Appendix 1

List of participants and excused persons

Participants EFC WP15 meeting 23th April 2009 Schwechat

Name	Surname	Company	Country
Costain	Jim	GE S&I	UK
de Bruyn	Hennie	Borealis AS	NORWAY
Dean	Frank	Ion Science Ltd	UK
Deves	Jean Marie	AXENS	FRANCE
Fenton	Stephen	Performance Polymers b.v	NETHERLANDS
Glaser	Andreas	OMV	
Holliday	Roy	GE Betz	BEGIUM
Janka	Friedric	Borealis AS	
Kennedy	Tom	Ion Science Ltd	UK
Kulic	Miomi	Nalco	
Loukachenko	Natalia	Arcelor Mittal	FRANCE
Pugh	John	BP	UK
Reynolds	Steve	Performance Polymers b.v	NETHERLANDS
Richez	Martin	Total	FRANCE
Ropital	François	IFP	FRANCE
Vanhove	Andre	GE Betz	BEGIUM
Verschoren	Marc	GE Betz	BEGIUM

Excuses received for the EFC WP15 meeting 23th April 2009 Schwechat

Name	Company	Country
Ksenija Babic	Baker Petrolite	USA
Mathieu W. Lanfant	SOFRAP	FRANCE
David Owen	GE Betz	UK
Betrand Szymkowiack		FRANCE
Dr Andrew M Pritchard	Corrosion & Fouling Consultancy	UK
Joanna Hucinska	Gdansk University of Technology	POLAND
Larry Lambert	Nynas AB	UK
André Claus	GE Betz	BEGIUM
Dr Stefan Winnik	Exxon Mobil Chemical	UK
Robin D. Tems	Saudi Aramco	SAUDI ARABIA
Dr Alec Groysman	Oil Refineries Ltd	ISRAEL
Sylvain Authier	Exxon Mobil	FRANCE
Kari Saarinen	Zerust Oy	FINLAND
Melitza Lobaton	Couronnaise de Raffinage	FRANCE
Nicholas Dowling	Shell Global Solutions International B.V.	NETHERLANDS
Richard Carroll	BG Group	UK
Rob Scanlan	Conoco	UK
Maarten Lorenz	Shell Global Solutions International B.V.	NETHERLANDS
Mike Zetlmeisl	Baker Petrolite	SPAIN
Joerg Maffert	Dillinger Huttenwerke	GERMANY
Iris Rommerskirchen	Butting Edelstahlwerke GmbH&Co KG	GERMANY
Martin Hofmeister	Bayernoil Raffineriegesellschaft mbH	GERMANY
Johan van Roij	Shell Global Solutions International B.V.	NETHERLANDS
Dagmar Blendin-Fuelz	Bayernoil Raffineriegesellschaft mbH	GERMANY
Mario Vanacore	Nalco	ITALY
Michael MeLampy	Hi-Temp Coatings Technology	USA

Appendix 2

EFC WP15 Activities

Presentation of the activities of WP15

European Federation of Corrosion (EFC)

- Federation of 31 National Associations
- 18 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 (20% discount on books price)
- for more information http://www.efcweb.org

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

EFC Working Party 15 « Corrosion in Refinery » Activities

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

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 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 ?

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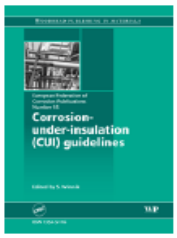
Tel: +44 (0)1223 891 358 Fax: +44 (0)1223 893 694 Email: wp@woodheadpublishing.com

Corrosion under insulation (CUI) guidelines: (EFC 55)

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 occurs underneath externally clad/jacketed insulation as a result of the penetration of water. By its very nature CUI tends to remain undetected until the insulation and cladding/jacketing 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, ENI, Exxon-Mobil, IFP, MOL, Scanraff, Statoil, Shell, Total and Borealis. The guidelines within this document are 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/jacketing materials and protection guards. The guidelines also include case studies.

ISBN 1 84569 423 6
[ISBN-13: 978 1 84569 423 4]
March 2008
176 pages 234 x 156mm hardback
£115.00 / US$230.00 / €170.00

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Usually dispatched within 24 hours

EFC

EFC Working Party 15 plan work 2008-2010

. Proposal of Nace to co-organize a conference on "Corrosion in refineries – practical applications" around July 2010 that will take place in Europe (Rotterdam)
Task group of WP15 with Nace STG34 (Carol Laughlin)

. Sessions with other EFC WP at Eurocorr (2010 in Moscow, 2011 in Stockholm) on which topics?

- Typical corrosion failure cases atlas
- Publications
- Education – qualification - certification

http://www.eurocorr.org

Nice 7-10 September 2009

Tuesday 8 September

Authors will be informed by 30 April and the program will be on Website

Tuesday 8 September 2009		**SS 13 Corr. in Refinery Ind. EFC/NACE**
	14:00 - 14:20	8232- B. Chambers, Honeywell International, Houston, TX/USA; S. Srinivasan, K. Yap, Honeywell Process Solutions, Houston, TX/USA; R. Kane, iCorrosion LLC, Houston, TX/USA **Corrosion in crude distillation unit overhead operations: a comprehensive review**
	14:20 - 14:40	8295- P. Eaton, Champion Technologies Inc., Houston, TX/USA; H. Kaur, M.R. Gray, University of Alberta, Edmonton/CDN **Factors affecting salt hydrolysis in heavy crude**
	14:40 - 15:00	7783 -K. Babic-Samardzija, B. Harrell, M. Zetlmeisl, Baker Hughes Incorporated, Sugar Land, TX/USA **Overhead corrosion control while processing opportunity crudes**
	15:00 - 15:20	7847- C. Claesen, NALCO, Kontich/B; P. Thornthwaite, NALCO, Manchester/UK; S. Lordo, NALCO, Sugarland, TX/USA **Changing crude oil quality and refinery corrosion inhibition**
	15:20 - 15:40	7765- E. Lyublinski, Y. Vaks, Northern Technologies International Corporation, Beachwood, OH/USA; J. Damasceno, Petrobras, Rio de Janeiro/BR; R. Singh, Zerust, Sao Paulo/BR **Application experience of system for corrosion protection of oil storage tank roofs**
	15:40 - 16:10	
		SS 13 Corr. in Refinery Ind. EFC/NACE
	16:10 - 16:30	**Key Note Lecture 7905-** R. Tems, Saudi Aramco, Dhahran/SAR **Managing the cost of corrosion**
	16:30 - 16:50	
	16:50 - 17:10	7894- J. Hucinska, G. Gajowiec, Gdansk University of Technology/PL; D. Derewnicka, Institute of Precision Mechanics, Warszawa/PL **Mechanism of carburisation and metal dusting of 2.25Cr-1Mo steel in catalytic reforming unit**
	17:10 - 17:30	7756- S. Pillot, P. Bourges, Industeel Creusot, ArcelorMittal Group, Le Creusot/F; C. Chauvy, L. Coudreuse, Industeel Loire, ArcelorMittal Group, Rive de Gier/F; P. Toussaint, Industeel Belgium, ArcelorMittal Group, Charleroi/B; K. Orie, ArcelorMittal USA, ArcelorMittal Group, Coatesville/USA **Effect of temper and hydrogen embrittlement on fracture mechanics and CNV properties of 2,25Cr1Mo steel grade - application to minimum pressurising temperature (MPT) issues**
	17:30 - 17:50	8051- N. Meck, N. Koon, K. Kruger, Haynes International, Inc., Kokomo, IN/USA **Corrosion performance of nickel-based alloys in sodium hydroxide at high temperature**

7

http://www.eurocorr.org

Nice 7-10 September 2009

Wednesday 9 September

Wenesday 9 September 2009		**SS 13 Corr. in Refinery Ind. EFC/NACE**
	08:40 - 09:00	7781- G. Lobley, T. Nuaim, Saudi Arabian Oil Company, Dhahran/SAR **Internal and external chloride stress corrosion of austenitic stainless steels in refineries**
	09:00 - 09:20	8346- Adeyinka ADELEKE, Honeywell Corrosion Solutions, Houston Texas, USA, Nandani NEERANJAN, Vivek SEERERAM,Point Lisas Nitrogen Limited, Trinidad, West Indies **Performance degradation of the heat exchanger tubes exposed to high temperature environment**
	09:20 - 09:40	7739- A. Groysman, ORT Braude College, Karmiel/IL **Corrosion monitoring in the oil refining industry**
	09:40 - 10:00	8235- J. Costain, GE, Coventry/UK; J. Cuffe, GE, Lewistown, PA/USA; E. van der Leden, C. Caunter, GE, Coventry/UK **Installed ultrasound sensors for improved asset integrity and process control**
	10:00 - 10:20	7780- D. Masouri, M. Askari, Pars Oil & Gas Co., Tehran/IR **Improvement of used materials in sour gas treating plant**
	10:20 - 10:50	
	10:50 - 18:00	**WP15 Business Meeting**

8

Appendix 3

Corrosion of the overhead of a FCCU primary fractionator

Martin Richez (Total)

