Honeywell is proposing a Joint Industry Program (JIP) in order to evaluate corrosion in simulated CDU overhead conditions and construct a prediction model based on that corrosion rate data
- Honeywell has launched Phase I of this effort earlier in 2012
  - Phase examines corrosion due to HCl, NH_3, H_2S, and H_2O in conditions relevant to the CDU Overhead System
- Following successful completion of the Phase I effort, Phase II will be launched to assess the impact of amine neutralizers

Proposed Honeywell JIP – CDU Overhead Corrosion

- The focus of the Phase I effort of the JIP is twofold:
  - NH_4Cl salt formation and consequent underdeposit corrosion
  - Aqueous corrosion in typical CDU overhead environments
- The objectives of the Phase I effort of the JIP are:
  - Identify the principal parameters that contribute to CDU overhead system corrosion
  - Develop corrosion rate data in appropriate CDU overhead simulations for a wide variety of conditions
  - Evaluate a number of typical materials utilized in the CDU overhead
  - Generate a phase behavior and corrosion prediction model that can assist end users in quantifying corrosion in CDU overhead systems

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JIP Program Principals

- Principal Investigator: Dr. Brian Chambers
- Software Engineer: Kwei Meng Yap
- Program Manager: Sridhar Srinivasan
- Principal Consultant: Dick Horvath
- Technical Advisor: Dr. Russell Kane (iCorrosion)
- Phase Behavior Consultant: Dr. Andre Anderko (OLI Systems)

Details of the Honeywell CDU Overhead JIP

- This Phase I JIP effort focuses on the corrosion related to the presence of:
  - HCl
  - NH_3
  - NH_4Cl
  - H_2O
  - H_2S
- The Phase I JIP will not focus on the development of corrosion data related to amine neutralizers or resulting amine hydrochlorides (planned for Phase II)
- Effects of other species which may occur in the CDU overhead such as oxygen, sulfuric acid, etc. are not planned for investigation in Phase I
- Organic phase (naphtha) and corrosion inhibitors will not be included in the investigation → The JIP results will be considered worst case corrosion rates and provide indications of where particularly corrosive conditions exist

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Task Breakdown – CDU Overhead JIP

- Six tasks are proposed in the CDU Overhead JIP:
  - Task 1 – Development of NH_4Cl Phase Behavior Model
  - Task 2 – Development of Baseline Parametric Data
    - Subtask 2A – Vapor Phase Tests for Underdeposit Corrosion and Condensing Conditions
    - Subtask 2B – Aqueous Phase Tests for Corrosion in Conditions below the Aqueous Dew Point and Post-Water Wash
  - Task 3 – Data Development on the Effect of H_2S
    - Subtask 2A – Vapor Phase Tests for the Effect of H_2S on Underdeposit and Condensing Conditions
    - Subtask 2B – Aqueous Phase Tests for the Effect of H_2S in Conditions below the Aqueous Dew Point and Post-Water Wash
  - Task 4 – Thermodynamic / Ionic Modeling for Experimental Tasks
  - Task 5 – Development of Prediction Model for CDU Overhead Corrosion
  - Task 6 – Predict-Crude OH Software Development

Task 1 – Phase Behavior Model

- Task 1 – Development of NH_4Cl Phase Behavior Model that Focuses on Relevant Input Conditions for the Phase I JIP:
  - NH_3, HCl, H_2O, and H_2S
  - Temperatures of the CDU overhead system
- The Phase Behavior Model will predict:
  - Reaction to form salts
  - Condensation at or below aqueous dew point
  - Concentrations of constituents in the vapor and aqueous phases
- OLI Systems will serve as a consultant on the development of the Phase Behavior Model
- This model will be critical to define and understand experimental conditions in the JIP

Tasks 2 & 3 – Corrosion Experiments

- Tasks 2 & 3 are the bulk of the program and consist of laboratory experiments designed to simulate CDU overhead systems and evaluate corrosion for multiple alloys
- The test program consists of testing in two very different experimental setups (vapor phase & aqueous phase)
  - 73 total tests allocated to vapor phase tests
  - 42 total tests allocated to aqueous phase tests
- The proposed experimental program is presented in the prospectus and herein
  - Many experiments are recommended to be selected once initial results are collected
- As with other Honeywell JIPs, the entire experimental program, including the initial test matrix, is open for sponsor review and revision as needed

Materials for Evaluation

- Six (6) materials are planned for evaluation in the JIP
- It is proposed that the 6 materials consist of typical alloys from various classes of materials commonly used in the CDU overhead system
  - Carbon steel (example – C1018)
  - Ferritic or Martensitic stainless steel (example – 410 SS)
  - Ni-Cu alloy (example – Alloy 400)
  - Duplex stainless steel (example – Alloy 2205)
  - Nickel-based alloy (example – Alloy 625)
  - Titanium alloy (example – Ti grade 2)
- As possible, the materials will be evaluated quantitatively for both localized corrosion and general corrosion rates
  - Pits on flow-through coupons difficult to quantitatively measure

