Appendix 1

List of participants and excused persons

Participants NACE-EFC WP15 meeting 30th March 2006 Venizia

Name	Company	Country
Giuseppe Sala	SANDVIK ITALIA S.p.A.	ITALY
Martin Richez	Total	FRANCE
Carmelo Aiello	Eni	ITALY
Chris J Claesen	Nalco	BELGIUM
Maarten Lorenz	Shell Global Solutions International B.V.	NETHERLANDS
Stefano Baronti	Eni Raffineria Livorno	ITALY
Martin Hofmeister	Bayernoil Raffineriegesellschaft mbH	GERMANY
Dave Harvey	TWI	UK
François Ropital	Institut Français du Pétrole	FRANCE
Stefano Trasatti	University of Milan	ITALY
Lorenzo Bellan	Ineos Vinyls Italia Spa	ITALY
Massimiliano Belloni	Eni Raffineria Livorno	ITALY
Luca Cantoni	Bodycote	ITALY
Aldo Cozza	OMR Spa	ITALY
Sandro Doria	General & Marine applications SRL	ITALY
Giovanna Gabetta	Eni Div.E&P	ITALY
Daniele Gatti	Eni Div & MKT Sannazzaro	ITALY
Giovanni Gronda	Foster Wheeler IT	ITALY
Nicola Guarino	Siot Spa	ITALY
Neil Mac Donald	Aquilex Welding Services	ITALY
Paolo Motti	Gam Raccordi Spa	ITALY
Carlo Orlando	Raffineria Novara	ITALY
Mauro Ostacoli	Bodycote Crema	ITALY
Andrea Pacchiarotti	Aquilex Welding Services	ITALY
Daria Palumbo	ERG Raffineria	ITALY
Paolo Passoni	Cescor Srl	ITALY
Silvano Patron	Venezia Tecnologie	ITALY
Damiano Pastore	Ineos Vinyls Italia Spa	ITALY
Maurizio Pezzato	Ineos Vinyls Italia Spa	ITALY
Algra Rinndert	RTD Group	ITALY
Jacco Rosendal	RTD Group	ITALY
Marco Scapin	Venezia Tecnologie	ITALY
Sergio Volonte	Tecnimont	ITALY
Michael Welch	Welding Services Inc.	ITALY
Giovanni Zangari	Process Control Consulting	ITALY

Excuses received for NACE-EFC WP15 meeting 30th March 2006 Venizia

Surname	Name	Company	Country
Curt	Christensen	Force Institutes	DENMARK
André	Claus	GE Betz	BEGIUM
Michael	Davies	CARIAD Consultants	GREECE
Nicholas	Dowling	Shell Global Solutions International B.V.	NETHERLANDS
Charles	Droz	Exxon Mobil	FRANCE
Sebastien	Duval	Saipem	FRANCE
Carlo	Farina	Corrosion Consultant	ITALY
Tiina	Hakonen	FORTUM Oil & Gas Oy	FINLAND
Martin	Holmquist	AB Sandvik Steel	SWEDEN
Andrew	Kettle	Chevron Texaco Ltd	UK
Mario	Lanciotti	Polimeri Europa S.p.A	ITALY
Morten	Langøy	Bodycote Materials Testing AS	NORWAY
Istvan	Lukovits	Chemical Research Center	HUNGARY
Richard	Pargeter	TWI	UK
Kirsi	Rintamaki	FORTUM Oil & Gas Oy	FINLAND
Iris	Rommerskirchen	Butting Edelstahlwerke GmbH&Co KG	GERMANY
Liane	Smith	Intetech Ltd	UK
Betrand	Szymkowiak	IFP Technology Group - AXENS	FRANCE
John	Thirkettle	Thor Corrosion	UK
Alan	Turnbull	National Physical Laboratory	UK

Appendix 2

EFC WP15 Activities

Presentation of EFC WP15 Activities

François Ropital

Venizia 31 March 2005

NACE INTERNATIONAL

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

Presentation of the activities of WP15

European Federation of Corrosion (EFC)

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

European Federation of Corrosion (EFC)

http://www.efcweb.org

EFC Working Parties

- WP 1: Corrosion Inhibition
- WP 3: High Temperature
- WP 4: Nuclear Corrosion
- WP 5: Environmental Sensitive Fracture
- WP 6: Surface Science and Mechanisms of corrosion and protection
- WP 7: Education
- WP 8: Testing
- WP 9: Marine Corrosion
- WP 10: Microbial Corrosion
- WP 11: Corrosion of reinforcement in concrete
- WP 12: Computer based information systems
- WP 13: Corrosion in oil and gas production
- WP 14: Coatings
- WP 15: Corrosion in the refinery industry
- WP 16: Cathodic protection
- WP 17: Automotive
- WP 18: Tribocorrosion
- WP 19: Corrosion of polymer materials
- Task Force 2: Corrosion and Protection of steel structures

WP 15 was created in sept. 96 with J. Harston as first chairman

EFC Working Party 15 « Corrosion in Refinery » Activities

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

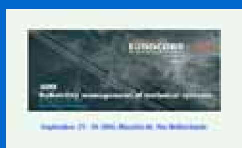
Publications

EFC Working Party 15 « Corrosion in Refinery » Activities

WP Meetings
· One WP 15 working party meeting in Spring,
(this year on 31 March 2006 in Venezia)

