Appendix 1

List of participants

Participants EFC WP15 meeting 14th April 2011 Paris (France)

NAME	Company	Country
Stein Brendryen	Statoil	Norway
Martin Richez	Total	France
Valerie Beucler	Nalco	France
Stefano Trasatti	University Milan	Italie
Edoardo Guerrini	University Milan	Italie
Alain Pothuaud	GE Betz	France
Claudia Laverte	GE	France
Johan van Roij	Shell	Netherlands
Fernando Bonilla	Vallourec	France
Hennie de Bruyn	Johnson Mattey	United Kingdom
Rachel Mansfield	Johnson Mattey	United Kingdom
Carmelo Aiello	Consultant	Italie
Ridha Yahyaoui	Axens	France
Michel Munier	Axens	France
Francois Weisang-Hoinard	Outokumpu	France
Pascale Vangeli	Outokmupu	Sweden
Johan Sentjens	Temati	Nertherlands
Grzegorz Sielski	Sandvik	Poland
François Ropital	IFP Energies nouvelles	France

Appendix 2

EFC WP15 Activities

(Francois Ropital)

Welcome to the EFC Working Party Meeting

"Corrosion in Refinery" WP15

Paris 14 April 2011

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

AGENDA EFC Working Party 15

Corrosion Refinery Industry Meeting

9h30-10h00	Welcome and WP15 Activities (F. Ropital) next Eurocorr sessions and workshops, collaborations with NACE publications, other points
10h00-10h45	Corrosion of sour gas unit treatment Opportunity of duplex use in the amine units, for CO2 treatment (F. Weisang-Hoinard, P. Vangeli Otokumpu) Revision of the EFC n° 46 "Amine unit corrosion in refineries" (F. Ropital)
10h45-11h00	Break
11h00-11h30	Mercury Corrosion and Removal form Refinery Streams (H. De Bruyn)
11h30-12h00	Naphthenic acid corrosion:an analytical approach (S. Trasatti)
12h00-12h30	Failure Cases - failure case of Dpcell Orifice flange for Hydrotreater unit (C. Aiello) failure case from the audience

AGENDA EFC Working Party 15

Corrosion Refinery Industry Meeting

13h30-14h15	Corrosion under insulation Presentation "CUI and coatings" (Johan Sentjens - Temati) Revision of the EFC CUI guideline n° 55
14h15-14h45	New stainless steels Sandvik SAF 2707HD heat exchanger tubes for demanding application in crude oil refinery (Grzegorz Sielski)
14h45-15h15	Water treatment 3D Trasar for boiler technology (V. Beucler Nalco)
15h15- 15h45	Monitoring Corrosion Monitoring system can help refinery plant to process opportunity crude by monitoring the corrosion rate to control inhibitor, to improve both plant versatility and profitability (Claudia Lavarde –A. Pothuaud GE)
15h45	Other topics of discussion from the audience End of the meeting.

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". 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

Presentation of the activities of WP15

News from European Federation of Corrosion (EFC)

The start of February 2011 has brought a change at the European Federation of Corrosion (EFC) with the appointment of a new Scientific Secretary/Public Relations officer.

Juliet Ippolito will now succeed Dr. Paul McIntyre who held this position for the past 14 years.

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 ?

EFC Working Party 15: Future objectives of the group

How to manage our working party meetings / Eurocorr sessions

· Eurocorr Sessions

✓Implements 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

EFC Working Party 15 plan work 2010-2012

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

. Sessions with other EFC WP at Eurocorr (2011 in Stockholm, 2012 in Istanbul, 2013 Estoril-Portugal) 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

Eurocorr 2011

Stockholm 5-8 September 2011

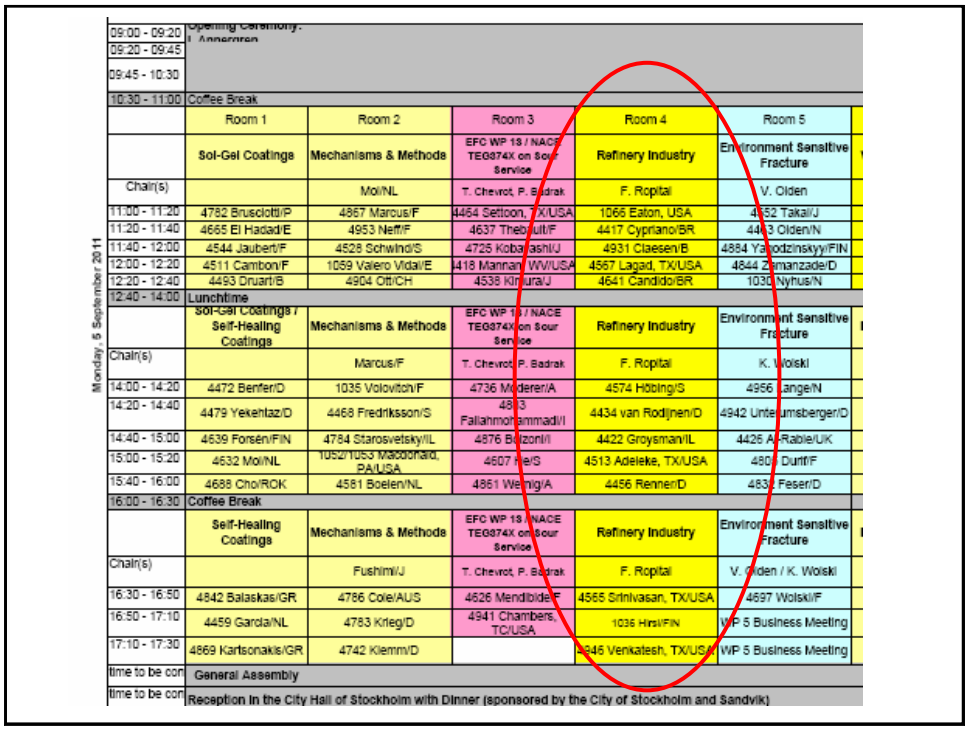
Authors will be informed by mid April and
the program will be on Website

Monday 5 September: Refinery corrosion session

Tuesday 6 September: Joint workshop WP 3 + 15 on the high temperature corrosion in the refinery and process industries

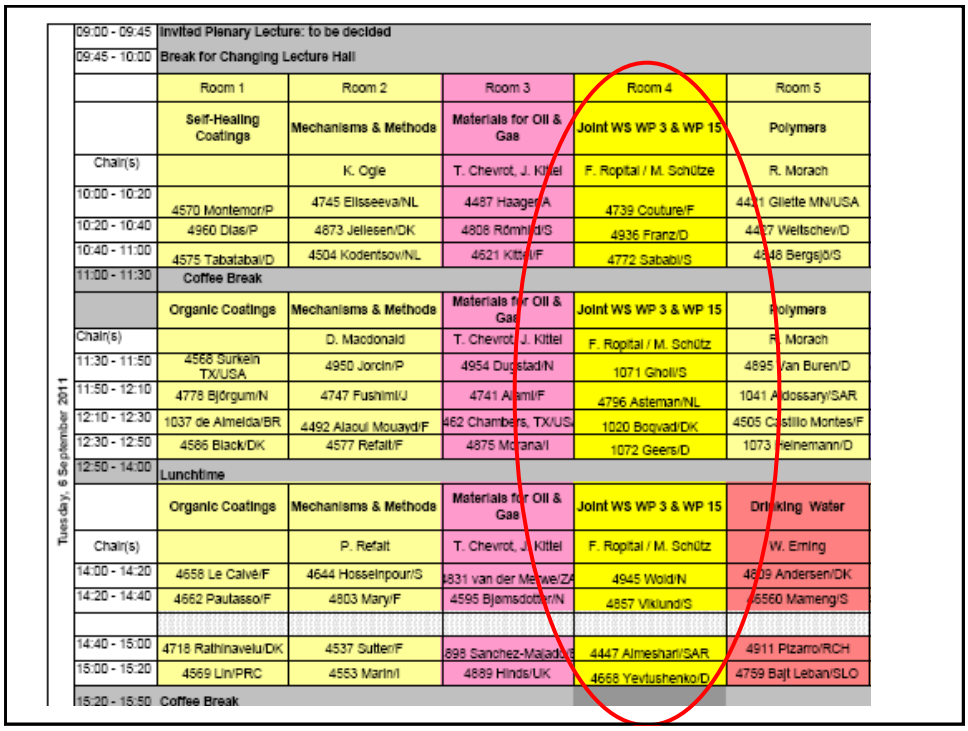
Wednesday 7 September: annual WP15 working party meeting

http://www.eurocorr.org



Monday, 5 September 2011

	Room 1	Room 2	Room 3	Room 4	Room 5
09:00 - 09:20	Opening Ceremony: L. Angenieren				
09:20 - 09:45					
09:45 - 10:30					
10:30 - 11:00	Coffee Break				
	Sol-Gel Coatings	Mechanisms & Methods	EFC WP 13 / NACE TEG374X on Sour Service	Refinery Industry	Environment Sensitive Fracture
Chair(s)		Mol/NL	T. Chevrot, P. Badrak	F. Ropital	V. Olden
11:00 - 11:20	4782 Brusciotti/P	4867 Marcus/F	4454 Settoon, TX/USA	1066 Eaton, USA	4552 Takal/J
11:20 - 11:40	4665 El Hadad/E	4953 Neff/F	4637 Thebault/F	4417 Cyprlano/BR	4463 Olden/N
11:40 - 12:00	4544 Jaubert/F	4528 Schwind/S	4725 Kobayashi/J	4931 Claesen/B	4884 Yagodzinskyy/FIN
12:00 - 12:20	4511 Cambon/F	1059 Valero Vidal/E	4418 Mannan, WV/USA	4567 Lagad, TX/USA	4844 Zamanzade/D
12:20 - 12:40	4493 Druart/B	4904 Ott/CH	4538 Kimura/J	4641 Candido/BR	1030 Nyhus/N
12:40 - 14:00	Lunchtime				
	Sol-Gel Coatings / Self-Healing Coatings	Mechanisms & Methods	EFC WP 13 / NACE TEG374X on Sour Service	Refinery Industry	Environment Sensitive Fracture
Chair(s)		Marcus/F	T. Chevrot, P. Badrak	F. Ropital	K. Wolski
14:00 - 14:20	4472 Benfer/D	1035 Volovitch/F	4736 Moderer/A	4574 Höbing/S	4956 Lange/N
14:20 - 14:40	4479 Yekehtaz/D	4468 Fredriksson/S	4813 Fallahmohammadi/I	4434 van Rodijnen/D	4942 Unterumsberger/D
14:40 - 15:00	4639 Forsén/FIN	4784 Starosvetsky/IL	4876 Bonzoni/I	4422 Groysman/IL	4426 Al-Rabie/UK
15:00 - 15:20	4632 Mol/NL	1052/1053 Macdonald, PA/USA	4607 He/S	4513 Adeleke, TX/USA	4801 Durif/F
15:40 - 16:00	4688 Cho/ROK	4581 Boelen/NL	4861 Wernig/A	4456 Renner/D	4833 Feser/D
16:00 - 16:30	Coffee Break				
	Self-Healing Coatings	Mechanisms & Methods	EFC WP 13 / NACE TEG374X on Sour Service	Refinery Industry	Environment Sensitive Fracture
Chair(s)		Fushimi/J	T. Chevrot, P. Badrak	F. Ropital	V. Olden / K. Wolski
16:30 - 16:50	4842 Balaskas/GR	4786 Cole/AUS	4626 Mendibide/F	4565 Srinivasan, TX/USA	4697 Wolski/F
16:50 - 17:10	4459 Garcia/NL	4783 Krieg/D	4941 Chambers, TC/USA	1036 Hirsi/FIN	WP 5 Business Meeting
17:10 - 17:30	4869 Kartsonakis/GR	4742 Klemm/D		4945 Venkatesh, TX/USA	WP 5 Business Meeting
time to be con	General Assembly				
time to be con	Reception in the City Hall of Stockholm with Dinner (sponsored by the City of Stockholm and Sandvik)				



Tuesday, 6 September 2011

	Room 1	Room 2	Room 3	Room 4	Room 5
09:00 - 09:45	Invited Plenary Lecture: to be decided				
09:45 - 10:00	Break for Changing Lecture Hall				
	Self-Healing Coatings	Mechanisms & Methods	Materials for Oil & Gas	Joint WS WP 3 & WP 15	Polymers
Chair(s)		K. Ogle	T. Chevrot, J. Kittel	F. Ropital / M. Schütze	R. Morach
10:00 - 10:20	4570 Montemor/P	4745 Elisseeva/NL	4487 Haagen/A	4739 Couture/F	4431 Gliette MN/USA
10:20 - 10:40	4960 Dias/P	4873 Jellesen/DK	4808 Römhild/S	4936 Franz/D	4437 Weltschev/D
10:40 - 11:00	4575 Tabatabai/D	4504 Kodentsov/NL	4621 Kittel/F	4772 Sababi/S	4848 Bergsjö/S
11:00 - 11:30	Coffee Break				
	Organic Coatings	Mechanisms & Methods	Materials for Oil & Gas	Joint WS WP 3 & WP 15	Polymers
Chair(s)		D. Macdonald	T. Chevrot, J. Kittel	F. Ropital / M. Schütz	R. Morach
11:30 - 11:50	4568 Surkein TX/USA	4950 Jorcin/P	4954 Dugstad/N	1071 Gholi/S	4895 Van Buren/D
11:50 - 12:10	4778 Björgum/N	4747 Fushimi/J	4741 Alami/F	4796 Asteman/NL	1041 Addossary/SAR
12:10 - 12:30	1037 de Almeida/BR	4492 Alaoui Mouayd/F	4462 Chambers, TX/USA	1020 Boqvad/DK	4505 Castillo Montes/F
12:30 - 12:50	4586 Black/DK	4577 Refait/F	4875 Mohana/I	1072 Geers/D	1073 Heinemann/D
12:50 - 14:00	Lunchtime				
	Organic Coatings	Mechanisms & Methods	Materials for Oil & Gas	Joint WS WP 3 & WP 15	Drinking Water
Chair(s)		P. Refait	T. Chevrot, J. Kittel	F. Ropital / M. Schütz	W. Erning
14:00 - 14:20	4656 Le Calvé/F	4644 Hosseinpour/S	4831 van der Merwe/ZA	4945 Wold/N	4809 Andersen/DK
14:20 - 14:40	4662 Pautasso/F	4803 Mary/F	4595 Bjørnsdottir/N	4857 Viklund/S	4560 Mameng/S
14:40 - 15:00	4718 Rathinavelu/DK	4537 Sutter/F	898 Sanchez-Malajada/S	4447 Almesharl/SAR	4911 Pizarro/RCH
15:00 - 15:20	4569 Lin/PRC	4553 Marin/I	4889 Hinds/UK	4668 Yevtushenko/D	4759 Bajt Leban/SLO
15:20 - 15:50	Coffee Break				

Information :
Future conferences related to refinery corrosion

•5-8 September 2011
EUROCORR 2011 Stockholm, Sweden Website: www.efcweb.org/Events

•20-24 November 2011
18th International Corrosion Congress (ICC) Perth, WA, Australia,

•18-22 March 2012
CORROSION 2012/NACE Salt Lake City Website: www.nace.org

•20-25 May 2012
High Temperature Corrosion and Protection of Materials - Les Embiez (F)

•9-13 September 2012
EUROCORR 2012 Istanbul Turkey Website: www.efcweb.org/Events

Appendix 3

Opportunity of duplex use in the amine units for CO_2 treatment

(F. Weisang-Hoinard, P. Vangeli Otokumpu)

Stainless in Amine treatments

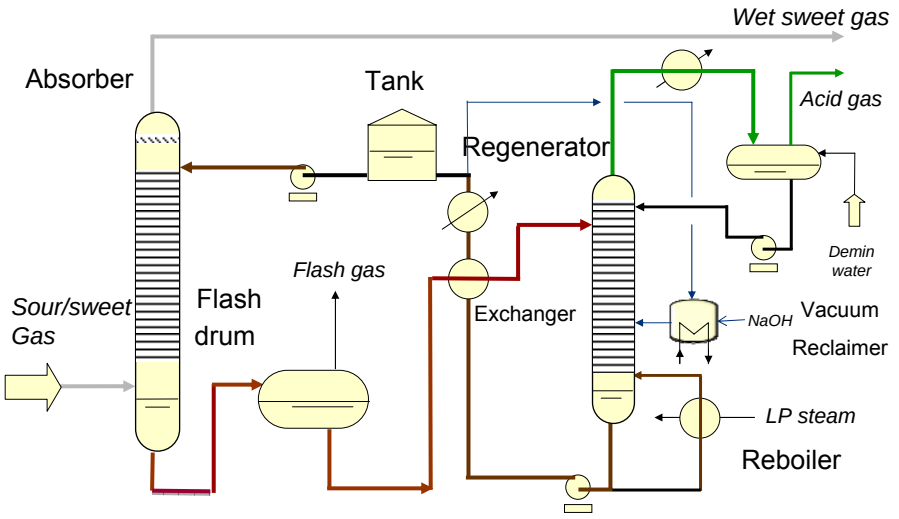
2011 April14 EFC(Paris)

www.outokumpu.com

Amine treatment : Gas treatment

- Use in refineries and CO_2 Capture
- CO_2& H_2S Absorption/ desorption
- Different types of Amines:
- MEA, DEA, MDEA & ….
- 2 wow in refineries:
  - Sour & sweet environments
  - H_2S from 30ppm to 50%
- CO_2 Capture/ low H_2S content

A Typical Scheme of an Amine Unit



Amine Unit Corrosion: Key Factors

- type of amine & concentration → MEA > DEA ≥ MDEA pH - Conductivity
- Amine loading → pH
- Temperature → Thermal activation
- Oxygen Entry → HSS
- Design → Velocity Turbulences

➔ Uniform weight loss corrosion
➔ Erosion – corrosion
➔ Amine stress corrosion cracking

Wet Acid Gas Corrosion: Key Factors

- Flue gas composition /Inadequate scrubbing → H_2S / CO_2 ratio/Condensation
- Inadequate design → Amine wall wetting/Condensation
- Too low gas flow rates → Water accumulation
- CO_2 content in treated gas → Condensation in the treated gas lines

➔ Uniform weight loss corrosion
➔ Hydrogen cracking (HIC, SSC...)

Main Corrosion Areas: Sweet Gas unit

Absorbeur:	
Bottom	Erosion/Corrosion
Head	Acid gas corrosion
Rich Amine lines:	
Degasing	Erosion/corrosion
Rich/lean amine HEX:	
	Stress corrosion cracking
Regenerator:	
Head	Erosion Corrosion
Acid gas outlet/condensor	wet acid gas corrosion
Bottom	uniform corrosion
Reboiler:	
HSS	Uniform corrosion
Lean Amine lines:	
HSS turbulence	Erosion/Corrosion

Corrosion Resistance applications

Upgrade Bottom of Absorber & Top of Regenerator with 304/316

Allows high intensity operation and debottlenecks

Are duplex grades an alternative to 300 serie?

Erosion/corrosion resistance
CO2/Cl- corrosion
HSS corrosion resistance
Costs

Chemical Composition and Properties

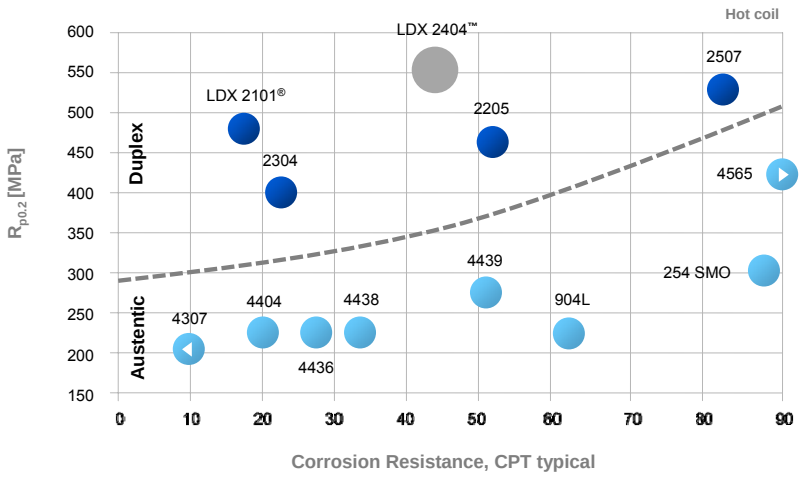
Typical chemical composition weight %

Outokumpu	EN	ASTM	Cr	Ni	Mo	N	PRE*	$R_{p0.2}$**	
LDX 2101®	1.4162	S32101	21.5	1.5	0.3	0.22	26	450***	Lean Duplex
2304	1.4362	S32304	23	4.8	0.3	0.10	26	400	Duplex
LDX 2404™	1.4662	-	24	3.6	1.6	0.27	33	480	Lean Duplex
2205	1.4462	S32205	22	5.7	3.1	0.17	35	460	Duplex
2507	1.4410	S32750	25	7	4	0.27	43	530	Super Duplex
4307	1.4307	304L	18.1	8.1	-	-	18	200	Austenitic
4404	1.4404	316L	17.2	10.1	2.1	-	24	220	Austenitic
4432	1.4432	316L	16.9	10.7	2.6	-	25	220	Austenitic
4439	1.4439	317LMN	17.3	13.7	4.1	-	33	310	Austenitic
904L	1.4539	N08904	20	25	4.3	-	34	220	Austenitic
254 SMO®	1.4547	S31254	20	18	6.1	0.20	43	300	Super Austenitic

* PRE = %Cr + 3.3x%Mo + 16x%N
** [MPa] Hot rolled plate, min values at 20ºC according to EN 10088
***Not yet in EN 10088, Rp0.2 according to ASTM A240

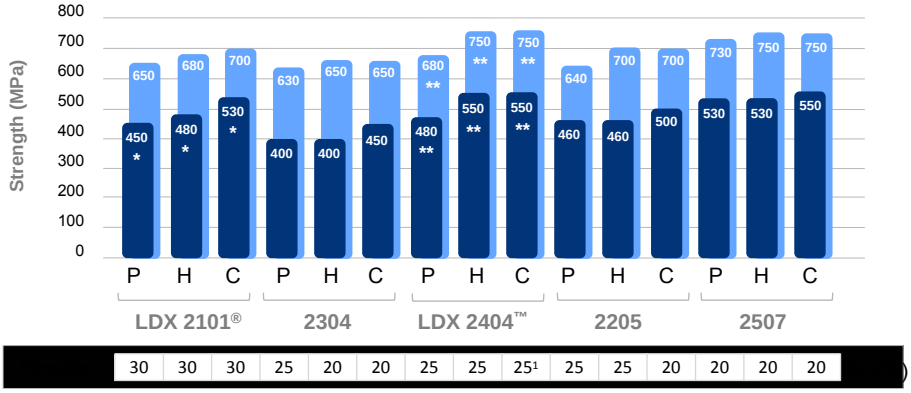
Positioning of Duplex grades

An excellent combination of high strength and corrosion resistance



Mechanical Properties

Data according to EN 10088



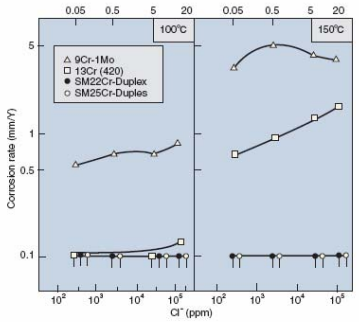
Proof strength, Rp0.2
Tensile strength, Rm

P = hot rolled plate and bar
H = hot rolled strip
C = cold rolled coil and strip, cold drawn bar

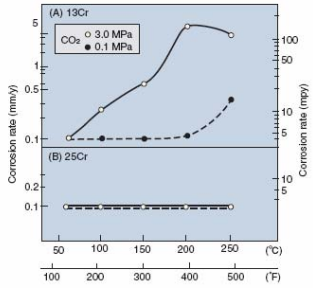
* Mechanical properties according to ASTM A240
** Mechanical properties according to internal standard AM 641.
1) Refers to A80 = 20% for gauges less than 3,0 mm

CO2 Corrosion

CO2 corrosion resistance depending of Cr level



Effect of Cl^- low concentration on the corrosion rate of Cr steels at 150°C in the autoclave.
(3.0MPa CO_2 at 25°C, test duration 96hr, flow velocity 2.5 m/s)



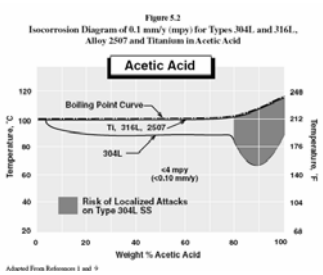
Effect of CO_2 partial pressure and temperature on corrosion rate of Cr steel
(5% NaCl, CO_2 3.0 and 0.1 MPa at 25°C, test duration 96hr, flow velocity 2.5 m/s)