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Task 2 – Baseline Experiments

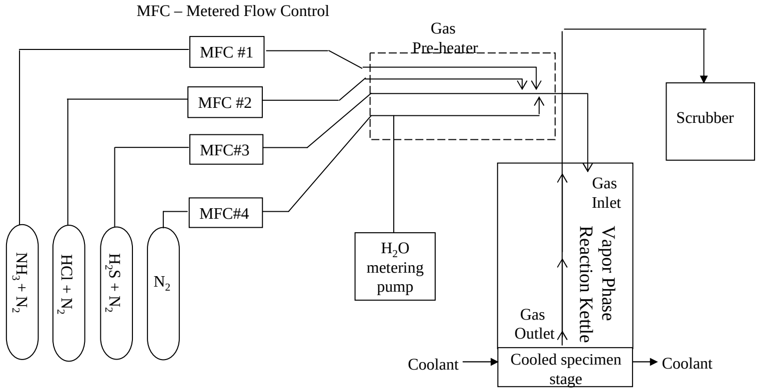
- Task 2 – Development of Baseline Parametric Data:
  - Establish trends in corrosion rate for different materials of construction
  - Experimental conditions will be designed and quantified using the Phase Behavior Model developed in Task 1
  - Experimental inputs varied to examine the three major corrosion scenarios considered in this JIP:
    - Underdeposit corrosion due to NH_4Cl salt formation (above aqueous dew point)
    - Corrosion in condensing water in the presence of HCl and NH_3
    - Corrosion in aqueous solutions containing HCl and NH_3 (continuous aqueous phase)
  - Task is divided into two subtasks based on the type of experiment
    - Vapor phase tests to evaluate:
      - Underdeposit corrosion
      - Condensing water corrosion
    - Aqueous phase tests to evaluate continuous aqueous phase systems

Task 2A – Baseline Experiments (Vapor Phase)

- Task 2A – Development of Baseline Parametric Data in Vapor Phase Experiments:
  - 57 total tests allocated
  - Experiments designed to examine two corrosion scenarios considered in this JIP:
    - Underdeposit corrosion due to NH_4Cl salt formation (above aqueous dew point)
    - Corrosion in condensing water in the presence of HCl and NH_3
  - Equipment will be a vapor phase reaction kettle with continuous input of gaseous constituents
  - Experiments designed to vary:
    - NH_3 partial pressure
    - HCl partial pressure
    - H_2O partial pressure
    - Temperature

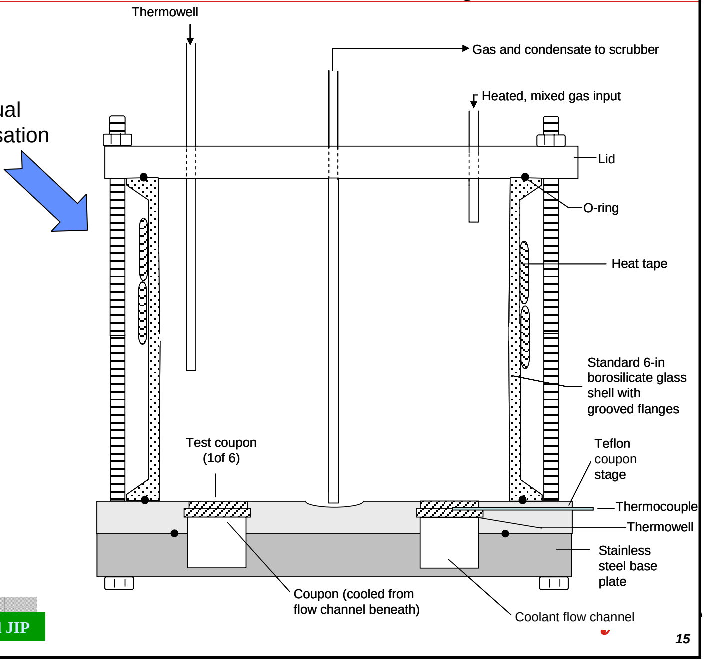
Vapor Phase Reaction Kettle

- Gaseous inputs fed continuously from mixed gas sources
- Gases metered in at appropriate rates to maintain desired partial pressure
- Gases preheated prior to mixing to prevent reaction prior to reaching coupons
- Stage containing cooled coupons provides target test temperature and test specimens