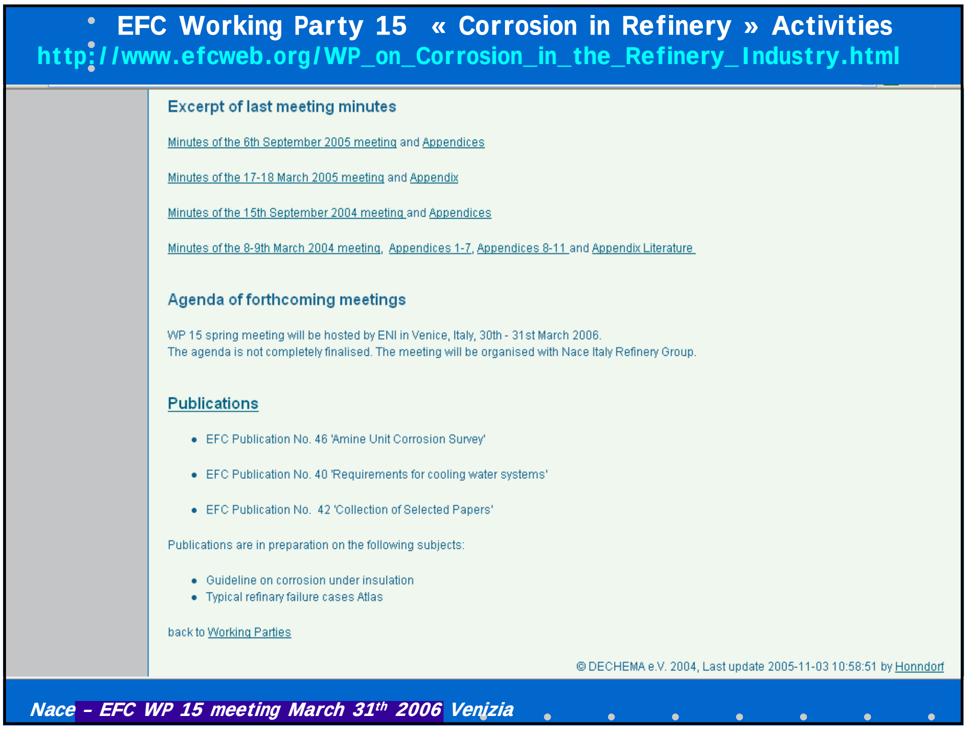
· One meeting at Eurocorr in conjunction with the conference,
(this meeting during Eurocorr 2006 24-28 September in Maastricht)

Eurocorr Conference sessions (September)
Refinery Corrosion Session
+ Workshops or Joint Session with other EFC WP parties



WP15 page in EFC Web site
http://www.efcweb.org/WP_on_Corrosion_in_the_Refinery_Industry.html

EFC Working Party 15 « Corrosion in Refinery » Activities
http://www.efcweb.org/WP_on_Corrosion_in_the_Refinery_Industry.html
EUROPÄISCHE FÖDERATION KORROSION
EUROPEAN FEDERATION OF CORROSION
FEDERATION EUROPEENNE DE LA CORROSION
SITEMAP I CONTACT I RUSSIAN I OUR WEBSITES
Home
Structure
Member Societies
Working Parties
WP on Corrosion by Hot Gases and Combustion Products
WP on Nuclear Corrosion
WP on Corrosion Education
WP on Corrosion in Oil and Gas Production
WP on Corrosion in the Refinery Industry
WP on Automotive Corrosion
WP on Corrosion of Polymer Materials
Board of Administrators
STAC
General Secretariat
EFC Working Party 15: Corrosion in the Refinery Industry
Vision:
The Working Party meetings objectives are:
Information Exchange
- Sharing of refinery materials /corrosion/inspection experiences by operating company representatives
Forum for Technology
- Sharing materials/ corrosion/ protection/ monitoring information by providers, users, R&D
Scientific exchange
- Sharing materials/ corrosion/ protection scientific works
Development of documents, guidelines, publications related to corrosion in the refinery industry
Strategy Plan:
Survey of corrosion problems in refinery industry
The group will collect information first on hydrotreatment and hydrocracking units, then processes as FCC, Catalytic reforming, Distillation, Sulfur plant, Alkylation, Sour water stripper will be considered. Guideline and publication will be issued.
Nace – EFC WP 15 meeting March 31th 2006 Venizia



EFC Working Party 15 « Corrosion in Refinery » Activities
http://www.efcweb.org/WP_on_Corrosion_in_the_Refinery_Industry.html
Excerpt of last meeting minutes
Minutes of the 6th September 2005 meeting and Appendices
Minutes of the 17-18 March 2005 meeting and Appendix
Minutes of the 15th September 2004 meeting and Appendices
Minutes of the 8-9th March 2004 meeting, Appendices 1-7, Appendices 8-11 and Appendix Literature
Agenda of forthcoming meetings
WP 15 spring meeting will be hosted by ENI in Venice, Italy, 30th - 31st March 2006.
The agenda is not completely finalised. The meeting will be organised with Nace Italy Refinery Group.
Publications
EFC Publication No. 46 'Amine Unit Corrosion Survey'
EFC Publication No. 40 'Requirements for cooling water systems'
EFC Publication No. 42 'Collection of Selected Papers'
Publications are in preparation on the following subjects:
Guideline on corrosion under insulation
Typical refinary failure cases Atlas
back to Working Parties
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Nace – EFC WP 15 meeting March 31th 2006 Venizia

http://www.eurocorr2006.nl

Eurocorr 2006 Refinery sessions

September 25 - 28 2006, Maastricht, The Netherlands

Workshops and thematics for refinery corrosion

Nace – EFC WP 15 meeting March 31th 2006 Venjzia

http://www.eurocorr2006.nl

Eurocorr 2006 "Inhibitors" (WP1) and "Refinery" (WP15) joint session

Author	Title
Holliday	Development and testing of a novel polymer for cooling water applications
Kawai	Effect of water treatment on the corrosion behavior of carbon steel under simulated lay-up conditions in fossil power plants
Leao	Evaluation of cooling water corrosivity at different points of an open evaporative recirculating system
Leao	Study of industrial cooling water effects on monel 400 alloy
Townsend	Causes, consequences and remedies of operational variability in cooling tower operation and treatment

Nace – EFC WP 15 meeting March 31th 2006 Venjzia http://www.eurocorr2006.nl

Eurocorr 2006
"Refinery" (WP15) session

Author	Title
Wilms	"risk based inspection" – a case study
Eaton	Effect of iron sulfide on corrosion/erosion in refinery overheads
Groysman	Corrosion and quality in the oil refining industry
Hucińska	Understanding degradation of 9cr-1mo steel in platforming ccr furnace environment
Elshawesh	Fatigue failure of flare expansion joints
Claesen	Practical field applications and guidelines for using overhead simulation models
Panossian	The influence of the added water ph on the nace test for the determination of corrosive properties of gasoline and distillate derivatives
Al-janabi	Corrosion control of the crude distillation unit (cdu) overhead system using chemical treatment (i) – lab evaluation
Lee ch	The corrosion resistance of supermartensitic and duplex stainless steel pipes welded by arc and power beam processes
Roehnert	Initial oxide scale formation during the incubation period of metal dusting

Publications

- EFC Guideline n°40 « Prevention of corrosion by cooling waters » available from Maney Editor http://www.maney.co.uk/search?fwaction=show&fwid=623
- EFC Guideline n° 42 Collection of selected papers (available mid of 2006)
- EFC Guideline n° 46 on corrosion in amine units (available mid of 2006)
- EFC Guideline on Corrosion Under insulation (we are working on it)
- Future publications
  - Typical refinery failure cases atlas
    Send your contribition to Francois Ropital
  - other suggestions ?

