Appendix 1

List of participants and excused persons
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<tr>
<th>Name</th>
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<td>Maria Luisa</td>
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Presentation of the activities of WP15

European Federation of Corrosion (EFC)

- Federation of 32 National Associations
- 19 Working Parties (WP) + 1 Task Force
- Annual Corrosion congress « Eurocorr »
- Thematic workshops and symposiums
- Working Party meetings (for WP15 twice a year)
- Publications
- EFC - NACE agreement
- For more information http://www.efcweb.org

EFC Working Parties

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

http://www.efcweb.org
Chairman: Francois Ropital
Deputy 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.

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

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

• EFC Guideline n° 42 Collection of selected papers

• EFC Guideline n° 55 Corrosion Under Insulation

• Future publications
  • suggestions?
### Corrosion under insulation (CUI) guidelines: (EFC SS)

Edited by S. Winnik, ExxonMobil, UK

- Guidelines cover inspection methodology for CUI, inspection techniques, including non-destructive evaluation methods and recommended best practice
- Case studies are included illustrating key points in the book

Corrosion under insulation (CUI) refers to the external corrosion of piping and vessels that occur underneath externally clad/packeted insulation as a result of the penetration of water. By its very nature CUI tends to remain undetected until the insulation and cladding/packaging is removed to allow inspection or when leaks occur. CUI is a common problem shared by the refining, petrochemical, power, industrial, onshore and offshore industries.

The European Federation of Corrosion (EFC) Working Parties WP13 and WP15 have worked to provide guidelines on managing CUI together with a number of major European refining, petrochemical and offshore companies including BP, Chevron-Texaco, Conoco-Phillips, Elf, Exxon-Mobil, IFP, ING. Scarfali, Shell, Total and REN. This document is intended for use on all plants and installations that contain insulated vessels, piping and equipment. The guidelines cover a risk-based inspection methodology for CUI, inspection techniques (including non-destructive evaluation methods) and recommended best practice for mitigating CUI including design of plant and equipment, coatings and the use of thermal spray techniques. Types of insulation, cladding/packaging materials and protection guides. The guidelines also include case studies.

ISBN 1 86166 423 5
March 2008
175 pages, 236 x 156mm hardback
£15.00 / US$23.00 / €170.00

Usually dispatched within 24 hours

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**http://www.eurocorr.org**

**Edinburgh 8-11 September 2008**

**Monday 8 September**

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<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>09:00</td>
<td>Opening Session: S. Lyon, M. Schulte</td>
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<tr>
<td>09:15</td>
<td>Welcome Address: Member of the Scottish Parliament</td>
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<tr>
<td>09:30</td>
<td>Cavallaro Medal Award Presentation</td>
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<tr>
<td>09:45</td>
<td>Invited Plenary Lecture: Infrastructure Maintenance - 100 Years of Painting the Forth Bridge, N.N.</td>
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<tr>
<td>10:00</td>
<td>Coffee Break</td>
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<tr>
<td>10:30</td>
<td>WP15 Meeting</td>
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<td>11:00</td>
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<td>12:00</td>
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<tr>
<td>13:00</td>
<td>Workshop Corrosion under Insulation</td>
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<tr>
<td>14:00</td>
<td>1197 Winnik/UK. A corrosion under insulation prevention strategy - Experience with an approach aligned with the EFC WP 13 and WP 15 corrosion under insulation guideline</td>
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<td>1045 Scanlan/UK. A refinery approach to address corrosion under insulation &amp; external corrosion</td>
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<td>1416 McLaury/MAUSA Comparison of cost, application characteristics, service life, reliability and reparability of systems for preventing corrosion under insulation</td>
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<td>15:15</td>
<td>1045 de Bruyn/UK. Risk-Based Approach to CUI Protection of Austenitic Stainless Steel</td>
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<td>Coffee Break</td>
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<tr>
<td>16:15</td>
<td>Discussion</td>
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<td>16:40</td>
<td>Discussion</td>
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<td>17:05</td>
<td>Poster Discussion / Poster Party with Beer and Pretzel</td>
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### Wednesday 10 September

#### Refinery Process Corrosion

<table>
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<tr>
<td>09:45 - 09:55</td>
<td>Break for Changing Lecture Hall</td>
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<tr>
<td>09:55 - 10:20</td>
<td>1331 Eaton TX/USA: Refinery corrosion by salt hydrolysis in opportunity crudes</td>
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<tr>
<td>10:20 - 10:45</td>
<td>1234 Matsuu/DK: Properties of austenite 347AP steel tube for use in desulfurizing plants in the petroleum refinery industry</td>
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<td>10:45 - 11:20</td>
<td>Coffee Break</td>
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<tr>
<td>11:20 - 11:45</td>
<td>Reuffles/D: Corrosion and stress corrosion cracking of heat treated 2205 duplex stainless steel in caustic solution</td>
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<td>11:45 - 12:10</td>
<td>Red: Reuse of water: Maintaining reliability by avoiding corrosion effects</td>
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<td>12:10 - 12:35</td>
<td>1234 de Freitas: Study of alternative systems for corrosion control in water cooling system operating in high concentration cycle</td>
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<tr>
<td>14:00 - 14:25</td>
<td>Lybomski OH/USA: Corrosion protection of oil storage tank tops</td>
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<td>14:25 - 14:50</td>
<td>Flayre/I: Corrosion in amine solvents used for the removal of acid gases</td>
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<td>15:25 - 15:40</td>
<td>Abadiyar-Gost: Stress corrosion cracking of carbon steel in ethanol gasoline blends</td>
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<td>15:40 - 16:15</td>
<td>Trassmann/D: Corrosion of metals for automotive applications in ethanol blended biofuels</td>
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<td>16:15 - 16:40</td>
<td>Break for Changing Lecture Hall</td>
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<td>16:40 - 17:05</td>
<td>Lybomski OH/USA: Training &amp; Certification of operating inspectors: A review of Norwegian standards NS 415-1 &amp; NS 415-2</td>
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<td>17:05 - 17:30</td>
<td>Dean/UK: The utility of hydrogen flux measurement in refineries</td>
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#### Ethanol Biofuel Corrosion

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<td>Matsuu/DK: Properties of austenite 347AP steel tube for use in desulfurizing plants in the petroleum refinery industry</td>
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#### Refinery Inspection - Monitoring