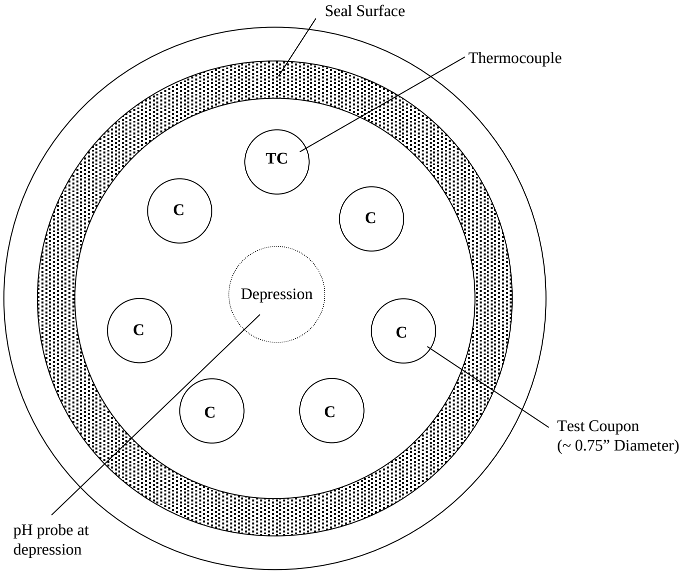


Vapor Phase Reaction Kettle Design

Camera will record visual observation of condensation and salt formation



Conceptual Reaction Kettle Design



Task 2A – Underdeposit Corrosion

- Task 2A – Underdeposit Corrosion Evaluation Experiments:
  - 39 total tests allocated
  - The expected range of input conditions:
    - 1-10 ppm HCl (1, 3, 10 ppm)
      - Approximately equivalent to typical accumulator levels of 40-400 ppm HCl
    - 10-10,000 ppm NH_3 (10, 100, 1,000, and 10,000 ppm), simulating:
      - Low concentrations (10 or 100 ppm) where NH_3 neutralizer is not used
      - High concentrations (1,000 or 10,000 ppm) where NH_3 neutralizer is used
    - 3, 6, and 9 psia H_2O partial pressure typical of ~10-30% H_2O in vapor
    - 220 F, 260 F, and 290 F covering a range of temperatures typical for CDU overhead systems above the aqueous dew point and below salt point
  - Test conditions where no corrosion should occur (above aqueous dew point and above salt formation point) are excluded from testing

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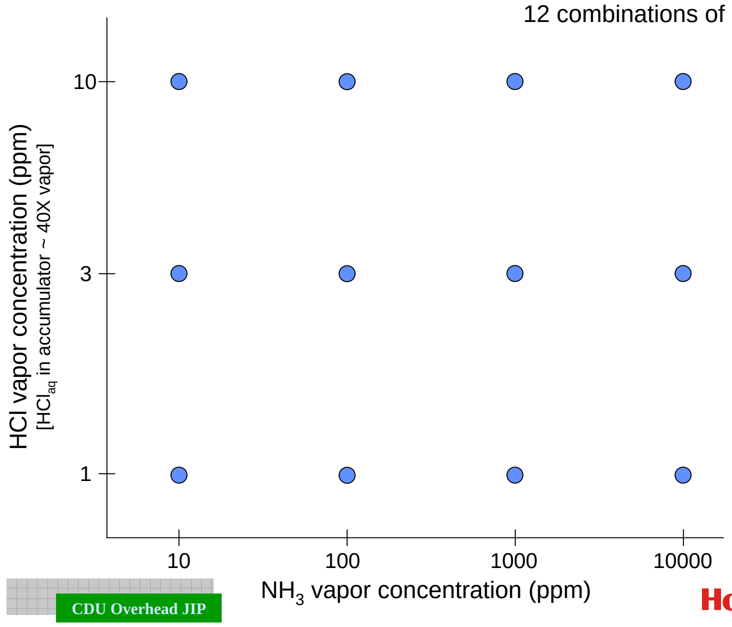
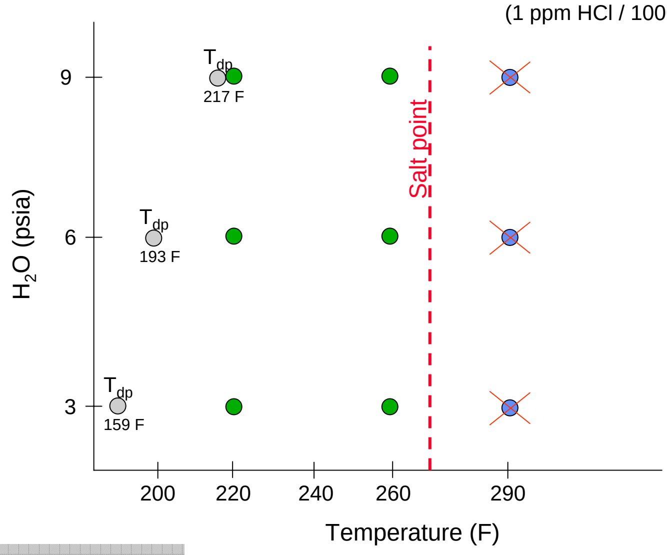
Task 2A – Underdeposit Corrosion