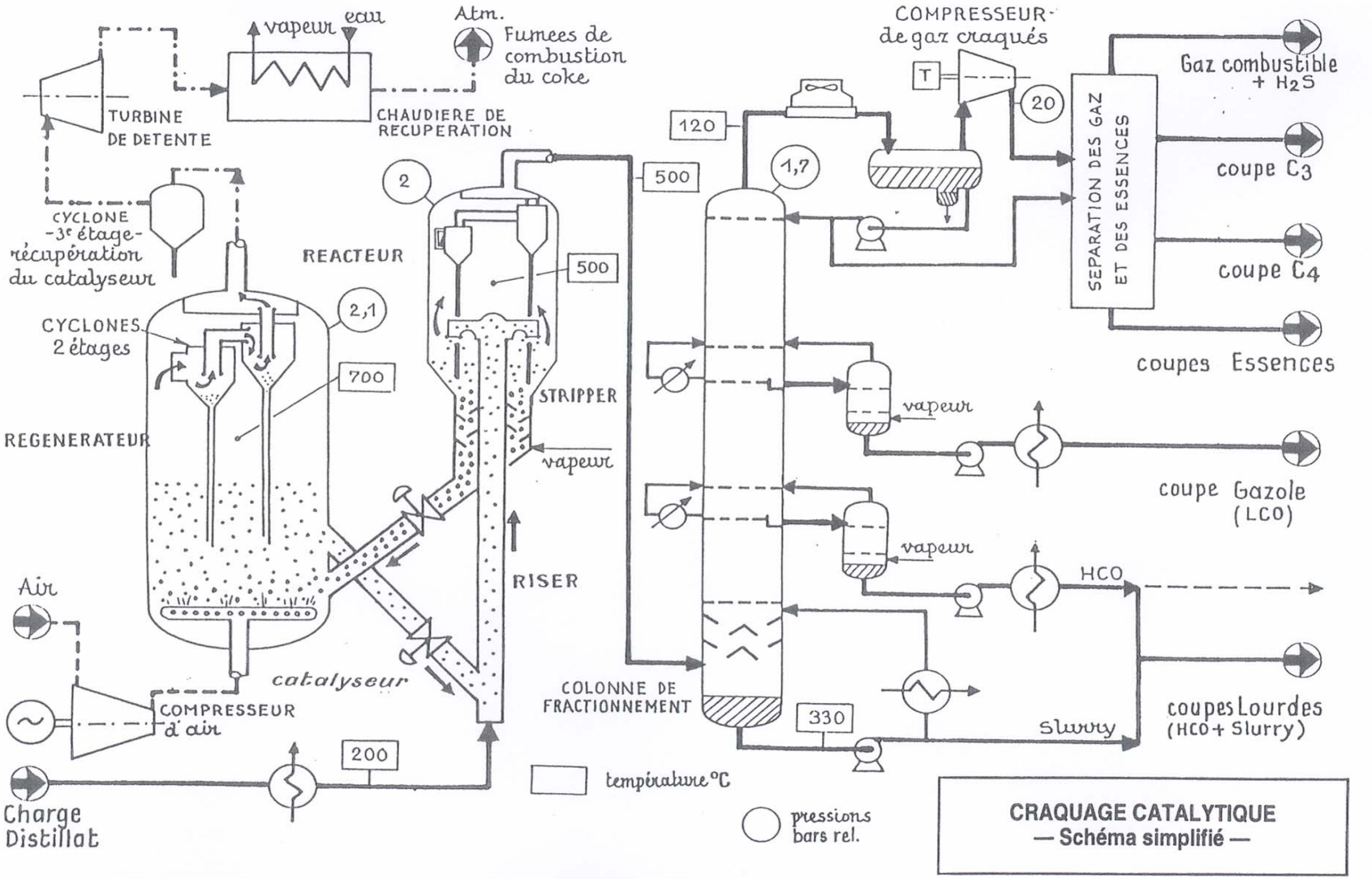
FCC Main Fractionator Overhead Line Corrosion

Martin RICHEZ

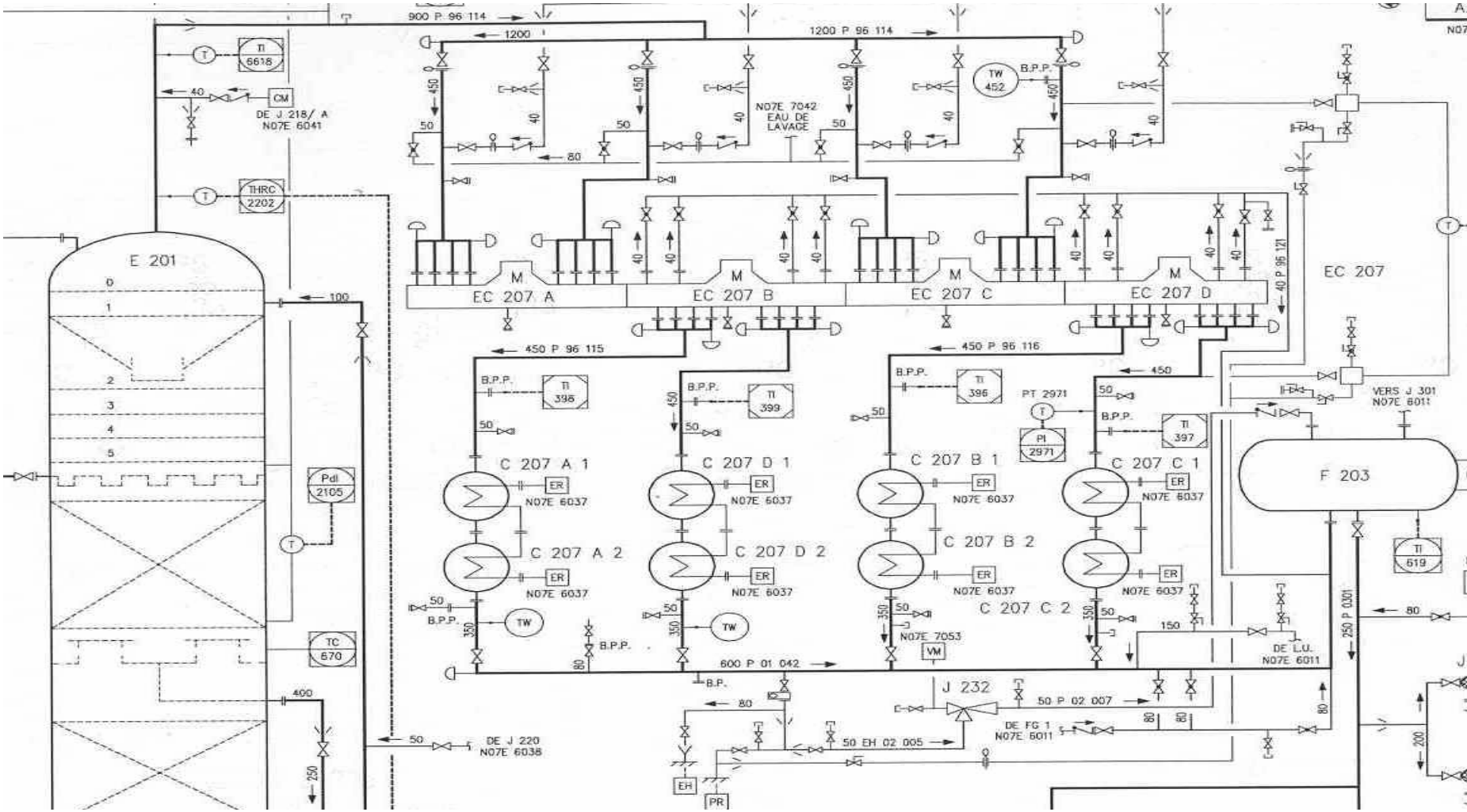
23 april 2009

FCC Unit

FCC unit


vapeur
eau
Atm.
Fumees de combustion du coke
TURBINE DE DETENTE
CHAUDIERE DE RECUPERATION
COMPRESSEUR de gaz craqués
T
20
Gaz combustible + H2S
coupe C3
coupe C4
coupes Essences
SEPARATION DES GAZ ET DES ESSENCES
120
1,7
500
2
CYCLONE -3e étage- récupération du catalyseur
REACTEUR
500
2,1
CYCLONES 2 étages
700
STRIPPER
vapeur
REGENERATEUR
vapeur
coupe Gazole (LCO)
vapeur
HCO
Air
RISER
catalyseur
COMPRESSEUR d'air
COLONNE DE FRACTIONNEMENT
330
Slurry
coupes Lourdes (HCO + Slurry)
200
température °C
pressions bars rel.
Charge Distillat
CRAQUAGE CATALYTIQUE
— Schéma simplifié —