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<td>1437 Kane TX/USA: Refining high acid crudes: When is an opportunity not an opportunity?</td>
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<td>10:20 - 10:45</td>
<td>1189 Invernizzi/I: The effect of molecular structure on the Naphthenic acid corrosion occurrence</td>
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<td>10:45 - 11:10</td>
<td>1128 Groysman/IL: New inhibitors for preventing naphthenic acid corrosion</td>
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<td>1248 Claessen: 25 years experience of successful naphthenic acid corrosion inhibition</td>
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<td>11:45 - 12:15</td>
<td>1118 Sandu TX/USA: Surface study of naphthenic acid corrosion inhibitors on carbon steel</td>
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#### Refinery Process Corrosion

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<td>1372 Haap/D: Reuse of water: Maintaining reliability by avoiding corrosion effects</td>
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<tr>
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<td>1370 Bhattacharya GA/USA: Corrosion and stress corrosion cracking of heat treated 2205 duplex stainless steel in caustic solution</td>
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### Thursday 11 September

#### Refinery - Naphthenic Acid Corrosion

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<td>13:25 - 13:50</td>
<td>Closing Remarks</td>
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<td>End of Scientific Programme</td>
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EFC Working Party 15: Future objectives of the group

How to manage our working party meetings / Eurocorr sessions

- **Eurocorr Sessions**
  ✓ Implement of Eurocorr sessions or workshops with other WP and NACE (a workshop can be on a topic without formal presentation)

  ✓ Implication of young corrosion students, PhD at Eurocorr session with a dedicated poster session

- **Working Party Meetings**
  ✓ Future topics of task forces
  ✓ Facilitating student trainings outside their countries in our companies
  ✓ Presentation of UE funding projects in our area (if they are)
  ✓ Collaboration on Standard

Increase the collaboration with NACE
exchange of information on our activities - joint Eurocorr sessions
Appendix 3

Case histories and 5 year track history of a liquid applied CUI coating

Michael MeLampy

(High-Temp Coatings Technology)
EFC Working Party 15
Corrosion Refinery Industry Meeting
Oegstgeest/Leiden
15th April 2008 9h30 - 16h

Corrosion Under Insulation and Case Histories

Michael MeLampy
Hi-Temp Coatings Technology
+1 978 635 1110
mmelampy@hitemcoatings.com

Steve Reynolds
Performance Polymers Ltd
+44 1367 242 732
steve@ppleu.net

Agenda

- A bit of history
- Insulation?
- Boiling water
- Coatings for Insulated Service
- Maintenance
- Case Histories
- Conclusions
“CUI occurs when the conditions … …meet with unprotected steel.

The second critical point is that the REASON the steel was not adequately protected in the first place is because when our plants were built, industry did not understand that the environment under the insulation was going to be almost like immersion conditions (or worse)….

…So the correct type of coatings were not used. As a result, almost NONE of the surfaces under insulation in every single facility which are older than 15 years, are NOT adequately protected from CUI. CUI is a phenomena because of our ignorance.”

➔ Monica Chauviere,
Non-metallic Materials. ExxonMobil Research and Engineering AAEO/Materials, Inspection, & Support
Insulation Leaks
.... Eventually
Novalac Epoxy
After 3 months service
Originally White
Cracking
Excessive DFT in places.

Overheated Epoxy
Corrosion under insulation
- Zinc Rich Systems – Galvanic Protection

What are the Consequences of Leaking Insulation?
Boiling Water

For a coating to last a long time in needs to survive boiling water or close to boiling water.

Surfaces at Elevated Temperatures

Require specialized coating systems

- appropriate levels of surface preparation
- coating application
- coating materials
  - Allow for future maintenance
- inspection procedures
In maintenance situations,
- Some systems can be applied while units are in service, often near or at the unit’s peak temperature operation.
- Some allow minimal surface preparation
- Some have very long recoat window

New Interest In High Temperature Coating Systems
- many older refineries and chemical plants
  - upgrade for higher quality products
  - improved efficiency
  - or simply expand,
<table>
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<th>Inert Multi-polymeric Matrix</th>
<th>Thermal Spray Aluminum</th>
<th>Traditional Elevated Temperature Silicones</th>
<th>Multi-polymer Primer</th>
<th>Inorganic Zinc</th>
<th>Novalac Elevated Temperature Epoxies</th>
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<tr>
<td>Max Operating Temp</td>
<td>750°C</td>
<td>630°C</td>
<td>540°C</td>
<td>425°C</td>
<td>400°C</td>
<td>220°C</td>
</tr>
<tr>
<td>Max DFT per Coat (in Microns)</td>
<td>150</td>
<td>200</td>
<td>37</td>
<td>150</td>
<td>75</td>
<td>100</td>
</tr>
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<td>Recoatable with self</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Max DFT (in microns)</td>
<td>300 +</td>
<td>112</td>
<td>200</td>
<td></td>
<td></td>
<td>200 mils Max</td>
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<table>
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<tr>
<th>Anodic Metal sacrifices in Electrolyte</th>
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<tbody>
<tr>
<td>Intermittent immersion in Salt Water</td>
<td>Yes</td>
<td>Fails</td>
<td>Fails</td>
<td>NR</td>
<td>Fails</td>
</tr>
<tr>
<td>Hot Apply °C</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>260°C</td>
<td>93°C</td>
<td>120°C</td>
<td>No</td>
<td>150°C</td>
</tr>
<tr>
<td>Surface Tolerant</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
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</tr>
<tr>
<td>Stainless Steel</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
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<td>Easy repair with Self</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Protects at Ambient</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Cryogenic Service</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Surface Preparation

- Near White Metal Clean
- Power Tool Clean
- Hand Tool Clean

But really…

How clean can you get?

And at what cost?
Case Studies

1. Blast Cleaned – Off-Shore
2. Direct to rust
3. Other Examples

Coating applied to Regeneration heater that has cyclic temperatures ranging from -12°C to 160°C. Once the coatings were applied several tests were done along with two follow up visits.
Subsequent Visits

- 2nd Visit - Coating found acceptable after visual test for cracks, delaminations and other failure modes, Adhesion and Impact tests
- 3rd Visit Visual Inspection, insulated and put back into service.
Off Shore Nigeria (Shell Bonga)

- Nozzles
- Before
- Blast Cleaned
- Primer
- Topcoat

Before
After Blast Cleaning
After 1027
After 1000VHA
Direct to Rust / Over Old Zinc
DOW CHEMICAL, PLAQUEMINE, LA.,

Project: New Construction and Plant Maintenance  
Location: Plaquemine, Louisiana  
Facility Type: Chemical Plant  
Start Date: 2003  
Owner/contact: Lynda Mink  
Contractor: Sipco/Protherm  
Contact: Johnny Thorning (B&H )  
Engineering: n/a  
Coatings: Hi-Temp 1027 10-15 mils DFT [250-375] Microns  
Substrate: Carbon Steel  
Surface Prep: Dry Abrasive Blast  
Environment: Chemical Plant  
Project size:  

PROJECT DESCRIPTION  
Multiple projects dating back to 2003. Hi-Temp Coatings products and systems are on the Dow Global Coatings specification.