12 combinations of HCl/NH_3



Task 2A – Underdeposit Corrosion

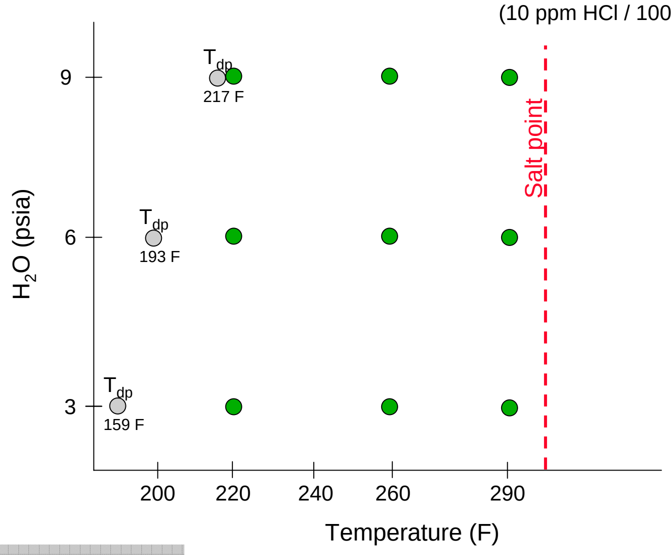
For a given HCl/NH_3 combination
(1 ppm HCl / 10000 ppm NH_3)



(T_{dp} varies per chemistry – primarily on H_2O psia)

Task 2A – Underdeposit Corrosion

For a given HCl/NH_3 combination
(10 ppm HCl / 10000 ppm NH_3)



(T_{dp} varies per chemistry – primarily on H_2O psia)

Task 2A – Condensing Conditions

- Task 2A – Condensing Condition Evaluation Experiments:
  - 18 total tests allocated
  - Only selected conditions evaluated from 36 possible conditions
    - 1-10 ppm HCl (1, 3, 10 ppm)
    - 10-10,000 ppm NH_3 (10, 100, 1,000, and 10,000 ppm)
    - 3, 6, and 9 psia H_2O partial pressure typical of ~10-30% H_2O in vapor
    - Aqueous dew point temperature
  - Initial proposed experiments:
    - 1 ppm HCl, 10 ppm NH_3 at different H_2O partial pressures
      - Examine a typical refinery condition where conditions are well controlled
    - 10 ppm HCl, 10 ppm NH_3 at different H_2O partial pressures
      - Examine refinery condition where HCl levels are elevated and low NH_3 neutralizer
    - 10 ppm HCl, 1,000 ppm NH_3 at different H_2O partial pressures
    - 10 ppm HCl, 10,000 ppm NH_3 at different H_2O partial pressures
      - Examine the effect of NH_3 neutralizer on acidic condensing conditions
    - Six (6) additional tests to be selected based on above results

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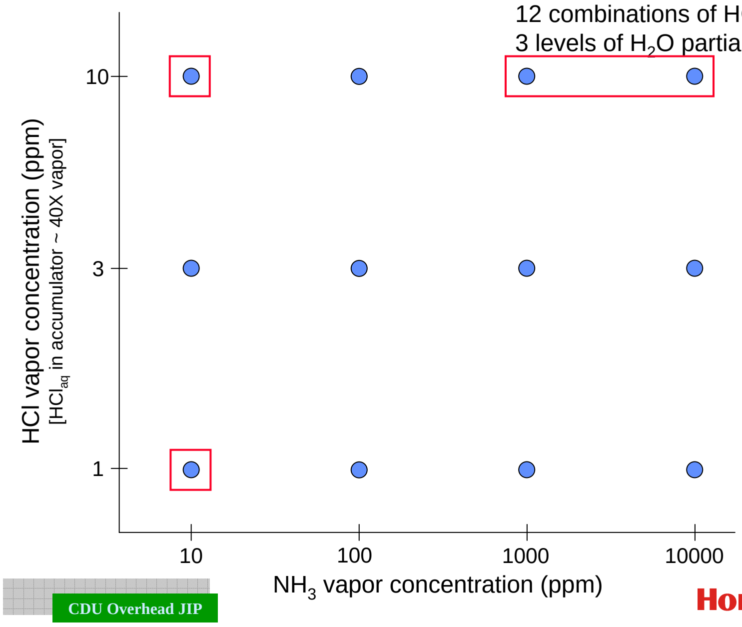
Task 2A – Condensing Conditions



12 combinations of HCl/NH_3
3 levels of H_2O partial pressure

Task 2B – Aqueous Corrosion Evaluation

- Task 2B – Aqueous Corrosion Evaluation Experiments:
  - 24 total tests allocated
  - Designed to simulate conditions where continuous aqueous phase present either due to significant condensation or water wash
  - Conditions to be evaluated initially include:
    - Two HCl / NH_3 concentration pairings (based on vapor phase):
      - 10 ppm HCl / 10 ppm NH_3
      - 10 ppm HCl / 10,000 ppm NH_3
    - Three temperatures (120 F, 160 F, and 200 F)
    - Three values of flow rate (10, 20, and 80 feet/sec)
  - Concentrations of HCl / NH_3 in the aqueous phase will be based on determined amounts from condensation from vapor phase conditions
    - Determined using phase behavior model developed in Task 1
  - Further experimental conditions will be selected based on results of initial experiments