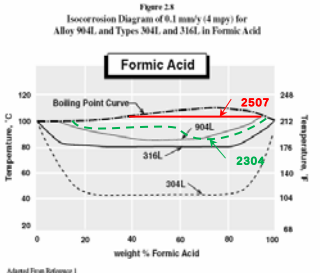
Ref: Sumitomo: SM-Serie Brochure 2010

Corrosion resistance to HSS

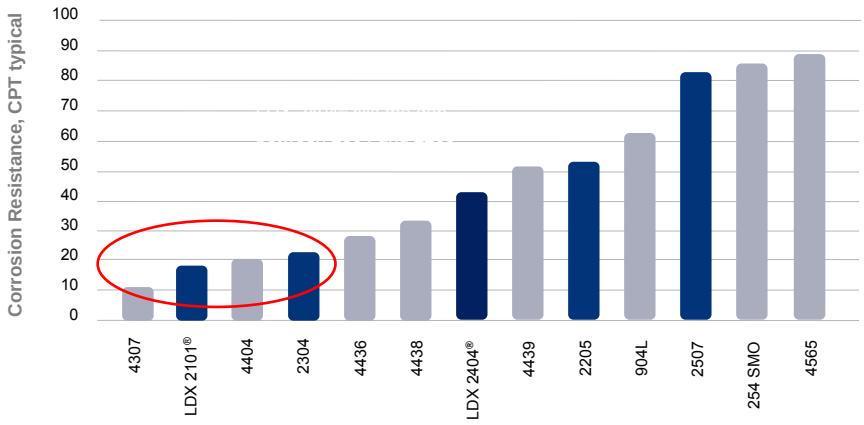
Amine degradation & heat Stable salts:
Formate, acetate, oxalate, Chloride, sulfate & phosphate in acidic conditions

Duplex has equal or better corrosion resistance as 304/316



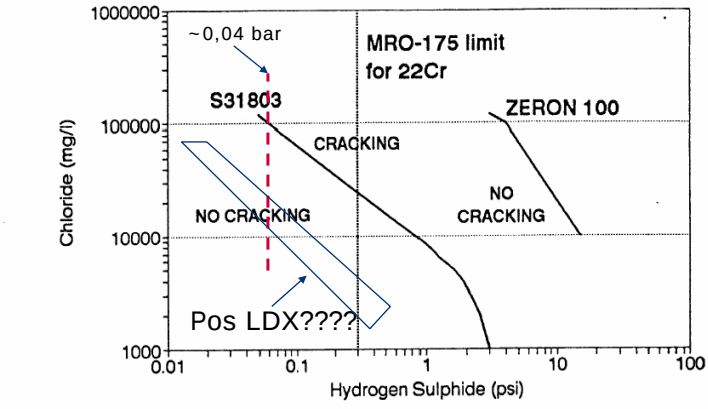


Corrosion resistance



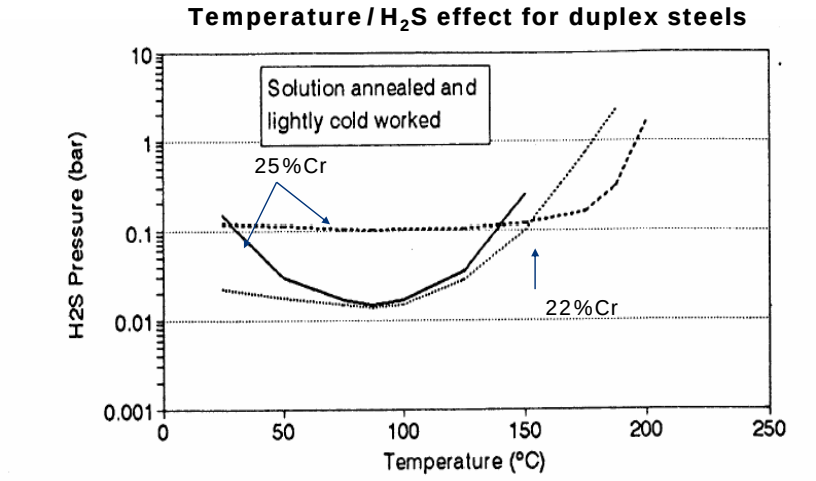
PRE	18	26	24	26	25	28	33	33	35	34	43	43	46

Use of Materials in Flowlines



Ref: Environmental cracking and embrittlement of duplex steel. R Francis TWI 1994

Effect of H2S/CO2 ratio



SSC tests

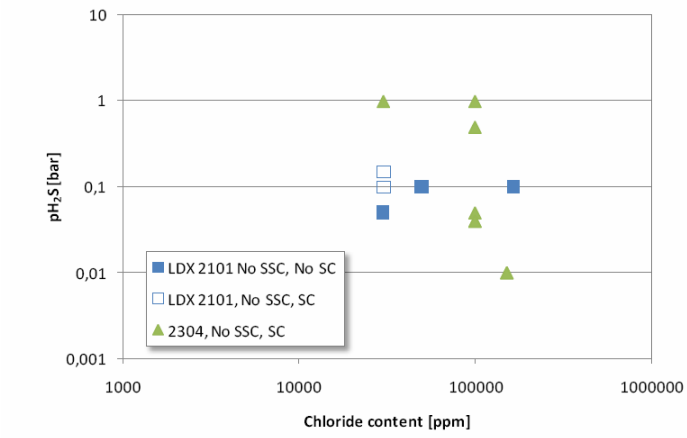
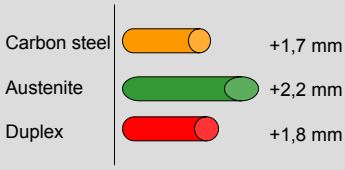


Figure 3. *Summary of SSC tests performed on LDX 2101® and 2304 [6,7,8]. SSC = sulphide stress cracking, SC = selective corrosion.*

Thermal expansion

		Thermal expansion *10^ -6/°C
Carbon steel	1.0345	12,0
304	1.4301	16,0
316	1.4401	16,0
317L	1.4438	16,0
904L	1.4539	15,8
254 SMO®	1.4547	16,5
LDX 2101®	1.4162	13,0
2205	1.4462	13,0
2507	1.4410	13,0

Temperature: -20°C to +50°C, 2 m panel



Stress Corrosion Cracking (SCC)

Chloride induced stress corrosion cracking in standard austenitic stainless steels - 4301, 4404

SCC is caused by a combination of:
- Corrosive environment
- Tensile stresses

Environments that can cause SCC:
- Chloride containing solutions (+H_2S)
- Hot alkaline solutions

+ Ni

904L
254 SMO®
4565

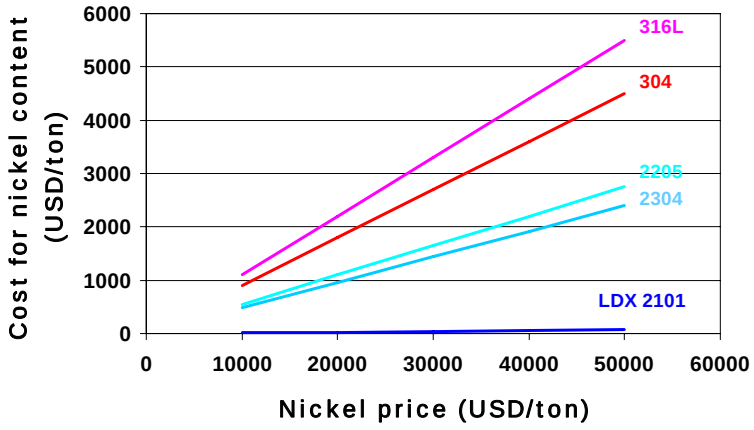
Austenitic stainless steels with high content of Ni and Mo

- Ni

LDX 2101®
2304
LDX 2404™
2205
2507

Duplex stainless steels

Alloying costs for the nickel content at different nickel price

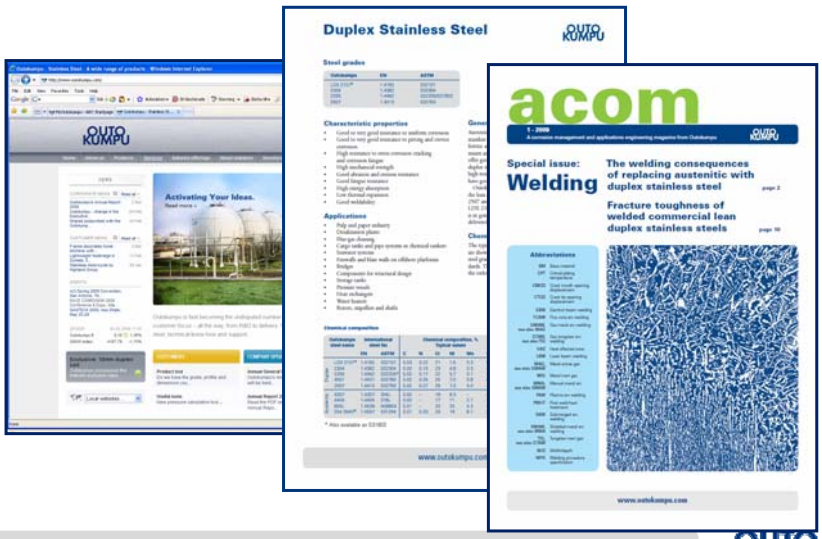


Duplex grades can be an alternative in CO2 Amine treatment

- Equal or higher **corrosion resistance**
- Minimal maintenance, longer lifetime
  - **life-cycle cost advantage!**
- Lower nickel content
  - **cost stability!**

→ **The Benefit is in the Cost!**

More information



Thank you!

Activating Your Ideas
Contact: francois.weisang-hoinard@outokumpu.com
www.outokumpu.com

Appendix 4

Corrosion and Removal form Refinery Streams

(H. De Bruyn, R. Mansfield Johnson Matthey Catalyst)

Mercury removal
Johnson Matthey Catalysts

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Catalysts

Mercury – A Refinery Issue ?

- Where is mercury containing crude oil found?
- Why remove mercury?
- Mercury Distribution
- PURASPEC$_{JM}$

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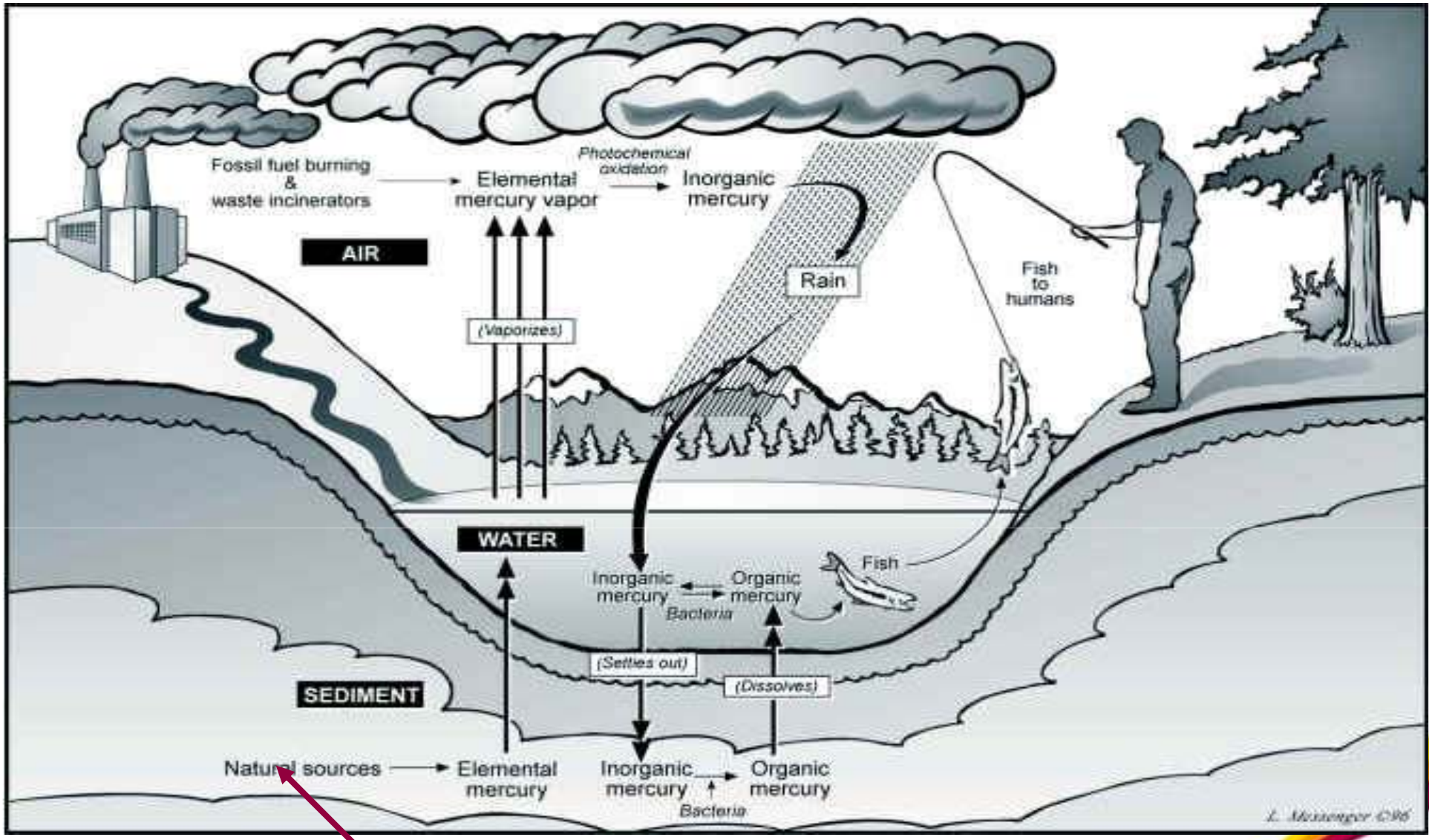

Including natural gas, crude oil, coal and other hydrocarbons

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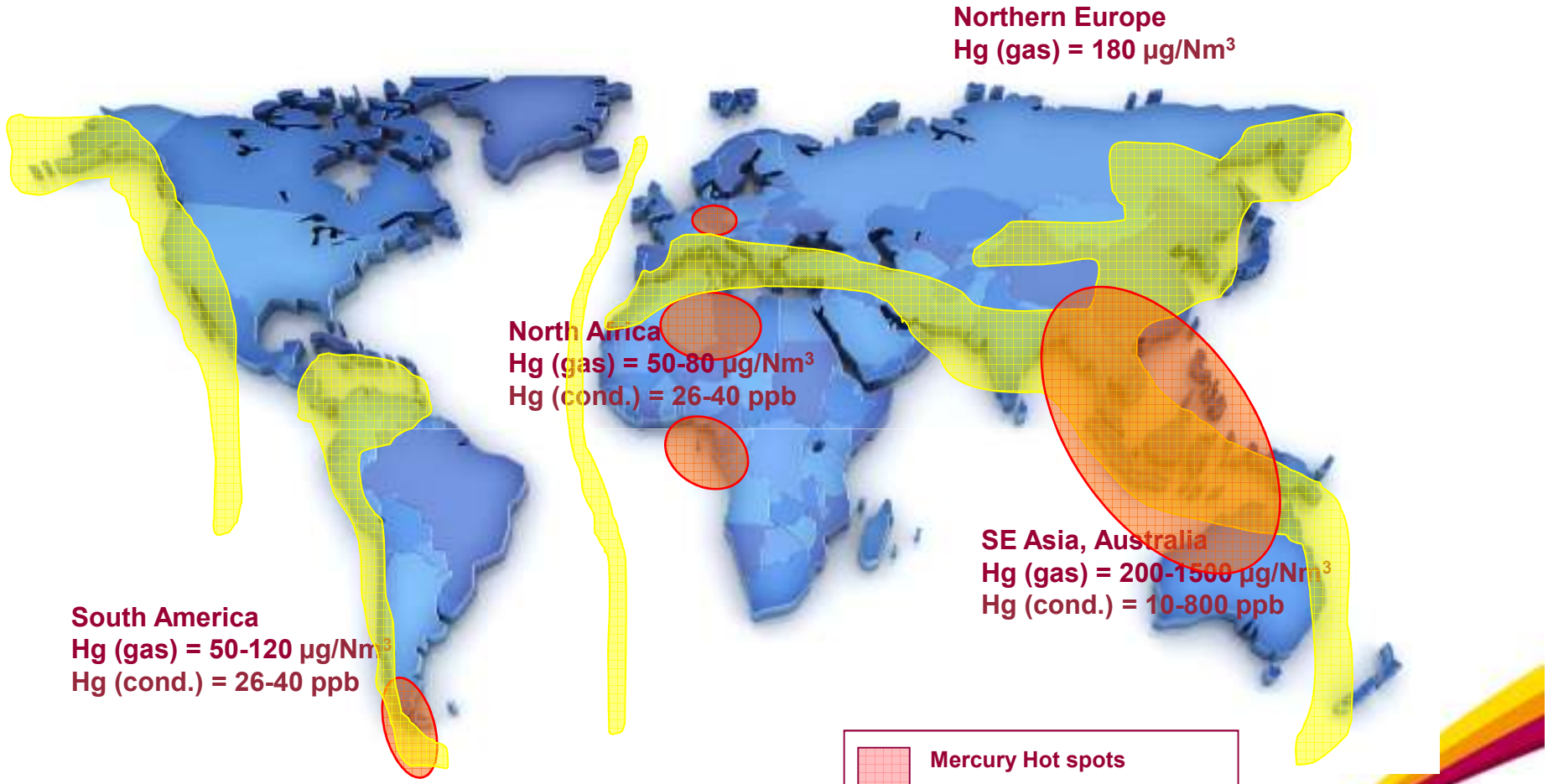
Mercury belt and global hot spots for mercury in oil and gas reserves



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Catalysts

Why Remove Mercury?

- Poisoning of catalysts in downstream plants
- Emission of mercury to atmosphere
- Exposure of workers to mercury
- Economical Issues
- Corrosion of process equipment

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Catalysts

Poisoning of downstream catalysts

- Pt and Pd are particularly prone to Hg poisoning
- React to form a 1:1 amalgam i.e. PtHg or PdHg that is stable at the low temperatures <150°C

  - **Ethylene Production**:
  - 2000 ppm have been found on the top of 0.05% palladium acetylene hydrogenation catalyst
  - Hg can be driven off by heating above 150 to 200 °C but this accelerates sintering and loss of active surface area.

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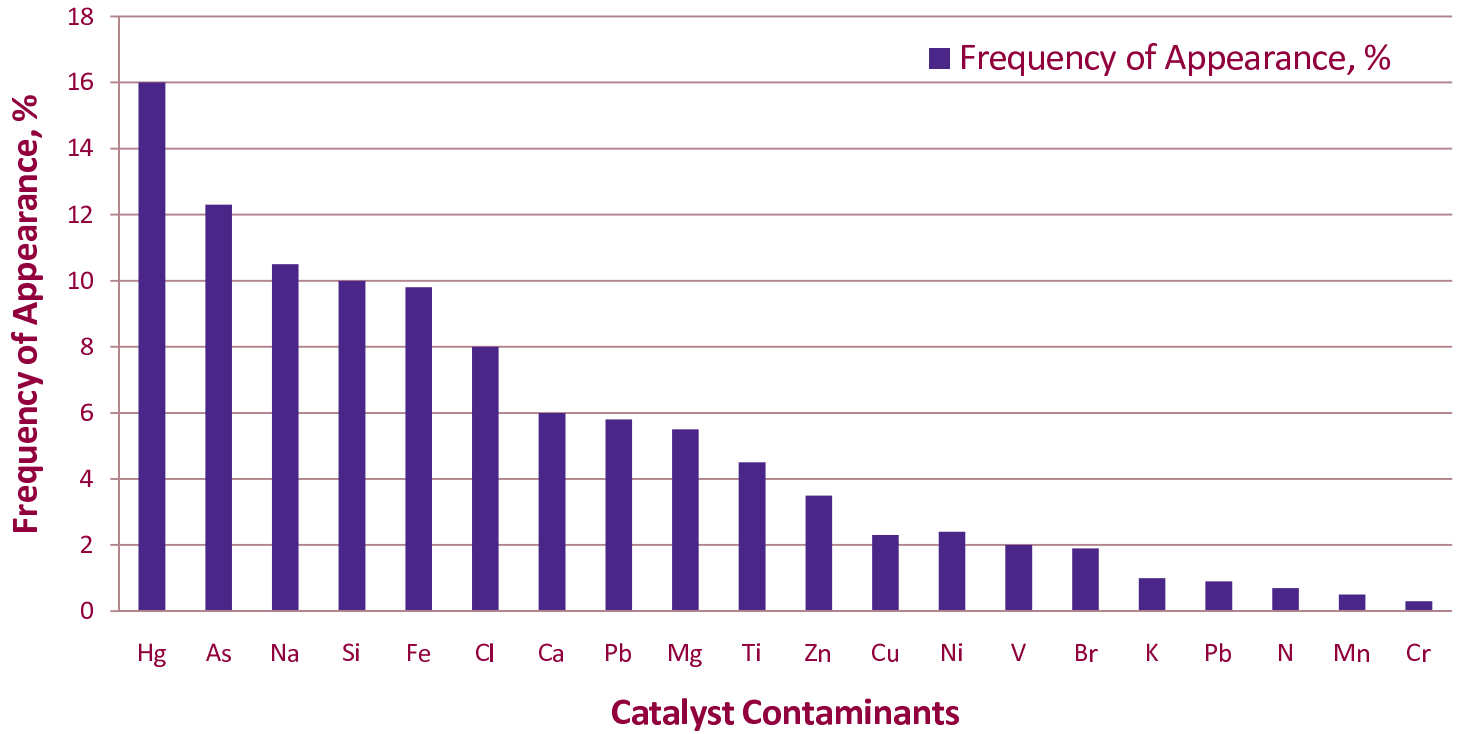
Catalysts

Selective Hydrogenation Catalyst Poisons



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Exposure of Workers

- Hg is known to be toxic
- Volatility combined with lack of smell makes Hg very dangerous
- In 2005, the European Union Scientific Committee on Operational Exposure Limits recommended a tightening Hg limits to
  - 0.02 mg/m3 for the 8 hour time weighted exposure (TWA) limit;
  - 0.01 mg/litre in blood samples.
- Adsorption/desorption on steel surfaces
  - Plant contaminated with Hg potentially pose significant risks to workers opening equipment up for maintenance and similar work
    - Inspection of refinery process equipment
    - Welding repairs
      - » Hg vapours are generated
  - Mercury can be absorbed through the skin, by inhalation and if swallowed through digestion.

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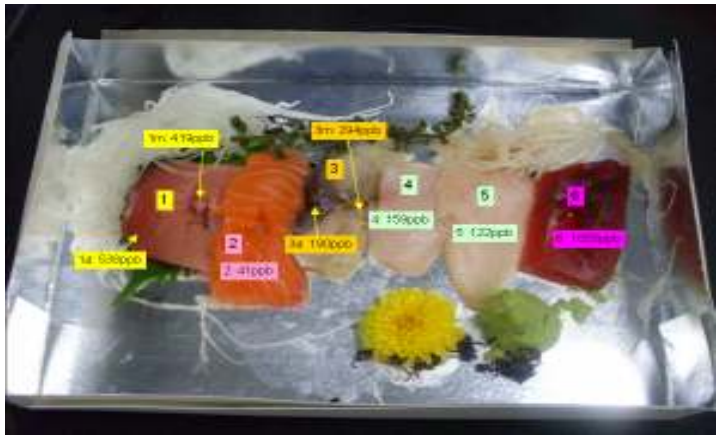
Emission of mercury to atmosphere

- Methyl mercury is a very toxic form of mercury found in aquatic systems where it concentrates in predatory fish
- United Nations Environmental Protection, UNEP
  - Examples of maximum allowed or recommended levels of mercury (Hg) in fish
- Maximum allowed/recommend levels in fish US:
  - 1.0 mg/kg (ppm)
  - US EPA reference dose: 0.1 μg methylHg/kg body weight per day
  - 60 kg person tolerable intake = 0.006 mg Hg/day
  - Tuna shown = 1.06 mg/kg
  - 5.7 grams of tuna would be equivalent to maximum tolerable level for 1 day



Analysis & photo of sashimi from Singapore restaurant courtesy Intertek

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Economical Issues

- Discounted crude available to refineries which have a mercury treatment strategy in place
- Asian Open-Spec Naphtha reveals potential value

  "Friday, Jun 26, 2009 :

  SINGAPORE (Dow Jones). Asian open-spec naphtha market participants said Friday they plan to test the mercury content of more grades to protect the interests of end-users.