VALERO REFINING, GOOD HOPE, LA.,

Project: Field Maintenance  
Location: Good Hope, Louisiana  
Facility Type: Petroleum Refinery  
Start Date: 2003 -- 2005  
Contractor: Mansfield / Brock  
Contact: Johnny Thorning (B&H )  
Engineering: n/a  
Coatings: Hi-Temp 1027 250-375 Microns  
Substrate: Carbon Steel  
Surface Prep: Dry Abrasive Blast  
Environment: Refinery / Chemical  
Project size: 15,000 sq.ft. / 1500 sq. M  

PROJECT DESCRIPTION  
Valero Refining, Good Hope, Louisiana, was one of the earliest users of Hi-Temp Coatings Systems for CUI (Coating Under Insulation) projects and for exposed elevated temperature plant equipment as part of turnarounds and routine plant maintenance since early 2003. The facility continues using Hi-Temp products, with a series of small insulated vessel exteriors being the most recent project.
VULCAN CHEMICAL, GEISMAR, LA.,

Project: New Construction and Plant Maintenance
Location: Geismar, Louisiana
Facility Type: Chemical Plant (now owned by Oxychem)
Start Date: 2003
Owner/contact:
Contractor: Johnny Thorning (B&H )
Engineering: n/a
Coatings: Hi-Temp 1027 10-15 mils DFT [250-375] Microns
Substrate: Carbon Steel
Surface Prep: Dry Abrasive Blast
Environment: Chemical Plant

PROJECT DESCRIPTION
Multiple projects dating back to 2003.

-Conclusions-
Surfaces at Elevated Temperatures

- Require specialized coating systems
  - appropriate levels of surface preparation
  - coating application
  - coating materials
  - inspection procedures.
Appendix 4

Unusual CUI failure

Hennie de Bruyn (Borealis Group)
Unusual CUI Failure

Hennie de Bruyn – Chief Engineer Material Technology

Nitrate SCC of Carbon Steel

• Benfield (CO2 –removal) unit
  • Linz – Austria
  • Material: St35
  • Line: DN500 / 11mm WT
  • Operating at: 120ºC / 30 bar
  • Lean caustic potash solution

• Insulation system
  • Installed in 1974
  • Pb-based primer; no topcoat
  • Unspecified mineral wool insulation
  • No maintenance
Nitrate SCC of Carbon Steel

- **Failure mode**
  - Intergranular cracking that initiated from the external surface
  - Cracking occurred away from any welds or other structural discontinuities
  - Main crack direction is longitudinal to the pipe
  - Wet chemical analysis from surface debris indicate high nitrate levels

- **Investigation**
  - Direct nitrate source not found
  - Old insulation material contains high levels of leachable nitrate
  - Possible atmospheric contamination from nearby nitric acid plant

- **Mitigation**
  - Extensive insulation removal program + inspection
  - Considering painting program / alternatively TSA

- **Key questions**
  - Has anyone else experienced similar failures?
  - Main reason: nitrate containing insulation or external contamination?
  - Experienced TSA applicators in Austria?
  - What about Al-foil wrapping? Sufficient electrochemical potential shift?
Appendix 5

Assessment of the resistance to HTHA of a 5% Mo steel equipment

Martin Richez (Total)
Assessment of the resistance to HTHA of a 0.5 % Mo steel equipment
Presentation

- HTHA mechanism
- Failure cases
- Resistance of 0.5 % Mo steel to HTHA (Hot Temperature Hydrogen Attack)
- Management of 0.5 % Mo equipments
- Assessment of an equipment by direct evaluation of metal resistance to HTHA
HTHA Mechanism
Hot Temperature (temp > 220°C)

Concerned units in refining:
- Hydrotreatments (HDT, HDS, Hydrocracker…) – Pressure from 30 to 170 bars, temp. from 350 to 430 °C
- Les reforming – Pressure from 4 to 35 bars, temp. from 490 à 550 °C
- Steam reforming (hydrogene production) 40 bars, 850 °C

2 different types of attack:
- Surface decarburation
- Internal decarburation
Décarburation interne

- Hydrogen ingress penetration in the metal
- Reaction with carbon to form methane CH₄
- Trapping of methane dans les discontinuités and at grain boundaries
- Internal stresses leads progressively to micro void formation, then micro cracks and cracks.
- Resistance to hydrogen attack is linked to carbide stability.
HTHA exemples
Exemples d’attaque à chaud

Figure 2  Blistering observed on C-0.5Mo nozzle flange used in Platformer unit

Cross section of HTHA elbow
Défaillance du à l’attaque à chaud

Réformeur 1989
Exemple d’attaque dans le raffinage TOTAL (2004)

- Réacteur d’hydrofinissage d’huile
- A 204 Gr B (0,5 % Mo), ép. 64 mm
- 260 à 350 °C
- ppH2 78 à 136 bars
Exemple d’attaque dans le raffinage TOTAL (2005)

- Fabrication 1967 – les 4 plus chauds: calandre A204 Gr.B (0,5 Mo) – TTAS – épaisseur 28mm
- Conditions de service pour les 4 plus chauds:
  - Température de service sortie calandre 420 à 450°C
  - Pression partielle d’hydrogène 12 à 18 bars
  - Durée d’exploitation 330 000 heures

• Hernies φ 80/100 mm le long soudure L2 sur calandre E5E

• Fissures longitudinales le long soudure L2 sur calandre E5J
ATOCHEM Carling (2007)

- fuite d'un mélange d'hydrogène / hydrocarbures

- Une soudure circulaire de la tuyauterie 4” (DN100) ép 6 mm ASTM A53 Gr.A est fissurée sur ¾ de sa section (fissure débouchante sur toute sa longueur).

- Condition de fonctionnement : 40 bar – # 300°C – mélange H2 + hydrocarbures (50% H2 molaire pour P totale 40 bar)

- Mise en service de la tuyauterie: 1968
Décarburation interne

Elements like chromium, molybdenum, titanium, or niobium... are beneficial to resistance to HTHA by forming stable carbides.