Publications EFC Guideline n°40

« Prevention of corrosion by cooling waters » available from Maney Editor

http://www.maney.co.uk/search?fwaction=show&fwid=623

CORROSION IN REFINERY INDUSTRY

CASE HISTORY n° 108 January 2002 FR-IFP-Materials Department

HYDROGENATION UNIT 217 – HOT SEPERATOR V23
SCREWS
CEDI – SOLAIZE - IFP

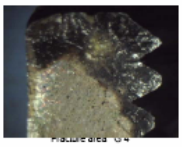
DATE OF INCIDENT AND/OR INFORMATION: 24/11/01 SA10

NATURE OF THE INCIDENT : temperature breakaway and breaks of screws

CONSEQUENCES : stop of the unit

MATERIAL: carbon steel

PHOTO AND SCHEME :



ASPECT : some parts of the fracture zone have a green colour and the others a dark brown one
The metallographic examination has revealed intergranular cracks.

MEDIA AND OPERATING CONDITIONS:
Air, normal operating temperature 380°C but increases up to 480°C

TIME TO DETERIORATION : A few months (design in august 2000)

CORROSION IN REFINERY INDUSTRY

CASE HISTORY n° 108 January 2002 FR-IFP-Materials Department ANSWER

TYPE OF CORROSION : MOLTEN METAL CORROSION

CAUSES :

X ray analysis have been performed with a Scanning Electron Microscope:

*on the fracture area Zinc, Cadmium, Sulphur, Oxygen were detected

*In the cracks Cadmium with Oxygen and locally Zinc, Chloride, Copper and Sulphur had been analysed.

As temperatures up to 480°C have been reached, Zinc and Cadmium were in the liquid state (the melting temperature of Cadmium is 320°C and the one of Zinc is 420°C) and they can provoke a molten metal type corrosion of the carbon steel screws. The blocking stresses have surely favoured the attack by the molten metals

REMEDY :

The origin of the zinc and the cadmium are looking for (paint, surface treatment of the screws, grease,… ?) in order to avoid them.

PUBLICATION - TECHNICAL REPORT: IFP technical note n°20/2002 RG30

BIBLIOGRAPHIC REFERENCES :

Typical refinery failure cases atlas

CORROSION IN REFINERY INDUSTRY FAILURE ATLAS CASE HISTORY n° xxx Date
Process Equipment
DATE OF INCIDENT AND/OR INFORMATION:
NATURE OF THE INCIDENT :
CONSEQUENCES :
MATERIAL COMPOSITION and REFERENCES
PICTURES AND SCHEMES :
ASPECT :
MEDIA AND OPERATING CONDITIONS:
TIME TO DETERIORATION :

CORROSION IN REFINERY INDUSTRY FAILURE ATLAS CASE HISTORY n° xxxx ANSWER
TYPE OF CORROSION : API 571 CLASSIFICATION:
CAUSES :
REMEDY :
PUBLICATION - TECHNICAL REPORT:
BIBLIOGRAPHIC REFERENCES :

Contributions are welcomed : contact francois.ropital@ifp.fr

Typical refinery failure cases atlas following API 571

5.0 REFINING INDUSTRY DAMAGE MECHANISMS

Contributions are welcomed : contact francois.ropital@ifp.fr

Appendix 3

Eurocorr 2006 Refinery Session Programs

DRAFT PROGRAMME EUROCORR2006
Monday

Session M	**Corrosion in the Refinery Industry**	**Dr. Francois ROPITAL (room Paris)**
11:00-11:30	Practical Field Applications and Guidelines for Using Overhead Simulation Models	Chris Claesen Nalco Company
11:30-12:00	Effect of Iron Sulfide on Corrosion/Erosion in Refinery Overheads	Paul Eaton Champion Technologies
12:00-12:30	Corrosion Control of the Crude Distillation Unit (CDU) Overhead System Using Chemical Treatment (I) – Lab Evaluation	Yahya Al-Janabi Aramco Saudi
12:30-14:00	**Lunch**	
14:00-14:30	Corrosion and Quality in the Oil Refining Industry	Alec Groysman/ Naphtali Brodsky Oil Refineries Ltd
14:30-15:00	Understanding degradation of 9Cr-1Mo steel in Platforming CCR furnace environment	Joanna Hucińska Gdańsk University of Technology
15:00-15:30	Initial oxide scale formation during the incubation period of Metal Dusting	Daniel Roehnert Karl-Winnacker-Institut der Dechema e.V.
15:30-16:00	"Risk Based Inspection" – a case study	Dimphy Wilms Röntgen Technische Dienst B.V.
16:00-16:30	**Coffeebreak**	
16:30-17:00	Analysis of acoustic emission generated by corrosion on steel in aggressive crude oil	Salah Mechraoui Université de Technologie de Compiègne
17:00-17:30		
1800-end	**Welcome reception town hall Maastricht**	

DRAFT PROGRAMME EUROCORR2006
Tuesday

Session M	**Corrosion in the Refinery Industry**	**Dr. Francois ROPITAL (room Rome)**
09:00-09:30	The Corrosion Resistance of Supermartensitic and Duplex Stainless Steel Pipes Welded by Arc and Power Beams Processes	Lee Chi-Ming TWI Ltd
09:30-10:00	The influence of the added water pH on the NACE test for the determination of corrosive properties of gasoline and distillate derivatives	Zehbour Panossian Institute for Technological Research of the São Paulo – State (IPT)
10:00-10:30	Corrosion of Welded 304 Austenitic Stainless Steel Pipes	Khalifa Abusowa Petroleum Research Center
10:30-19:00	**WORKING PARTY 15 FULL MEETING**	