  Japanese and South Korean petrochemical producers, which are major receivers of open-spec naphtha, recently voiced concerns over high mercury content, considered a contaminant that can damage plants".
- Increased regeneration/replacement of catalysts
- Disposal of contaminated equipment

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Corrosion LME (Liquid Metal Embrittlement)

- Liquid Metal Embrittlement (LME) is a form of environmental cracking: molten metals in contact with specific alloys
- Change in the fracture mode (ductile to brittle)
- Failure due to LME: instantaneous or it may take place after some time
- Presence of stress is necessary. The stresses may be tensile, shear or tortional in nature, but not compressive.
- Tensile stress contributes to crack propagation rates.
- Cracking under load can be extremely rapid such that cracks may pass through the wall thickness within seconds of contact with the molten metal.
- Very small quantities, even a few micrograms of the low melting point metal, are sufficient to cause LME.

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Corrosion LME (Liquid Metal Embrittlement)

- Liquid metal embrittlement can occur in a variety of alloy and molten metal combinations
- Well known combinations:
  - Aluminium & aluminium alloys – mercury
  - Austenitic stainless steel – zinc
  - Copper alloys – mercury
  - Alloy 400 (Monel) – mercury
  - High Strength Steels – Cadmium, Lead
- Different theories
  - Commonly accepted that the molten metal diffuses along grain boundaries
  - Weakens inter-atomic bonds
  - Cracking frequently develops along grain boundaries

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Corrosion – LME (liquid metal embrittlement)

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Corrosion LME (Liquid Metal Embrittlement)

- Hg can induce corrosion and can lead to failure of equipment items
- Hg only (no co-action of air, H_2O)
- Hg diffuses into grain boundaries
- Weakens structure such that cracks develop along boundaries - rapid
- LME affects:
  - Aluminium alloys
  - Copper-base alloys
  - Monel 400
  - Titanium alloys

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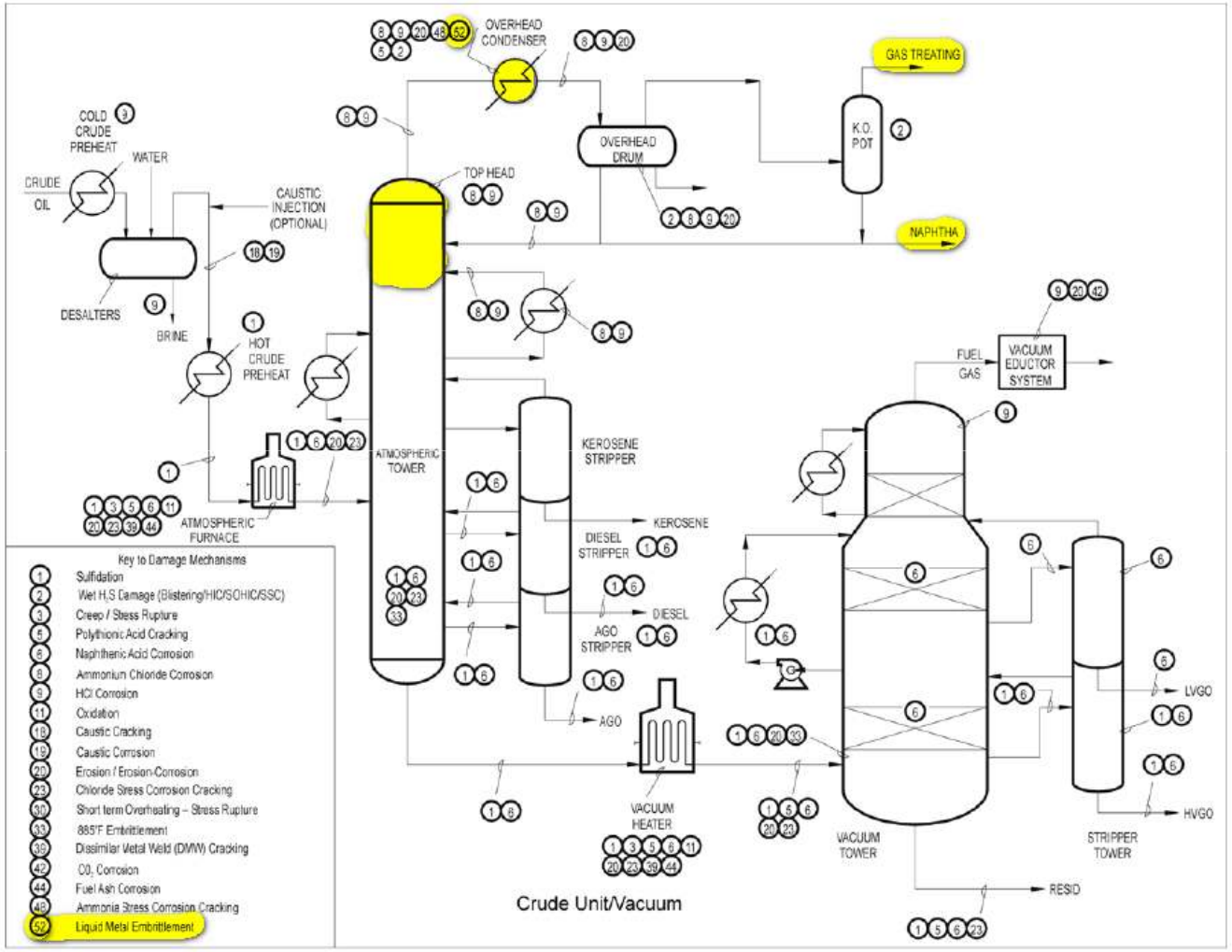
API 571 – Damage Mechanisms Affecting Fixed Equipment in the Refinery Industry



Crude Unit/Vacuum

API 571 indicates only the overhead condensers in a crude unit as a potential area for liquid metal embrittlement.

Hg will also affect Monel 400 in an atmospheric column top, as well as equipment in the gas treating units.

Hg can concentrate in naphtha streams, posing significant problems for downstream ethylene cracking units (cold separation section where aluminium is used extensively.

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Corrosion - Amalgam Corrosion

- Elemental Hg forms amalgams with various metals
  - Al, Cu, Brass, Zn, Cr, Fe and Ni
- Damage to the stable oxide layer required before amalgamation can occur
- Mechanism is self-sustaining when water and air is present
- Example:
  - Hg + Al = Hg(Al)
  - $Hg(Al) + 6H_2O = Al_2O_3.3H_2O + H_2 + Hg$

- Presence of amalgams in refinery process equipment my render the materials susceptible to other corrosion mechanisms (organic acids, sour water, etc.)

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Corrosion - Amalgam Corrosion

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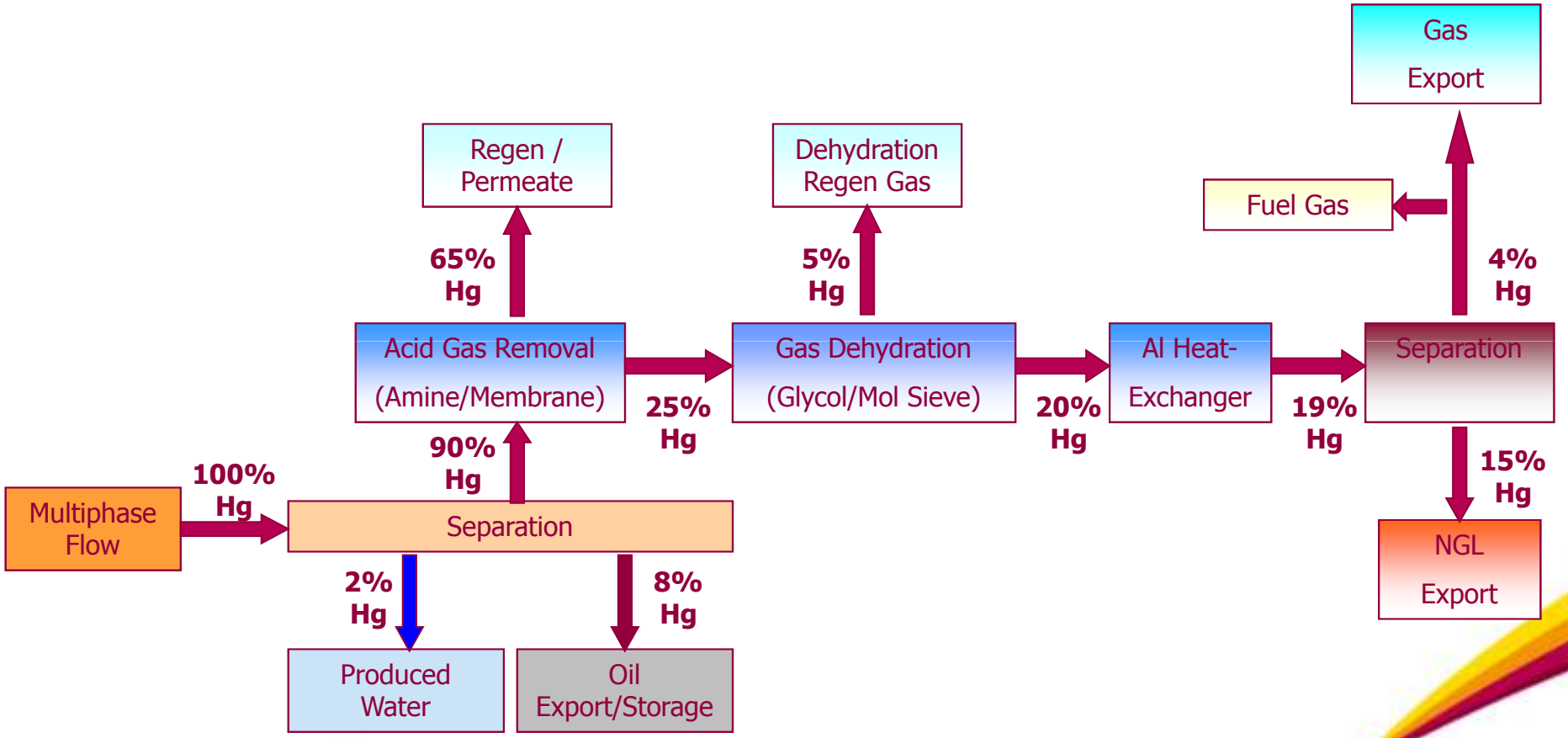
Mercury distribution



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Mercury Compounds in Refinery

- Elemental mercury (Hg^0)
  - Relatively volatile species, with a high vapour pressure, which will mainly transfer with the LPG & naphtha streams
- Ionic & Suspended Mercury
  - Mainly removed in desalting unit
  - Any residual suspended/particulate mercury which is found within lighter streams can be removed by physical separation
  - Any residual ionic/suspended Hg and “heavy” asphaltene Hg will exit with the bottom fractions from the atmospheric and vacuum units
    - Bound within petroleum coke
    - Can produce atmospheric emissions if used as boiler fuel
    - Recycle to FCC and transformed to elemental Hg
- Organo-mercury
  - Hydrotreaters will convert most species to elemental form (Hg^0)

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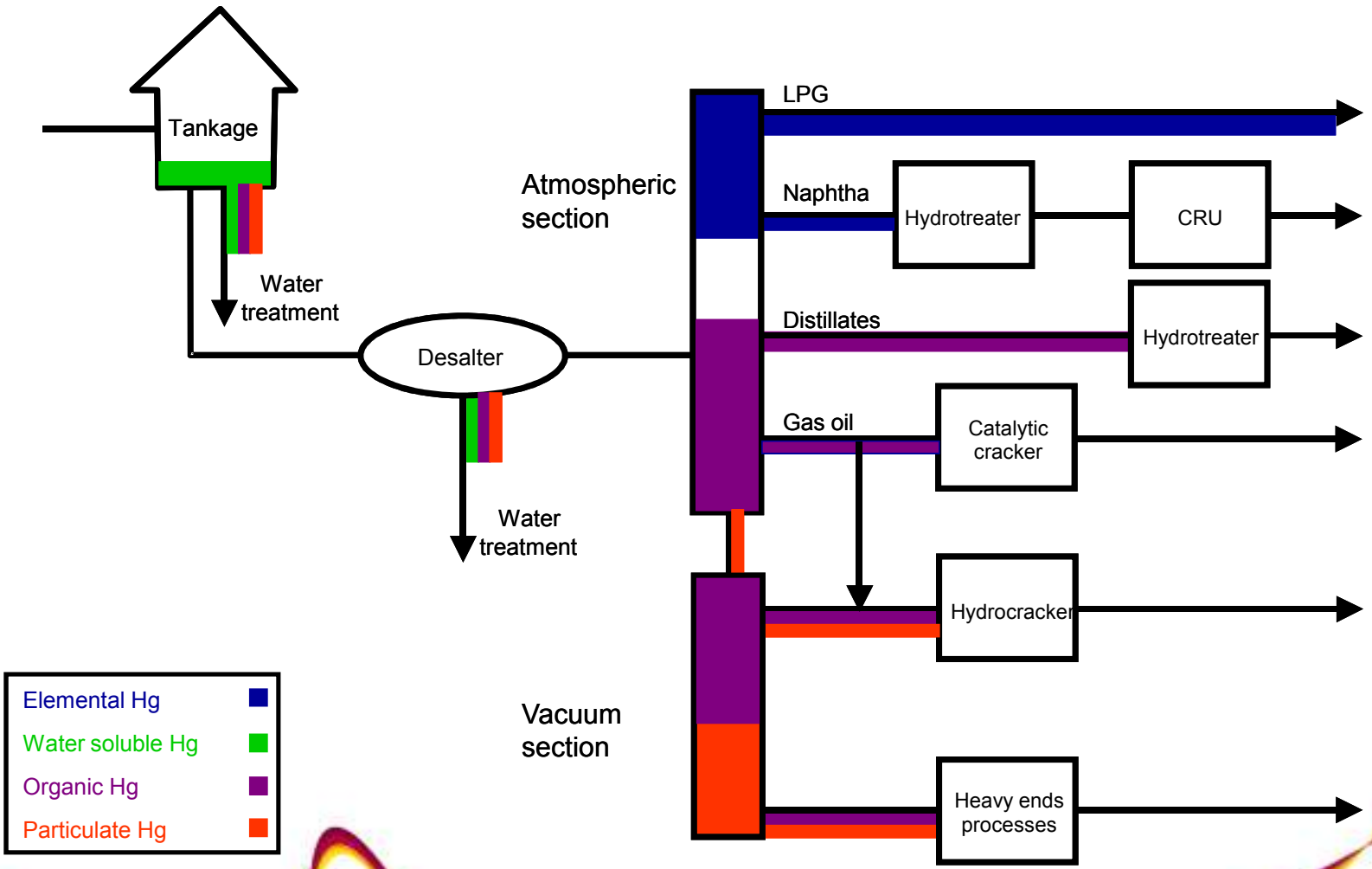
Mercury Transport in Refineries



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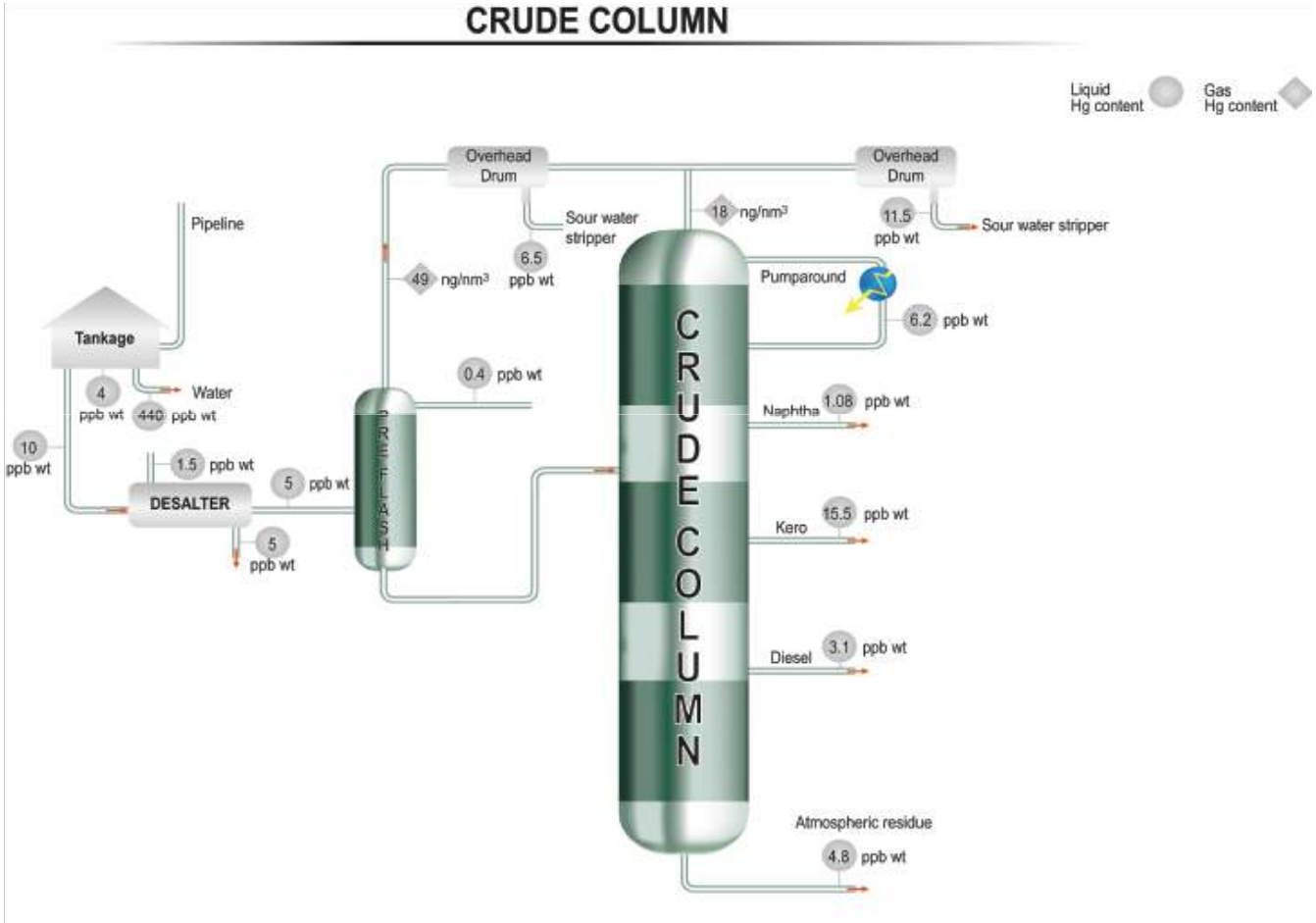
Mercury Distribution in Crude Column



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PURASPEC$_{JM}$ Developing Technology

- **Removal of Elemental Hg**
- Gas & liquid duties
- Sulphur removal by reaction with metal oxide

  $MO + H_2S \rightarrow MS + H_2O$
- Mercury removal by reaction with metal sulphide

  $MS + Hg \rightarrow M_2S + HgS$

- PURASPEC chemically reacts with the sulphur &/or mercury therefore become bound in the structure of the absorbent pellet.
- Sulphur & Mercury cannot be liberated into the process

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PURASPEC$_{JM}$ Developing Technology

- For over 15 years PURASPEC has provided the optimal solution to removal of Elemental Hg
- Hg can be present in other forms, and if there is an aqueous phase associated with the Hg containing stream, then the presence of Hg salts is potentially within it
- Development product currently being tested for Hg removal from water

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Advantages of PURASPEC Processes

- Simple fixed bed technology
- Selective - precise removal
- Flexible & robust
- Can be used on liquids
- No utilities required
- No operator involvement
- No effluents or emissions
- Cradle to Grave Service

Puraspec℠

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Side-stream Trials
Process Design
Laboratory Tests
Loading & Commissioning
Mercury Surveys
Puracare JM
Operations Support
New Product Development
Bed Change-out
Sample Analysis
Reprocessing
Puraspec JM
JM
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Catalysts

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Appendix 5

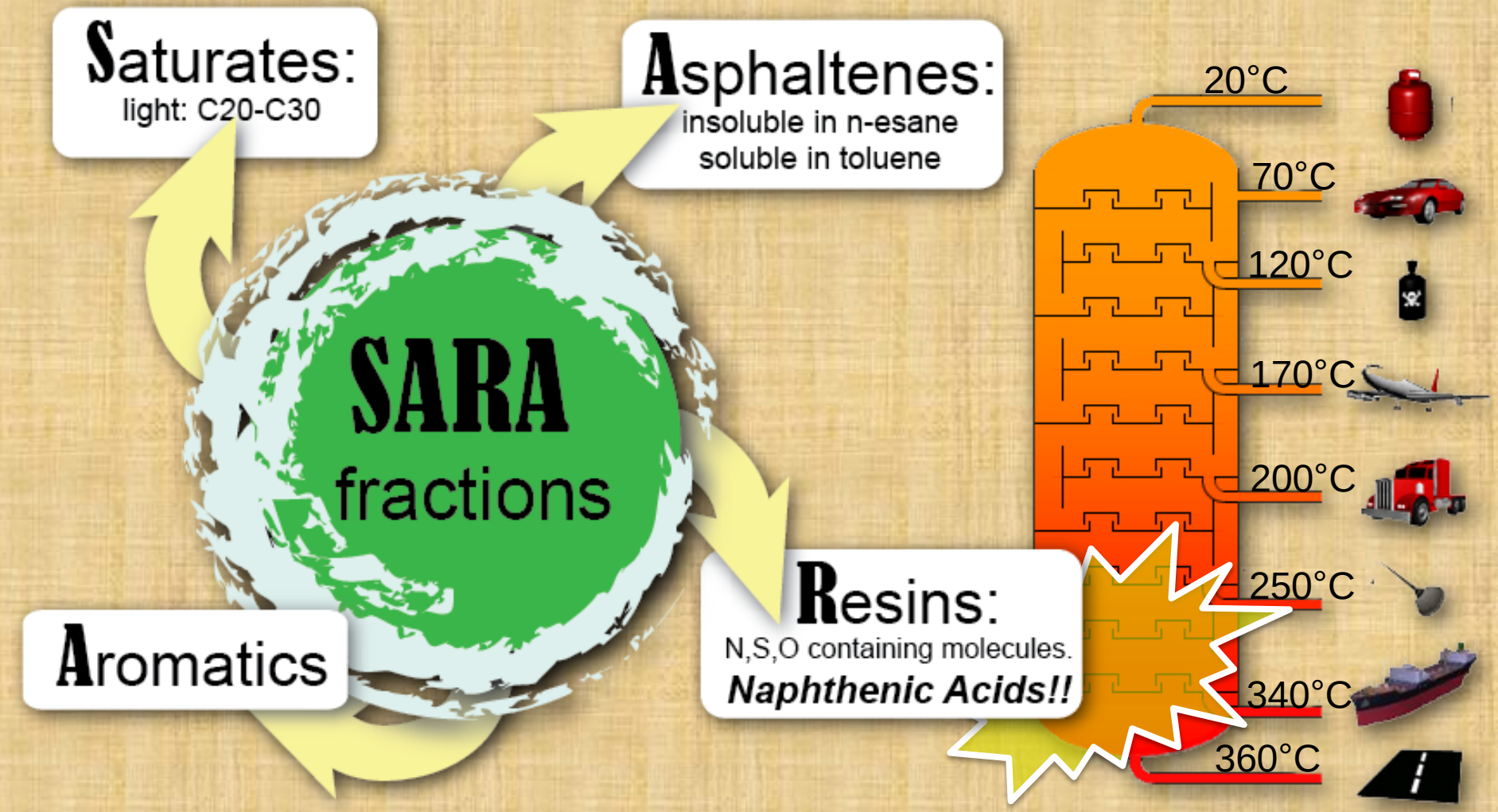
Naphthenic acid corrosion: an analytical approach (E. Guerrini, S. Trasatti, Milan University)

Naphtenic Acids Corrosion: an analytical approach

Edoardo Guerrini[1], Stefano Trasatti[1], Cristina Flego[2], Luciano Montanari[2] Marino Tolomio[3]

[1] University of Milan, Milano, Italy
[2] eni, r&m, Research Centre, San Donato Milanese, Italy
[3] Venezia Tecnologie, Porto Marghera, Venice, Italy

Crudes composition



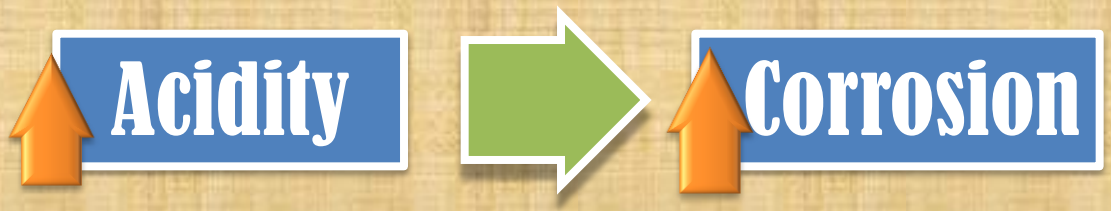
Separation by polarity classes or by distillation

Total Acidity: *Is there a correlation between Acidity and Corrosion?*

NO CORRELATION

(almost not sure)