O.5 % Mo non sufficient to stabilize carbides

HTHA happen in 3 phases:

- Incubation time, during which metallurgical evolutions are not detectables
- Degradation phase, during which mechanical properties are decreasing
- Then properties reach their final value (depletion of carbon)
Courbes de Nelson
Courbes de Nelson

- Ces courbes empiriques représentent l’expérience de l’industrie du raffinage
- Premières courbes publiées par George NELSON dans les années 40
- Première publication dans l’API 941 en 1969
- Les aciers à 0,5 % de Mo sont abaissés de 33°C en 1977 suite à des expériences défavorables
- Dans l’édition de 1983, une note particulière est émise concernant des cas de HTHA sur des réformeurs catalytiques.
- De nouveau cas d’attaque sur l’acier 0,5 % Mo sont observés jusqu’à 110 °C en dessous de la courbe publié en 1977
- En 1990 les courbes concernant l’acier à 0,5 % Mo sont retirées
- L’expérience semble montrer que l’acier à 0,5 % Mo a une résistance très variable
Courbes de Nelson publiées en 1977
Résistance des aciers contenant 0,5 % de Mo
Facteurs influençant la tenue à l’hydrogène

- Temps d’exposition
- Température et Pression (ppH2)
- Les méthodes de production (histoire thermique)
- La présence ou non d’une barrière à la diffusion de l’hydrogène
- Le niveau de contrainte
Incidence d’un revêtement métallique

- Les aciers ferritiques ont un fort coefficient de diffusion de H₂ mais une faible solubilité, comparés aux aciers austénitiques.
- Les revêtements en aciers austénitiques sont un obstacle à la diffusion de l’hydrogène dans l’acier. L’efficacité de cette barrière dépend :
  - L’épaisseur relative d’acier austénitique et ferritique
  - Du bon état du revêtement
  - De la température

- Les aciers ferritiques type 410, n’assurent aucune protection.
- La pression effective sur la paroi peut être calculée par la formule suivante :

\[ P_{\text{Interface}} = \frac{P_0}{\left[ 1 + 0.18 \frac{t_{\text{Clad}}}{t_{\text{Base}}} \exp \left( \frac{2984}{T} \right) \right]^2} \]

<table>
<thead>
<tr>
<th>temperature</th>
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<th>PPH2</th>
<th>PPH2 Interface</th>
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</thead>
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<tr>
<td>°C</td>
<td>austenitic</td>
<td>Ferritic</td>
<td>bar</td>
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<td>390</td>
<td>2</td>
<td>70</td>
<td>35</td>
</tr>
<tr>
<td>390</td>
<td>4</td>
<td>70</td>
<td>35</td>
</tr>
<tr>
<td>390</td>
<td>3</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>300</td>
<td>3</td>
<td>20</td>
<td>35</td>
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</table>

Exemple :
Incidence d’un revêtement métallique

<table>
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<tr>
<th>°C</th>
<th>Thickness</th>
<th>PPH2</th>
<th>PPH2 Interface</th>
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<tbody>
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<td>35</td>
</tr>
<tr>
<td>300</td>
<td>3</td>
<td>20</td>
<td>35</td>
</tr>
</tbody>
</table>
Management of O.5 % Mo equipment
Zones de risque

Severity area for HTHA of 0,5 Mo

H2 partial pressure (bar)

Temperature (°C)

Carbon steel
0,5 Mo 1977
CS + 25°C + 3 bars
0,5 Mo - 40°C
Risk Area

- **Area 0** – Below carbon steel curve. Degradation probability is considered as null.

- **Area 1** – Between carbon steel curve and carbon steel + 3 bars and 25 °C. In this area no failure case on 0.5 % Mo steel has been reported. HTHA risk is considered as very low.

- **Area 2** – It is an intermediate area where risk is considered as low for equipment made of normalized steel and PWHT.

- **Area 3** – Between 1977 0.5 % Mo steel curve and 40°C below. In this area degradation risk is considered as high on old.

- **Area 4** – Located above 0.5 % Mo curve of 1977. This is an area where degradation risks are very high and unacceptable.
<table>
<thead>
<tr>
<th>Secteur</th>
<th>Inspection HTHA</th>
<th>Remplacement</th>
<th>Sévérisation des conditions procédé</th>
</tr>
</thead>
</table>
| Secteur 0 | Néant | Néant | Sévérisation des conditions procédé autorisée si :
- L'équipement est en zone 1 après prise en compte du clad.
- Le clad est en bon état
- L’appareil est traité thermiquement s’il se retrouve en zone 1. |
| Secteur 1 | - Partielle si l’appareil est traité thermiquement.
- Complète si l’appareil n’est pas traité thermiquement. | - En cas de détection d’HTHA et,
- Systématique si tuyauteries | Sévérisation des conditions procédé autorisée si :
- L’équipement est en zone 1 après prise en compte du clad.
- Le clad est en bon état
- L’appareil est traité thermiquement |
| Secteur 2 | Complète | - En cas de détection d’HTHA ou,
- Si l’équipement n’est pas traité thermiquement ou,
- Tuyauteries ou équipements peu inspectables | Sévérisation des conditions procédé non autorisée sauf si :
- L’équipement est en zone 1 après prise en compte du clad.
- Le clad est en bon état. |
| Secteur 3 | Complète | - En d’HTHA ou,
- Si l’équipement n’est pas traité thermiquement ou,
- Si le clad est détérioré ou,
- En l’absence de clad protecteur ou,,
- Tuyauteries ou peu inspectable | Sévérisation des conditions procédé non autorisée. |
| Secteur 4 | Néant (appareil à remplacer) | - A remplacer systématiquement et dans les délais les plus bref. | Sans objet (appareil à remplacer) |
Inspection for High Temperature Hydrogen Attack on a Carbon 0.5% Molybdenum Vessel
52V-2 Hot Separator
Vessel Specifics

- Built in 1962 - 45 years in Hydrotreater Hot Separator Service
- Design Pressure 803 PSI
- Operating Hydrogen Partial Pressure 587 psia
- Design Temperature 600 degrees F
- Operating Temperature 595 degrees F
- Shell 6’ Diameter  Height 21’1”
- Shell Material A204 grade C with .078” TP 410 Clad
Scope

To evaluate the future performance of 52V-2, Lloyd’s Register Capstone performed HTHA exposure testing on Scoop Samples removed from the OD of the vessel. Two scoop samples were removed from 4 locations. These locations consisted of the top and bottom heads and each of the two shell courses. Two test coupons were made from each scoop sample. One coupon per location was subject to a 100 hour test while the other coupon was subjected to a 200 hour test. This left one full Scoop Sample per location for additional testing as needed.