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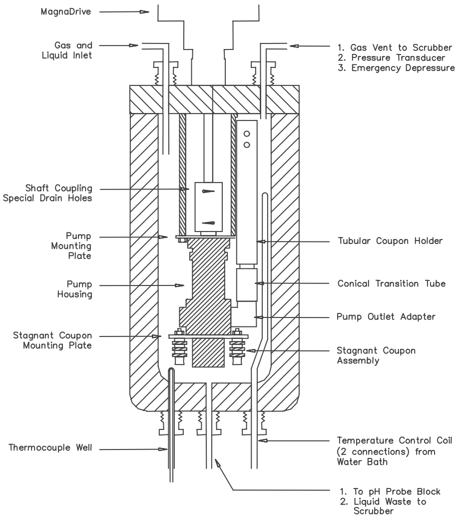
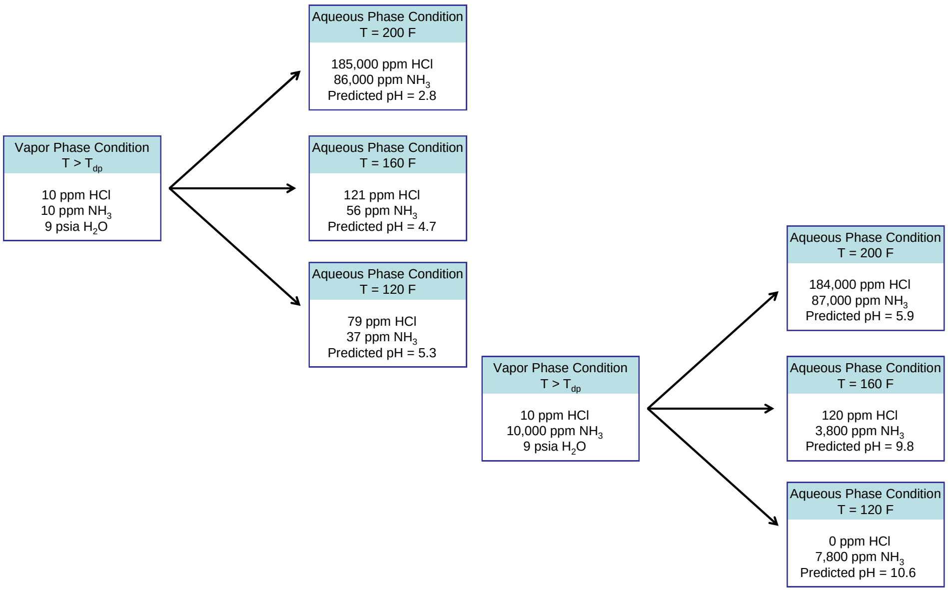
Aqueous Phase Experimental Apparatus

- Similar flow-through autoclave design as used in Amine and Sour Water JIPs at Honeywell
- Static and flow-through test coupons
- The use of glass for much of the wetted vessel housing is anticipated (low pH)
- C-276 parts will be used where metallic parts required



Task 2B – Aqueous Corrosion Evaluation



Vapor Phase Condition
T > T_{dp}

10 ppm HCl
10 ppm NH_3
9 psia H_2O

Aqueous Phase Condition
T = 200 F

185,000 ppm HCl
86,000 ppm NH_3
Predicted pH = 2.8

Aqueous Phase Condition
T = 160 F

121 ppm HCl
56 ppm NH_3
Predicted pH = 4.7

Aqueous Phase Condition
T = 120 F

79 ppm HCl
37 ppm NH_3
Predicted pH = 5.3

Vapor Phase Condition
T > T_{dp}

10 ppm HCl
10,000 ppm NH_3
9 psia H_2O

Aqueous Phase Condition
T = 200 F

184,000 ppm HCl
87,000 ppm NH_3
Predicted pH = 5.9

Aqueous Phase Condition
T = 160 F

120 ppm HCl
3,800 ppm NH_3
Predicted pH = 9.8

Aqueous Phase Condition
T = 120 F

0 ppm HCl
7,800 ppm NH_3
Predicted pH = 10.6

Task 3A – Effect of H_2S – Vapor Phase Evaluation

- Task 3A – Effect of H_2S in Vapor Phase Experiments:
  - 16 total tests allocated
  - Experiments consider the two vapor phase corrosion scenarios:
    - Underdeposit corrosion (above aqueous dew point)
      - NH_4Cl salt formation and corrosion in the presence of H_2S
      - NH_4HS salt formation
    - Corrosion in condensing water in the presence of HCl, NH_3, and H_2S
  - Equipment will be a vapor phase reaction kettle with continuous input of gaseous constituents
  - Experiments will based on results of Task 2A with selected inputs of HCl, NH_3, H_2O, and temperature with the added variation of H_2S:
    - 0.01% H_2S
    - 0.1% H_2S
    - 1% H_2S
  - Experimental matrix will be designed to produce amplification factors for corrosion in the presence of H_2S