…but



NOT only Acidity, but many more parameters

Analytical approach

The present work is part of a research project on Crudes Aggressiveness of

venezia tecnologie

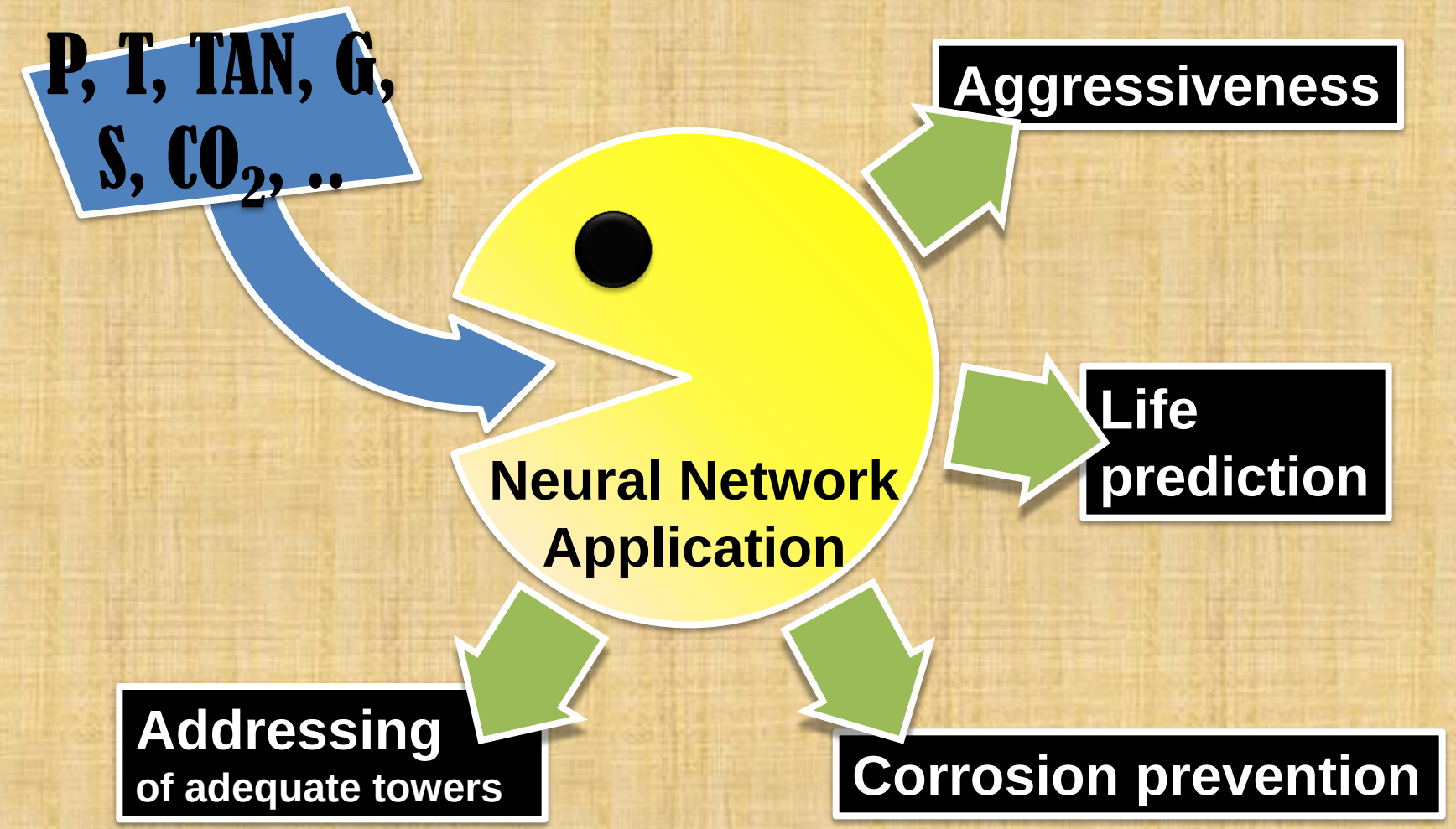
Parameters: *A starting point*

1. **TAN: Total Acid Number**
   ASTM D974 regulated implementation.
2. **Conductance (G)**
   G vs. T, D_0
3. **Naphthenic Acids fractions**

Distillation

Salification

How to weight parameters?



… too many tasks?

START: Find parameters within a reproducible environment

MIX: build-up of a mixture of NA in a non corrosive matrix

Chemical	Type	TAN
Diesel	matrix	0,019
SynthOil	matrix	0,23
CNA	NA	213,8
FLUKA	NA	220,4
DNA	NA	221,9

Synthetic Mix manipulation

re-Separation of NA

- yield evaluation
- application to Crudes

Fractionation

- praticability
- Total and single yield

Synthetic vs. natural Crudes

-Separation of NA into fractions

TAN: ASTM D974

Kind: colorimetric titration

Solvent: 50% toluene; 49,5% isopropanol; 0,5% water

Titrant: KOH 0,1M in isopropanol

Problems: CO_2, natural colour.

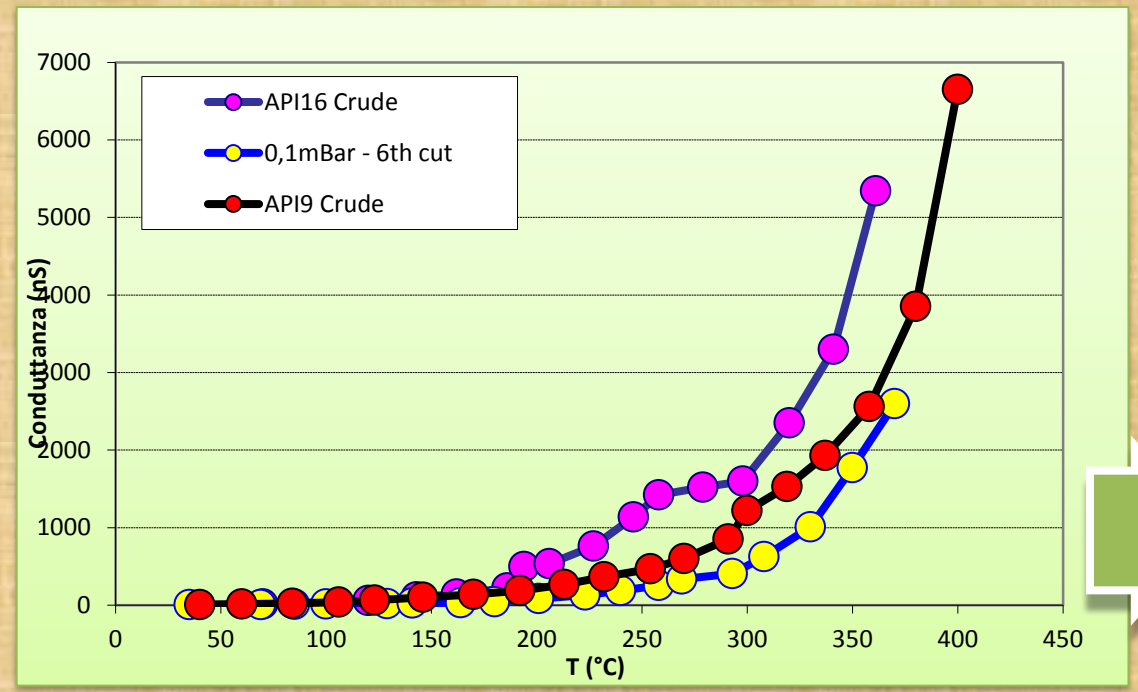
±5%

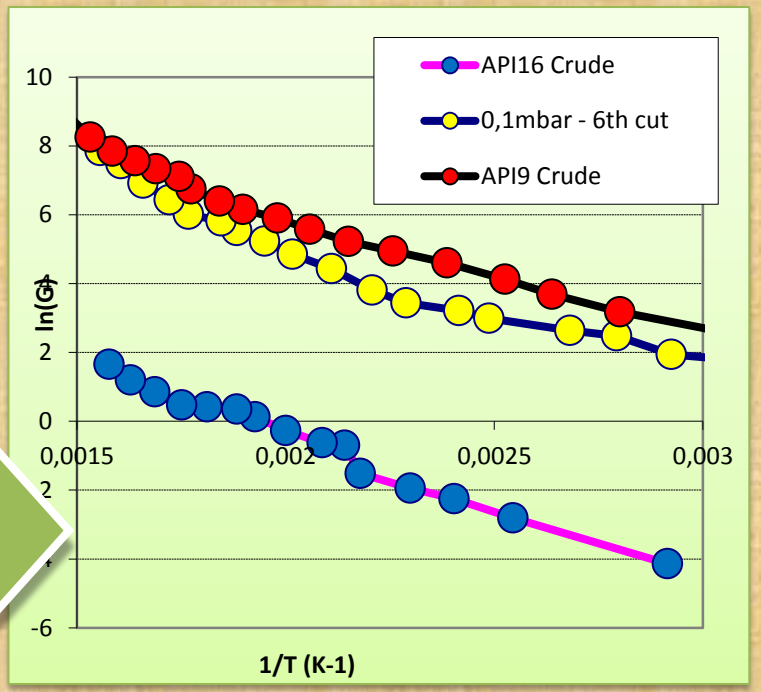
Chemicals	TAN
Isopropanol	**0,064**
Toluene	**0,051**
Solvent (blank)	**0,055**

Chemical	TAN
Diesel	0,019
SynthOil	0,23
CNA	**213,8**
FLUKA	**220,4**
DNA	**221,9**

Use of ASTM D664?: potentiometric, more precise and accurate

Conductance (G)



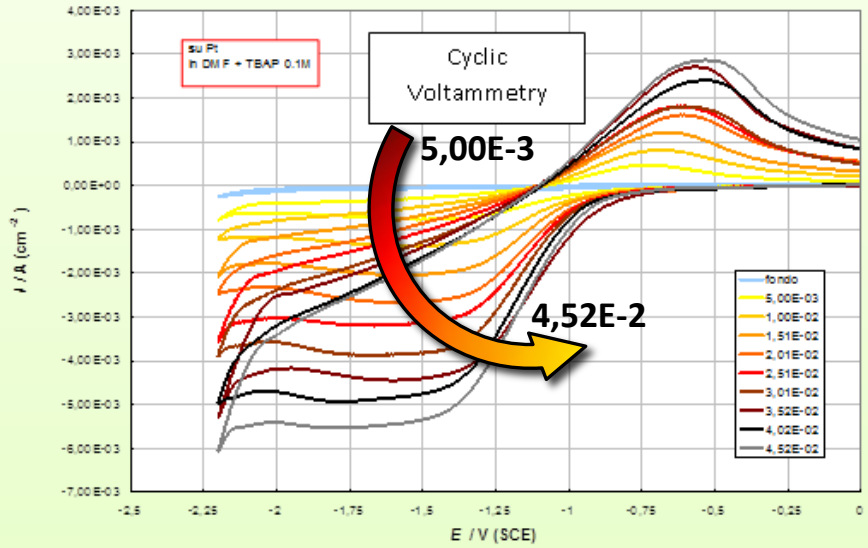


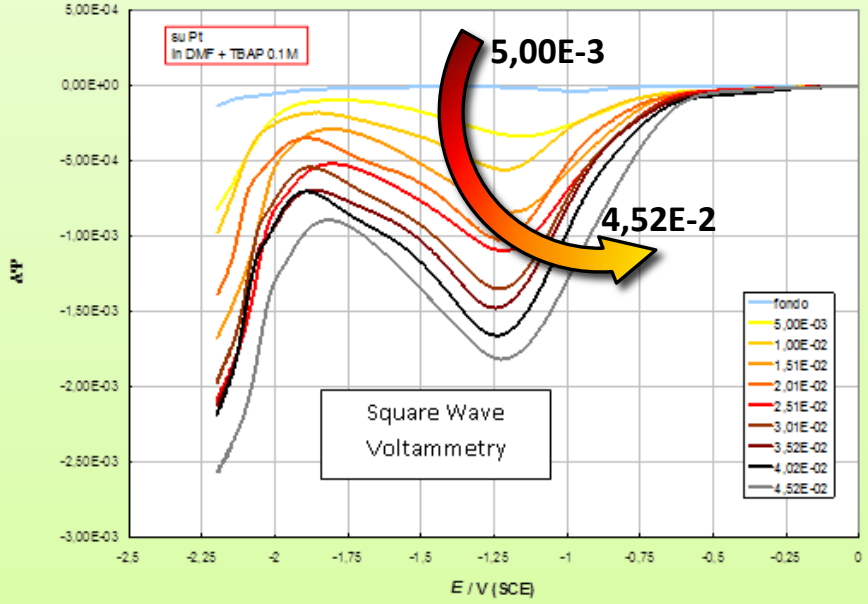
polar groups (NA)
salts
temperature

organic chains
chelants

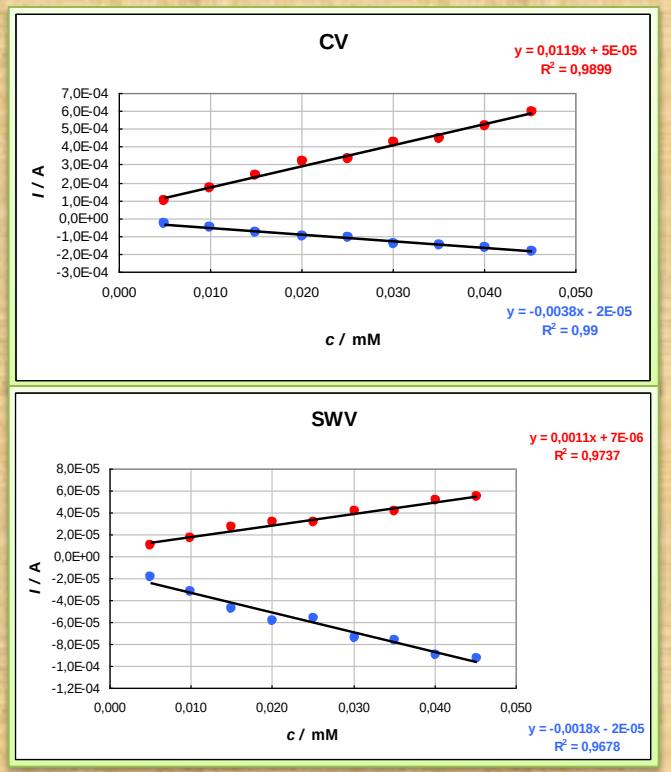
Overall evaluation of chemicals

Voltammetry





! Peak potentials change

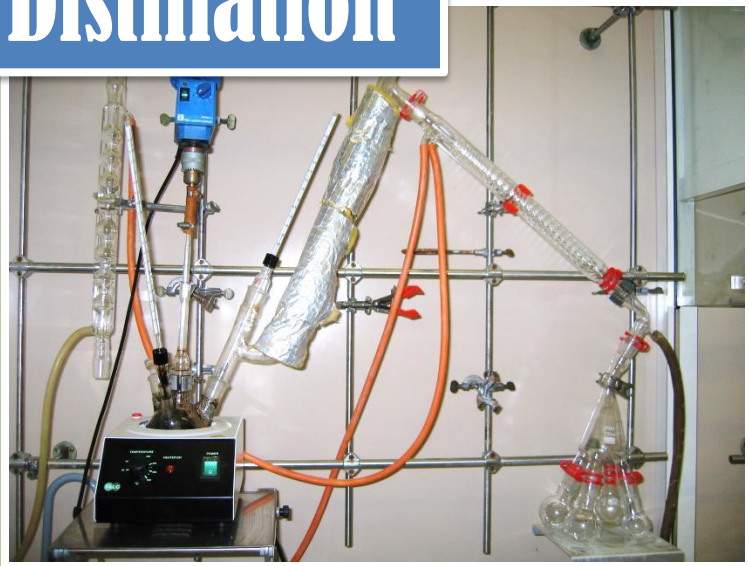


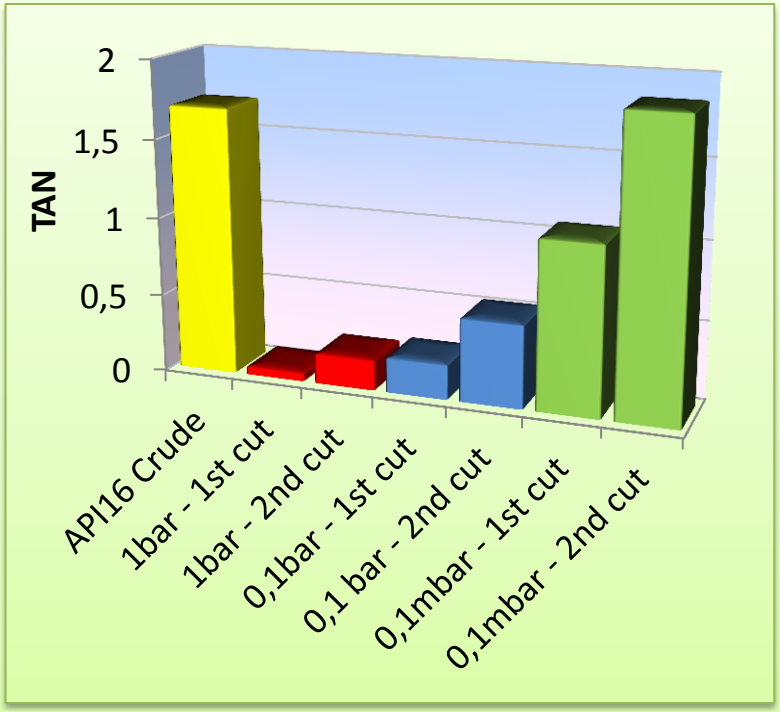
! NA are electro-active

! Straight calibration line

NA fractions: *How to obtain them*

Distillation





! cuts have lower TAN than crude

! NA are not separated by distillation

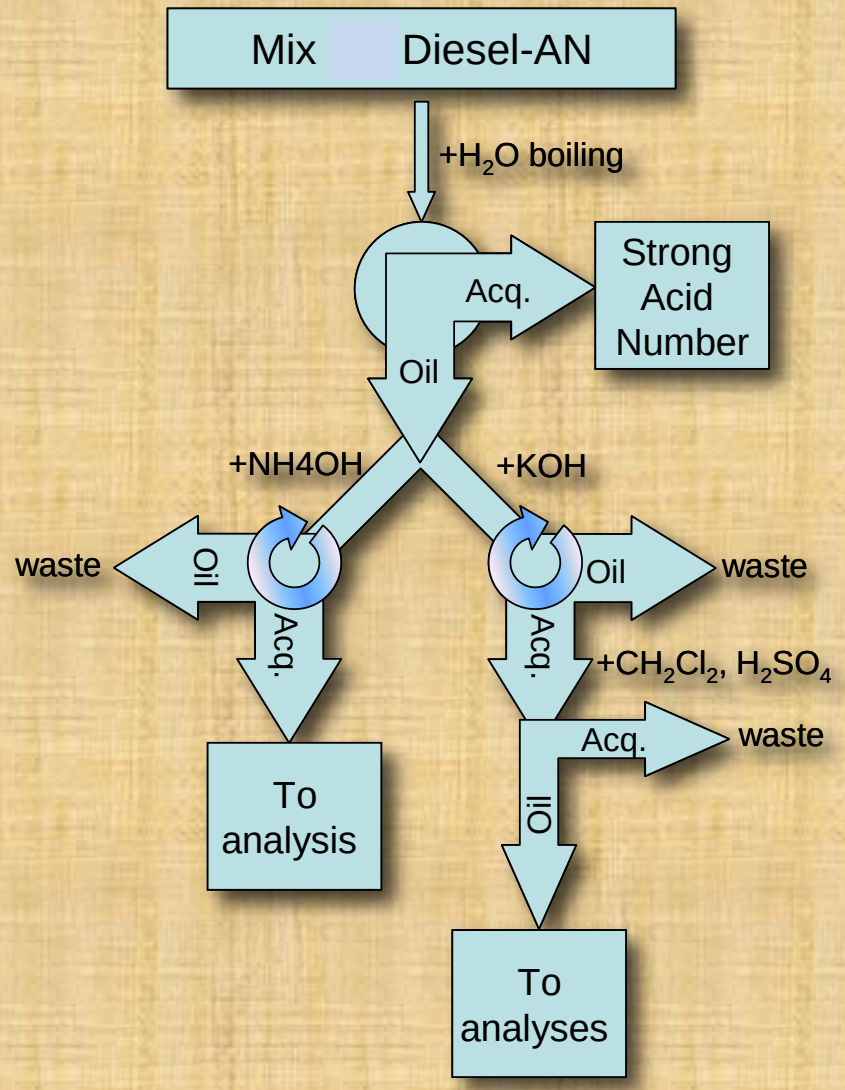
Extraction

$$AH_{(OIL)} \underset{+H^+}{\overset{+KOH}{\rightleftharpoons}} A^-_{(water)}$$

NA fractions:

TOTAL extraction feasibility

Upon 100% molar add of KOH



MIX:	Yield (%w)
Diesel + DNA	**~ 96**
Diesel + CNA (**centrifuge**)	**~ 108%**
Diesel + CNA	**73%**
SynthOil+ DNA	**84%**
SynthOil+DNA (centrifuge)	**87%**
SynthOil+ CNA (**centrifuge**)	**101%**

- ! NA extractions are possible
- ! More complex mixtures give less NA extraction
- ! Centrifuge step needed
- ! Co-extraction of organics

NA fractions: *PARTIAL extraction feasibility*

Upon ***3*** consecutive 33mol% additions of KOH

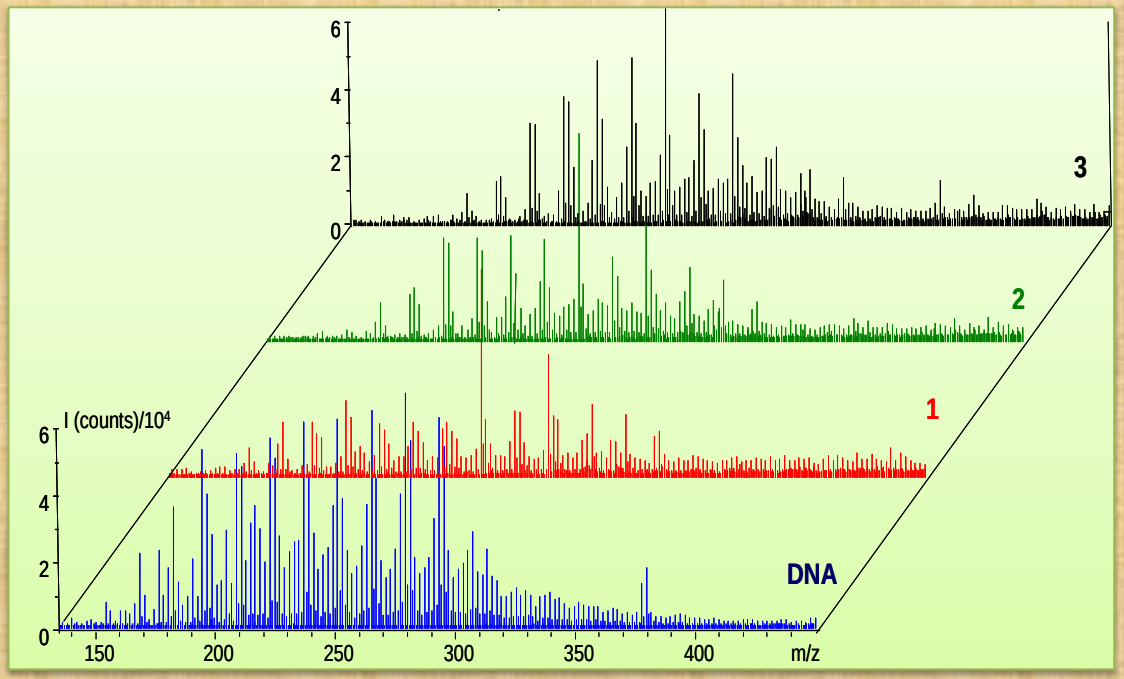
Increasing K_{acid} of N.A.s

Fraction 1: **33% KOH**

Fraction 2: **33% KOH**

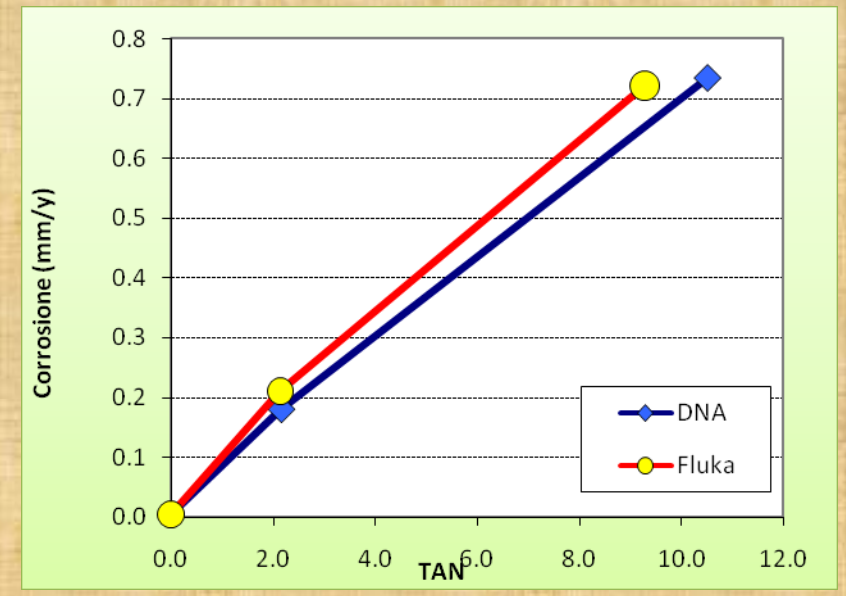
Fraction 3: **33% KOH**

fraction	Yield %	TAN
1	20	**226.9**
2	52.5	**200.1**
3	25.1	**176.7**
Total:	**97.6**	