L.R. Capstone also performed internal metallurgical examination using field metallography and replication, (FMR).

Advanced Ultrasonic Backscatter Techniques (AUBT) were used to examine the base metal and weld joints were examined using angle beam spectrum analysis (ABSA).
Test Procedure for Scoop Samples

Figure 1 and 2 show the Scoop Samples that were removed from the vessel OD surface. These were removed using LR Capstone’s proprietary Scoop Sampler\textsuperscript{SM}. Depth of the resultant divots were less than the maximum allowable based on local thin area calculations that were previously performed in the 1999 evaluation. Therefore, the excavations were blended to minimize local stress concentrations with no further repairs needed.

It can be seen that a total of eight Scoop Samples were removed from the vessel. Two Scoop Samples were removed from each of four locations; two test coupons were able to be removed from a Scoop Sample. One coupon per location was subjected to a 100 hour test while the other coupon was subjected to a 200 hour test. This left one full Scoop Sample per location for additional testing if needed. Sample locations are given below in Table 1.

Table 1. Scoop Sample Locations

<table>
<thead>
<tr>
<th>Location</th>
<th>Scoop Sample ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom Head</td>
<td>1 and 2</td>
</tr>
<tr>
<td>Bottom Course</td>
<td>3 and 4</td>
</tr>
<tr>
<td>Top Course</td>
<td>5 and 6</td>
</tr>
<tr>
<td>Top Head</td>
<td>7 and 8</td>
</tr>
</tbody>
</table>
Scoop Samples

Figure 1. OD surfaces of the removed Scoop Samples.
Test Procedure Cont.

The coupons were welded around their perimeter to seal them in place at the end of the test chamber, which had hydrogen inside and argon on the OD. The single side exposure testing was performed by exposing only one side of the coupon to high pressure hydrogen while the argon on the other side was set at a pressure equal to the hydrogen pressure. This balanced pressure approach minimized the potential for a leak or crack of the coupon to hydrogen chamber seal weld. Thermocouples were placed against the test coupon in the hydrogen chamber to monitor temperature during the test. Test temperature was set at 950 degrees F at a hydrogen pressure of 1215 PSIA.
Carbon Steel Reference Sample

Figure 4: Macoscopic view of a carbon steel reference sample at the accelerated test conditions, 100 hour exposure. Decarburization depth is approximately 0.1” (23% through wall). Depth of cracking was approximately 0.13” (30% through wall). 3% Nital Etch, 6.7X.
Nelson Curve
Included in this figure are the 100 hour incipient damage curves for carbon steel and C-0.5Mo steel and past and future operating conditions. It can be seen that the test conditions are very severe and if susceptible they should have produced damage in the test coupons.

Figure 3: HTHA damage curves from API 941. Past to future operating conditions plus the accelerated test conditions are plotted to show severity of the various operating conditions.
Figure 5. Scoop Sample 6, representative base metal microstructure, pre-exposure. 3% Nital Etch, 400X.
Results:
No evidence of decarburization, methane voids, or microfissuring was found in any of the samples.

Figure 6: Scoop Sample 1, representative base metal microstructure Test 1. 3% Nital Etch, 400X.
Results cont.
All of the C-0.5 Mo steel materials displayed good resistance to HTHA type of damage.

Figure 10: Scoop Sample 1, representative base metal microstructure Test 2. 3% Nital Etch, 400X
DISCUSSION

The test conditions were set approximately 65°F above the 100 hour C - ½ Mo steel incipient damage curve. It also corresponds to the 100 hour incipient damage as predicted using both $P_V$ and $P_w$ calculations. The equations used to calculate $P_V$ is given below and are taken from the API 580 document. Critical values for $P_V$ “worst case” annealed material is low susceptibility at $P_V = 4.78$, medium susceptibility at $P_V = 4.87$, and a high susceptibility at $P_V = 4.95$. For “good” normalized material, low susceptibility starts at a $P_V$ of 5.43, a medium susceptibility at $P_V$ of 5.51, and a high susceptibility at $P_V$ of 5.60. Based on published literature and some work by Japanese researchers, the critical value for “good” C - ½ Mo steel base metal is $P_V$ of 5.80.

$$P_V = \log (P_{H2}) + 3.09 \times 10^{-4} T (\log t + 14)$$

$P_{H2}$ : Hydrogen partial pressure (kgf/cm²)
$t$ : Total operating time (hr)
$T$ : Operating Temperature (K)

<table>
<thead>
<tr>
<th>Materials</th>
<th>High Susceptibility</th>
<th>Medium Susceptibility</th>
<th>Low Susceptibility</th>
<th>Not Susceptible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Steel</td>
<td>$P_V &gt; 4.70$</td>
<td>$4.61 &lt; P_V \leq 4.70$</td>
<td>$4.53 &lt; P_V \leq 4.61$</td>
<td>$P_V \leq 4.53$</td>
</tr>
<tr>
<td>$\frac{1}{2}$ Mo$^a$ (Annealed)</td>
<td>$P_V &gt; 4.95$</td>
<td>$4.87 &lt; P_V \leq 4.95$</td>
<td>$4.78 &lt; P_V \leq 4.87$</td>
<td>$P_V \leq 4.78$</td>
</tr>
<tr>
<td>$\frac{1}{2}$ Mo$^a$ (Normalized)</td>
<td>$P_V &gt; 5.60$</td>
<td>$5.51 &lt; P_V \leq 5.60$</td>
<td>$5.43 &lt; P_V \leq 5.51$</td>
<td>$P_V \leq 5.43$</td>
</tr>
</tbody>
</table>
The $P_{w}$ factor has a similar logarithmic equation with slight differences and is included here for reference, where:

$$P_{w} = \log t + 3 \log P - 9.18/T$$

JPVRC revealed in their investigation\(^5\) that the critical values of $P_{w}$ on HTHA of C-0.5Mo steel were the followings:

- For base metal $P_{wcr} = -4.80$
- For HAZ with PWHT $P_{wcr} = -5.25$
- For HAZ without PWHT $P_{wcr} = -7.90$

The results of the calculated $P_{v}$ and $P_{w}$ factors are given in Table 2. The test conditions for Test 1 (102 actual hour test) gave a calculated $P_{v}$ of 5.81. It can be seen that Test 1 produced conditions that exceeded the critical $P_{v}$ value of 5.80 and Test 2 exceeded the thresholds by a wide margin for both the $P_{v}$ and $P_{w}$ factors yet the test samples did not display any evidence of HTHA damage. Therefore, it is concluded that the 52V-2 Hot Separator Drum has HTHA resistance similar to normalized “good” C - ½ Mo steel.