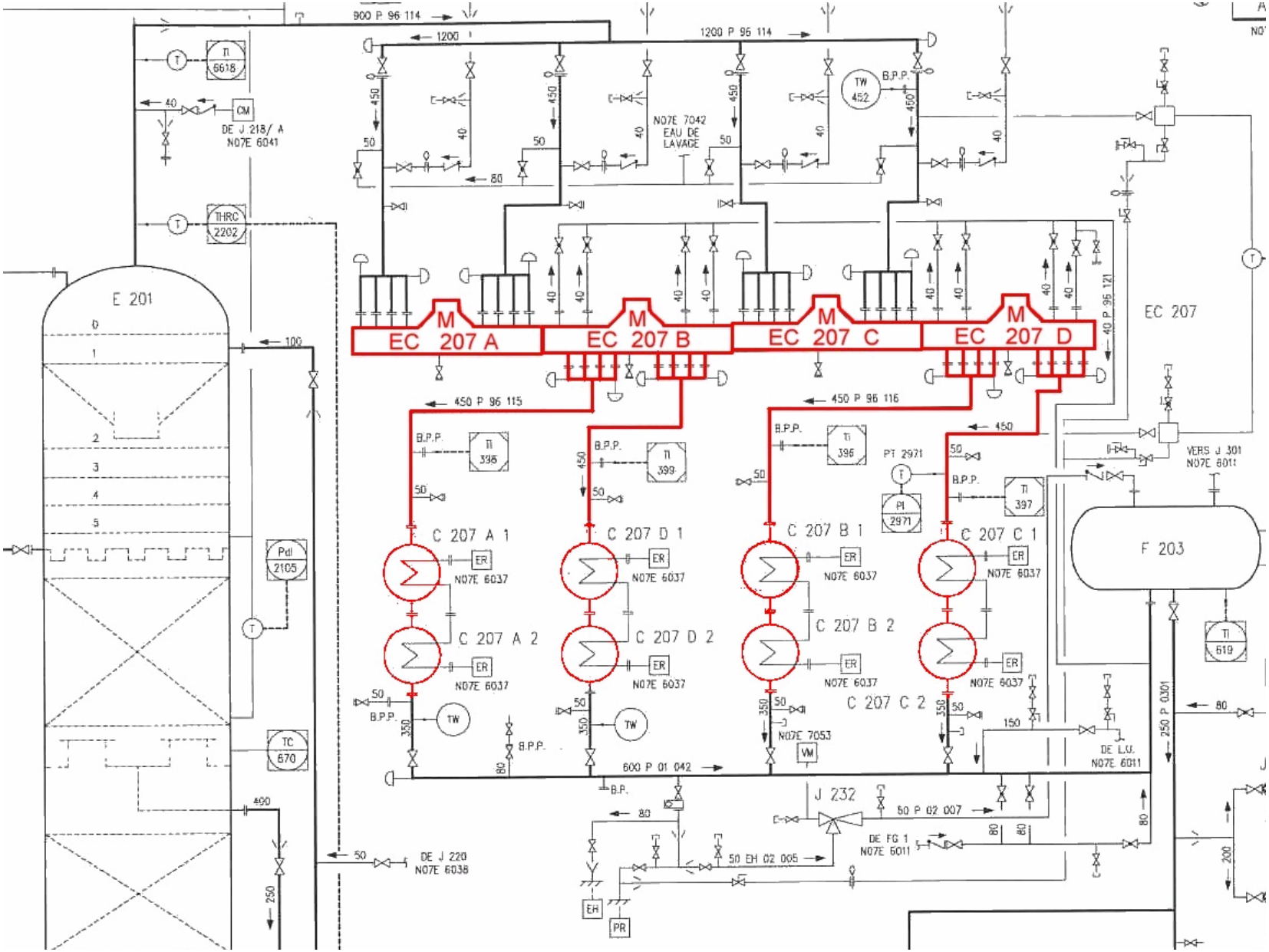
FCC Unit



TOTAL

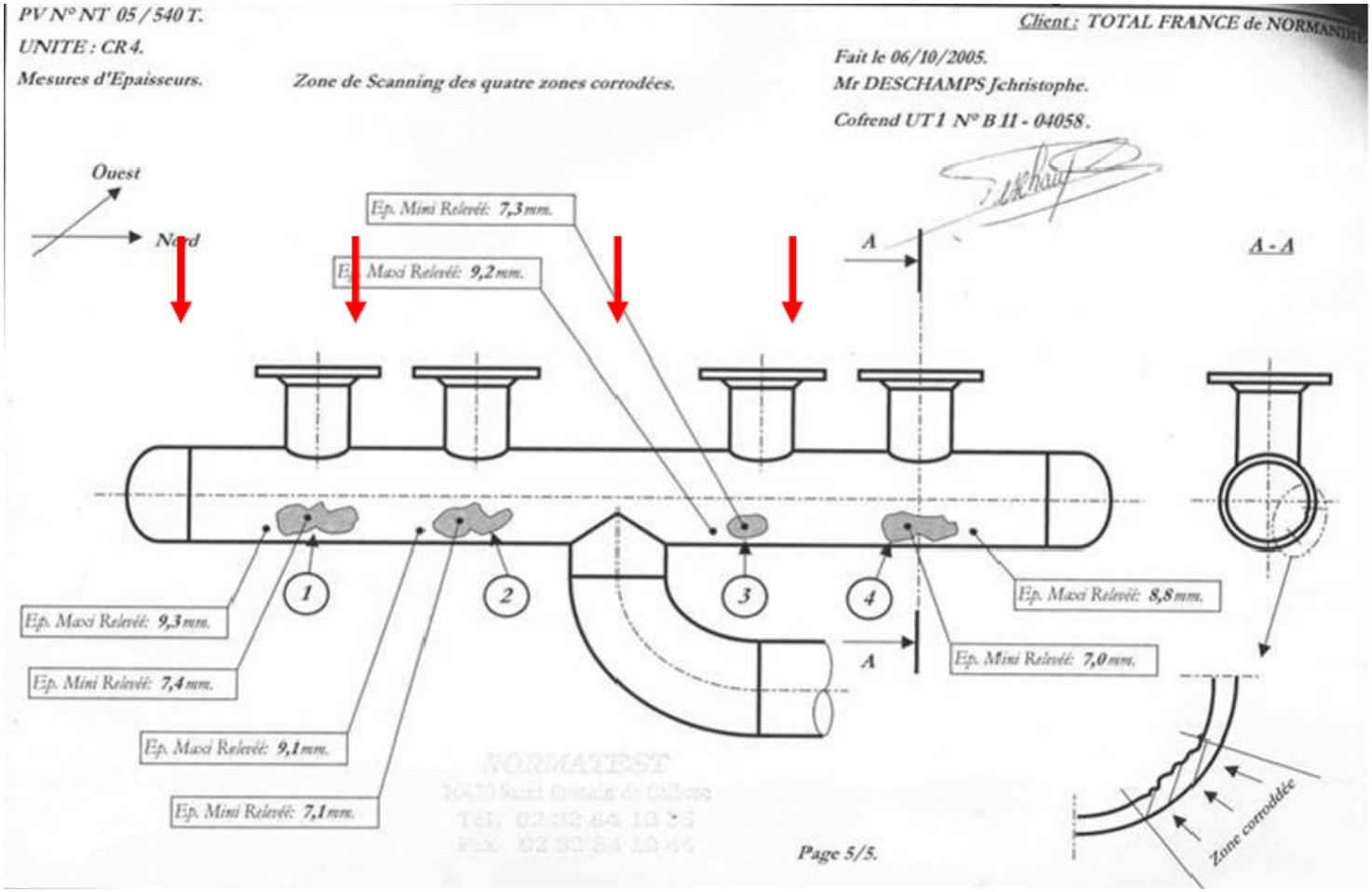
FCC Corrosion Analysis

RN FCC Unit Corrosion

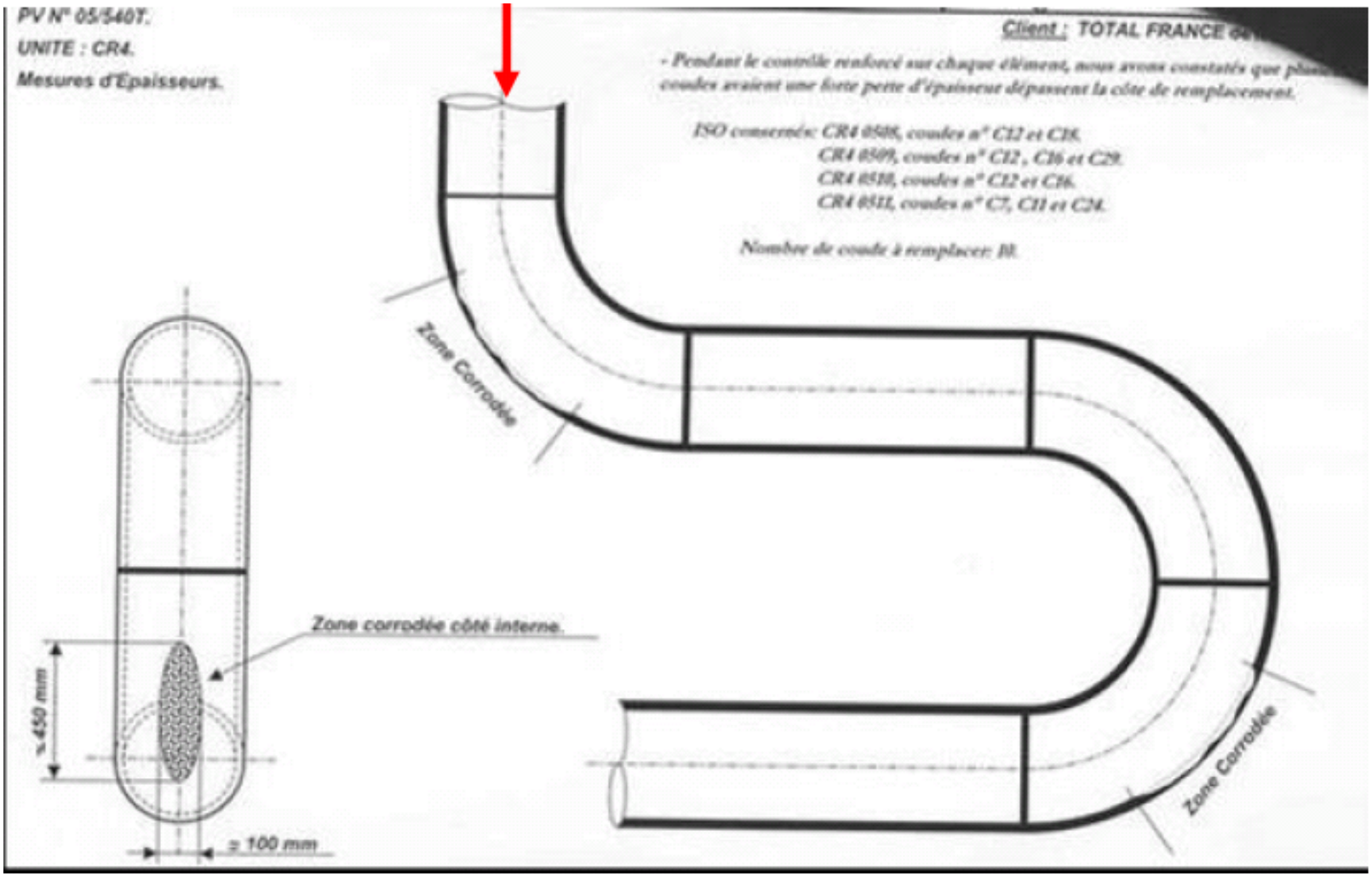


TOTAL

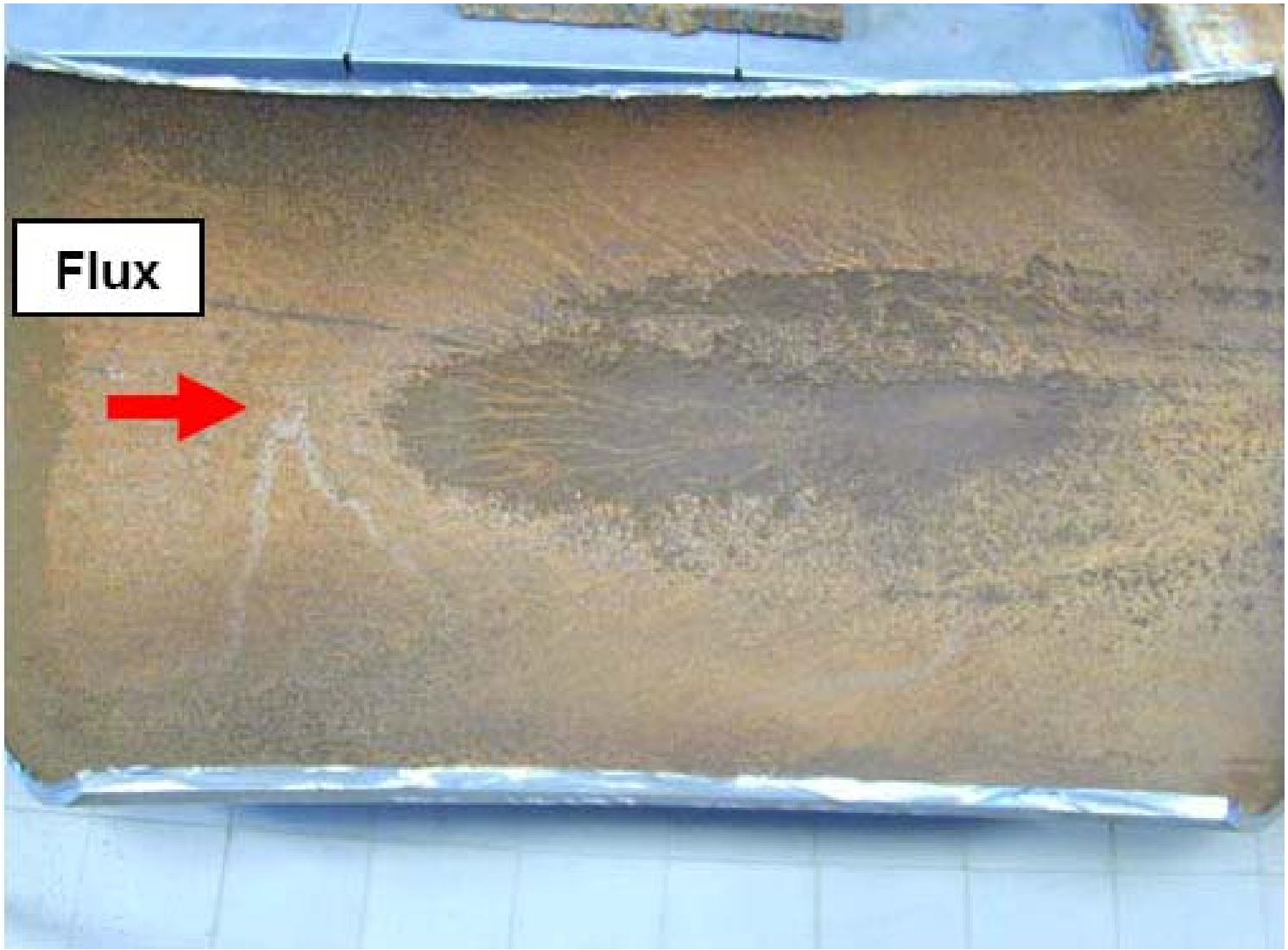
Air Cooler Box Corrosion



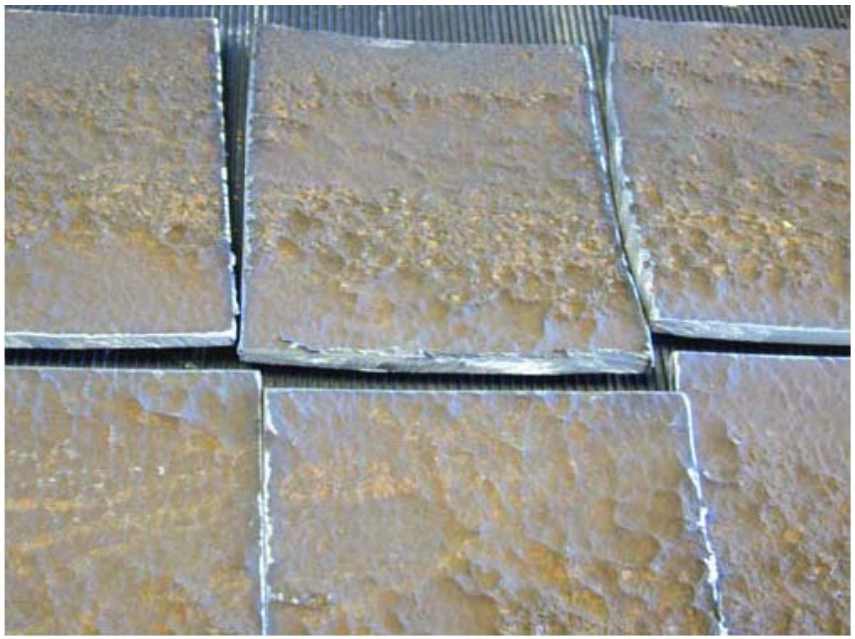
Line Corrosion



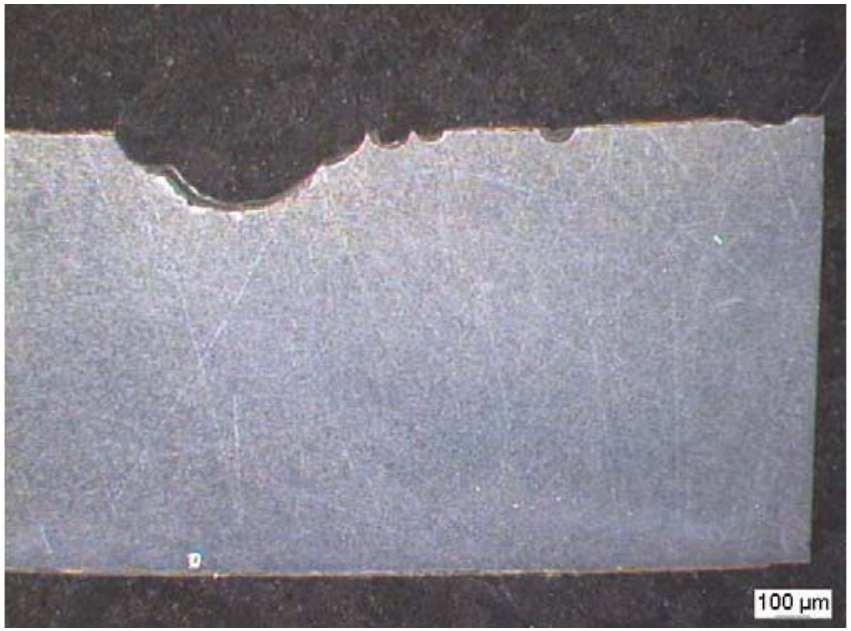
Macroscopic Observation

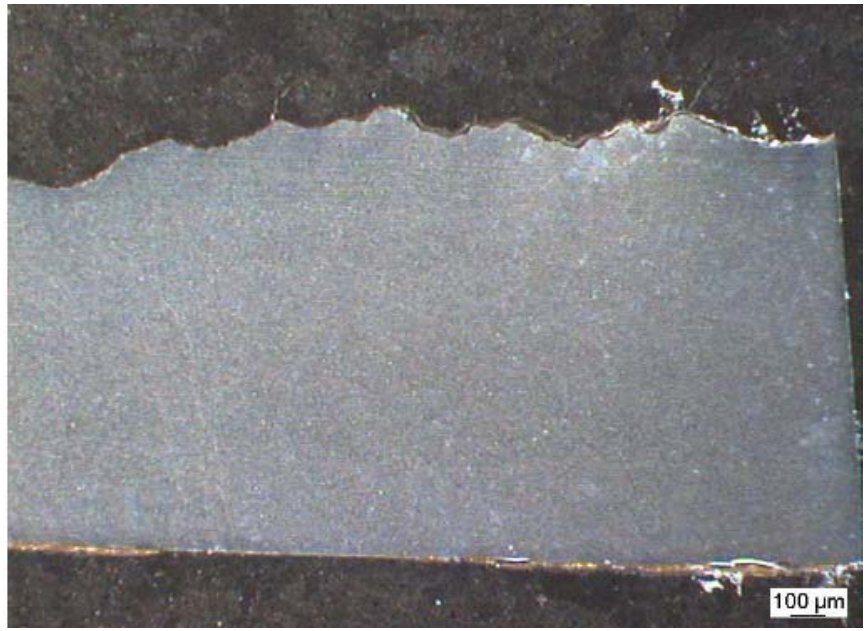


Macroscopic Observation