DRAFT PROGRAMME EUROCORR2006
Thursday

Session T	**Joint Session Corrosion and Scale inhibition and Corrosion Refinery Industrie**	**Prof. Dr. Günter SCHMITT and Dr. Francois ROPITAL (room Athene)**
09:00-09:30	Development and testing of a novel polymer for cooling water applications	Roy Holliday GE Infrastructure
09:30-10:00	Effect of Water Treatment on the Corrosion Behavior of Carbon Steel under Simulated Lay-up Conditions in Fossil Power plants	Noboru Kawai Central Research Institute of Electric Power Industry
10:00-10:30	EVALUATION OF COOLING WATER CORROSIVITY AT DIFFERENT POINTS OF AN OPEN EVAPORATIVE RECIRCULATING SYSTEM	Elizabete R. Caruso Leao Federal University of Rio de Janeiro
10:30-11:00	Causes, consequences and remedies of operational variability in cooling tower operation and treatment	Geoff Townsend Nalco Limited
11:00-11:30	**Coffeebreak**	
11:30-12:00		
12:00-12:30		
12:30-13:00		
13:00-14:00	**LUNCH**	

Please note that the organization committee reserves the right to adapt the draft programme

Appendix 4

Application of duplex stainless steels to prevent corrosion in refineries

Giuseppe Sala (Sandvik Italia)

Application of duplex stainless steels to prevent corrosion in refineries

Giuseppe Sala

Sandvik Materials Technology

Oil refinery heat exchangers

Typical corrosion issues

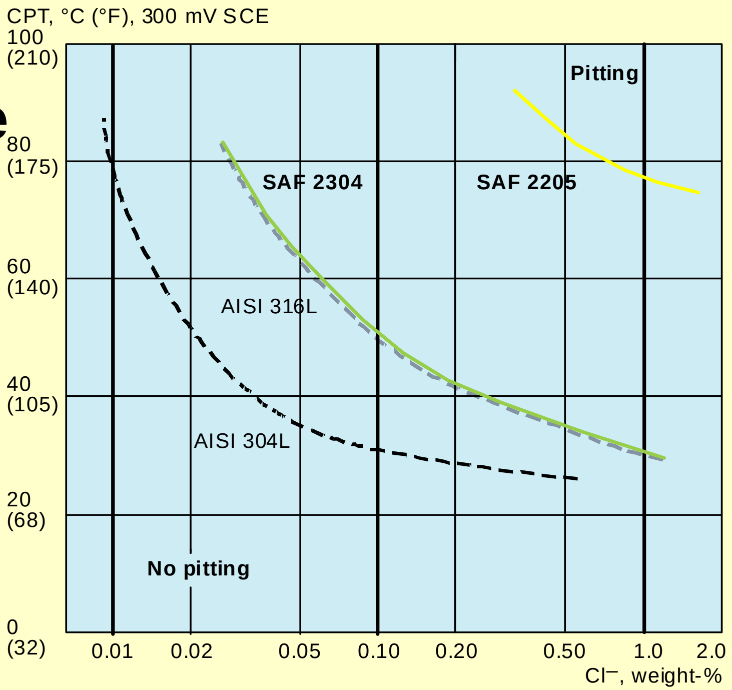
- General corrosion, under deposit
- SCC (chlorides, ammonia, polythionic acid, amines)
- Hydrogen attack
- Erosion corrosion (tube ends)

Common Materials

- Carbon and Low Alloy Steels - up to 12%Cr
- Stabilised or ELC austenitic stainless steels
- Ferritic stainless steels
- Brasses, Bronzes
- Duplex SAF2205,
- Super-duplex SAF2507
- Ni alloys &Titanium

Materials need to withstand variety of process conditions

- **Hydrocarbons**
- **Chlorides/HCl, from any source**
- **Ammonium chloride NH_4Cl**
- **Hydrogen sulphide H_2S**
- **Ammonium bisulphide NH_4HS**
- **Naphtenic acids**
- **Polythionic acids**
- **Cyanides**
- **Organic acids**

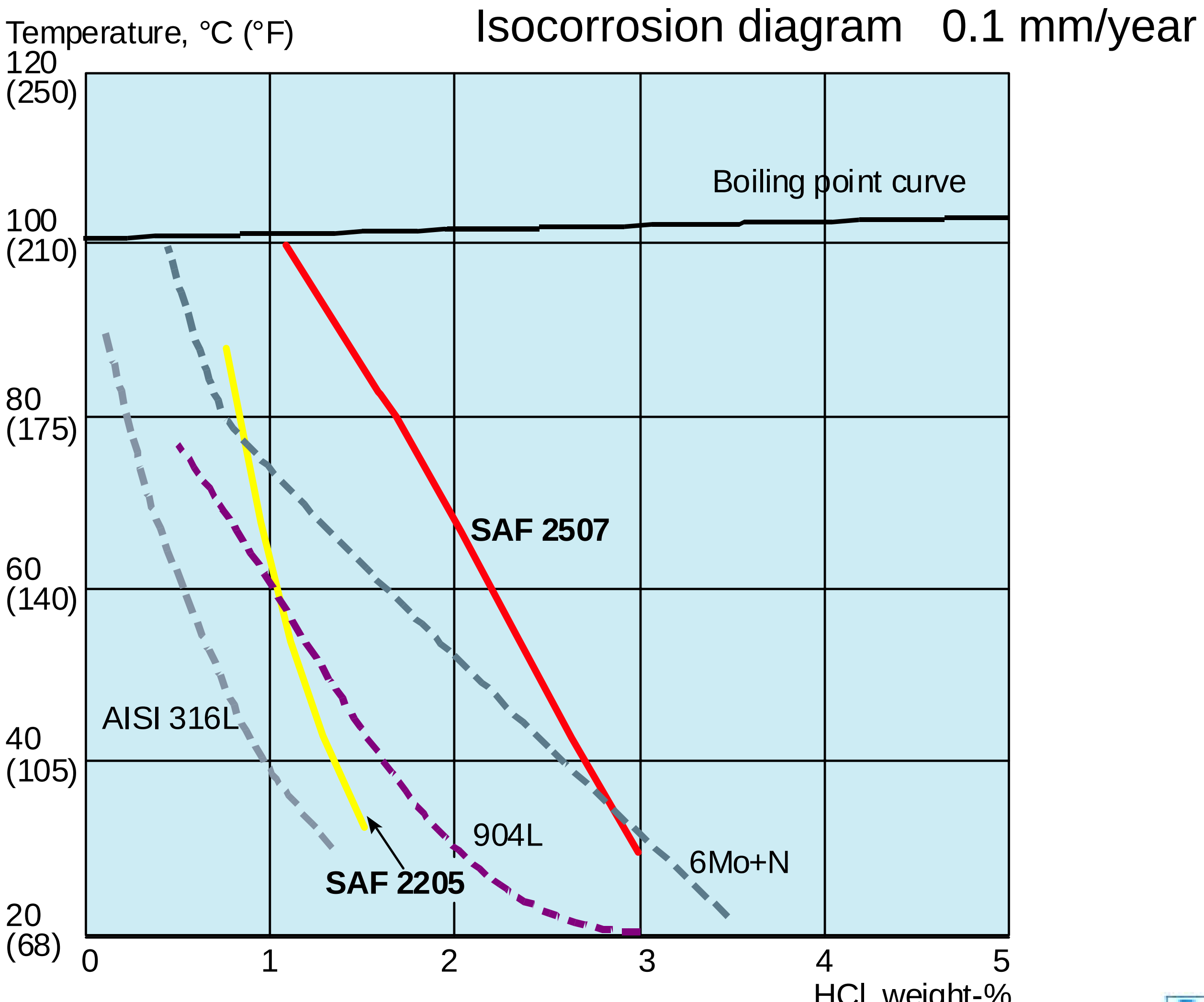


Pitting Resistance Equivalent (PRE)