<table>
<thead>
<tr>
<th>Table 2. HTHA Test Results w/ $P_{v}$ and $P_{w}$ Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Test 1 - No Damage</td>
</tr>
<tr>
<td>Test 2 - No Damage</td>
</tr>
<tr>
<td>50 °F SF</td>
</tr>
<tr>
<td>50 °F SF</td>
</tr>
<tr>
<td>Clad benefit</td>
</tr>
<tr>
<td>Clad benefit</td>
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</table>
Table 2. HTHA Test Results w/ $P_v$ and $P_w$ Calculations

<table>
<thead>
<tr>
<th></th>
<th>T, °F</th>
<th>$P_v$, psia</th>
<th>Hours</th>
<th>$P_v$</th>
<th>$P_w$</th>
<th>Years</th>
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</thead>
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<tr>
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<td>950</td>
<td>1215</td>
<td>102</td>
<td>5.81</td>
<td>-4.86</td>
<td>---</td>
</tr>
<tr>
<td>Test 2 - No Damage</td>
<td>950</td>
<td>1215</td>
<td>223</td>
<td>5.89</td>
<td>-4.52</td>
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<tr>
<td>50 °F SF</td>
<td>645</td>
<td>587</td>
<td>1,283,039</td>
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<td>50 °F SF</td>
<td>645</td>
<td>587</td>
<td>1,150,000</td>
<td>5.42</td>
<td>-5.25</td>
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<tr>
<td>Clad benefit</td>
<td>645</td>
<td>549</td>
<td>1,825,941</td>
<td>5.43</td>
<td>-5.13</td>
<td>208</td>
</tr>
<tr>
<td>Clad benefit</td>
<td>645</td>
<td>549</td>
<td>1,400,000</td>
<td>5.41</td>
<td>-5.25</td>
<td>160</td>
</tr>
</tbody>
</table>

The value of using $P_v$ and $P_w$ factors is that they can be used to evaluate different sets of operating conditions and make comparisons based on specified hours of service. Using the proposed upper temperature of 595°F plus a 50 °F safety factor (645°F) and a hydrogen partial pressure of 587 psia, the drum could operate for 146 years before reaching a low susceptibility for HTHA damage based on a $P_v$ of 5.43.

Based on a medium value susceptibility for $P_w = -5.25$, the drum could operate for 131 years. While the benefit of the 410 stainless steel cladding on the inside of the drum is not as much as would be given for a 304 stainless steel material, however, it can be seen that at a minimum, the 410 clad provides a fully resistant layer that reduces the hydrogen partial pressure in the C - $\frac{1}{2}$ Mo steel based on the ratio of clad versus base metal thickness. Assuming a 0.109” thick cladding layer and a 1.6” shell, the cladding reduces the hydrogen partial pressure from 587 psia to 549 psia. This is not as significant of a factor at high pressures, but at the operating pressures given, there is an increase in remaining life of approximately 20 - 40%. A less conservative estimate of the pressure reduction associated with the cladding material is prescribed in the API 941 committee Base Resource Document, which indicates a further reduction of hydrogen partial...
pressure to approximately 352 psia. The remaining life according to this pressure would be on the order of 2000 years.

While the majority of the vessel is clad, there are six locations where the cladding has been removed. The follow-up field metallography and replication (FMR) inspection in March 2007 repeated the examinations at the previous locations. Upon removal of the internal scab plates, the exposed base metal was found to have a thick layer of black scale, presumed to be FeS. No significant wall loss occurred at these locations, in fact, previous grind marks were still visible in the base metal around the perimeter of the clad removal area. Field metallography and the AUBT inspection found no evidence of HTHA damage.

It appears that the scab plates created a stagnant zone where sulfur was able to react with the exposed base metal resulting in a stable FeS scale. It is known that FeS can provide some protection against HTHA damage, as noted in API 941. Therefore, it appears that the scab patches were successful in fostering a stable FeS scale thus avoiding direct hydrogen and base metal contact as would occur if the scab patches did not have a gap in the weld.
Ultrasonic Inspection

- Seven locations were inspected from the outside and inside surfaces using several techniques at approximately 3” X 3” windows in the insulation.
- From the OD, Advanced Ultrasonic Backscatter Techniques (AUBT) were used to examine the base metal.
- Weld joints were examined using Angle Beam Spectrum Analysis (ABSA)
Explanation for HTHA detection by AUBT

**Back-Scattering Technique**

10 MHz Probe

![Diagram showing back-scattering technique with 1st and 2nd back wall signals and a defect signal labeled as HTHA or inclusions?]

**Spectrum analysis**

10 MHz Probe

![Diagram showing spectrum analysis with dB on the y-axis and frequency on the x-axis, showing sound area with and without HTHA]

**Velocity Ratio Technique**

5 MHz Probe Long wave

6 MHz Probe Shear wave

![Diagram showing velocity ratio with dB on the y-axis and frequency on the x-axis, showing velocity ratio of V_L and V_S with V_S/V_L ≤ 0.55 indicating no HTHA and V_S/V_L > 0.55 indicating HTHA]

Velocity Ratio = \( \frac{V_S}{V_L} \)

V_S/V_L ≤ 0.55 ---- No HTHA

V_S/V_L > 0.55 ---- HTHA
Advanced Ultrasonic Backscatter Technique (AUBT) Inspection

Examination Summary

All selected areas of Reactor by the client were performed AUBT for HTHA detection by 0 degree. The inspection was performed to detect backscatter indications in the base metal. Spectrum analysis was applied using the LeCroy system if indication was detected. The probe selected was 0.50” diameter, high frequency (10MHz & 5MHz), and 0 degree to detect small indications such as micro-fisher in the base metal. Also, Angle Beam Spectrum Analysis (ABSA) was applied on the weld seam to detect crack-like indication on the Heat Affected Zone (HAZ) due to HTHA. The probe selected was 0.50” diameter, high frequency (10MHz) 45 & 60 degree shear wave probe. The purpose for this inspection is to locate and evaluate backscatter indications in the base metal, and to determine if these indications are the result of HTHA.
Scan Map

Mainway

Area #6 & #7

Area #3, #2 & #5

Area #4

MUT Shear wave

AUBT (Base metal)

Circumferential seam

8”

12”

2”

Area #4

Area #3

Slag Inclusion
Depth: 0.99” - 1.10”

Detail of Indication on Nozzle at Area #3
Typical signal form

Figure 7: Typical signal form of Backscatter (Area 5 & 6)

Figure 8: Typical signal form of Backscatter / Spectrum Analysis (Area 7)
AUBT Results

The areas inspected were focused on high stress and suspected areas; such as T-cross section on the shell and head. Drawings are included in this report that shows the location of these areas. The AUBT procedure starts by looking for backscatter indications in the base metal by 0 degree. If indications are detected then analysis is performed to determine whether these indications were the result of HTHA.