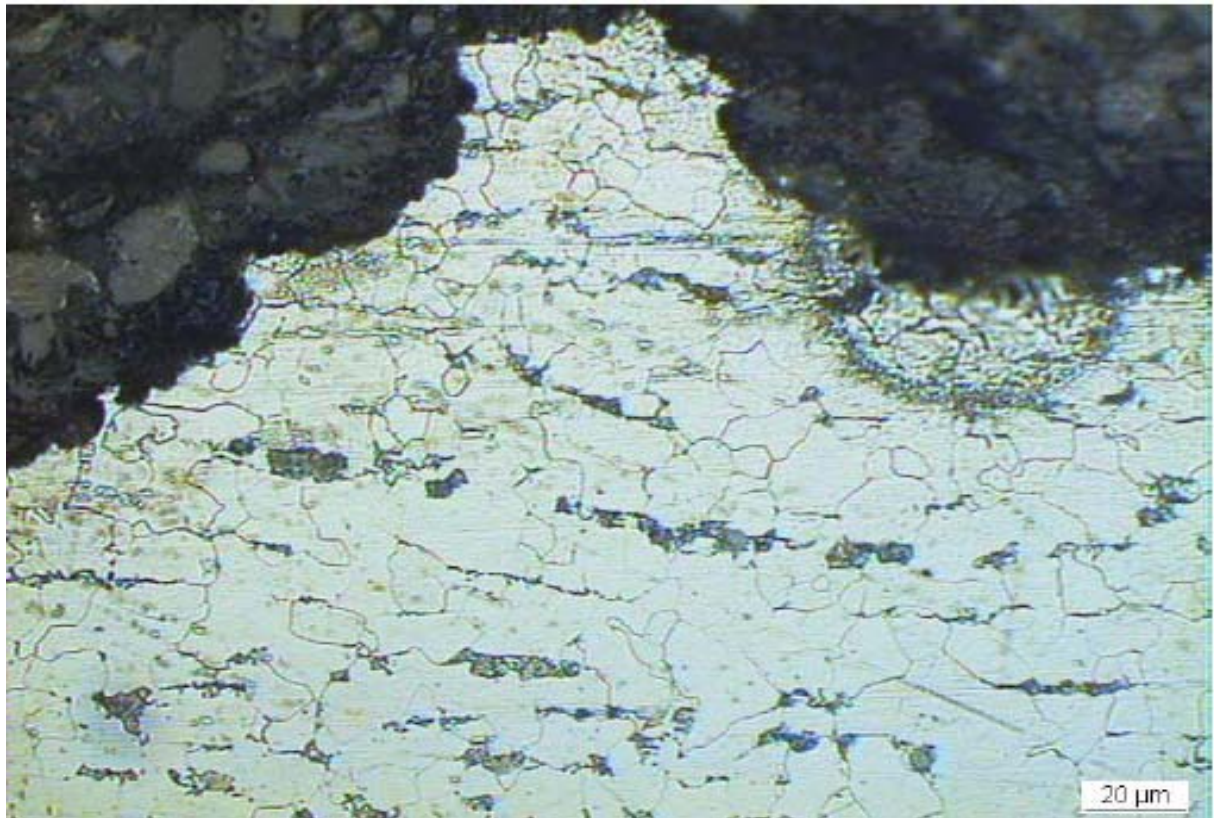


Cut Observation





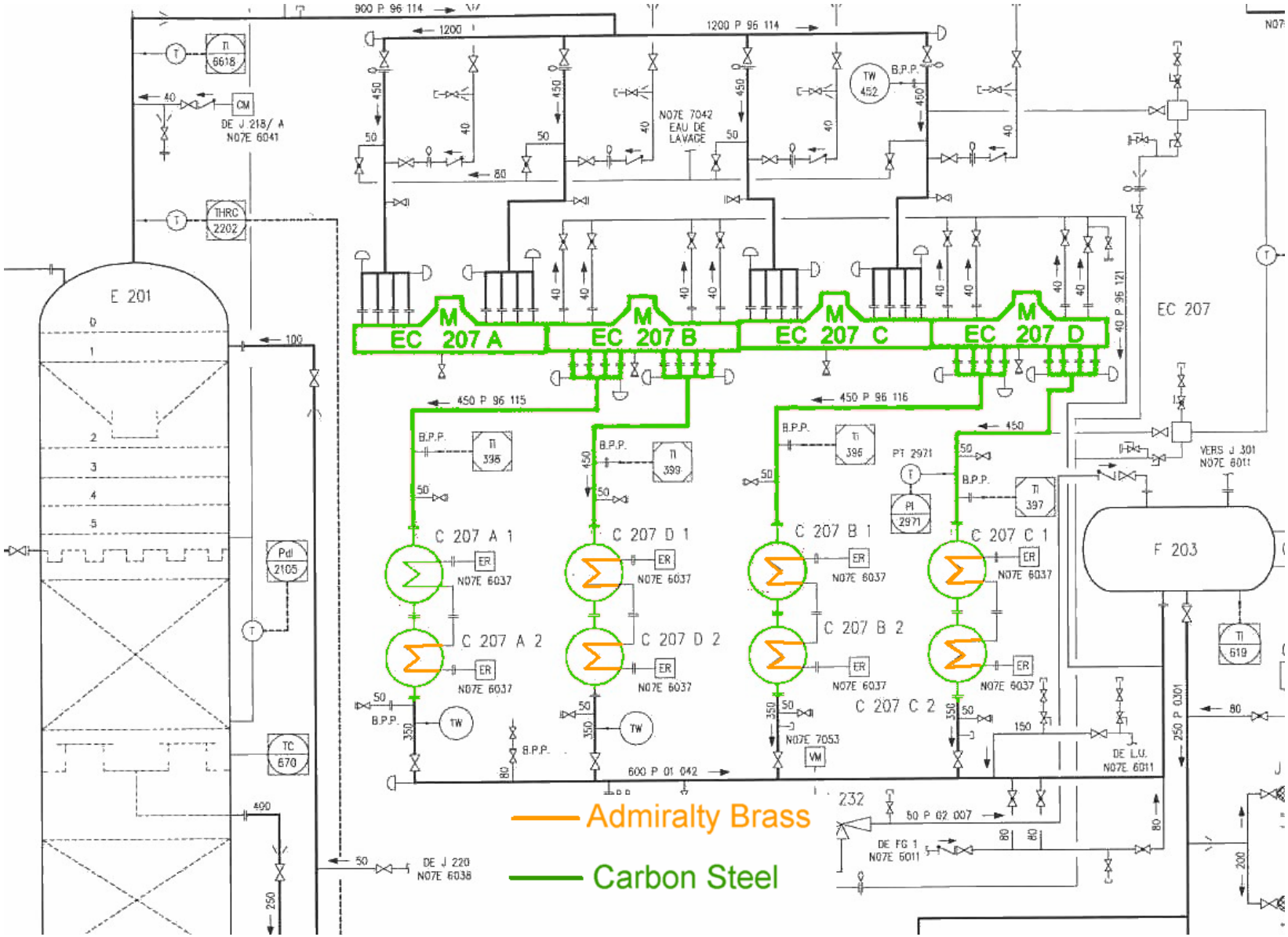
Micrograph Observation



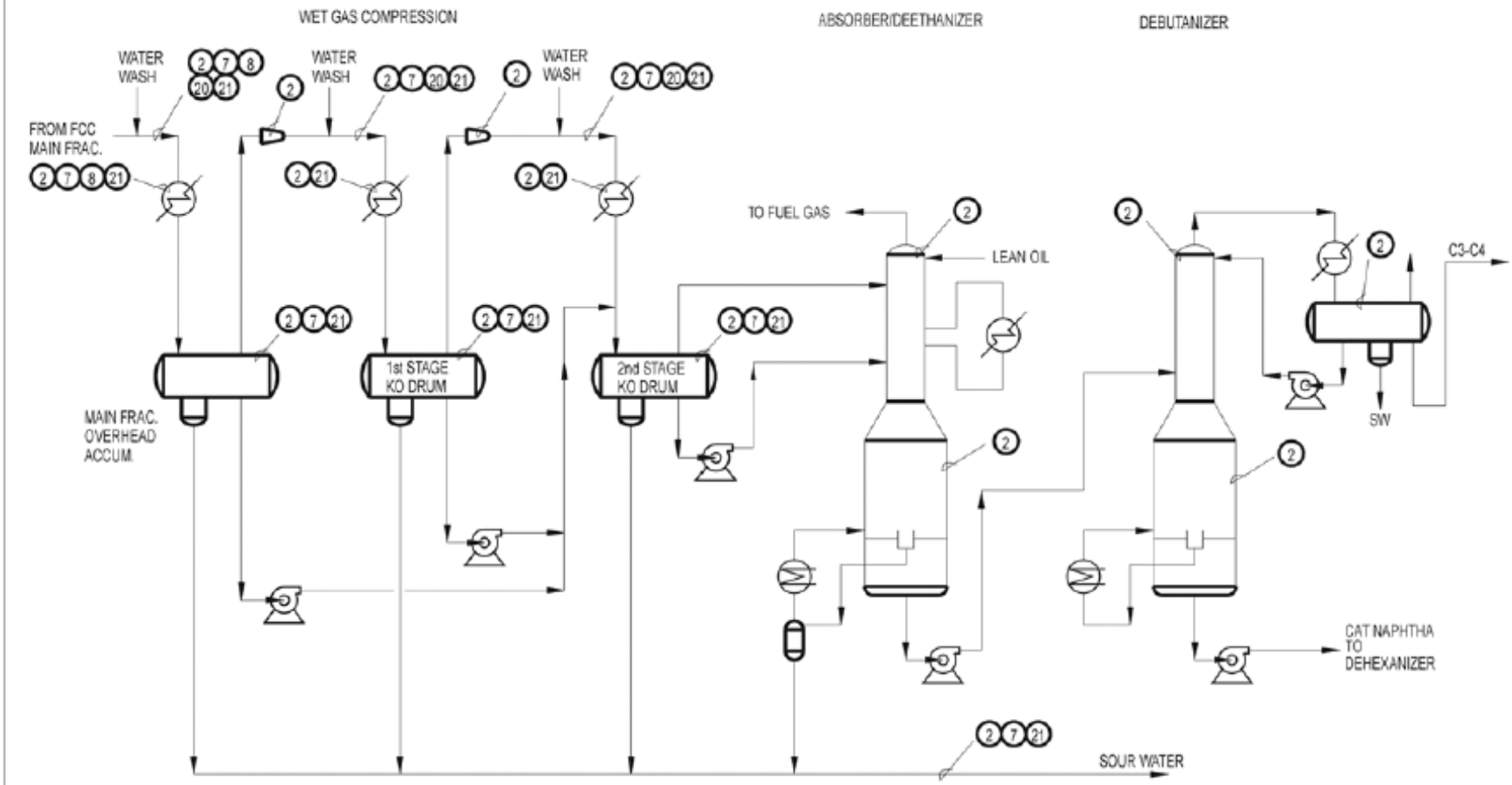
Corrosion without corrosion products

FCC Corrosion Understanding

FCC unit metallurgy



API 571



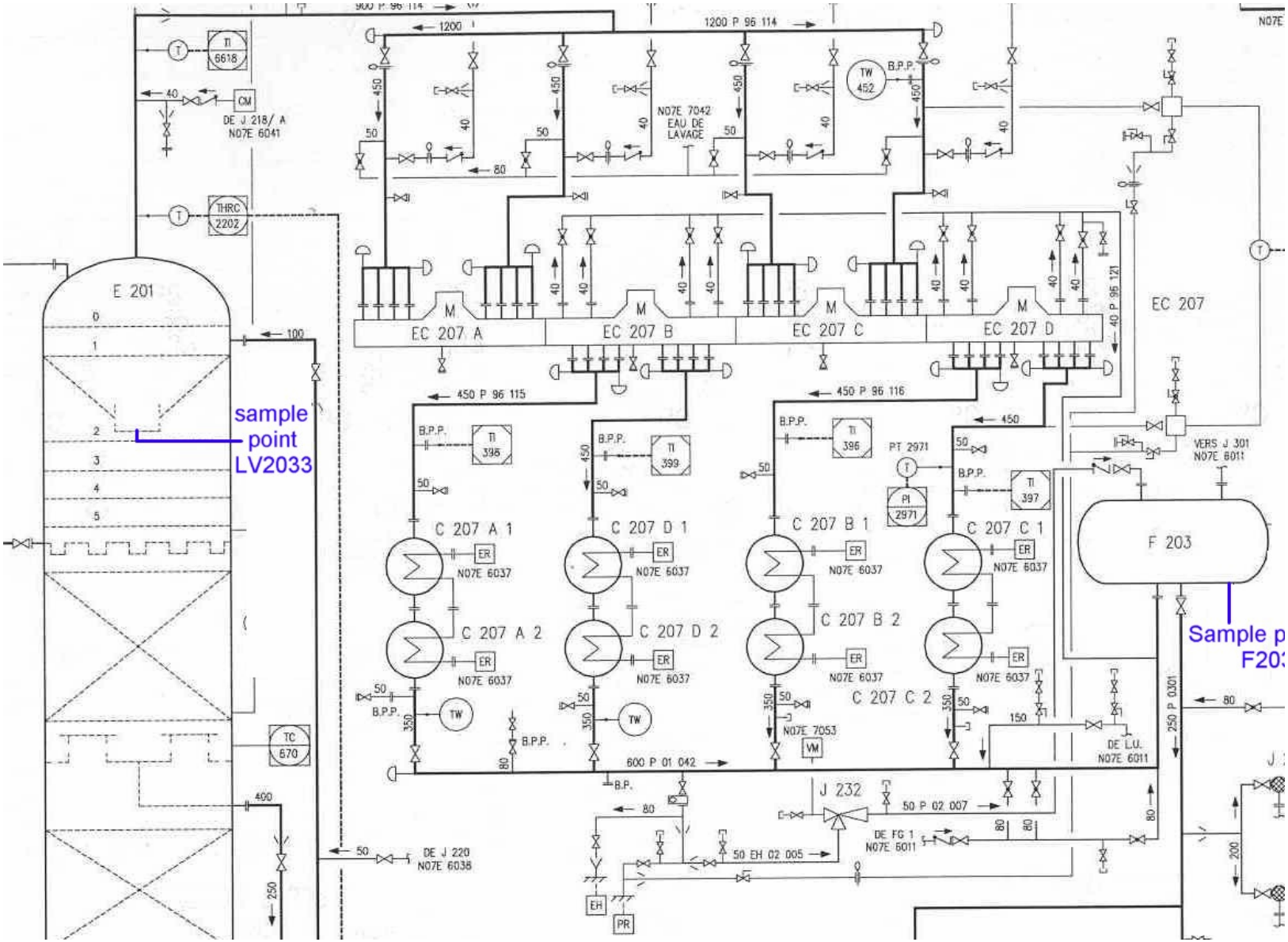
Key to Damage Mechanisms

- (2) Wet H_2S Damage (Blistering/HIC/SOHIC/SSC)
- (7) Ammonium Bisulfide
- (8) Ammonium Chloride Corrosion
- (20) Erosion / Erosion-Corrosion