Task 3B – Aqueous Corrosion Evaluation

- Task 3B – Effect of H_2S on Aqueous Corrosion:
  - 18 total tests allocated
  - Designed to simulate conditions where continuous aqueous phase present either due to significant condensation or water wash
  - Experiments will based on results of Task 3A with selected inputs of HCl, NH_3, H_2O, and temperature with the added variation of H_2S:
    - 0.01% H_2S
    - 0.1% H_2S
    - 1% H_2S
    - As with other variables in Task 2B, H_2S levels in the aqueous phase will be determined based on the above H_2S vapor phase equivalents
  - Experimental matrix will be designed to produce amplification factors for corrosion in the presence of H_2S

Task 4 – Thermodynamic / Ionic Modeling

- The Phase Behavior Model developed in Task 1 will support the experimental tasks (2A, 2B, 3A, 3B):
  - Provide loading conditions for aqueous phase tests
  - Determine reaction temperature to form salts
  - Determine aqueous dew point

- Task 4 is performed concurrently with the experimental tasks

Task 5 – Corrosion Prediction Model

- A quantitative prediction model will be developed based on the results of Tasks 2-4
- This model will serve the basis for the software development in Task 6

Task 6 – Predict-Crude OH Software

- Task 6 – Predict-Crude OH Software Contains Several Pertinent Parts:
  - Phase behavior model predicting phase concentrations based on the content of HCl, NH_3, H_2S, and H_2O
    - Salt formation temperatures
    - Aqueous dew point temperatures
    - Phase breakdown between vapor, aqueous, and salt phases
  - Flow modeling calculations based on different plant piping configurations
  - Corrosion prediction model for six (6) materials over a wide range of applicable CDU overhead conditions, including:
    - Various chemical constituent compositions (HCl, NH_3, H_2S, H_2O)
    - Flow velocities
    - Temperatures

- The program is anticipated to be performed over a period of approximately 30 months from the date of start-up
- Minimum sponsorship for program start-up is 6 companies
- Full sponsorship is 12 companies

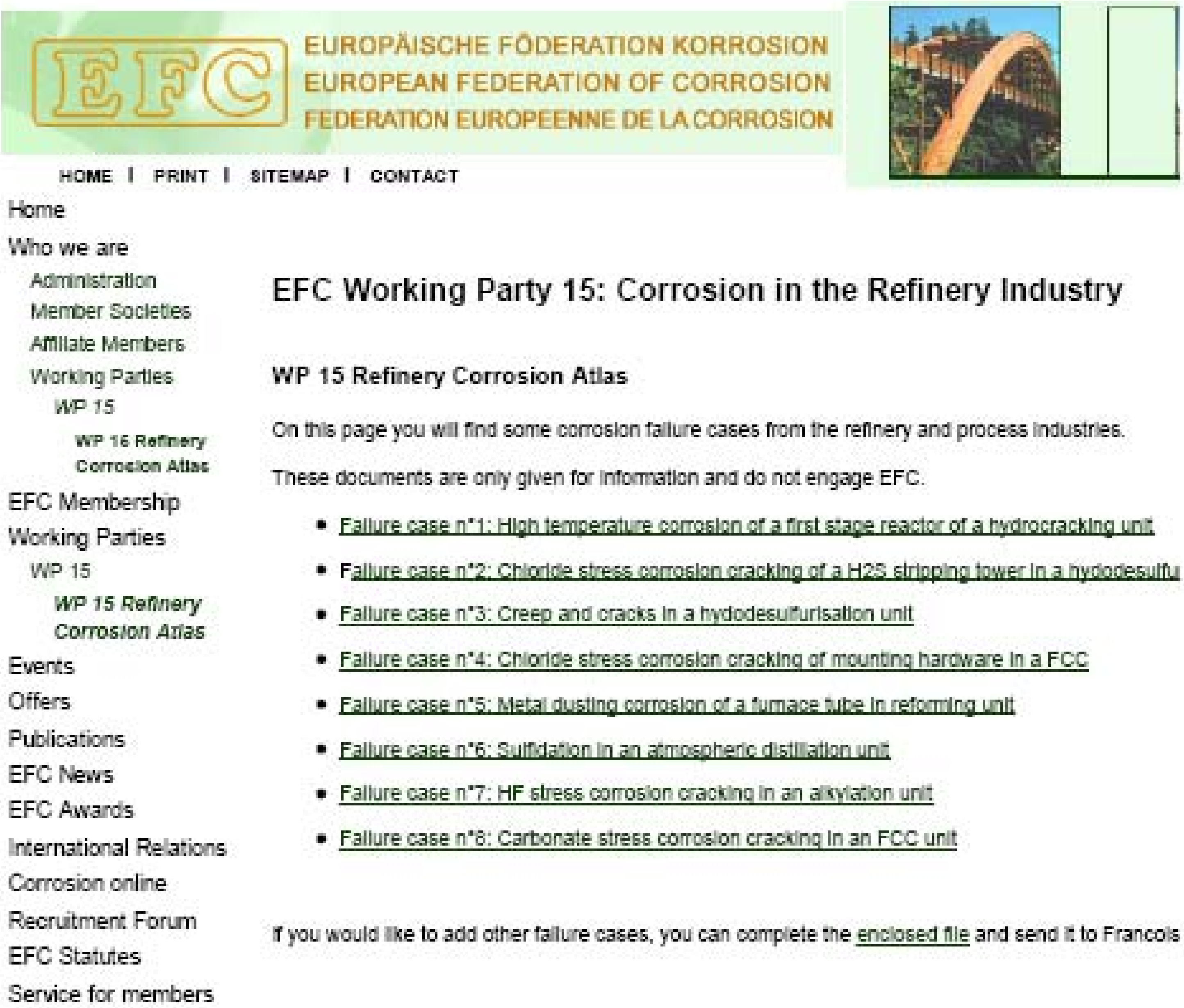
- Please contact:
  - Brian Chambers
    - brian.chambers@honeywell.com or 281-248-0705
  - Sridhar Srinivasan
    - sridhar.srinivasan@honeywell.com or 281-248-0700