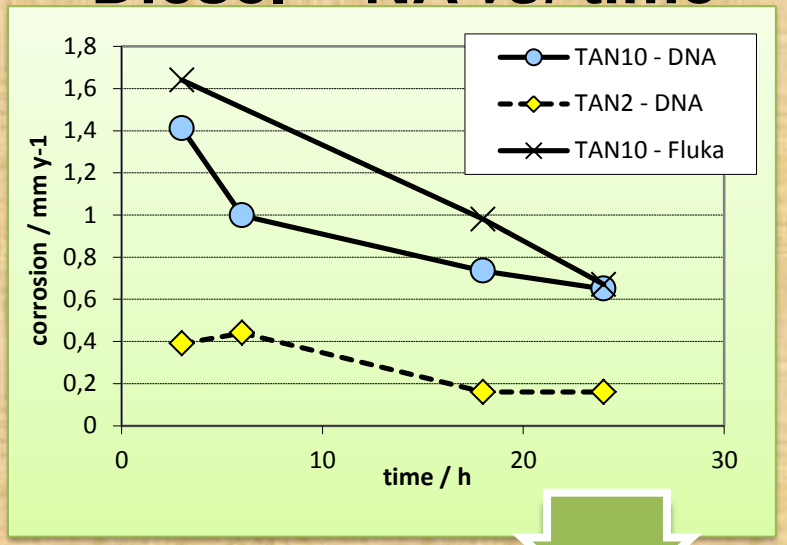


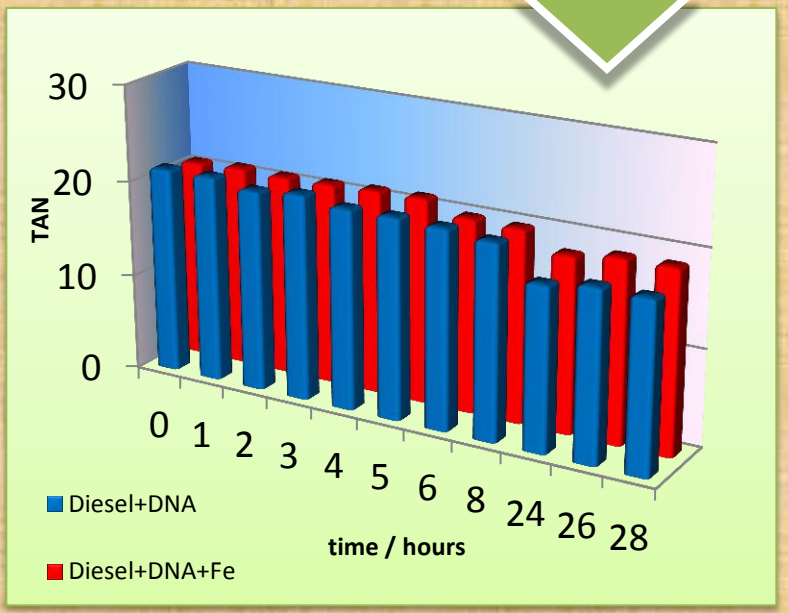
Corrosion tests

Diesel + NA *vs.* TAN



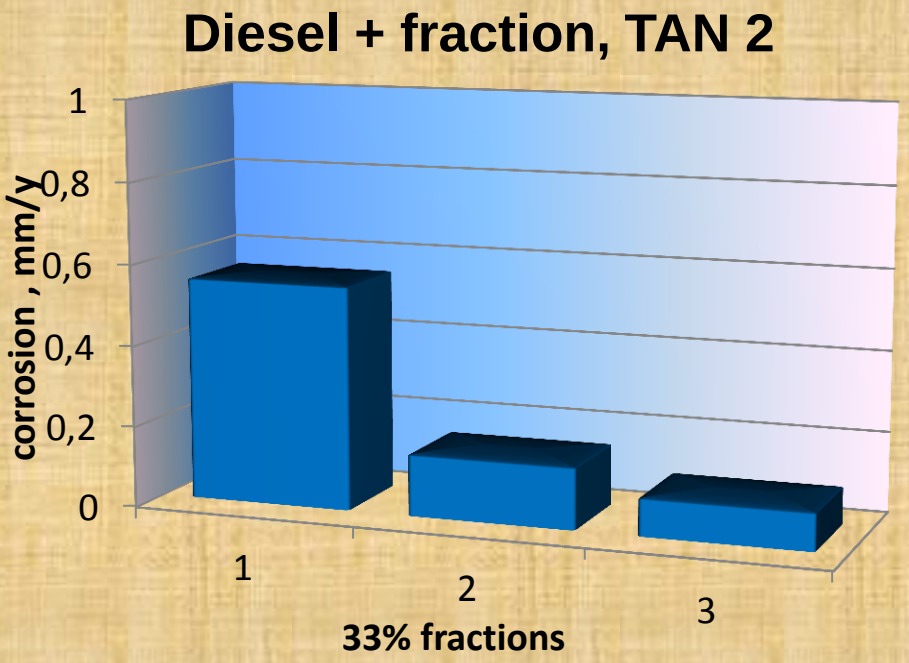
Diesel + NA *vs.* time

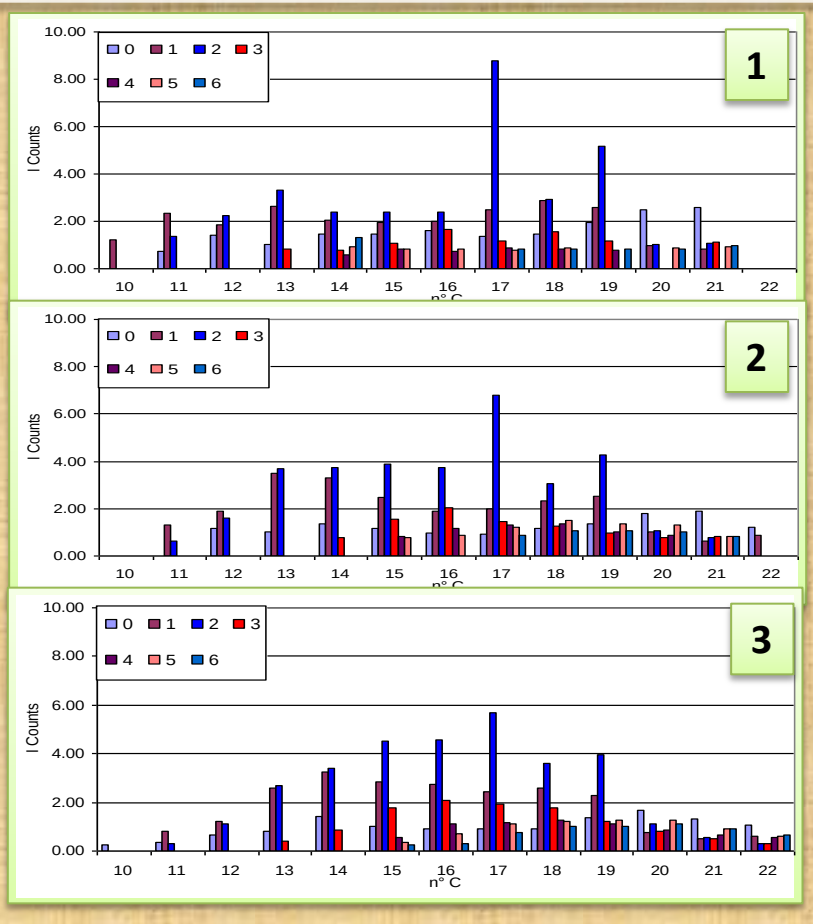




- ! NA differentiation
- ! Short-time differentiation
- ! TAN doesn't vary
- ! High T → SynthOil
- ! O_2 problems

Corrosion tests *On extraction fractions*





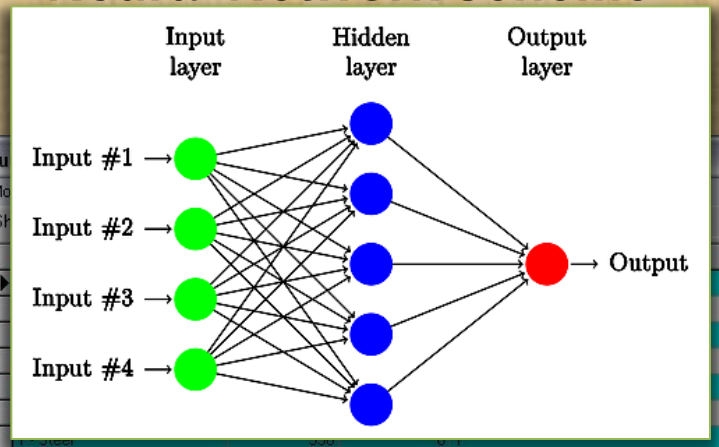
! The first extraction gives more aggressive acids (<C and <z)

! Second fraction has more acids with 1 or 2 rings

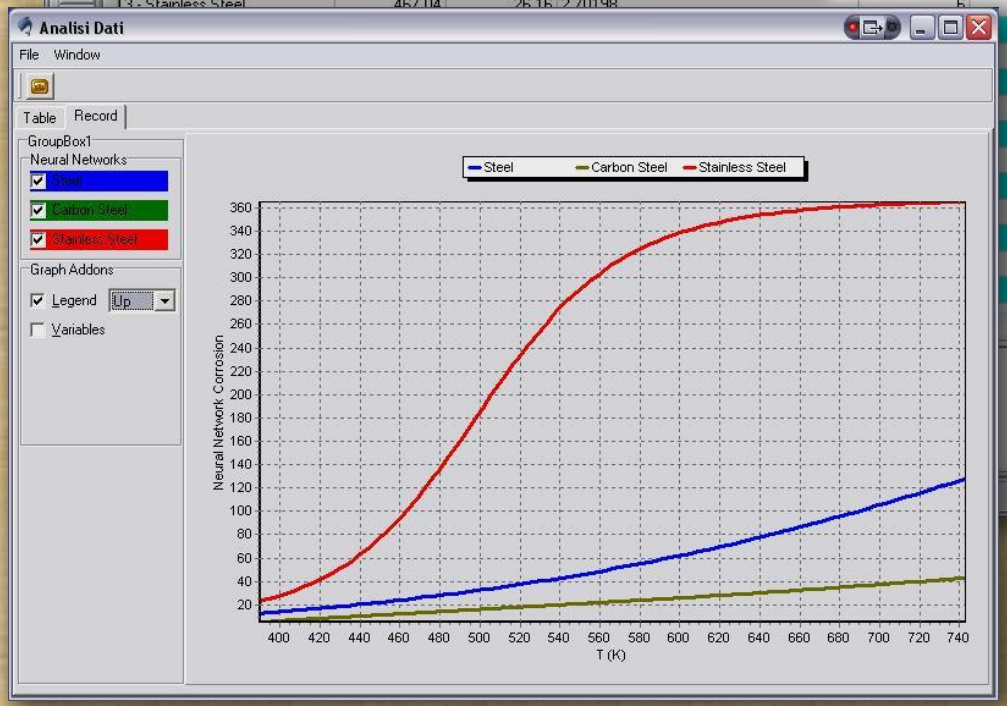
! Third fraction is less aggressive (>C and >z)

Neural Networks: *Development of an application*

Neural Network scheme



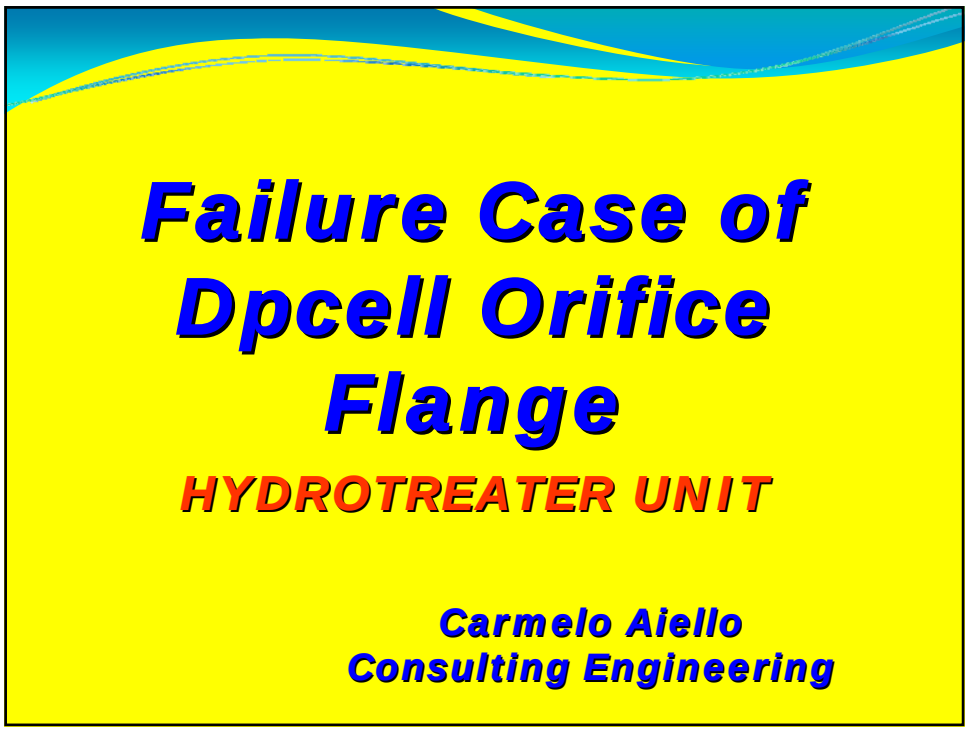
Input	units	Min	Max
Temperature	F	390	750
Pressure	bar	1	69
Flow Rate	m/s	0,09	7
Time	h	6	60
TAN	mg KOH/g	0,5	47
S	% weight	0,1	4,1
Cr	% weight	0,1	18
Mo	% weight	0,1	4,4



Appendix 6

Failure case of Dpcell Orifice flange for Hydrotreater unit

(C. Aiello)


Failure Case of Dpcell Orifice Flange
HYDROTREATER UNIT
Carmelo Aiello
Consulting Engineering


As you know the majority of accidents in petrochemical and refinery plants are due to failure of small components!!

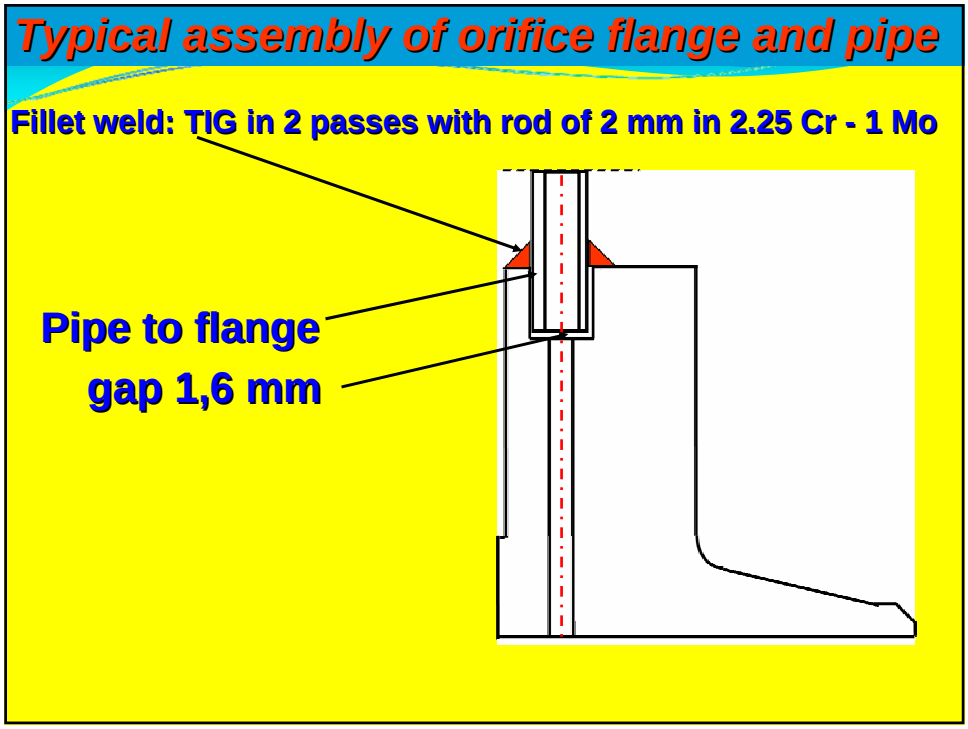
However, very often, a failure is due to several concomitant causes.

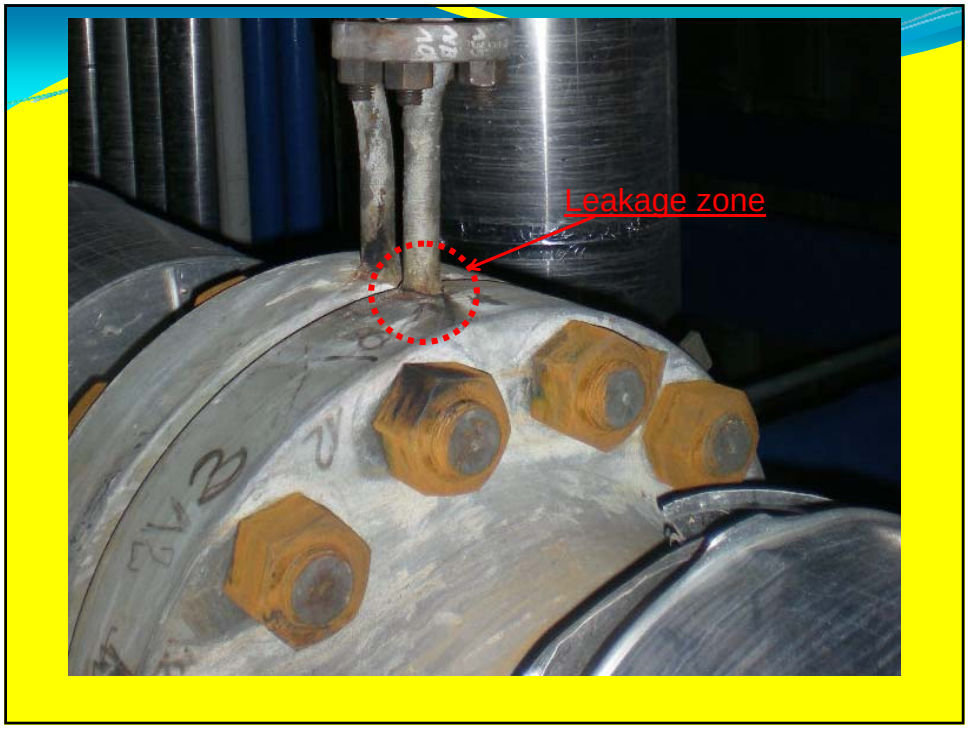
During start up operations after the commissioning of a Hydrotreater Unit there was a leakage of hydrocarbons, fortunately without consequences, by a fillet weld of a Dpcell pipe on the orifice flange.
The stream had the following design conditions:

- **Hydrocarbons + H_2S at 450°C and 90 bar**

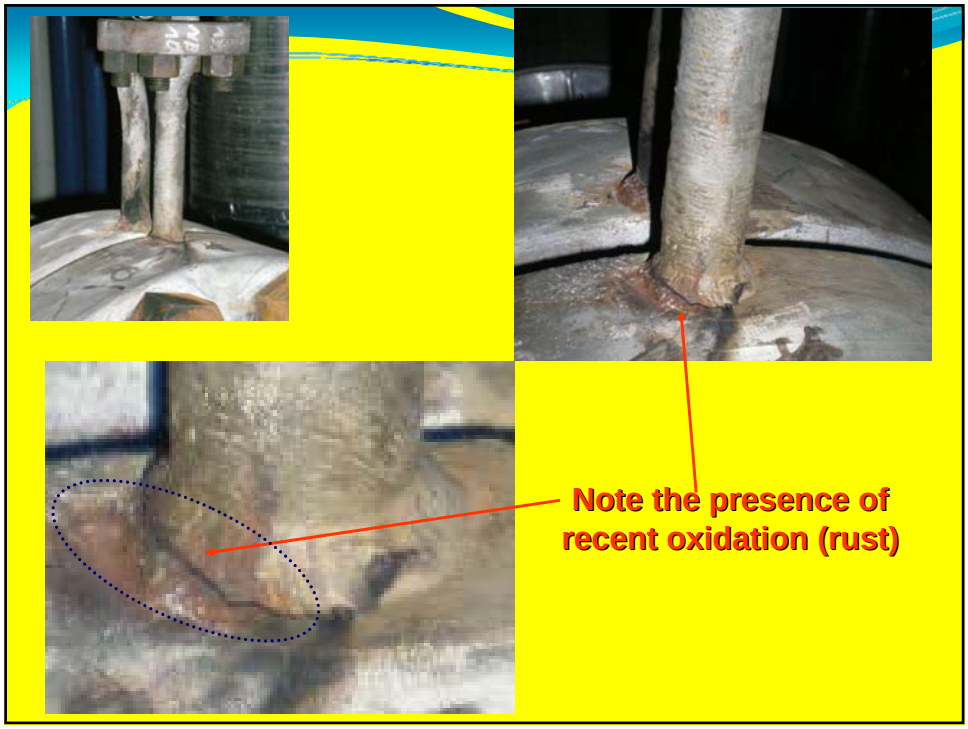
- **Materials :**

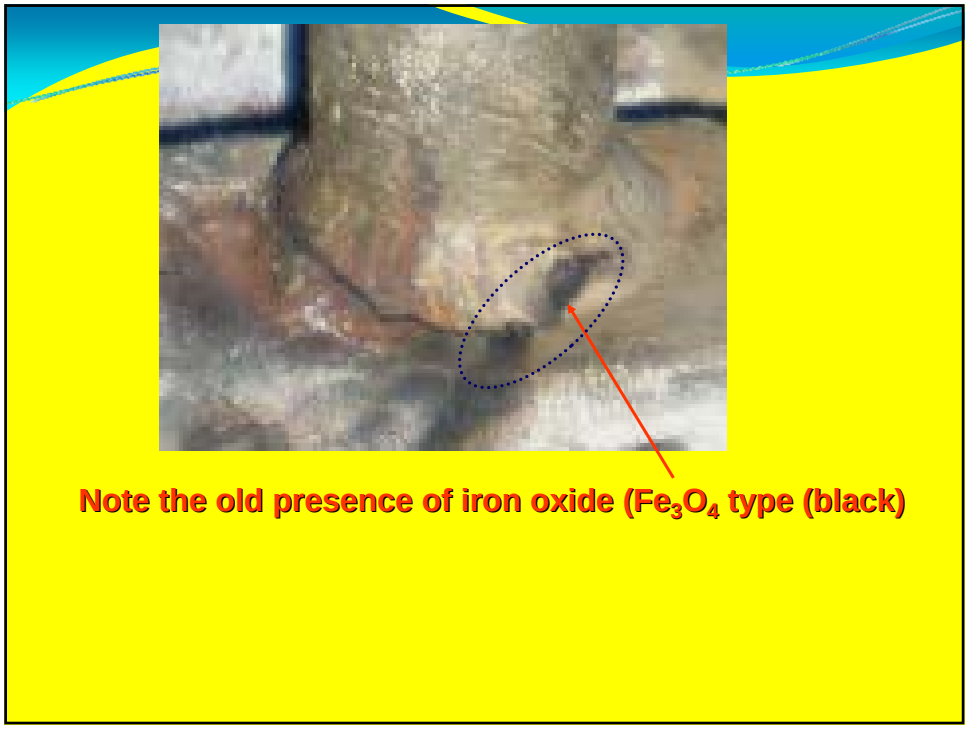
Flange 8” – 900#RF – ASTM A 182 F22
Pipe ¾” – Sch. 160 – ASTM A 335 P22





Una "nuova" figura professionale :
l'ispettore di impianto in un contesto di
global inspection service





Una "nuova" figura professionale :
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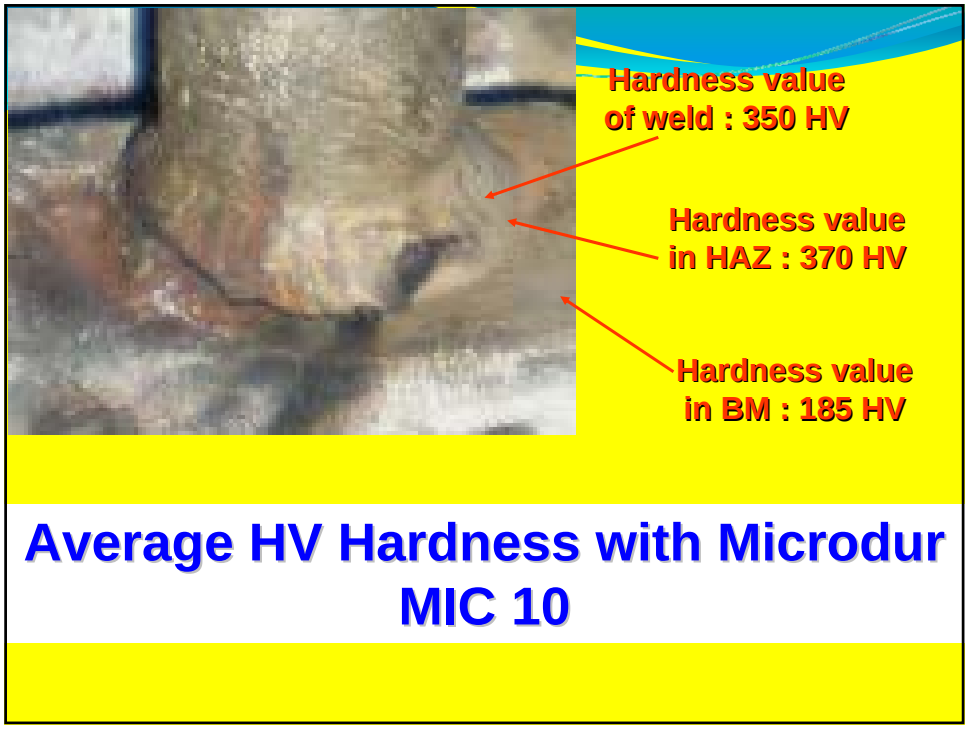


Average HV Hardness with Microdur MIC 10

ANALYSIS

Flanged tube on orifice flange had been assembled off-site, about 1 month before assembling the piping, by TIG welding with 2-1/4 Cr – 1 Mo rod material in 2 passes.