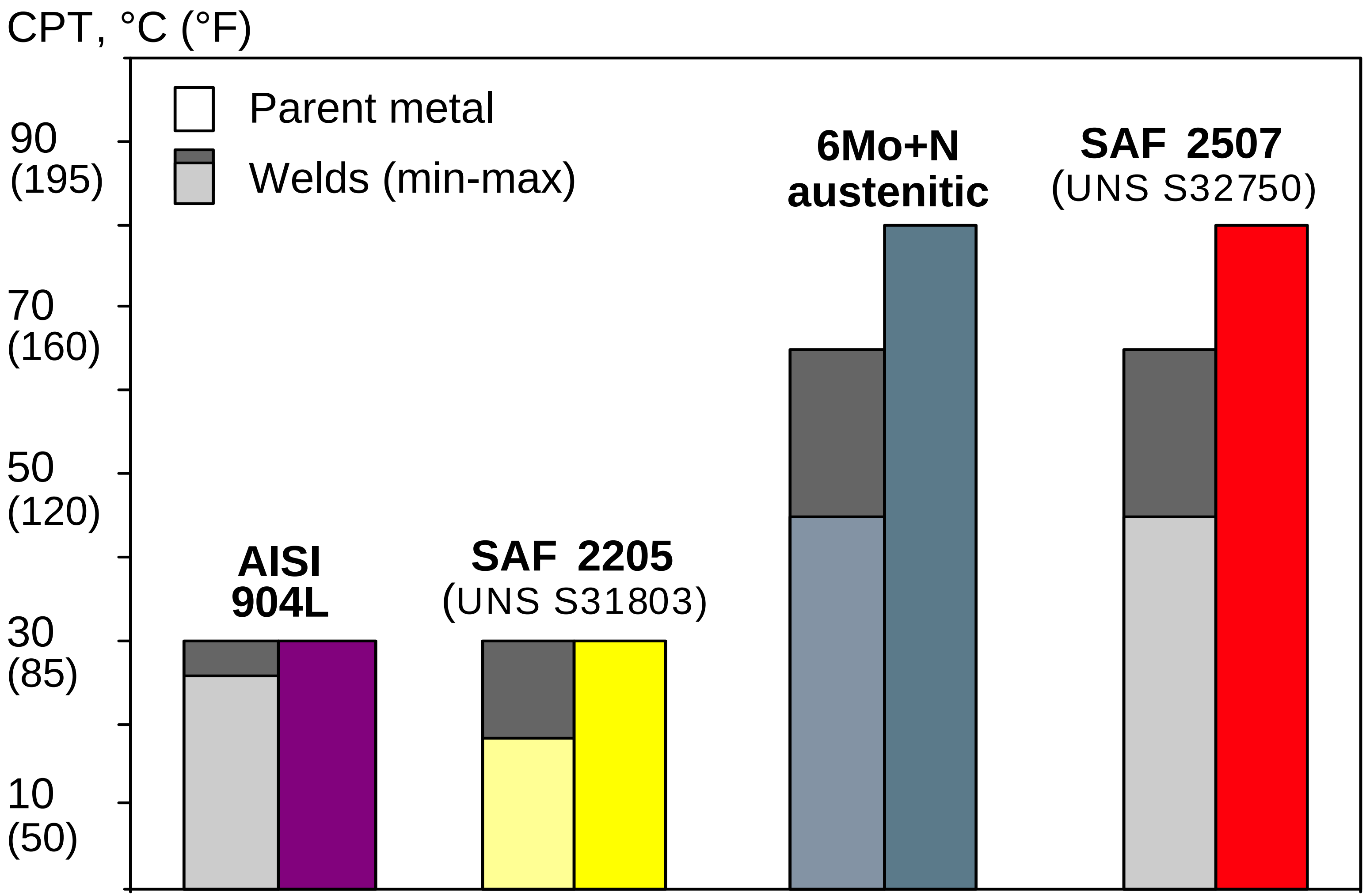
Alloy	% Cr	% Mo	% N	PRE
SAF 2707HD	UNS S32707			49
SAF 2507	25	4	0.3	42,5
254 SMO	20	6.1	-	40
SAF 2205	22	3.2	0.18	35
3RE60	18,5	2,6	0,08	28
AISI 316L	17	2.2	-	24