Appendix 6

Corrosion failure atlas

EFC

EUROPEAN FEDERATION OF CORROSION
FÉDÉRATION EUROPÉENNE DE LA CORROSION
EUROPÄISCHE FÖDERATION KORROSION



EFC Working Party 15: Corrosion in the Refinery Industry

WP 15 Refinery Corrosion Atlas

On this page you will find some corrosion failure cases from the refinery and process industries.

These documents are only given for information and do not engage EFC.

- Failure case n°1: High temperature corrosion of a first stage reactor of a hydrocracking unit
- Failure case n°2: Chloride stress corrosion cracking of a H2S stripping tower in a hydodesulfu
- Failure case n°3: Creep and cracks in a hydodesulfurisation unit
- Failure case n°4: Chloride stress corrosion cracking of mounting hardware in a FCC
- Failure case n°5: Metal dusting corrosion of a furnace tube in reforming unit
- Failure case n°6: Sulfidation in an atmospheric distillation unit
- Failure case n°7: HF stress corrosion cracking in an alkylation unit
- Failure case n°8: Carbonate stress corrosion cracking in an FCC unit

If you would like to add other failure cases, you can complete the enclosed file and send it to Francois

EFC
EUROPEAN FEDERATION OF CORROSION
FÉDÉRATION EUROPÉENNE DE LA CORROSION
EUROPÄISCHE FÖDERATION KORROSION

CORROSION IN REFINERY INDUSTRY FAILURE ATLAS

CASE HISTORY n° xxx Date

Process
Equipment

DATE OF INCIDENT AND/OR INFORMATION:

NATURE OF THE INCIDENT :

CONSEQUENCES :

MATERIAL COMPOSITION and REFERENCES

PICTURES AND SCHEMES :

ASPECT :

MEDIA AND OPERATING CONDITIONS:

TIME TO DETERIORATION :

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CORROSION IN REFINERY INDUSTRY FAILURE ATLAS

CASE HISTORY n° xxxx **ANSWER**

TYPE OF CORROSION :
API 571 CLASSIFICATION:

CAUSES :

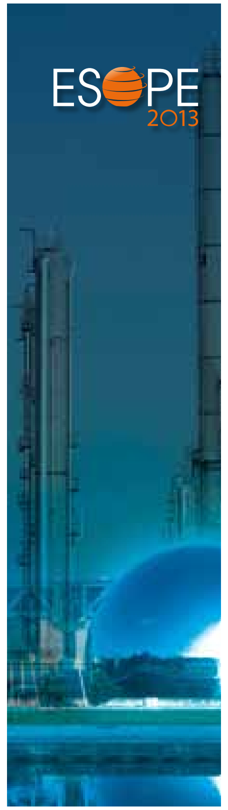
REMEDY :

PUBLICATION - TECHNICAL REPORT:

BIBLIOGRAPHIC REFERENCES :

Appendix 7

ESOPE 2013 Conference



INFORMATIONS PRATIQUES

FRAIS D'INSCRIPTION (TTC)
- Adhérents AFIAP : 900 €
- Non-adhérents : 1000 €
- Auteurs-Conférenciers : 600 €

Conditions particulières pour les étudiants et retraités.

Les frais d'inscription taxes incluses comprennent : le programme détaillé du symposium, le CD-Rom, l'entrée à l'exposition internationale, le cocktail, les pauses-café et les déjeuners.
Non compris : la participation à la soirée parisienne (plus de renseignements prochainement)

PRACTICAL INFORMATION

REGISTRATION FEES (taxes included)
- *AFIAP and associated members: 900 €*
- *Others: 1000 €*
- *Authors-speakers: 600 €*

Specific conditions for students and pensioners.

***Registration fees include:** conference preprints, CD Rom, international exhibition entrance, cocktail, coffee breaks and lunches.*
***Not included:** parisian night (more information soon)*

✂ -

VOUS SOUHAITEZ FAIRE UNE COMMUNICATION ?
☐ orale ☐ poster Session technique : ....
Veuillez joindre le titre, la liste des auteurs et le résumé (environ 10 lignes en français ou en anglais)

WOULD YOU LIKE TO MAKE A PRESENTATION ?
☐ oral presentation ☐ poster Technical session : ....
Please send us title, authors and abstract attached (about 10 lines in French or English)

Veuillez indiquer vos nom, prénom, société, adresse postale, pays, e-mail et téléphone :
Please indicate your name, first name, company, address, country, e-mail and phone:

....
....
....