- (21) Carbonate SCC

FCC Light Ends Recovery

TOTAL

Water Sampling Point



Water Sampling and analyses during normal operation

	06/07/2006	06/07/2006
	LV2033	**F203**
pH	**9,1**	**8,4**
Cd (µS*cm)	**2120**	**12150**
S-- (ppm)	**322,12**	**3028**
Cl- (ppm)	**22,6**	**7,5**
Fluorures	nd	nd
Bromures	nd	nd
Nitrites	nd	nd
Nitrates	**nd**	**nd**
Phosphates	nd	nd
Sulfates	**28**	**88**
Sulfites	**199**	**284**
Thiosulfates	**127**	**465**
Acétates	**126**	**40**
Propionate	**49**	**13,5**
Formiate	1,1	<1
Sodium	1	1
Ammonium	**530**	**1960**
Potassium	1	<1
Magnésium	1	<1
Calcium	**4**	**1,3**
Phénols	**547**	**380**
Crésols	**162**	**64**
Xylénols	**17**	**2**
Calculated pH	**9,2**	**8,6**

TOTAL

Analyse interpretation

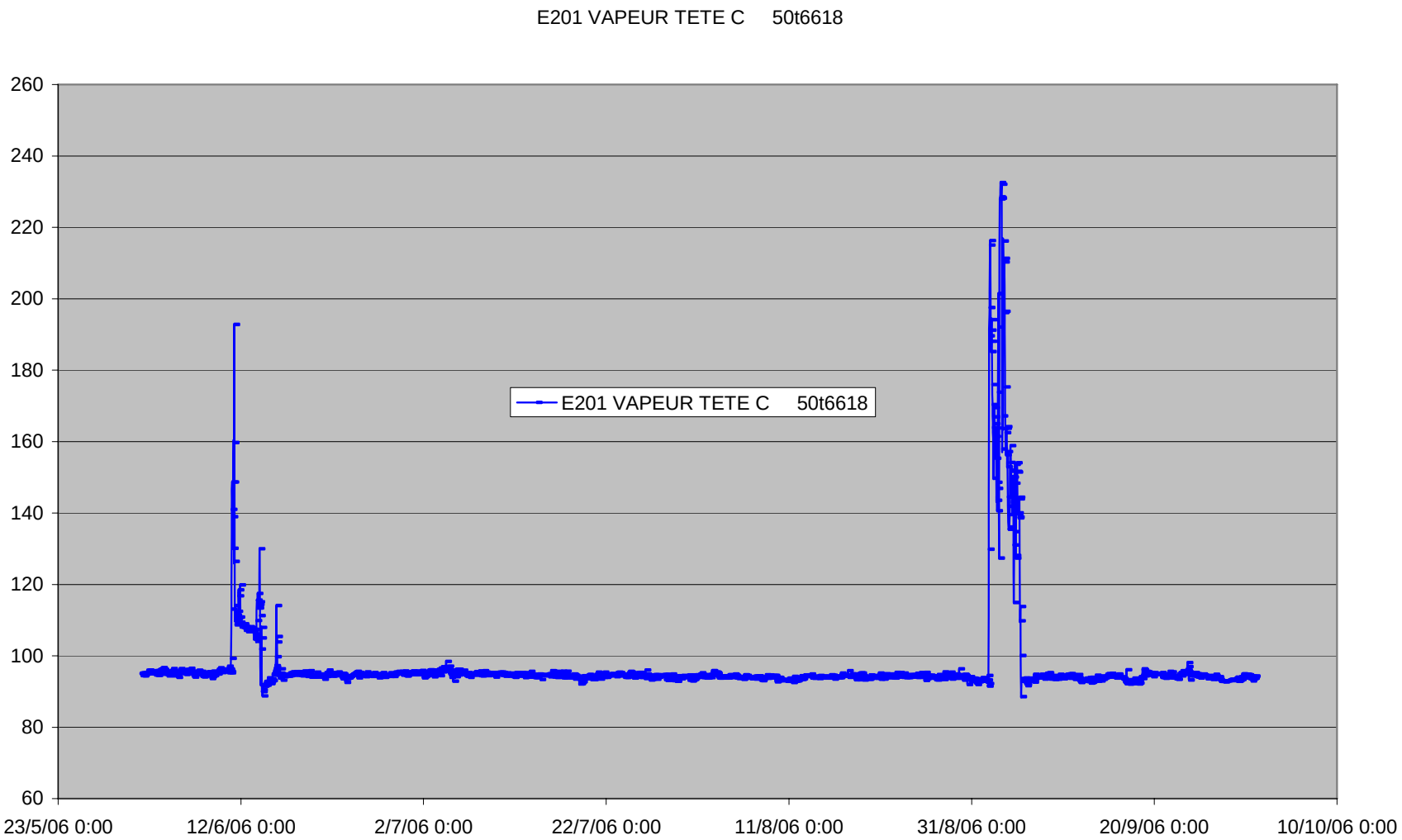
- **Analyse made during normal run doesn't explain the corrosion**
- **Normal pH**
- **Normal H2S, NH3 value**
- **High Cl value : high salt deposition risk**