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

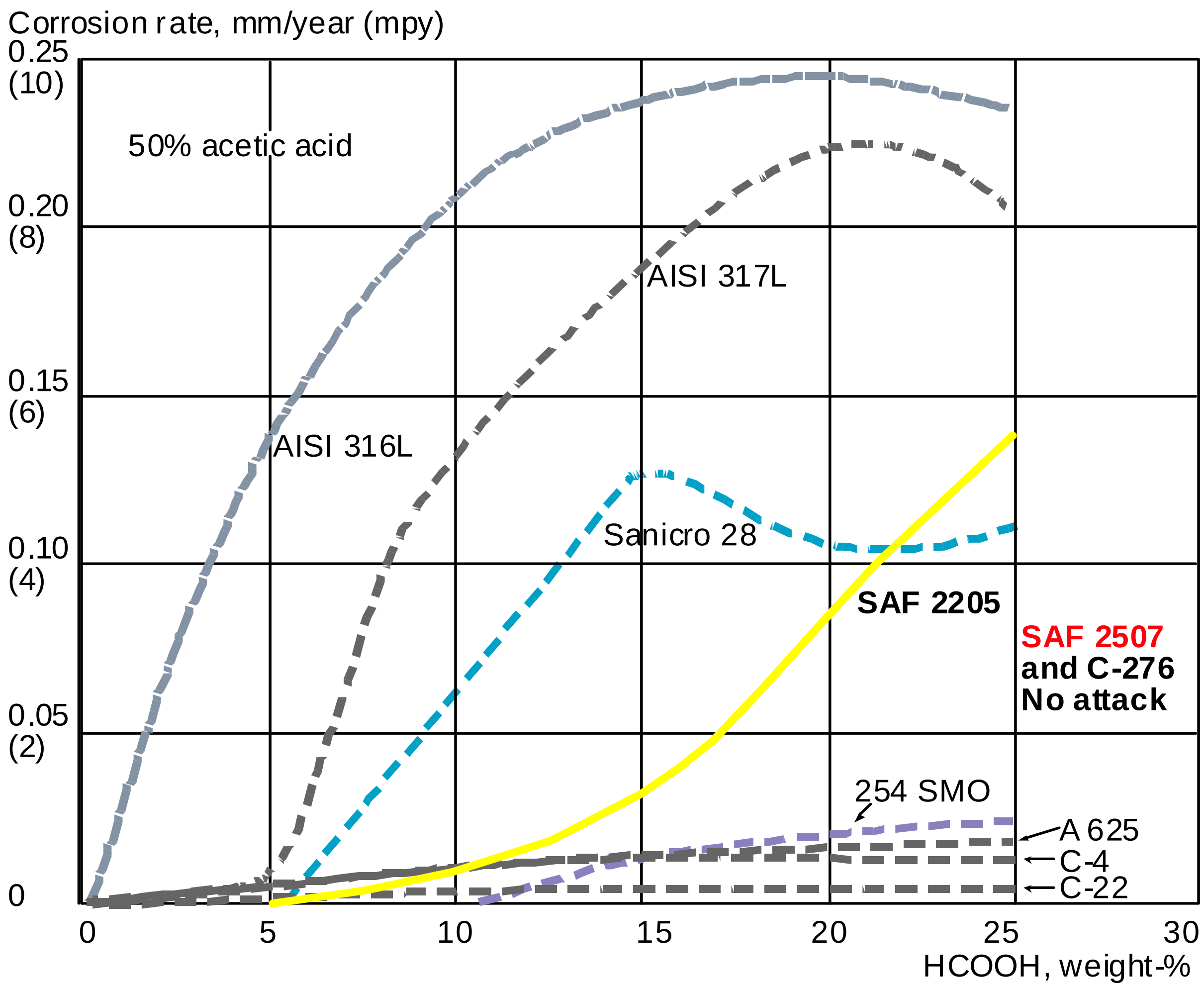
Hydrochloric acid, HCl



Critical Pitting Temperature (CPT)
6%FeCl3, ASTM G48 A

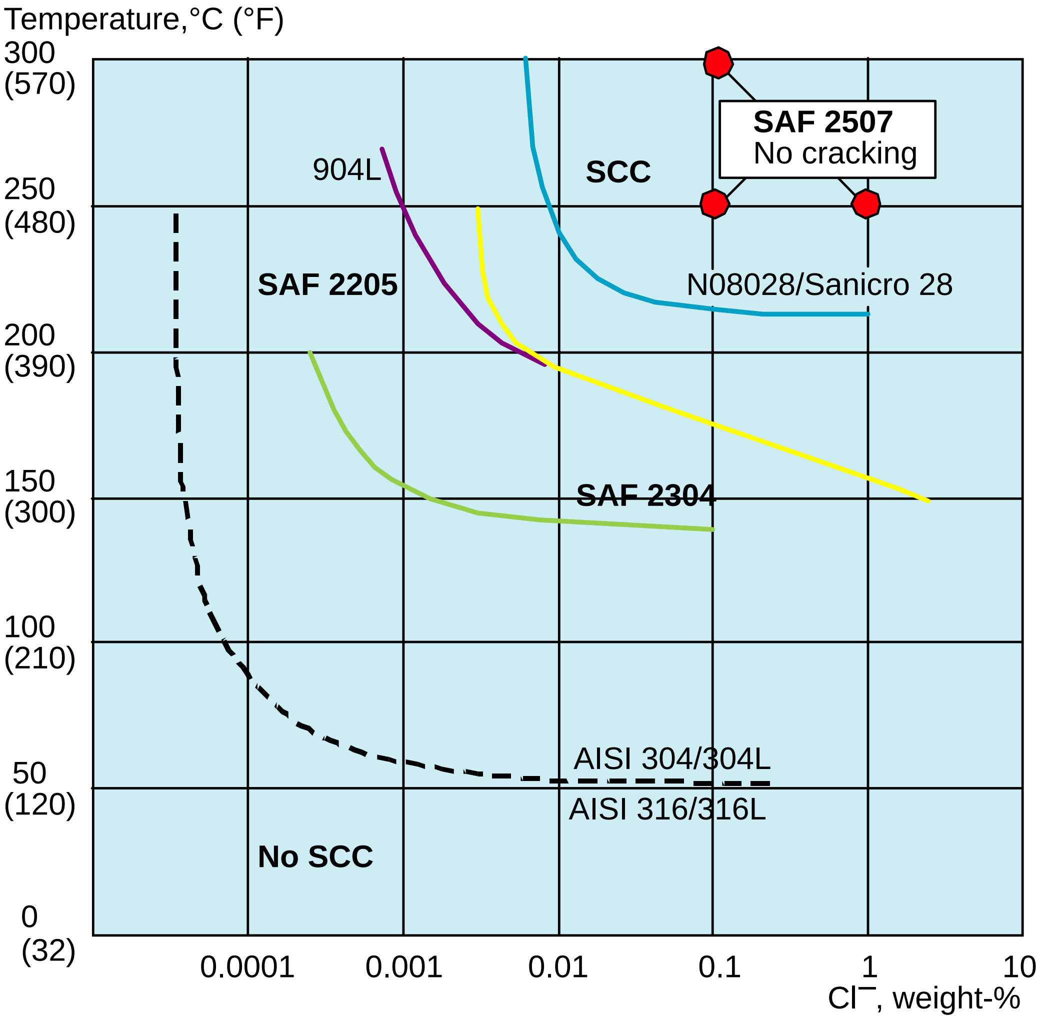


50%Acetic acid + Formic acid
Corrosion rates



SCC Resistance

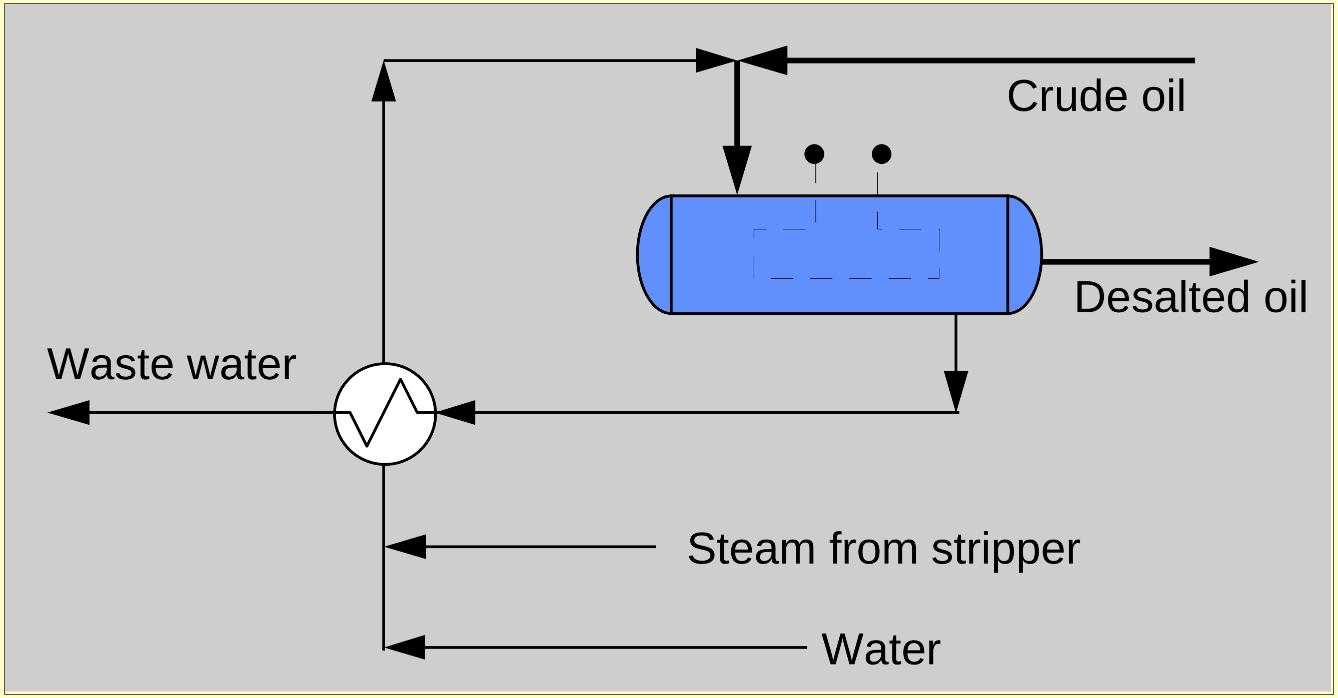
Oxygen bearing neutral chloride solutions (abt 8 ppm)



Testing time 1000 h

Applied stress equal to yield strength at testing temperature

Crude Oil Desalting



Feed/Effluent Exchanger
3RE60
SAF 2205 or higher PRE

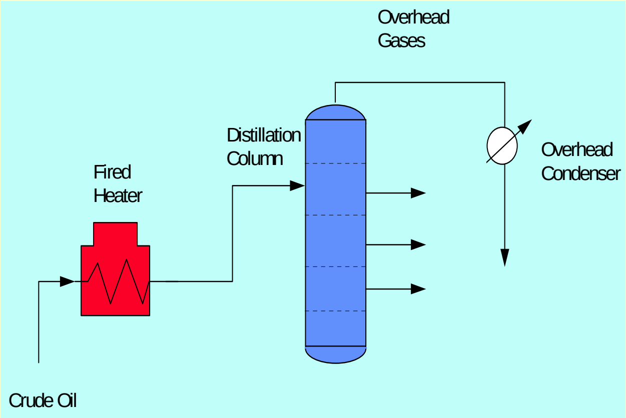
Specific Problems
Chlorides
- SCC, pitting

Crude Oil Desalting

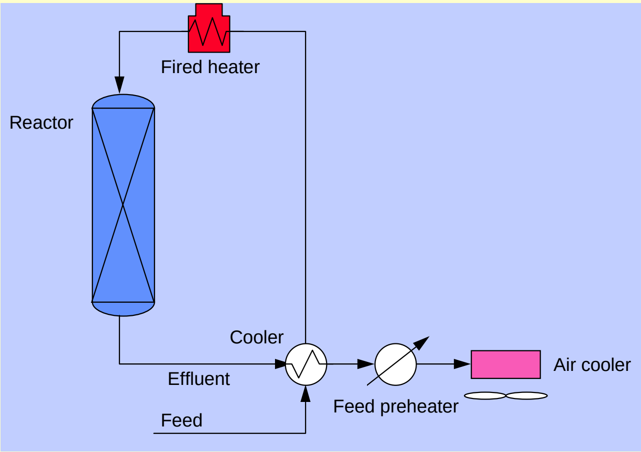
Country	**Germany**	