Don't existed any certificate of NDT and PWHT

After construction and assembling of the sketch a pressure test with nitrogen, at 135 bar for 2h, was performed and certified.

However, during the start up of unit there was a leakage

How did this happen?

NDT EXAMINATION AFTER THE LEAKAGE

Visual inspection

Presence of old iron oxide (black) and recent oxidation (rust) close the crack

Hardness test (average values):

Weld = 350 HV
HAZ (flange side) = 370 HV
BM flange = 185 HV

CONSIDERATIONS

Hardness tests carried out lead to the following considerations:

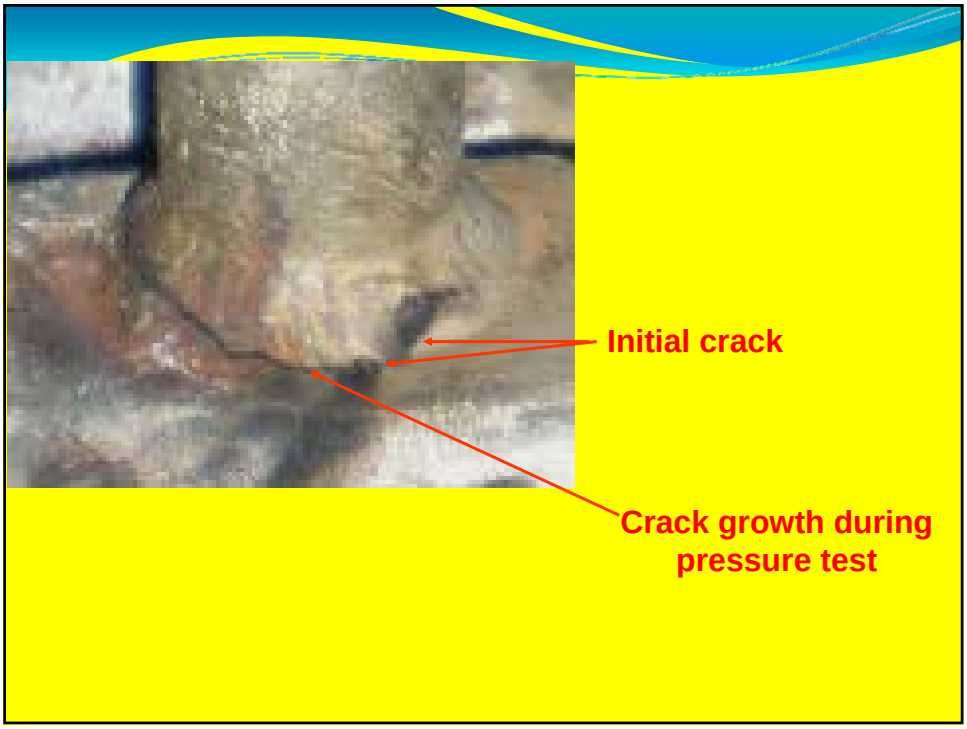
- If was done preheating was not performed in a workmanlike manner
-PWHT has not been carried out

Probably, given the rapid cooling caused by the thick flange and residual stress, has triggered a crack on the HAZ of the flange, already at first pass that has evolved on the surface at the end of welding after cooling.

So the crack was present before assembling made a few months later and had a greater oxidation.

After the assembly was performed pressure test with N_2 that led to the crack growth. Did not detect any pressure drop during the pressure certified test.

Why??



CONCLUSIONS

As we have seen the failure is occurred for concomitant several causes:

- ***Incorrect execution of the welding without respect of WPS***
- ***Lack of non-destructive testing***
- ***Incorrect pressure test even if certified***

The description of this failure case wants to alert Companies as follows:

- ***Design a plant with adequate management of technical operations***
- ***Carry out quality control in fabrication and construction of plant components with people reliable***

All for to a targeted and appropriate control of WPS and tests of small parts such as vents, drains, nipples for DpCell, drains for glass level, etc

Appendix 7

Unusual Corrosion Under Insulation

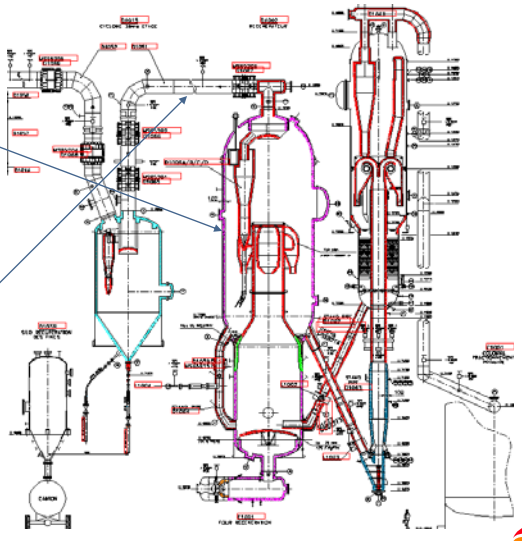
(M. Richez Total)

Unusual corrosion under insulation

Martin RICHEZ

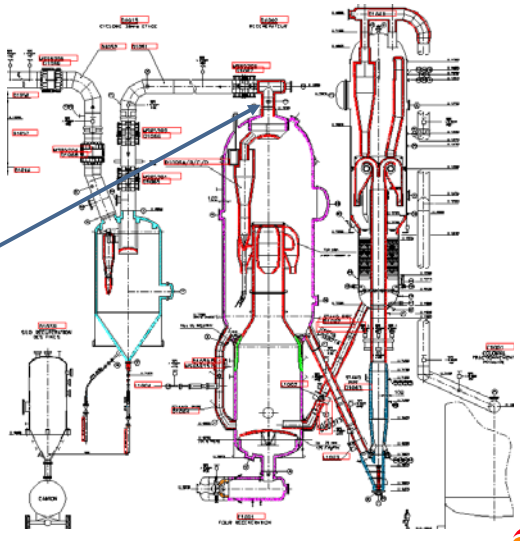
FCC reaction zone

- FCC unit
- Equipment concerned : regenerator.
- Operating condition 2,4 bars ans 760°C
- Cold wall equipment, made of carbon steel with an internal insulating refractory.
- Flue gaz line are hot wall made of 304H or 321H



Failure of the FCC regenerator top nozzle

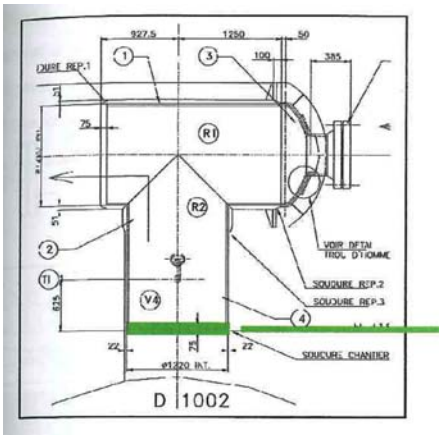
- Leak under insulation on the regenerator's top nozzle
- Shut down of the FCC to investigate
- Operating temperature 750°C



TOTAL

Failure of the FCC regenerator top nozzle

- FCC was built around 1981, nozzle is 22mm thick
- T was enterely replaced in 2007 (creep damage). Nozzle wall thickness measured in 2007 15 mm
- 2010 minimum thickness measured 6mm



TOTAL

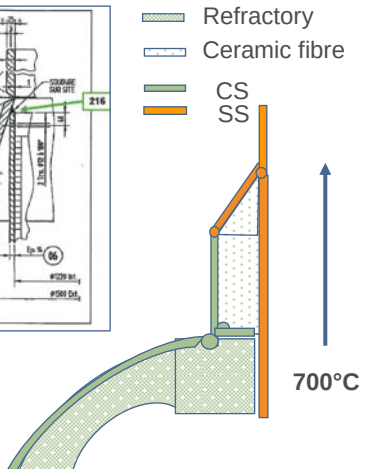
Failure of the FCC regenerator top nozzle

- **Severe corrosion (wall loss of 8mm) led to cracking near the weld**

TOTAL

Failure of the FCC regenerator top nozzle

- **The operating temperature being 700°C, an insulation acts as a barrier between the jacket sleeve (SS) and the carbon steel as shown in the picture.**
- **Yearly thermographies are done to monitor the wall temperatures and to alert for hot spots**



Thermographies from 03/2010 and 09/2010 did not show a clear sign of a potential problem

TOTAL

Failure of the FCC regenerator top nozzle

- **What really changed in 2007**

2007 **2010**

Insulation was extended up to the regenerator and covered the carbon steel area

TOTAL

Failure of the FCC regenerator top nozzle

Two causes:

- **The carbon steel was not cooled by the ambient temperature creating a high temperature oxydation under the insulation**
- **The insulation material (in the inside) put in place in 2007 was not sufficient (twice the normal quantity was adviced on the drawings)**

  - **The carbon steel's temperature got up to 600°C creating conditions for oxydation and creep**

TOTAL

Failure of the FCC regenerator top nozzle

Repairs:

- **Replacement of the top nozzle**

Learnings:

- **Modifications in the insulation can have a great impact. Great care shall be take on cold wall equipment to keep the initial design or to evaluate the consequence of any change.**

TOTAL

Appendix 8

CUI and coatings (J. Sentjens - Temati)

C.U.I.

EFC working party 15

Meeting April 14th 2011

Johan Sentjens

Statement

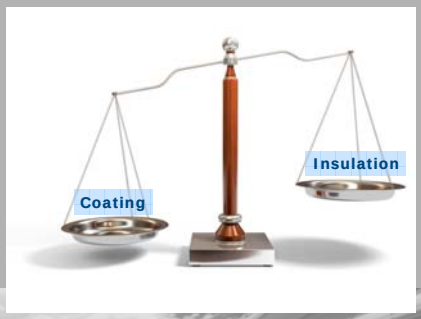
Insulation = Coating

=

Statement

Insulation = Coating

Form of protection



Agenda

- CUI
  Don't only talk about the ***C*** but also about the ***I***
- Life Cycle Engineering
- Inspection-detection
- Insulation Systems: "OPEN" versus "CLOSED"
- Questions / Discussion

Temati *in a nutshell*

- Technical Insulation
- Insulation System Supplier
- Knowledge & Solution Provider

Statement

CUI is not a

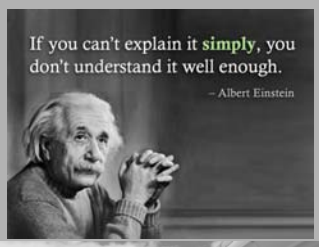
Technical Issue

but an

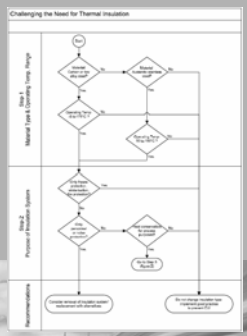
Organisation Issue

Who's or where is the insulation expert/expertice?

No rocket science

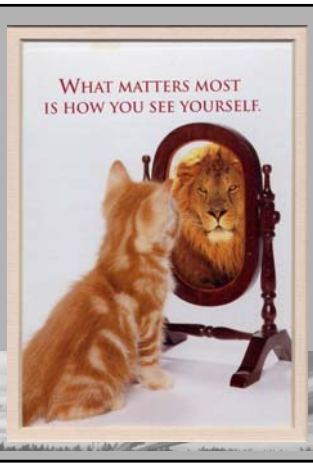


The reason for insulating



The reason for insulating

- **Energy control**
- **CO_2 of NO_X emission reduction**
- Sound control
- **Personal protection Past & Present**
- Fire proofing
- **Process conditions**



Mission and Vision

ExxonMobil

We are committed to maintaining a **safe work environment** enriched by diversity and characterized by open communication, trust, and fair treatment.

Above all other objectives, we are dedicated to running **safe and environmentally responsible operations**.

Mission and Vision

Safety is always our **top priority**. We aim to have **zero fatalities** and **no incidents** that harm people, or put our neighbours or facilities at risk. focuses on global development and **environmental challenges** linked to the impact of energy and globalisation.

Mission and Vision

BASF
The Chemical Company

We act in a **responsible** manner and support the Responsible Care ® initiatives. Economic considerations do not take **priority** over **safety and health** issues and **environmental protection**.

Mission and Vision

Dow

Values:

- Integrity
- Respect for People
- Protecting Our Planet

Strategic Themes:

- Financial Discipline
- Sustainability
- Performance Culture
- Profitable Growth

The reason for insulating

Coal-fired power plant: **1100 MW**
300.000m2 insulated surfaces

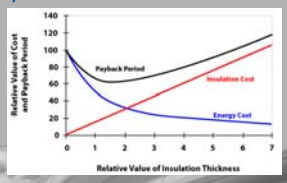
heat loss reduction **25%** when insulated sustainable.

This saves around **25.500 tons** of **coal** every year, reducing annual **CO2** emissions by **27.000 tons**. This is roughly equivalent to 12.890 cars with an annual mileage of 15.000 km. In financial terms, this would enable the plant operators to produce added power equivalent to **€ 4.8 million**.

The reason for insulating

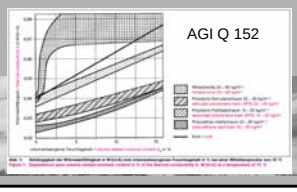
Return on investment?

Payback time 1 to 2 years

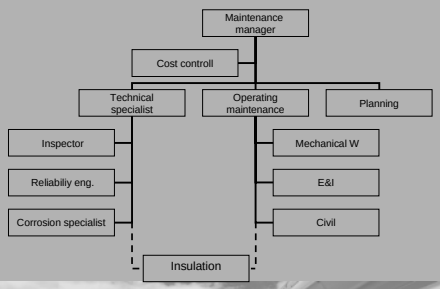


Food for Thought

- Moisture doesn't only cause:
  1. Corrosion
  2. Decreases life cycle insulation material
  3. Decreases thermal conductivity



Maintenance organisation



The need for insulation expertice?

Identifier	Is insulation present?	Insulation condition	Item metallurgy	Item surface temperature	Exposure to cyclic service?	Service condition?	CUI PROBABLE?
C-1001	Yes	Good	Carbon steel	112°C	yes	In service	YES
12"-1210-P1	Yes	Reasonable	Stainless steel	39°C	No	In service	no
TK-231	No	-	Carbon steel	102°C	No	In service	no
TK-401	Yes	Reasonable	Carbon steel	40°C	No	In service	YES
E-1400	Yes	Reasonable	Aluminium Alloy	83°C	No	In service	no
C-1203	Yes	Poor	Carbon steel	18°C	No	Out of service	YES
E-1603	No	-	Stainless steel	243°C	No	In service	no

The need for insulation expertice?

Insulation deficiency/defect checklist	Tick box if applicable
Caulking/sealant that has hardened and separated	
Circumferential cracks in GRE/GRP jacketing	
Corrosion of cladding	
Damaged or loose cladding	
Damaged vapour barrier/stop	
Failure at bends (open joints)	
Foot traffic damage	
Gaps due to uncontrolled expansion contraction	
Hot/Cold spots	
Icing and/or condensation	
Incorrectly installed at flanges/valve boxes	
Longitudinal cracks in GRE/GRP jacketing	
Missing insulation (not re-installed after shutdowns)	
Missing insulation at flanges/valve boxes	
Missing self tapers, rivets or SS bands	
Rust stains and bulges in metal cladding	
Sagged insulation and cladding	
No termination at flanges/valves	
No termination in a vertical pipe or piece of equipment	
Water increase at penetrations (e.g. nozzles)	

Corrosion team

Maintenance man.

Sr. inspector

Reliability eng.

Production man.

Insulation expert

Contractor/manufacturer

Contractor manufacturer supplier

C.U.I. projects

- Existing / older installations

C.U.I. projects

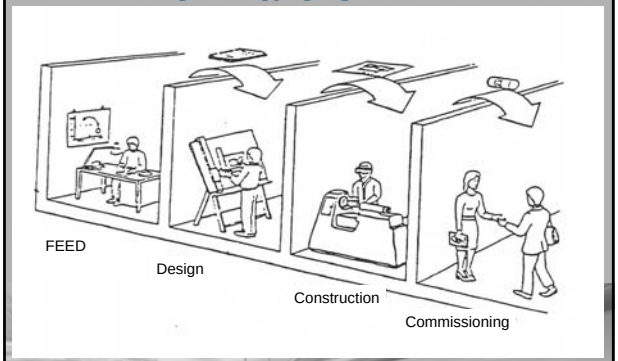
- Existing / older installation:
  - ✓ Little history
  - ✓ Full scale dismantling insulation
  - ✓ Fix / renew coating
  - ✓ Install new insulation

Same Insulation System ??

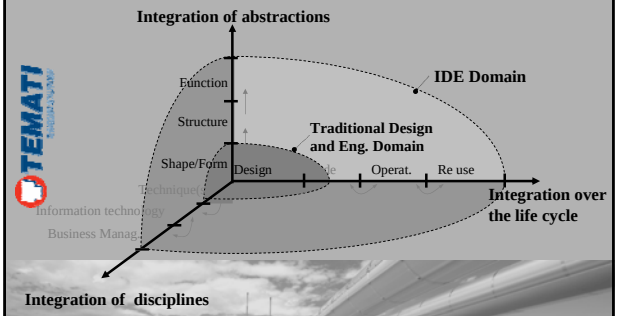
Can we learn from the past ?

Life Cycle Engineering & C.U.I

L.C.E. & C.U.I ??



L.C.E. & C.U.I



How to Prevent C.U.I.

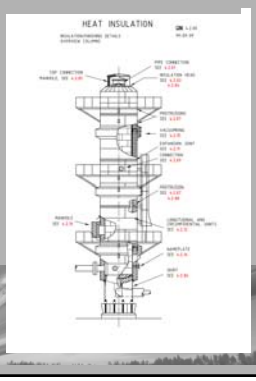
Design "fit-for-purpose" insulation **SYSTEM**

How to Prevent C.U.I.

Design "fit-for-purpose" insulation **SYSTEM**

Cini © DIN AGI Arbeitsgemeinschaft Industriebau e.V. (AGI) BSI British Standards ASTM ASME SETTING THE STANDARD

CINI manual



CINI = Guideline

The need for insulation expertice?

Smart engineering

K I S S !

Smart engineering

Pipe line distance

Smart engineering

Pipe line distance

Smart engineering

Steel structures

Smart engineering

Pipesupports

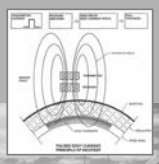
Finding C.U.I.

Inspection/Detection

- Direct
- Indirect

Finding C.U.I.

- Indirect
  - Guide Wave
  - Eddy Current pulsed wave
  - Incotest®

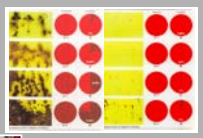


Finding C.U.I.

- Indirect
  - Thermografic

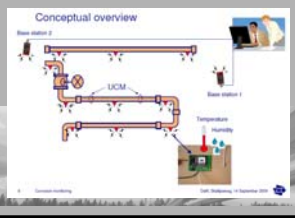
Finding C.U.I.

- Direct
  - Visual inspection
  - Dismantling insulation
  - VIP (Vessel Inspection Plug)



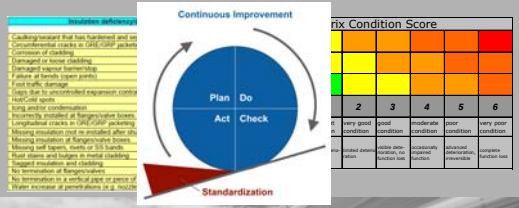
Finding C.U.I.

- Direct / Indirect
  - Leak detection
  - (Semi)permanent moisture detection
  - (Semi)permanent film thickness measurement



Why only inspect coating?

Inspection Quality Insulation System



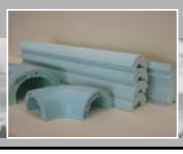
Insulation solutions for C.U.I.

Insulation Systems

- "CLOSED" system
- "OPEN" system
- Non-Contact insulation

Insulation materials

1. Permeable
   - Mineral wool
   - Aerogel type
2. Impermeable
   - Cellular Glass
   - PIR/PUR
   - Phenolic Foam

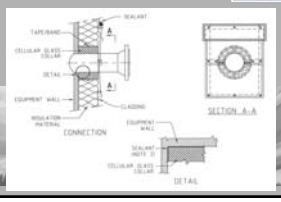


"CLOSED" System

- Most implemented and traditional system
- Permeable insulation materials
- Non hygroscopic / water absorbing insulation material
- Cladding with sealed watertight joints
- 100% flashing of protrusions

The right Sealant for the right application

- Foster 95-44
- Kiiltoflex
- Gasket Sealant
- Foster 60-44



Glass Reinforced Plastic (G.R.P.)

- Watertight joints
- High mechanical resistance
- Stepping on insulation

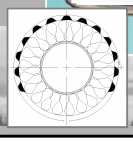
"OPEN" System

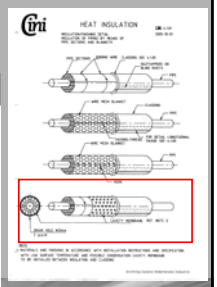
- Permeable insulation material
- Non hygroscopic / water absorbing insulation material
- Cladding with watertight joints
- 100% flashing of protrusions
- *Aircavity*
- *Drainage*

Solutions for C.U.I.

Aircavity Outside

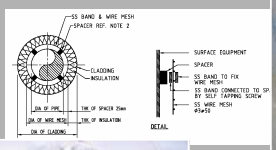
- Temafol





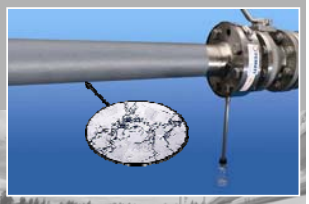
Non-Contact System

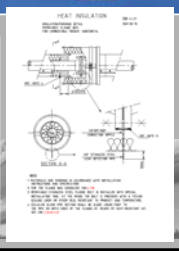
Aircavity Inside



Solutions for C.U.I.

- PMU Drain Plug
- Protectem® Flangebelt™
- Foster® 57-73 Coating





Insulation Solutions for C.U.I.

No insulation

- Personel Protection
- Perforated sheet
- Wired mesh

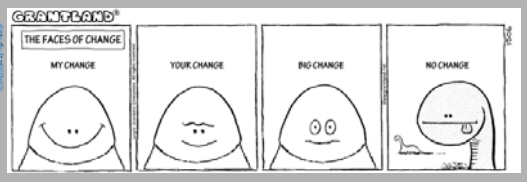
Insulation solutions for C.U.I.