That Corrosion doesn't occur during normal Run

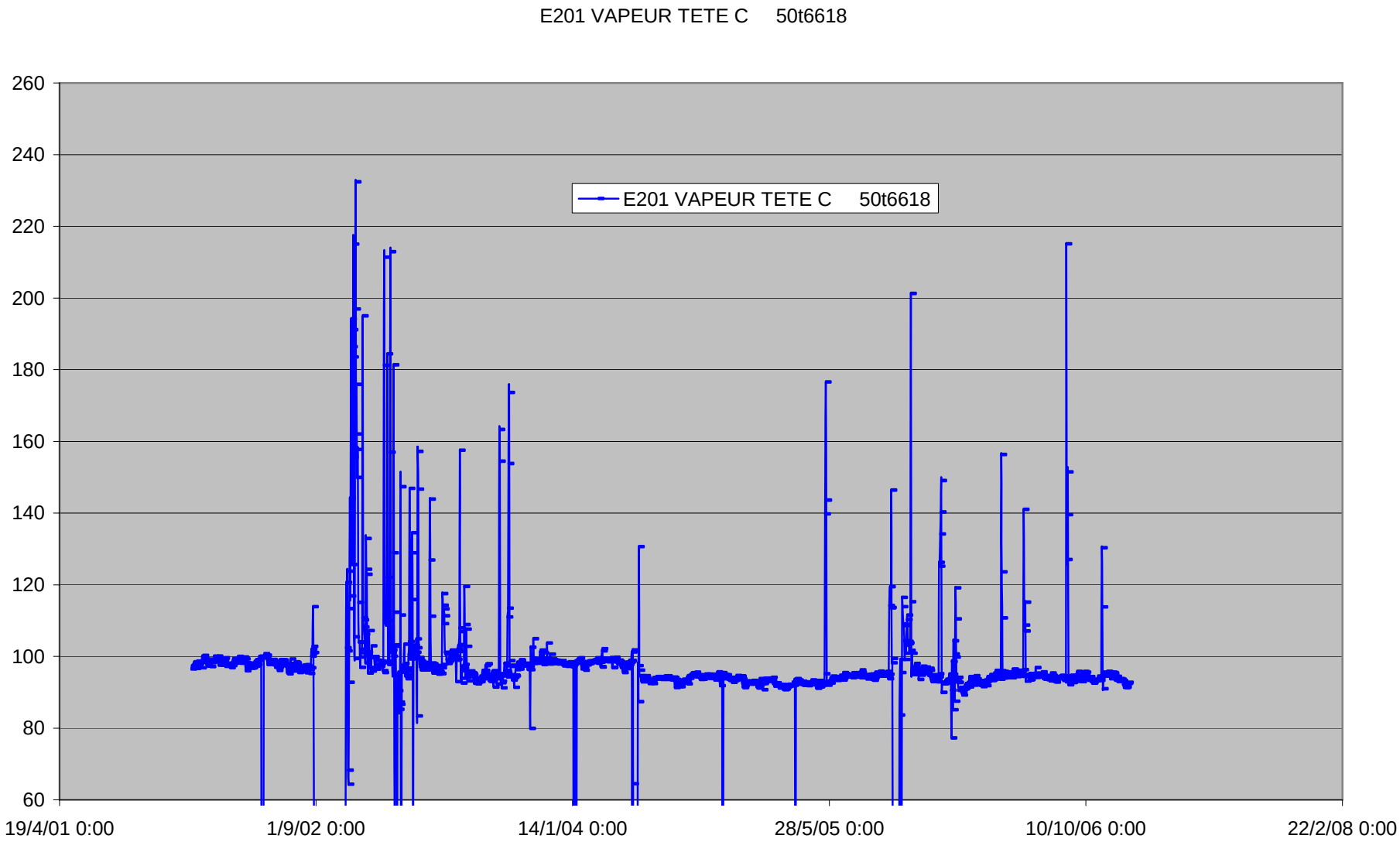
Corrosion induced by unsteady state conditions?

During 2002-2006 :Long unstable condition period

Unstable condition: Increase of Overhead Main Fractionnator column temperature



Unstable conditions period 2002-2006



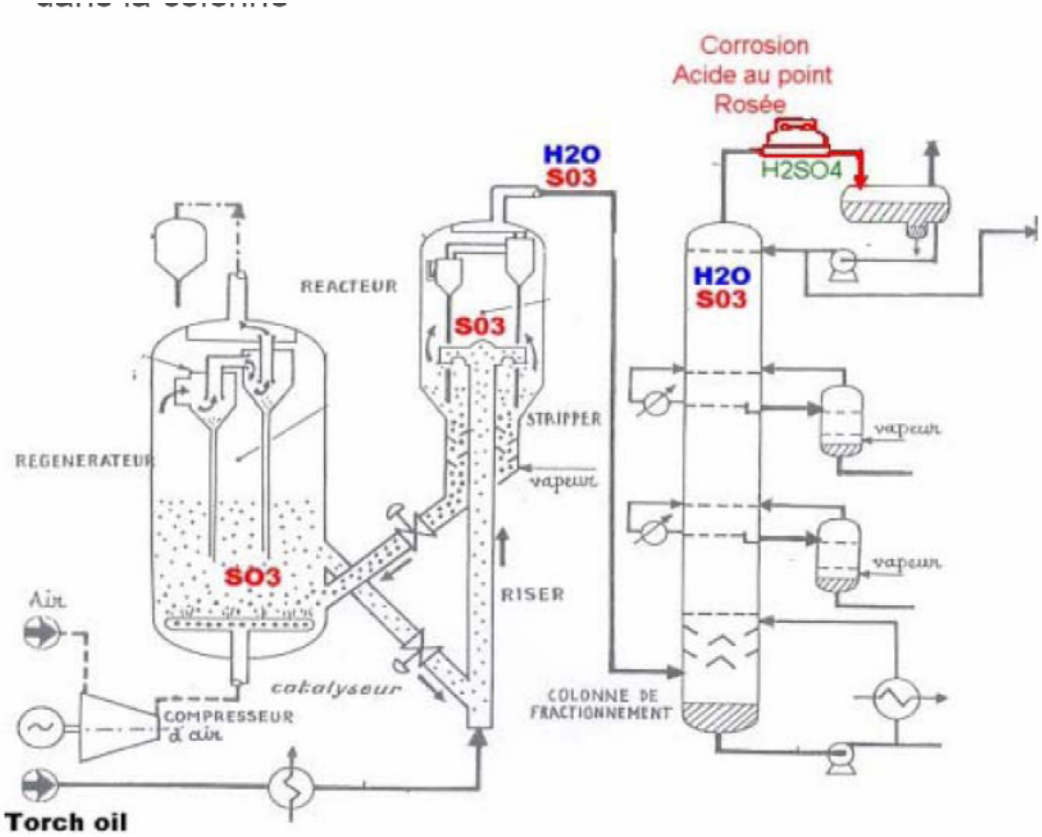
Water Sampling and analyses during unstable condition

	04/09/2006	04/09/2006
	LV2033	**F203**
pH	**3,2**	**3,9**
Cd (µS*cm)	**120**	**95**
S-- (ppm)	**<sd**	**6**
Cl- (ppm)	**1**	**1**
Fluorures	nd	nd
Bromures	nd	nd
Nitrites	nd	nd
Nitrates	<1	<1
Phosphates	nd	<1
Sulfates	**24**	**24**
Sulfites	**///**	**///**
Thiosulfates	**<1**	**<1**
Acétates	**1,2**	**1,4**
Propionate	nd	nd
Formiate	<1	<1
Sodium	**1,4**	**1,2**
Ammonium	**3,9**	**6,6**
Potassium	<1	<1
Magnésium	<1	<1
Calcium	<1	<1
Phénols	**///**	**///**
Crésols	**///**	**///**
Xylénols	**///**	**///**
Calculated pH	**3,4**	**3,8**

TOTAL

Conclusion on corrosion phenomena

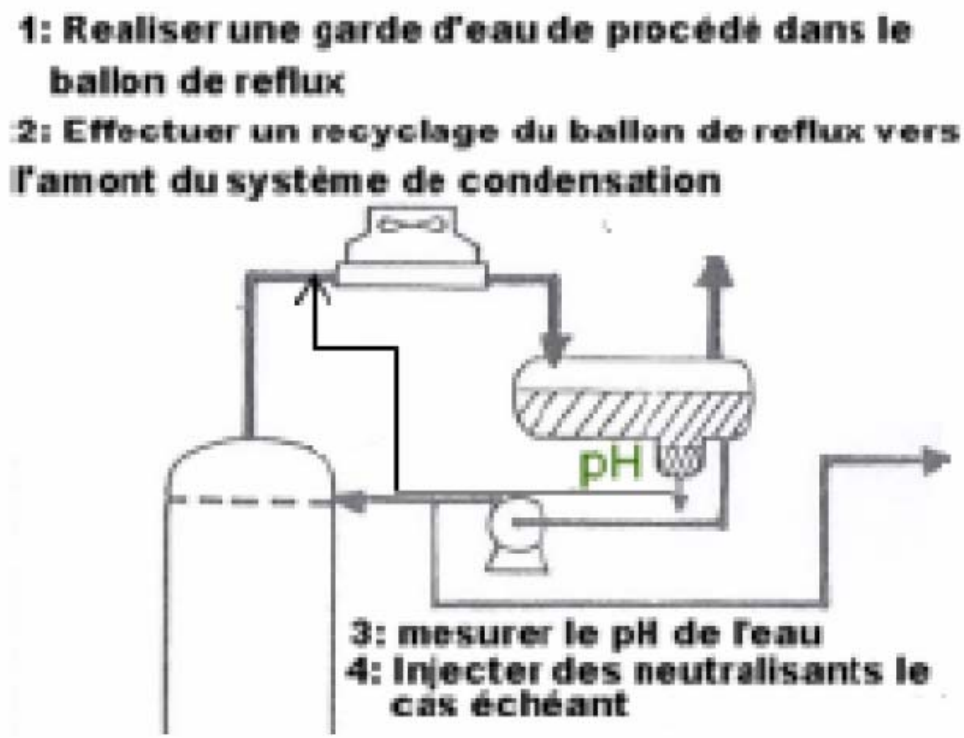
- Generalized corrosion
- During catalyst recirculation
- By sulfuric acid
- In aqueous phase below the dew point (in the column or the over head line)