Size / Quantity	**19.05 x 2.11 x 4880mm, 2400m**	
Service conditions	**Tube side :**	**Waste water with 700-900 ppm chlorides, pH 6.6 Temp. inlet 190°C Temp outlet 75°C**
	Shell side :	**Feed water with 2 ppm chlorides, pH 7.1 Temp. inlet 35°C Temp outlet 145°C**
Previous experience	**Carbon steel failed after 12-18 months due to general corrosion. AISI 410 showed evidence of pitting**	
Sandvik SAF 2205	**3RE60 in service for 17 years without any sign of attack on the tubes. Replaced with two parallel lines, each with three heat exchangers in SAF 2205**	

SAF2507/SAF2205 in refinery heat exchanger applications

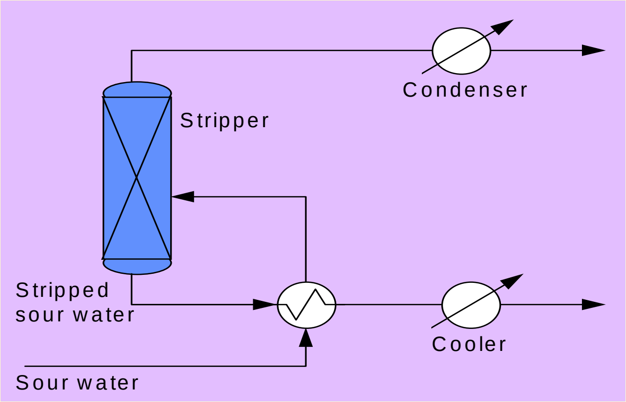
* Crude distillation (OH condensers)