Formulaire à renvoyer à / *Form to be sent to*
AFIAP - 39-41, rue Louis Blanc - 92400 COURBEVOIE - FRANCE
afiap@afiap.org ou / or Fax : +33 (0)1 47 17 62 77

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avec des encres végétales

IMPRIM'VERT

2ème ANNONCE - Appel à communications
2nd ANNOUNCEMENT - Call for papers

ESOPE
2013

JOURNÉES D'ÉTUDES EUROPÉENNES
Equipements sous pression

EUROPEAN SYMPOSIUM
On pressure equipment

CITÉ DES CONGRÈS DE LA VILLETTE
PARIS
8 >10 OCTOBRE 2013
8 >10 OCTOBER 2013

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www.esope-paris.com

ESOPE 2013, organisé tous les trois ans par l'AFIAP depuis 1977, est consacré aux technologies, codes, normes et directives européennes pour les équipements sous pression fixes et transportables
Le thème général est :
« Retour d'expérience après plus de 10 ans d'application des directives européennes sur les ESP fixes et transportables ; Dispositions appliquées dans les différents pays pour le suivi en service. »

Le Symposium comporte :
- deux sessions plénières et une table ronde
- des sessions techniques
- une session posters dans l'exposition internationale (incluant la remise d'un prix)
- la remise du Prix AFIAP 2013 à un étudiant

Traduction simultanée : français-anglais et anglais-français

COMITÉS

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Président de l'AFIAP & personnalités représentant les différentes sensibilités dans le domaine des ESP
Comité d'honneur
Personnalités et membres fondateurs de l'AFIAP
Comité européen
Personnalités européennes et responsables des sessions

DATES À RETENIR

Soumission du titre et du résumé : **30 novembre 2012**
Acceptation pour présentation : **30 janvier 2013**
Réception du texte définitif : **30 mai 2013**

EXPOSITION INTERNATIONALE

ESOPE : manifestation privilégiée pour les professionnels du marché des équipements sous pression. Ce rendez-vous offre un panorama toujours plus riche de la chaudronnerie industrielle, regroupant: fabricants, distributeurs, transformateurs, spécialistes des traitements thermiques, fournisseurs de matériaux, ingénierie des risques, bureaux d'études, éditeurs de logiciels, prestataires de services, syndicats…
L'édition 2013 devrait, sur une surface de plus de 2000 m^2, rencontrer le même succès qu'en 2010 : plus de 70 sociétés exposantes (dont 23% de sociétés internationales), et près de 1500 visiteurs professionnels, tous donneurs d'ordre et prescripteurs de l'industrie venus pour échanger avec les experts présents.

Votre contact :
Cyril Ladet - Tel : +33 1 77 92 96 84 – Fax : +33 (0)1 77 92 98 34 – E-mail : cladet@infopro.fr

ESOPE 2013, organized by AFIAP every three years since 1977, is dedicated to construction technologies, codes, standards and European directives for stationary and mobile pressure equipment
The general theme is:
« Feedback after more than 10 years of application of European directives on fixed and transportable pressure equipment; Regulation in the different European countries for inservice equipment. »

The Symposium includes:
- *two plenary and one panel sessions*
- *technical sessions*
- *a poster session organized in the international exhibition (including an award)*
- *the AFIAP 2013 award attribution to a student*

Simultaneous translation: french-english and english-french

COMMITTEES

Organizing Committee
AFIAP chairman & representatives from the various sectors in the field of pressure equipment
Committee of honor
Personalities and founder members of AFIAP
European committee
European representatives and sessions chairmen

DEADLINES

Submitting titles and abstract: ***november 30th, 2012***
Notification of paper acceptance: ***january 30th, 2013***
Deadline for final papers: ***may 30th, 2013***

INTERNATIONAL EXHIBITION

ESOPE: a unique meeting place for pressure equipment professionals
This meeting offers a wide overview on industrial boilerworks, gathering manufacturers, distributors, transformers, surface treatment specialists, materials and service suppliers, risk management analysis consultancies, trade unions, software editors…
With over 2000m^2, the 2013 edition is expected to meet the same success than the 2010 edition: more than 70 exhibitors (including 23% of international companies), as well as 1500 visitors, from the industries top management or purchasing advisors, coming to meet and share with the experts at ESOPE.

Your contact:
Cyril Ladet - Ph: +33 1 77 92 96 84 – Fax : +33 (0)1 77 92 98 34 – E-mail : cladet@infopro.fr

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- Conception
- Fabrication-soudage
- Matériaux (métalliques, non métalliques et composites)
- Inspection, contrôle
- Vie des équipements
- Codes et normes

Des informations plus précises seront disponibles sur le site internet : www.esope-paris.com

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- *Inspection and testing*
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- *Codes and standards*

More information will be available on the website: www.esope-paris.com