- Insulating coating
- Based on ceramic technology
- λ > 0,03 W/m.K

C.U.I. challanges

Knowhow & solutions are at hand

Change the mindset



Insulation Knowledge

Thank you for your attention

Johan Sentjens

Appendix 9

Sandvik SAF 2707HD heat exchanger tubes for demanding application in crude oil refinery

(G. Sielski - Sandvik)

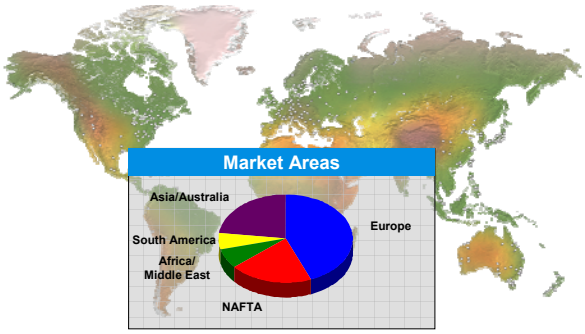
SANDVIK

EFC Working Party 15 Corrosion
Refinery Industry Meeting

Paris, April 14th 2011

Sandvik Materials Technology, EMEA
Grzegorz Sielski – Technical Marketing

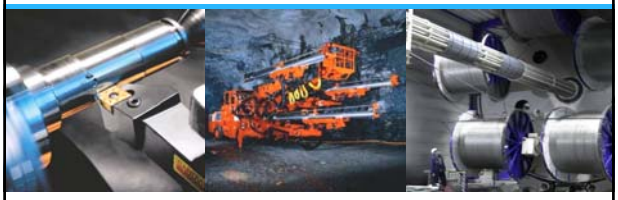
Global Presence



Sandvik – Global leader

Three business areas

Sandvik Tooling | Sandvik Mining and Construction | Sandvik Materials Technology



Sandvik Materials Technology

- High-technology special alloy materials and value-added products, developed in close co-operation with customers
- Tube, strip, wire, resistance materials and process systems

SANDVIK

Mechanical properties, physical metallurgy, and corrosion resistance of the Hyper Duplex Grade SAF 2707 HD®

Outline

- **Introduction to SAF 2707 HD®**
- **Mechanical properties**
- **Physical properties**
- **Corrosion properties**
  - ✓ **Localized corrosion**
  - ✓ **General corrosion**
- **Summary**

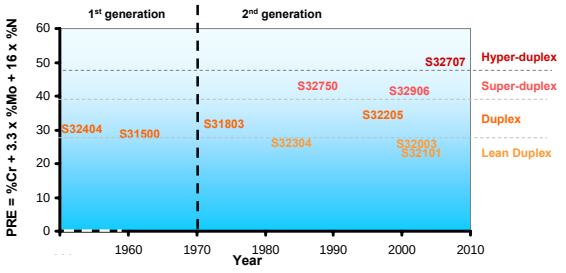
Introduction

- Long experience with super duplex stainless steel in oil and gas, petrochemical and chemical processing
- Good properties:
  - ✓ High corrosion resistance
  - ✓ Good mechanical properties
  - ✓ Relative low cost
- Super Duplex does not corrode in seawater at low temperature, but there are limitation at higher temperatures
- Clear desire for a new duplex grade with increased corrosion resistance in chloride enviroments
  - ✓ Hot tropical seawater

Goals for the new grade

- PRE ≥ 50
- CPT ≥ 100°C in 6% $FeCl_3$ (Critical Pitting Temperature)
- CCT ≥ 60°C in 6% $FeCl_3$ (Critical Crevice Temperature)
- Good mechanical properties
- Weldable

Development of Duplex Stainless Steels



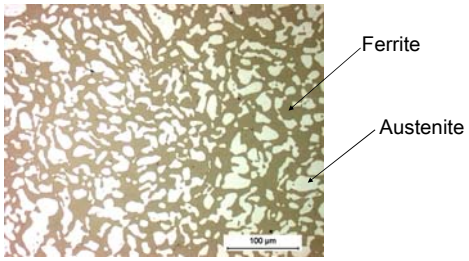
PRE = %Cr + 3.3 x %Mo + 16 x %N

Nominal Chemical Composition

Grade	UNS	%C max	%Cr	%Ni	%Mo	%N	PRE* Nominal
SAF 2507	S32750	0.03	25	7	4	0.3	42
SAF 2707HD	S32707	0.03	27	6.5	5	0.4	49
254 SMO	S31254	0.02	20	18	6.1	0.2	43

*PRE = %Cr + 3.3 x % Mo + 16 x %N

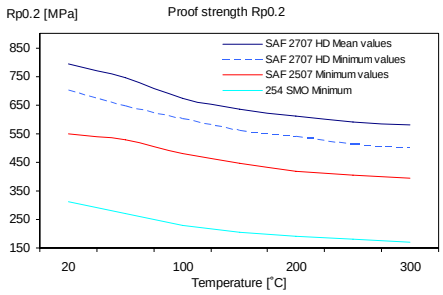
Microstructure



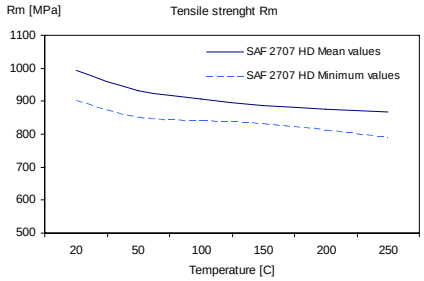
- 50 % ferrite
- Well-balanced composition
- Similar PRE number in the two phases
  - ✓ Within 1 PRE unit in average

Mechanical properties

Proof stength



Tensile strength

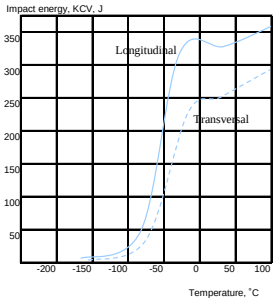


Elongation and hardness

	Elongation A [%]	A2"	Hardness HRC
Typical values			32
Min values	25	25	

Typical and minimum values for SAF 2707 HD heat exchanger tubes

Impact strength



Impact test of SAF 2707 HD in the temperature range -150˚C to 100˚C

High temperature

- **At higher temperatures 250-300°C for longer period**
- **Heat-exchanger tubes can often be used at higher temperature**
- **Contact Sandvik for more information at specific cases**

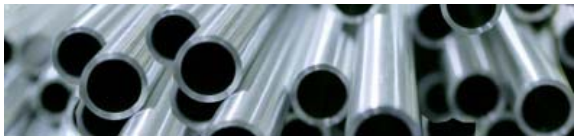
Physical properties

Physical properties

- **Density** 7.8 g/cm^3
- **Resistivity** 0.75 µΩm at 22°C

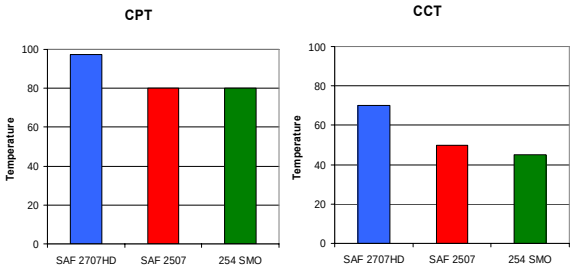
Modulus of elasticity (x10$_3$)

Temperature °C	Mpa
20	197
100	189
200	178
300	168

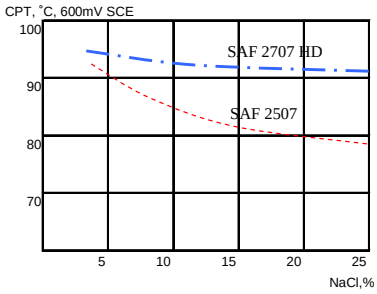


Corrosion properties

Pitting corrsion

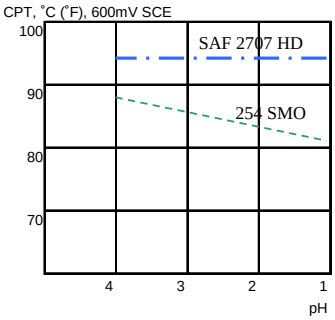


Potentiostatic test



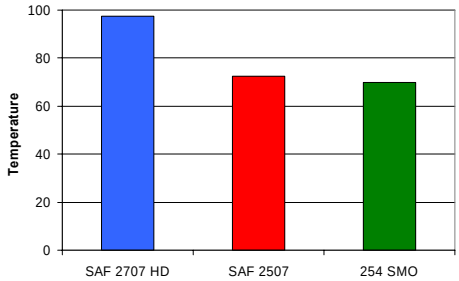
Potentiostatic test

3% NaCl

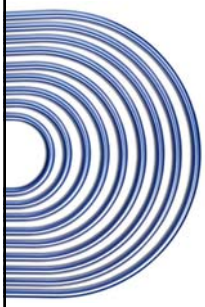


”Green Death”

1% $FeCl_3$ + 1%$CuCl_2$ + 11%H_2SO_4 + 1,2% HCl



Bending



- Bended tube also has a CPT of 97.5°C

Natural sea water at OCP pitting corrosion

- No pitting corrosion were found visualy
- No indication on pitting from the potential measurements

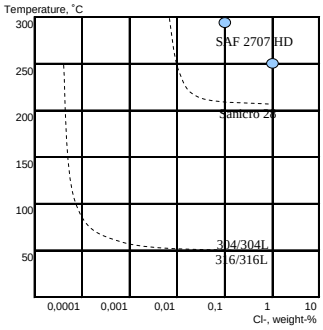
	SAF 2507	SAF 2707 HD	SAF 2707 HD weld
50°C	OK	OK	OK
65°C	Not measured	OK	OK
80°C	Not measured	OK	OK

Natural sea water at OCP crevice corrosion

- No corrosion were found visualy
- No indication on corrosion from the potential measurements

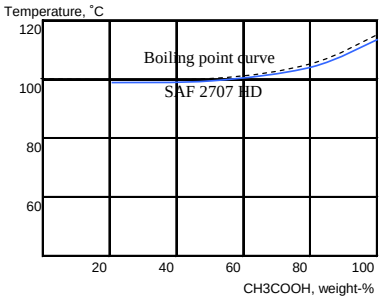
	SAF 2507	SAF 2707 HD
50°C	OK	OK
65°C	Not measured	OK
80°C	Not measured	OK

Stress Corrosion Cracking

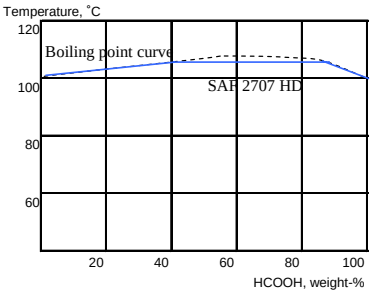


- Autoclave
- 100 bar
- 8 ppm O_2
- Load = proof strength
- NaCl-solution
- 1000h (6 weeks)

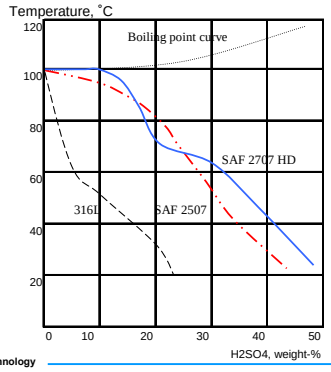
Acetic acid



Formic acid

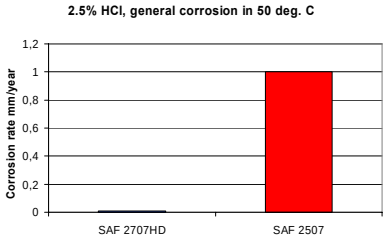


Sulphuric acid

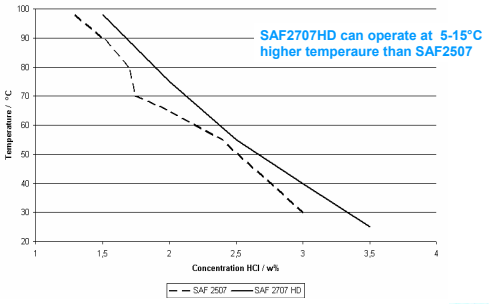


HCl

- General corrosion
  - ✓ Improved corrosion resistance compared to SAF 2507 in reducing acids such as HCl

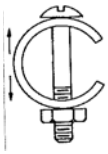


Hydrochloric acid
Iso corrosion diagram (0.1 mm/year)



Hydrogen embrittlement

- C-rings
- Undeformed and cold worked (10%) samples
- 90% of the proof strength $R_{p0.2}$
- 3% NaCl
- 500h
- 50°C
- Coupled electrically to Zn



- **No cracking was seen in the performed tests**

Summary

- Sandvik have developed a Hyper duplex stainless steel which is a new generation of duplex material
- SAF 2707 HD
- PRE 49 – well balanced structure
- CPT 97.5°C
- CCT 70°C

Goals for the new grade

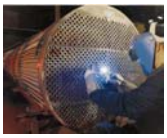
- PRE ≥ 50
- CPT ≥ 100°C
- CCT ≥ 60°C

- Good mechanical properties
  - ✓ Proof strength 800 MPa (typical value at room temperature)
  - ✓ Tensile strength 1000 MPa (typical value at room temperature)
  - ✓ Elongation over 25% in quenched annealed condision
  - ✓ Good impact strength

SAF 2707 HD welding

Welding

- Filler material: Sandvik 27.9.5.L
  - ✓ Increased %Ni compared to base metal
- Gas shielded welding (TIG/GTAW)
  - ✓ Use 2-3% N_2 in the shielding gas
- Recommended welding parameters:

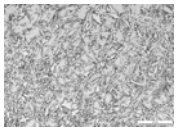


	Limit
Preheat	Not applicable
Interpass temperature	< 100 C (212 F)
Heat Input	0.2 – 1.5 kJ/mm

All weld metal - Properties

- TIG welding with Ar + 2%N_2
- Tensile properties

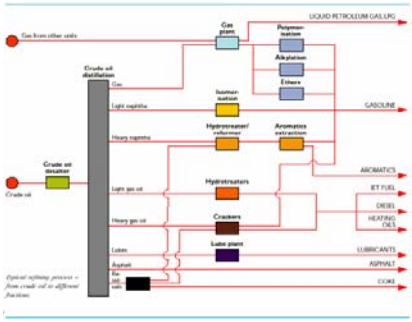
Typical values Sandvik 27.9.5.L TIG all weld metal		
R_p0,2, MPa	R_m, MPa	A, %
800	950	30



- %Ferrite : 30 - 70 %
- G48C CPT = 77.5°C

Refinery application

Oil Refining

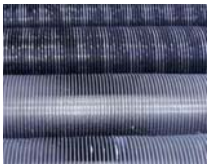


Application Example: Oil Refinery

- Pump around heat exchanger - atmospheric distillation unit - USA
- History:
  - ✓ C-steel: Service life of 9 months
  - ✓ Upgrade for SAF 2507. Successful in most heat exchangers, but operating close to limit. Pitting observed in the most severe locations, and one bundle experienced cracking (traced back to fabrication faults)
  - ✓ 2003: SAF 2707 HD installed in one complete bundle

Application Example: Oil Refinery

- Atmospheric crude distillation, overhead system aircoolers - Europe
- History:
  - ✓ C-steel: Service life maximum 2 years
  - ✓ SAF 2707 HD tubes with external Al fins installed
  - ✓ Inspection after one year in service: Tubes in excellent condition



Application Example: Oil Refinery

- Overhead condensers in refinery CDU unit - Europe
- History
  - ✓ C-steel: Service life 5-7 months
  - ✓ SAF 2707 HD installed in Jan 2006

Application Example: Sea water

- Seawater cooled heat exchanger in the Middle East
- Shell side: Condensing HC => HCl dewpoints, deposits
- Tube side: Seawater, with temperature up to 70°C (158° F)

Conclusions

Sandvik SAF 2707 HD has:

- Excellent resistance to pitting and crevice corrosion in Cl-containing environments. Same is valid for SCC.
- Very high resistance to organic acids.
- High mechanical properties, allowing design and cost advantages.
- Good weldability.
- Excellent performance has been verified in a number of process plant heat exchanger installations.

Questions ?????

Thank you !

Appendix 10

3D Trasar for boiler technology

(V. Beucler - Nalco)

3D TRASAR TECHNOLOGY

DETECT
DETERMINE
DELIVER

3D TRASAR® Boiler Technology

EFC Working Party 15
2011 April 14th

NALCO

3D TRASAR TECHNOLOGY

DETECT
DETERMINE
DELIVER

How can we improve boiler water treatment control without more manpower?

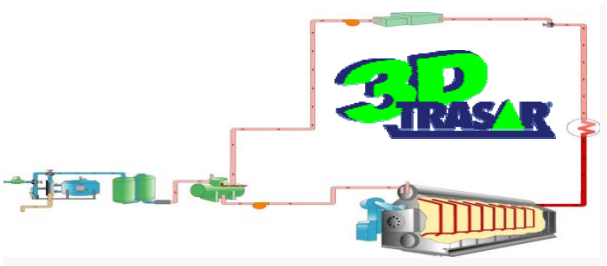
We all agree that boiler water treatment is important, but we are “running lean,” and we don’t have additional labor available to dedicate to this area of the plant.

NALCO

Nalco's 3D TRASAR Technology: *System Protection through On-line Control*

DETECT DETERMINE DELIVER

3D TRASAR Technology



NALCO

DETECT DETERMINE DELIVER

3D TRASAR

- Automatically ***Detects*** system variability
  - Nalco Corrosion Stress Monitor (NCSM)
  - TRASAR internal treatment control
  - Direct measurement assures appropriate response
- ***Determines*** appropriate response
  - Compares system condition to desired condition
  - Adjusts system control immediately before problems occur
- ***Delivers*** results through improved control
  - Equipment protection / capital preservation
  - Energy efficiency
  - Prevention of unplanned outages
  - Labor efficiency

NALCO

3D TRASAR Technology
Multiple Application Platforms

- **3D TRASAR Technology Delivers Exceptional Economic and Operational Advantages…Across all Applications and Industries.**
  - **Boilers**
  - **Cooling**
  - **Reverse Osmosis**
  - **Process Applications**

3D TRASAR Boiler Technology can meet many of CUSTOMER NAME water treatment needs …

- Simplified, accurate program control w/ reduced need for operator intervention
- Assurance that no damage is done to boiler system
- Energy and water savings
- Continuous monitoring and automatic control
- Alarming capability to report when a potential problem exists
- Nalco rep freed up to provide more value-added services to the plant

What is 3D TRASAR Boiler Technology? …

- ✓ Cost Effective & Upgradeable Boiler Performance Automation
  - – Advanced monitoring & control
  - – Performance sensors
  - – Traced chemistry
  - – Communication of results

Phase 2
Performance Automation

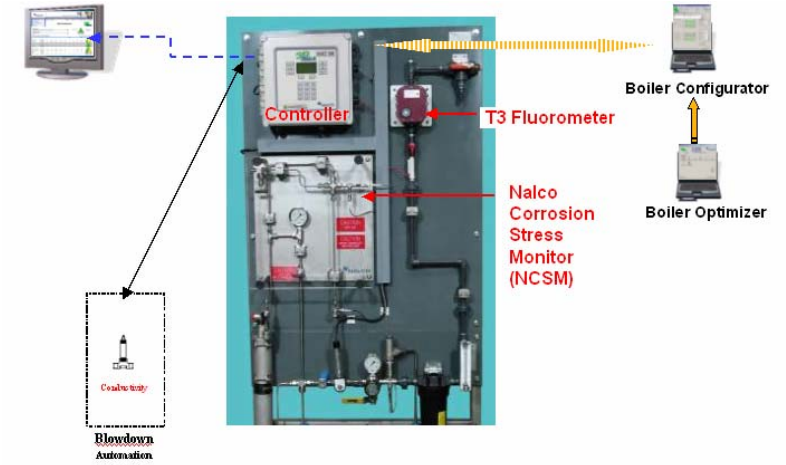
Phase 1
Feedwater control
Accessible Automation Platform

Product line upgrade to Traced
Improved Monitoring

Boiler Technology

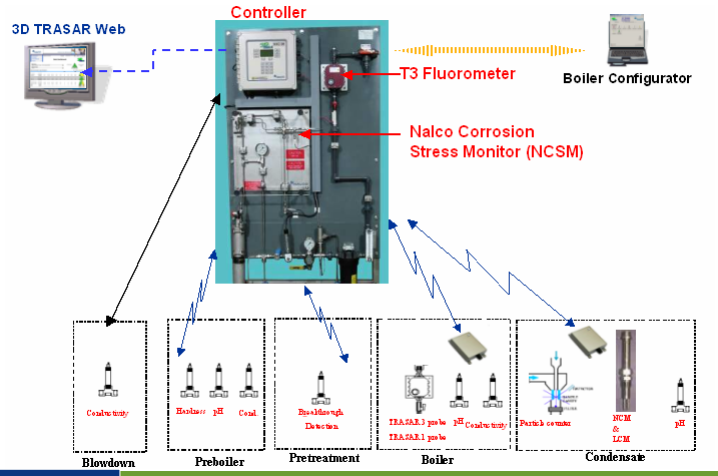
Performance Management for Boiler Systems

What is 3D TRASAR Boiler Technology? …



Phase 1 – Feedwater Automation Platform

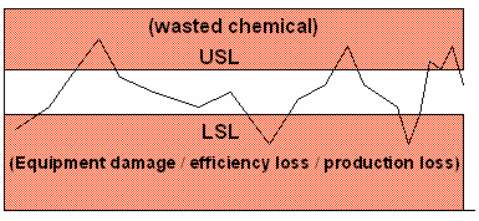
What is 3D TRASAR Boiler Technology? …

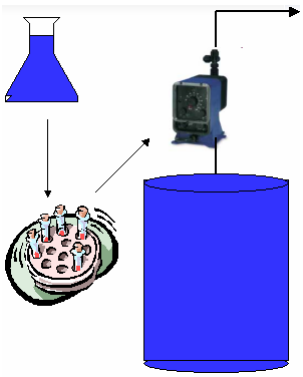


Phase 2 – Upgradeable & Customizable

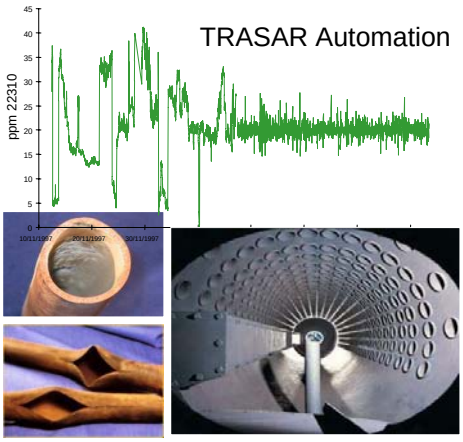
Until Recently, control of boiler chemistry looked like this … "test and adjust"

- Gather sample
- Test
- Adjust chemical feed
- "Repeat as necessary"





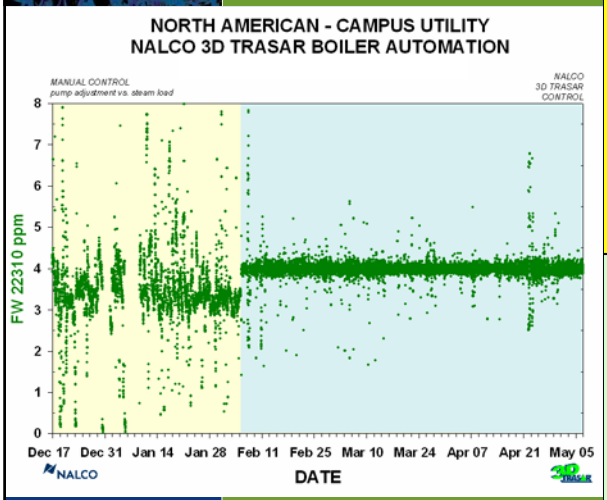
3D TRASAR Boiler Scale Control offers on-line, real-time control



- Automatically responds
- Directly measures and maintains optimum treatment levels
- Keeps your boiler clean

Compare this to …
- Take test …
- Adjust pump …
- Take test next day…
- Adjust pump

24/7 TARGETED CONTROL

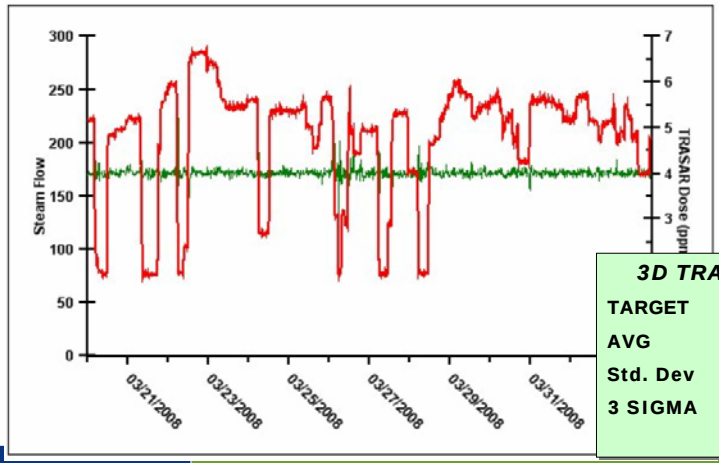


MANUAL CONTROL	
TARGET	4.00 ppm
AVG	3.08 ppm
Std. Dev	1.48 ppm
3 SIGMA	0.00 ppm
	7.53 ppm
OFFSET	- 23 %
TIME	50 days