In according to the results of Backscattering Technique and Spectrum Analysis 0 degree, no evidence of advanced or micro fissuring due to (HTHA) was detected in the scanned areas of Reactor. Indications such as inclusions were detected in the base metal on the area #7 of 52V-2 Reactor. These Indications of base metal were not described in this report. Typical signal forms of Backscatter Technique and Spectrum Analysis are shown in Figures 5, 6, 7 & 8.

Also, no crack-like indication was detected on the HAZ using ABSA on the longitudinal weld seam, circumferential weld seam and one nozzle weld. One long slag inclusion was detected on the nozzle weld. The detail of this indication is shown in Figure 2.
Review

- Scoop sampling and testing revealed no evidence of decarburization, methane voids, or microfissuring in any of the samples
- Field Metallography (FMR) – No evidence of HTHA
- Angle Beam Spectrum Analysis (ABSA) – No cracks found
- Advanced Ultrasonic Backscatter Technique (AUBT) – No advanced or microfissuring due to HTHA
Appendix 6

How to use the

EFC WP15 Refinery Cases Web page
**Failure cases atlas**

<table>
<thead>
<tr>
<th>Nº File</th>
<th>Writer</th>
<th>Date</th>
<th>Process</th>
<th>Equipment</th>
<th>Causes</th>
<th>API 571 Classification</th>
<th>Type of material</th>
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<tbody>
<tr>
<td>1</td>
<td>J. Hucinieka</td>
<td>2006</td>
<td>Hydrocracking</td>
<td>Reactor</td>
<td>Sulphidation</td>
<td>5.1.1.5</td>
<td>347 SS</td>
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<tr>
<td>2</td>
<td>F. Ropital</td>
<td>29/06/1995</td>
<td>Vessel making</td>
<td>Furnace</td>
<td>Naphthenic acid corrosion</td>
<td>5.1.1.7</td>
<td>5% Cr steel</td>
</tr>
<tr>
<td>3</td>
<td>A. Visgaard Nielsen</td>
<td>13/09/2007</td>
<td>Hydrodesulfurization</td>
<td>Heater</td>
<td>Creep</td>
<td>4.2.6</td>
<td>304 SS</td>
</tr>
<tr>
<td>4</td>
<td>F. Ropital</td>
<td>20/12/2007</td>
<td>Continuous Catalytic Reforming</td>
<td>Furnace</td>
<td>Metal dusting</td>
<td>4.4.5</td>
<td>2.25%Cr steel</td>
</tr>
</tbody>
</table>

**Guide line: how to use the failure case web page available**

EFC WP15 Spring meeting 15 April 2008 Leiden The Netherlands
Welcome to the share common zone for the Working Party 15 "Corrosion in refinery" of the European Federation of Corrosion.

In the Failures Cases Atlas Index you will find all the information to include your own failure cases and to consult the data base.

In the EFC CIU Final Version Index you will find information on the Continuing User Interface implemented at the publication and that will be soon available as EFC guidebook n°75.

In the Library Index you will find:
- Relevant and helpful documents on CLA - please do not hesitate to complete it.
- The literature data base on corrosion in refinery elaborated by Harrie de Bruijn (Access file) - please use it and complete it.
- All the minutes of WP15 Working party (without appendices).

In the Members Index you will find the address of the members (authors and readers) of this common zone (email, phone, mailing).

For any other question contact:
Francesco Pizziello
email: francesco.pizziello@bp.com

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Appendix 7

PASCC case in a FCCU

Wim Verstijnen (Shell)
FCCU Liftpot Failure & Repair

Wim Verstijnen

Head Engineering Support

Shell Nederland Raffinaderij
Pernis - Rotterdam
The Process: Catalytic Cracker Unit
Process “Liftpot”

- Feed mixes with Catalyst of 680 degC
- Mix of Feed and Cat “cools” to 520 degC @ 2.5 barg Riser outlet
- Steam ring at bottom of riser liftpot to enhance/assist mixing and transport of catalyst.
- Medium: Oxygen, Air, H2S, Steam/water, Salts(?), Hydrocarbons
Materials

- Reactor liftpot Avesta 253MA (austenitic SS ~ SS 304H)
- Wall thickness head/wall 40mm / 25mm
- Erosion resistant liner of 35 mm.
- Dished end filled with insulating concrete
- Other riser parts SS 304H
History Liftpot:

- Installed in 1986
- No problems till crack was found
Crack in Liftpot Body
Metallography of Crack (Boat Sample)

Crack in HAZ

Weld
Findings:

- Leakage (Inspection, operations)
- Visual/NDT: Crack in Circumferential weld
- Metallurgical investigation:
  - Sensitized HAZ weld,
  - Inter-crystalline attack in HAZ,
- NDT: Other welds and (plate) material free from cracks

Conclusion:

- Polythionic Stress Corrosion Cracking of sensitized weld area.
Solution Short/Long-term

- **Short-term actions:**
  - Repair with external reinforcing ring.