Corrosion Mitigation

Corrosion mitigation

- Acidity shall be neutralize
- Keep the water wash running (amonia act as a buffer)
- Monitor the pH
- Add neutralizer if needed



Conclusion

Conclusion

- During specific operation, corrosion mechanism can change
- Corrosion rate can increase
- In unstable conditions corrosion can occur in unexpected area

Appendix 4

Case study on stress relaxation cracking

Hennie de Bruyn (Borealis Group)

Cracking in Ethylene Furnace Cross-Over Lines

Hennie de Bruyn

EFC WP 15 Meeting

Spring 2009

BOREALIS

SHAPING the FUTURE with PLASTICS

Failure Case

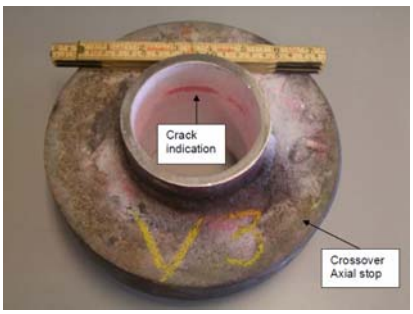
Cracking in Ethylene Furnace Cross-Over Lines

- Stenungsund, Sweden (February 2009)
  - Inspection of ethylene cracker furnace
  - Pressure testing revealed cracks in 2 cross-over lines
  - Further inspection (PT) revealed a 3rd cracked cross-over line
  - Cracking occurred in all cases at an axial stop (fixed point in the piping)
  - Cross-over line: line between last bank in convection section & radiant section

- Further notes
  - Material: Sanicro 31HT (alloy 800 HT)
  - Operating temperature: ~ 700°C
  - Cross-over lines are insulated

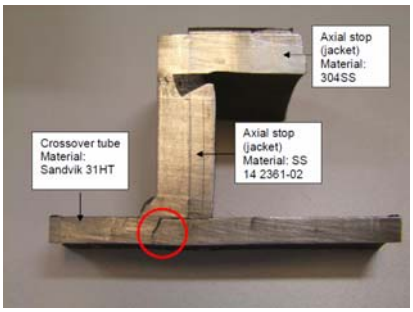
Failure Case

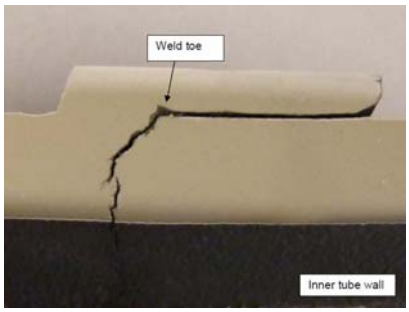
Cracking in Ethylene Furnace Cross-Over Lines



Failure Case

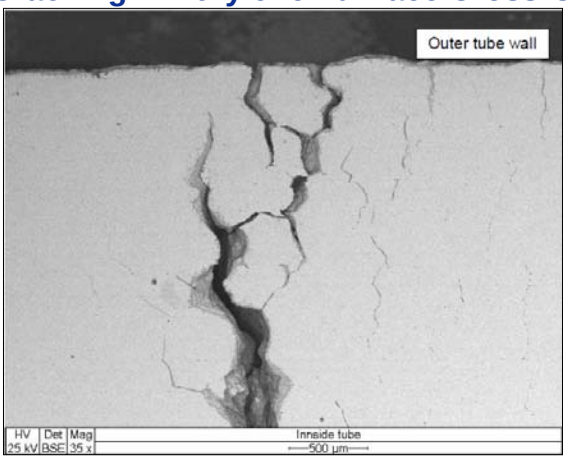
Cracking in Ethylene Furnace Cross-Over Lines





Failure Case

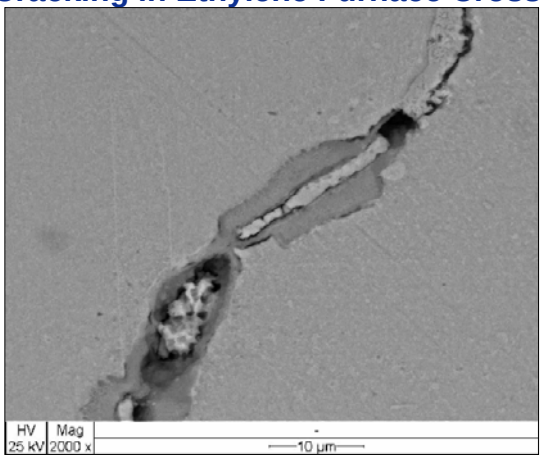
Cracking in Ethylene Furnace Cross-Over Lines



Scanning electron micrograph of cracked region showing the presence of multiple parallel cracks

Failure Case

Cracking in Ethylene Furnace Cross-Over Lines



Scanning electron micrograph of cracked Sanicro 31HT showing a nickel-rich filament on the grain boundary surrounded by chromium-rich oxide

Failure Case

Cracking in Ethylene Furnace Cross-Over Lines

- Conclusions
  - Clear case of stress relaxation cracking
    - Susceptible material
    - Susceptible temperature range
    - Point of highest stress in the cross-over line (piping fixed point)
    - Intergranular cracking
    - Presence of nickel-rich filaments in the cracks
- Take Care!
  - Most literature suggest that cracking will occur within 1 year
  - These cross-over lines are 6 years old!
  - If stress relaxation cracking was not observed after the first inspection – keep on looking and inspect also later

End of presentation

Hennie de Bruyn

23 April 2009

Appendix 5

Stress relaxation cracking of stainless steels

Advancement of the Cefracor survey

CEFRACOR
French Corrosion Society

Corrosion in Oil and Gas Industries
High Temperature Working Group

Chairman: François Dupoiron
Members :

CETIM , EPA, Haynes Intl , Heurtey, IFP , Industeel , Rhodia, Ugitech, Technip, Total

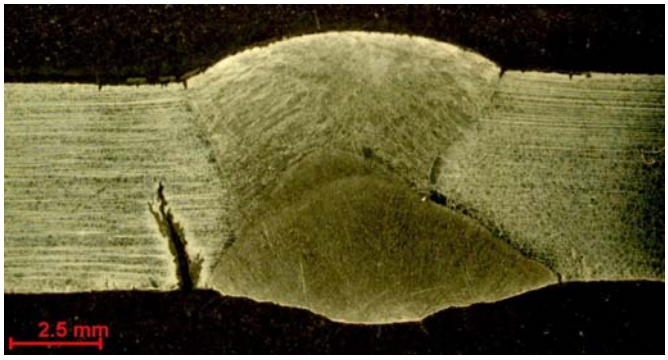
Oil and gas High temperature group :
specific commission in the CEFRACOR

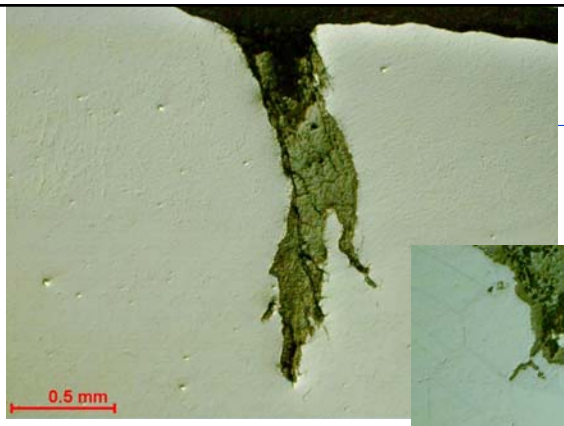
- Main goals :
  - –return of experience exchanges
  - –« forum « between users (O&G company) , research center , producers , fabricators, engineering .
  - –Works on specific topics : Stress relaxation cracking

Stress Relaxation Cracking :

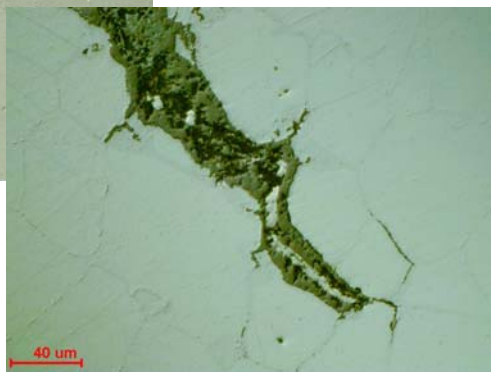
Cracking phenomenon of the austenitic grades working at high temperatures 450 to 800°C and particularly in case of high stress and strain.

Location : primarily in heat affected zone but not only !





Intergranular



nickel filament

Stress Relaxation Cracking (From C.Shargay Fluor) :

- **450-800°C**
- Thicker walls (>1") more susceptible for cracking during fabrication; all thickness can crack in-service
- Location – primarily HAZ
- Intergranular; Ni filament
- ASME Sect. VIII, UNF-56 (e) recently added a requirement to PWHT Alloy 800,H,HT at 885 min. for services >530°C
- No similar requirement in B31.3 or CODAP or other codes yet

Stress Relaxation Cracking :

- Many works and publications : **see particularly H.Van Wortel , Ecole Mines Paris publications**
- Sometime mentioned by steels and alloys producer
- Often experimented by users : 347 , 321 , 304 , 800H, 617, 803 ....

Working group actions program (1) :

- **Return of experience in France**
  - Grades
  - Fabrications conditions
  - Service conditions
- **Propose a best practice guide in order to limit the risk :**
  - Grades sensitivity versus temperature;
  - Design recommendation
  - Fabrication recommended method (geometry , welding practices , filler material)

Working group actions program (2) :

- **Characterization test proposal** (based on the TNO methodology)
- Discussion with producers
  - to include the temperature range sensitivity in the grades brochures and documentations
- Discussion with Codes authorities
  - to add the recommendations
- **Open for international cooperation**