3D TRASAR CONTROL	
TARGET	4.00 ppm
AVG	3.99 ppm
Std. Dev	0.24 ppm
3 SIGMA	3.27 ppm
	4.71 ppm
OFFSET	-0.2 %
TIME	92 days

LARGE STEAM LOAD SWINGS

540% STEAM LOAD SWINGS

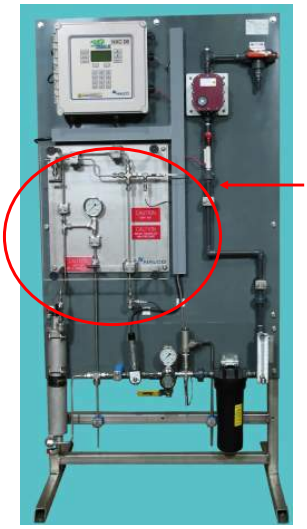


3D TRASAR CONTROL	
TARGET	4.00 ppm
AVG	3.99 ppm
Std. Dev	0.24 ppm
3 SIGMA	3.27 ppm
	4.71 ppm

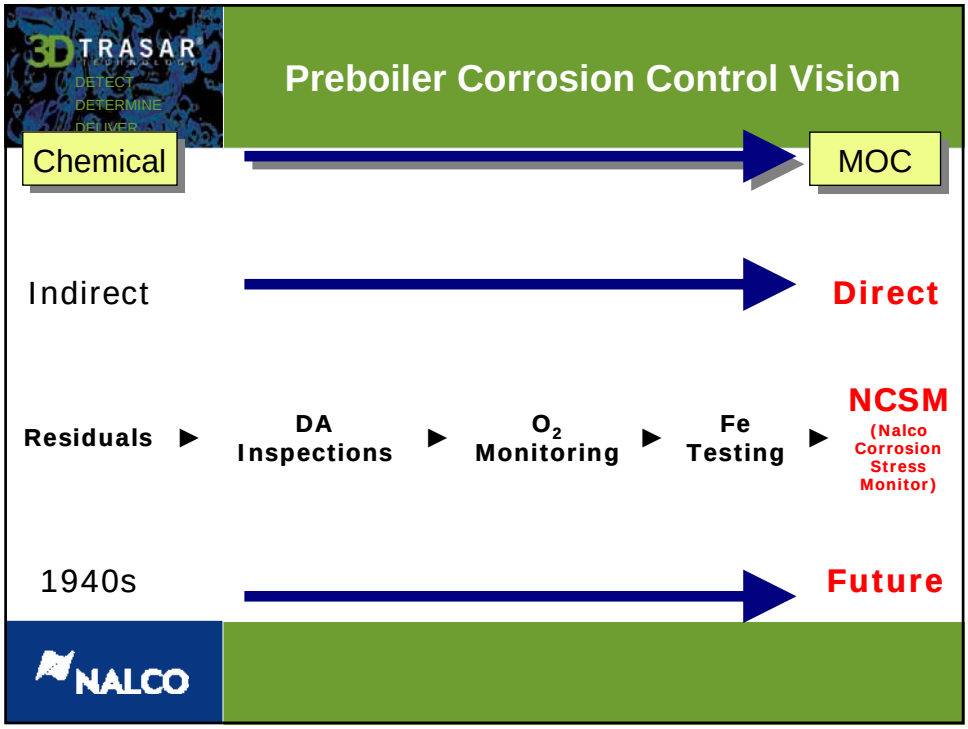
Taking a closer look …

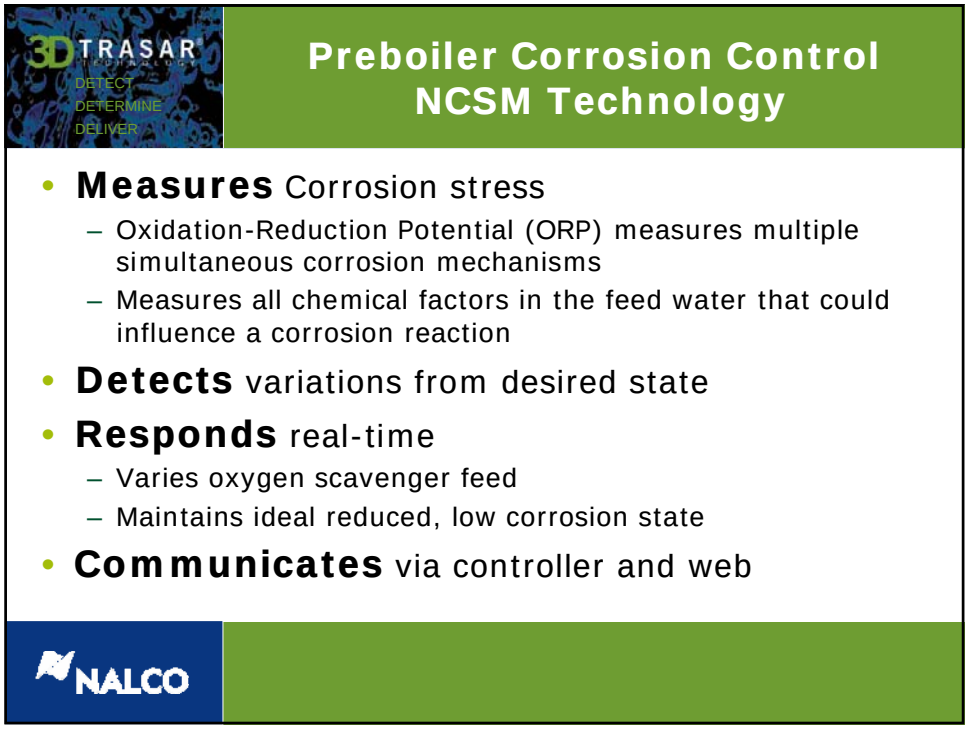
Pre-Boiler Corrosion Control

Controller



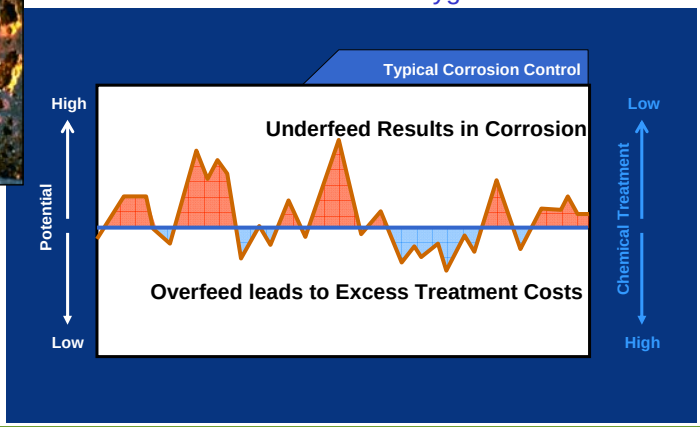
Nalco Corrosion Stress Monitor (NCSM)


3D TRASAR
DETECT
DETERMINE
DELIVER
Preboiler Corrosion Control Vision
Chemical
MOC
Indirect
Direct
Residuals
DA Inspections
O_2 Monitoring
Fe Testing
NCSM
(Nalco Corrosion Stress Monitor)
1940s
Future
NALCO


3D TRASAR
DETECT
DETERMINE
DELIVER
Preboiler Corrosion Control
NCSM Technology
• Measures Corrosion stress
– Oxidation-Reduction Potential (ORP) measures multiple simultaneous corrosion mechanisms
– Measures all chemical factors in the feed water that could influence a corrosion reaction
• Detects variations from desired state
• Responds real-time
– Varies oxygen scavenger feed
– Maintains ideal reduced, low corrosion state
• Communicates via controller and web
NALCO

3D TRASAR Preboiler Corrosion Monitoring

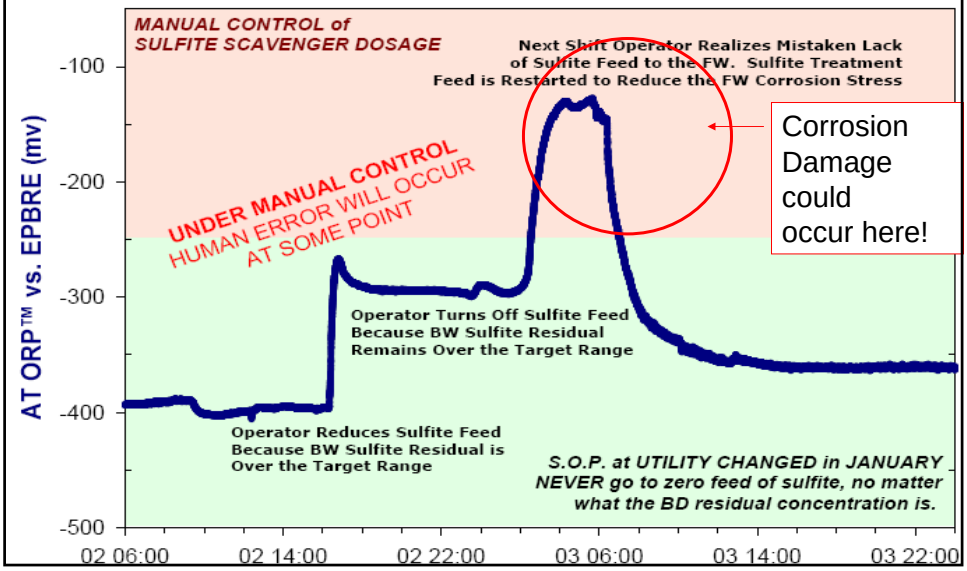
Corrosion due to oxygen in feedwater



Today we have fixed feed rates regardless of the boilers water's potential to corrode

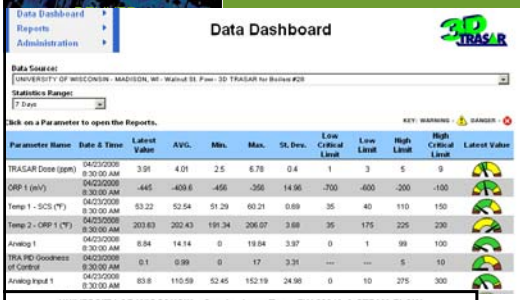
Feedwater Corrosion Stress Event

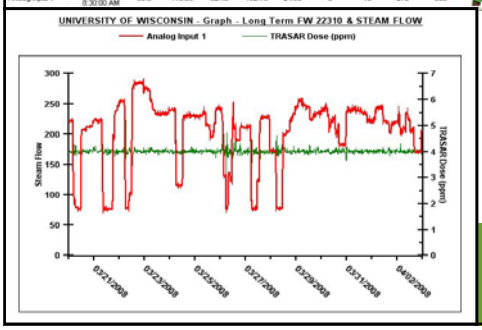
NCSM Monitoring Data



Corrosion Damage could occur here!

Communication of Results





3D TRASAR Web is...

- Convenient for both customer and Nalco Rep
- View all systems
- Displays performance detail
- Printable, receive via e-mail
- Downloads to PC for advanced data analysis
- Alarming

New Best Practice for Preboiler Corrosion Control

Nalco Corrosion Stress Monitor (NCSM)

- **Performance-based control of corrosion stress**
- Maintains Reduced Conditions
- Minimizes corrosion

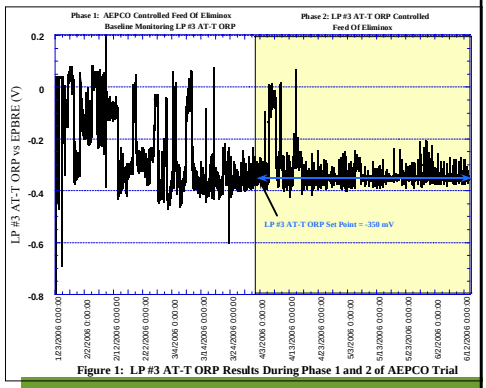


Figure 1: LP #3 AT-T ORP Results During Phase 1 and 2 of AEPCO Trial

Customer Value

- **Safety, Reliability**
  - Minimizes failures
  - Maximizes reliability & availability
- **Minimize Cost**
  - Reduces iron deposits to promote energy efficiency
  - Minimizes downtime & repair cost

Appendix 11

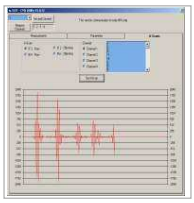
Corrosion Monitoring system can help refinery plant to process opportunity crude by monitoring the corrosion rate to control inhibitor, to improve both plant versatility and profitability

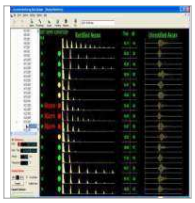
(Claudia Lavarde –A. Pothuaud - GE)

GE Energy - Inspection Technologies
GE Energy – Water & Process Technologies

Rightrax + Predator

Effectively Manage Corrosion Rates for HAC



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Claudia LAVERDE
GE IT - Product Leader
Alain POTHUAUD
GE W&PT - Technical Manager

Why Rightrax is used

Aging	Cost	Safety	Image
•Most assets are old •60% of worlds pipelines are ~40y old •Increased inspection requirements	•Inspections are expensive •Corrosion abatement is expensive •Loss of production is biggest cost factor	•HSE is expensive •Safety comes first •Dangerous site access	•Image damage to company if accidents happen •Multi million dollar fines

AND IMPROVED DATA QUALITY !

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Where Rightrax is used

Access

- Building scaffolding
- Removing insulation
- Buried pipelines

Hazards

- Chemical area's
- Heat
- Radiation
- Height
- Explosion

Remote

- Offshore facilities
- Deserts facilities
- Jungle facilities
- Artic facilities

Process

- Corrosion
- Erosion

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Product versions

Flexible array (LT)

- Both manual and integrated version
- Flexible array with 14 individual transducer elements
- Glued to the object
- Repeatability up to +- 0.1mm / +- 0.004"
- Wall thickness 5mm to 100mm / 0.2" to 3.9"
- Pipe sizes of 6" and over, and flat surfaces
- Operational temperature -40°C up to 120°C / 248°F
- Certified for ATEX zone 2 and IECx

Advantage:
- Non intrusive, easy installation
- Array coverage of effected area

Sensor

Controlle

Display

Coax Max 70m

Serial Max 260m

High temperature (HT)

- Both manual and integrated version
- Single point transducer with delay line
- Clamped to the object
- Repeatability up to +- 0.0025mm / 0,001"
- Wall thickness 3mm to 16mm / 0.12" to 0.6"
- Pipe sizes of 3" up to 42"
- Surface temperature -20°C up to 350°C and 500°C / 662°F and 932°F
- Certified IS for use in zone 1 area's

Advantage:
- Non intrusive, easy installation
- Process related events due to high resolution

Sensor

Controlle

Display

Coax 5m

Serial Max 600m

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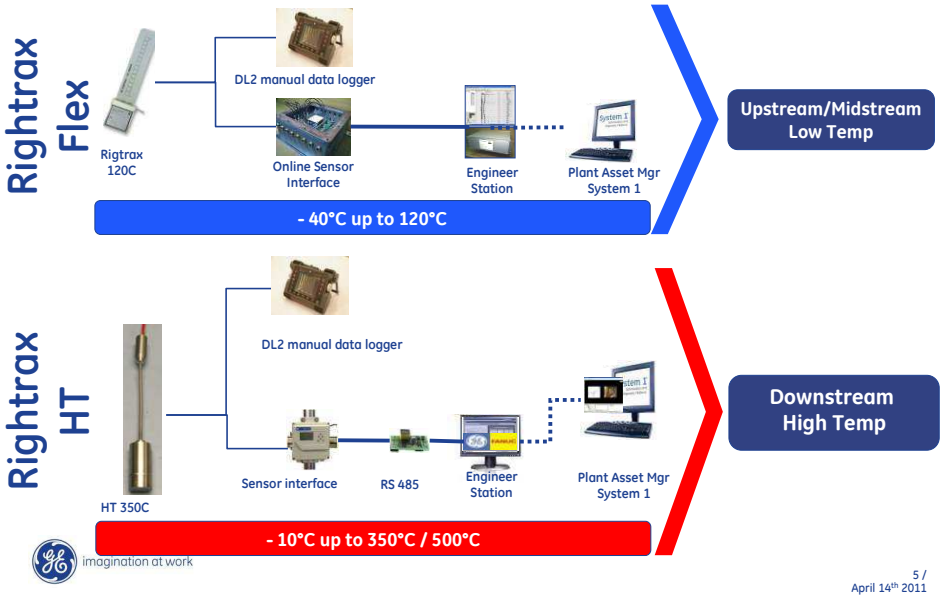
Online Corrosion Monitoring

Two product lines for corrosion and wall thickness monitoring available



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5 /
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Predator

Prediction

What to Expect and How to Manage It

Protection

Chemistry and Application Control

Detection

Fastest and Most Accurate Measurement

Predator is the GE patented platform to process and manage High Acid Crudes, based on 3 fundamental platforms : Prediction, Protection, Detection

Risk must become an opportunity

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6 /
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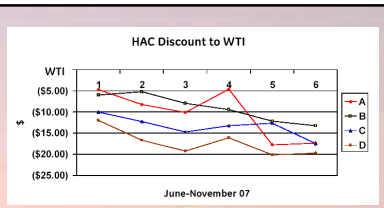
Why Predator?

Example of profitability $$



- Refinery capacity : 100.000 bbl/day
- 10 days per month with acid crude
- TAN=1.2 with 34% Baobab
- Crude cost differential : 5 $/bbl

  - **Treatment cost # 500 k$**
  - **Acid crude : 11% of total crude slate**
  - **Benefits on crude : 15 MM$**

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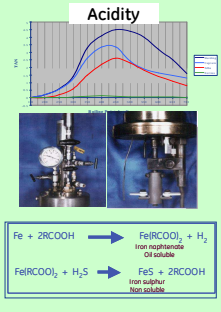
High Acid Crude Management

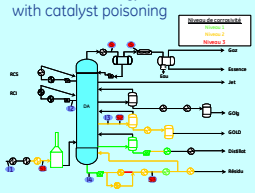
Prediction

- Risk assessment
- Nap Acids repartition depend directly from crude quality
- Experience & lab testing is mandatory



Protection

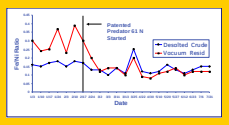
- Low phosphorous patented chemistry to create film on metal surface
- Low P to prevent fouling issues
- Non P technology to avoid issues with catalyst poisoning



	Low P Predator 63NE	Corrosion rate	High P	Corrosion rate
	ppm injected	mpy	ppm injected	mpy
Crude oil	0	2	6	3
AGO	3	1	0	2
HAGO	5	1	15	6
AResid	4	4	15	20
VGO	12	4	15	20
HVGO	4	3	15	20

Detection

- Corrosion probes
- H_2 probe
- Fe, Ni and ratio
- TAN, NAN, S=...



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8 /
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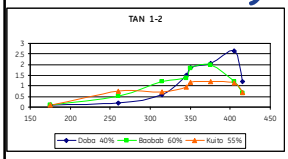
Case Study – Nap Acid Crude Monitoring



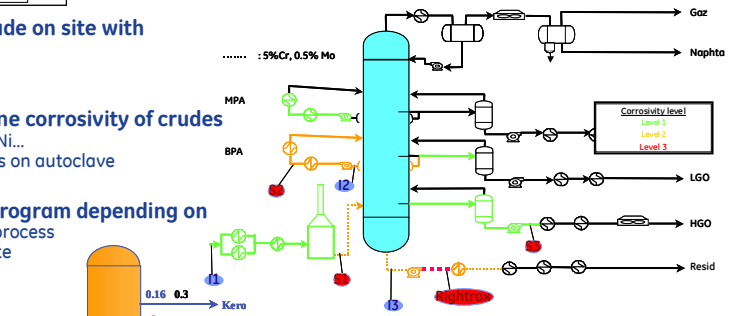
Circuit	Appareil	Fluid	Flow	Size	Size	Section	Velocity	Density at t°	Temperature	Risk level	TAN	Metallurgy
			T/h	mm	inch	m²	m/s		°C	1 to 3		Nature
							<2.1 m/s		<220 °C			Cr ≤ 5%
Atm Resid	Pipe	Resid	100	152.4	6	0.018	2.01	0.75	341	2		5%Cr, 0.5%Mo
0.94	Pump	-	100					0.75	341	2		
	Pipe	-	100	152.4	6	0.018	2.01	0.75	341	3		5%Cr, 0.5%Mo
	Exchanger	-	100									
	Pipe	-	100	152.4	6	0.018	1.93	0.79	240		2	
	Exchanger	-	100									
	Pipe	-	100	152.4	6	0.018	1.79	0.85	160			
	Pipe	-	42	152.4	6	0.018	0.75	0.85	160			
	Pipe	-	23.5	152.4	6	0.018	0.42	0.85	160			

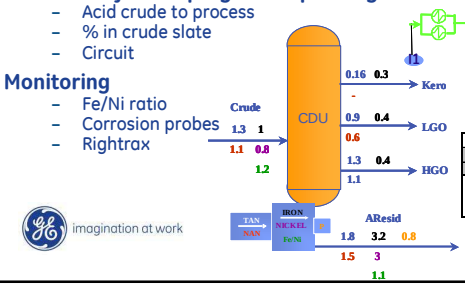
Risk assessment made on site with
- Operators
- Technology
- Inspection

Analysis to determine corrosivity of crudes
- TAN, NAN, Fe, Ni...
- Corrosion rates on autoclave
- Experience

Inhibitor injection program depending on
- Acid crude to process
- % in crude slate
- Circuit

Monitoring
- Fe/Ni ratio
- Corrosion probes
- Rightrax





Unit **	Injection Point		Product	TAN=0.5	TAN=0.8	TAN=1.2	TAN=1.5
	Place	ID		Doserate	Doserate	Doserate	Doserate
Unit **	Feed	I1	Predator ***	0	5	10	15
	BPA	I2	Predator ***	0	0	5	10
	Resid	I3	Predator ***	5	10	15	20

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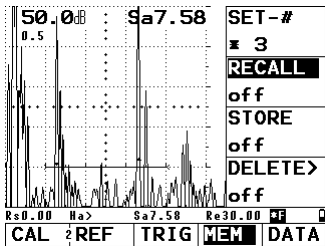
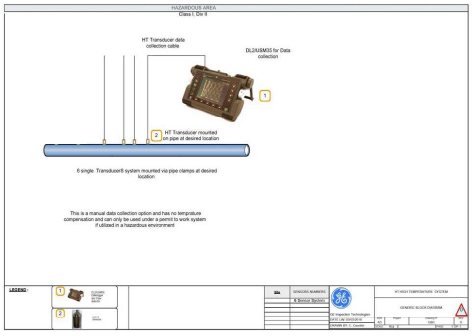
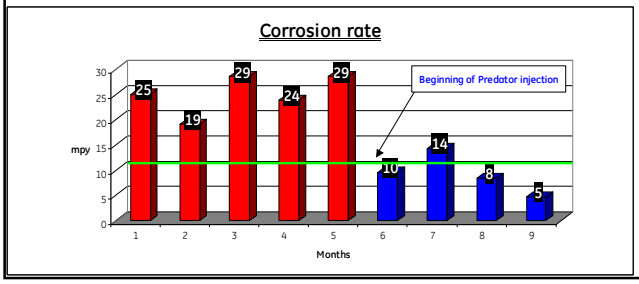
Case Study – Nap Acid Crude Monitoring







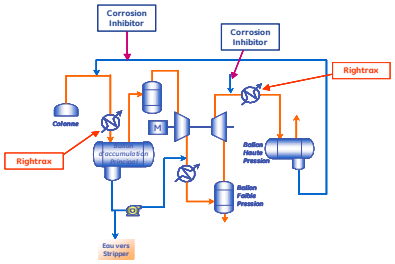
Record each month
- Wall thickness
- Corrosion rate

Help to optimize treatment
- Prefilming
- Dosage according to conditions

Other Applications

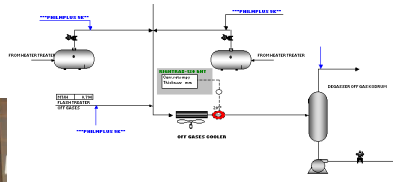
FCCU overhead

- High pH corrosion in wet environment
- Filming inhibitor injected in water wash



Wet Sour Gas Treater

- Filming inhibitor efficiency control



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11 /
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