- **Long-term actions:**
  - SCC resistant material
  - Different design
Thank you

Questions?
Appendix 8

Use of fitness for service assessments

Hennie de Bruyn (Borealis Group)
Use of Fitness-for-Service Assessments

Hennie de Bruyn
Chief Engineer Material Technology

Introduction

• Inspection results
  • Detect damage / degradation
  • Deviations from original design
  • What now?
    • Do nothing
    • Repair
    • Replace

• Fitness-for-Service (FFS)
  • FFS assessment facilitates the decision-making process

• FFS Definition (API 579-1)
  • FFS assessments are quantitative engineering evaluations that are performed to demonstrate the structural integrity of an in-service component containing a flaw or damage
Plant Integrity Management

The Role of FFS

Damage & Degradation

- Brittle fracture
- Metal loss
  - General
  - Localised
  - Pitting
- Hydrogen damage
- Weld misalignment / shell distortions
- Cracking / Plastic collapse
  - Stress corrosion cracking
  - Fatigue
- Creep
- Fire damage / other undesirable events
### Cracking / Plastic Collapse

**FFS methods, procedures & standards**

<table>
<thead>
<tr>
<th>Document</th>
<th>Title</th>
<th>Published by</th>
</tr>
</thead>
<tbody>
<tr>
<td>R6</td>
<td>Assessment of the integrity of structures containing defects</td>
<td>British Energy</td>
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<tr>
<td>BS 7910</td>
<td>Guide to methods for assessing the acceptability of flaws in metallic structures</td>
<td>British Standards Institution</td>
</tr>
<tr>
<td>API 579-1 / ASME FFS-1</td>
<td>Fitness For Service</td>
<td>American Petroleum Institute / American Society of Mechanical Engineers</td>
</tr>
<tr>
<td>ASME SEC XI</td>
<td>Rules for Inservice Inspection of Nuclear Power Plant Components</td>
<td>American Society of Mechanical Engineers</td>
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<tr>
<td>SINTAP</td>
<td>Structural Integrity Assessment Procedures for European Industry</td>
<td>EU open source</td>
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<tr>
<td>JSME S NA1</td>
<td>Codes for Nuclear Power Generation Facilities - Rules on Fitness-for-Service for Nuclear Power Plants</td>
<td>Japanese Standards Association (JSA)</td>
</tr>
<tr>
<td>RSE-M</td>
<td>Rules for in service inspection on nuclear power plant components</td>
<td>AFCEN</td>
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### Fatigue

**FFS methods, procedures & standards**

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</table>
## Creep

**FFS methods, procedures & standards**

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<tr>
<td>A16</td>
<td>Design and Construction Rules for Mechanical Components of FBR Nuclear Islands</td>
<td>AFCEN</td>
</tr>
<tr>
<td>API 579-1 / ASME FFS-1</td>
<td>Fitness For Service: includes now the Materials Properties Council (MPC) Omega method</td>
<td>American Petroleum Institute / American Society of Mechanical Engineers</td>
</tr>
</tbody>
</table>

## Thinning / Corrosion / Metal Loss

**FFS methods, procedures & standards**

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<th>Published by</th>
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<tbody>
<tr>
<td>ASME B31G</td>
<td>Manual for Determining the Remaining Strength of Corroded Pipelines</td>
<td>American Society of Mechanical Engineers</td>
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<tr>
<td>DNV RP F-101</td>
<td>Corroded Pipelines</td>
<td>Det Norske Veritas</td>
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<tr>
<td>PDAM</td>
<td>The Pipeline Defect Assessment Manual</td>
<td>Penspen Ltd (UK)</td>
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<tr>
<td>API 579-1 / ASME FFS-1</td>
<td>Fitness For Service</td>
<td>American Petroleum Institute / American Society of Mechanical Engineers</td>
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</tbody>
</table>
Open questions to EFC WP15

• Is your company using FFS assessments when damage/degradation is detected by inspection?

• What assessment methods/procedures/standards are used?

• Who is responsible to perform assessments in your company?

• Does your company allow inspectors to perform basic assessments?

• Are FFS assessments accepted by your regulating authorities?
Appendix 9

How, when and where to monitor

Dimphy Wilms (Applus\textsuperscript{+} RTD)
How, when and where to monitor?
What are you looking for?
Purpose of inspection

- Maintain the **integrity** of an asset
- Increase / maintain **reliability**
- Maintain a **safe workplace**
- Ensure **Fitness for Service**
- Do it at the **lowest possible cost**!
Condensed version of Seveso II

Define maintenance & inspection strategy

Register & categorise
  Design, material, history of break down

Assess results
  Improvements
  Repairs, changes procedures, ...

Risk analysis
  Degradation mechanism
  Hazard category

M & I choice
  Maintenance approach
  Inspection plan
  Timeline
SMART inspections

- Specifically for objects and degradation mechanism
- Minimum impact for operation
- Acceptable according to rules and regulations
- Reliability focused
- Time optimised
How to design a CUI programme?

Wall Temperature

- T < -10°C or T > 150°C
- -10°C < T < 60°C or 90°C < T < 150°C
- 60°C < T < 90°C

Condition of insulation:
- Perfect
- Good
- Reasonable
- Bad
Inspection strategy

- Combination of methods
- In line with rules and regulations
- Sampling to be decided
- Inspection effectiveness to be agreed upon
- Non-Intrusive?
- Screening or Measuring

- Update database in order to improve
What technique is the 'right' one?

A vessel was inspected by using four different NDT techniques:

- Automated C-scan
- INCOTEST
- UT raster
- Slofec
4 technologieën
## Capabilities compared

<table>
<thead>
<tr>
<th>Automated C-scan</th>
<th>INCOTEST</th>
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<tbody>
<tr>
<td>✷ 1 Day</td>
<td>✷ 4 hours</td>
</tr>
<tr>
<td>✷ Insulation removal &amp; surface prep</td>
<td>✷ No insulation removal</td>
</tr>
<tr>
<td>✷ Highest resolution</td>
<td>✷ Lowest resolution</td>
</tr>
<tr>
<td>✷ 100% coverage</td>
<td>✷ 100% coverage</td>
</tr>
<tr>
<td>✷ Accurate WT reading</td>
<td>✷ No absolute WT reading</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Manual UT Raster</th>
<th>Slofec</th>
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<tbody>
<tr>
<td>✷ 2 Days</td>
<td>✷ 2 hours</td>
</tr>
<tr>
<td>✷ Insulation removal &amp; surface prep</td>
<td>✷ Insulation removal only</td>
</tr>
<tr>
<td>✷ Medium resolution</td>
<td>✷ High resolution</td>
</tr>
<tr>
<td>✷ Bad coverage</td>
<td>✷ 100% coverage</td>
</tr>
<tr>
<td>✷ Accurate WT reading</td>
<td>✷ No absolute WT reading</td>
</tr>
<tr>
<td>✷ Standard UT set</td>
<td></td>
</tr>
</tbody>
</table>
Never forget the human factor
Never forget the human factor
How, when & where to monitor

- Using the appropriate method(s)
- At a time that is suitable
- At locations that need to be watched

No system replaces common sense, however it can help you making the right decision.