* Hydrotreating



* Waste water treatment



* Sour gas cleaning (Amine unit)

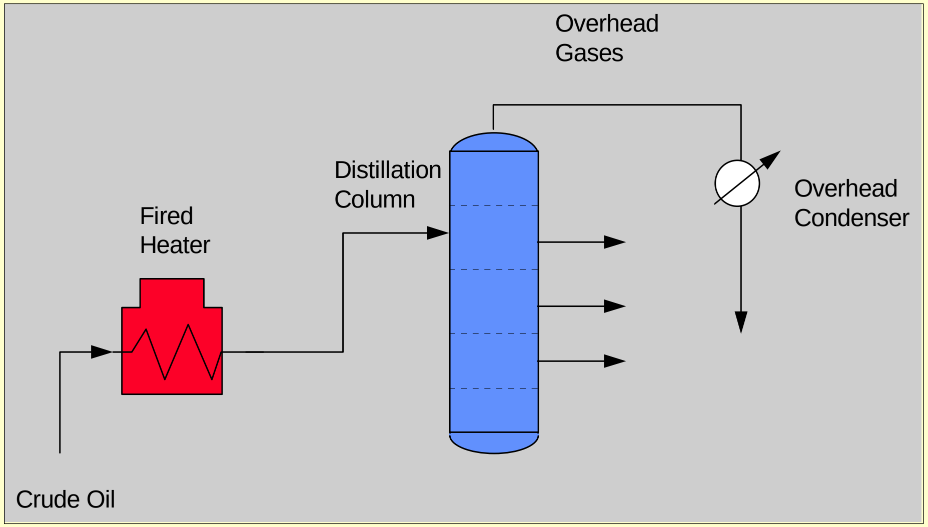
* Desalting

* Fluid Catalytic Cracking (FCC)

* Cooling waters containing Cl^-

* Sea water coolers

Crude Distillation Unit
OverHead condensers



__Specific Problems__

- HCl, dew-point corrosion
- Chlorides, pitting
- Ammonium chloride, under deposit corrosion
- H_2S

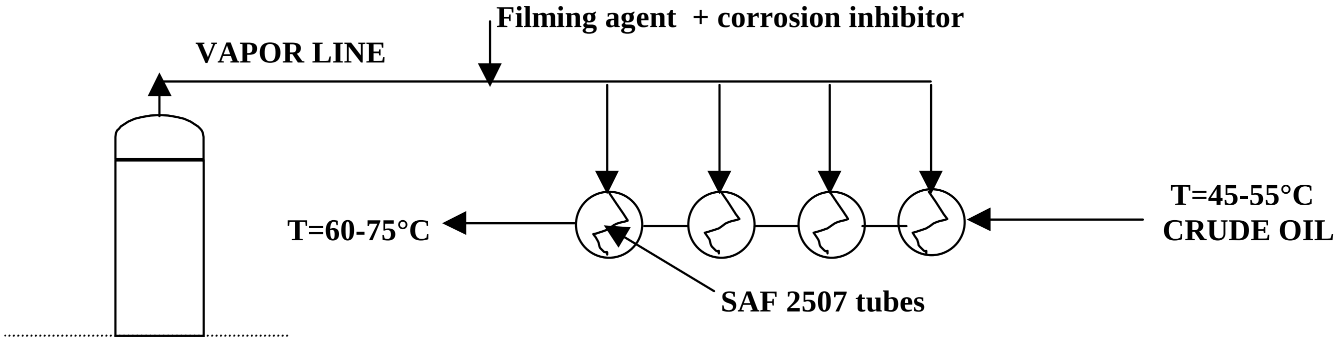
__Materials: SAF 2507 ➔ SAF 2707HD (PRE 49)__

CDU OH condensers
Reference example 1

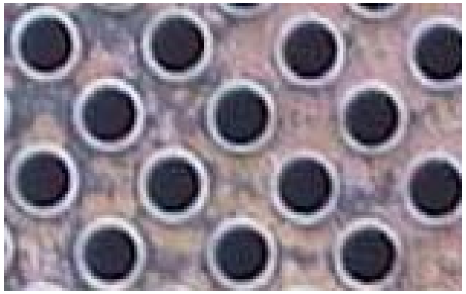
Country	**Italy**	
Size	**19.05 x 1.65 x 6096 mm, 951 tubes per HX**	
Service conditions	**Tube side :**	**Condensing hydrocarbons + H_2O(traces)** **Cl- 30 - 100 ppm, H_2S 200-1000 ppm** **pH 6-7** **Inlet temp 120 - 138°C** **Inlet pressure 0,8 - 1,2 kg/cmq**
	Shell side :	**Crude oil** **Inlet Temp 45-55 °C** **Outlet Temp 60-75 °C**
Previous experience	**Formerly tubed with C-steel with service life maximum 1-2 years.**	
Sandvik SAF 2507	**First condenser in service since 1992. Cleaning and inspection in April 2000 showed tubes still in excellent condition. Totally 4 HE's in service since 2002**	

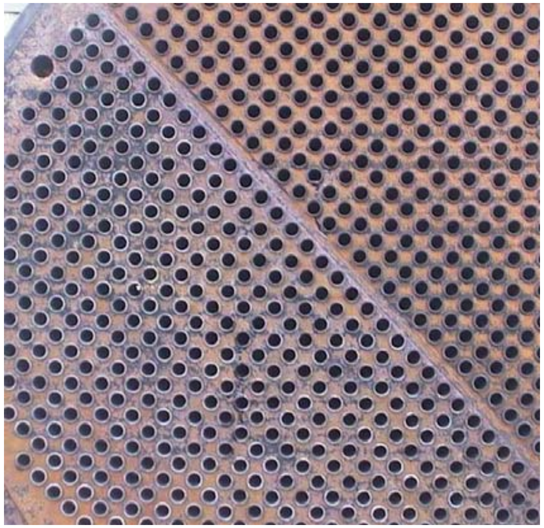
Atmospheric CDU OH condensers SAF 2507 (Ref. ex.1)

- **Detailed inspection in April 2000 included:**
  - ✓ Visual inspection
  - ✓ Eddy current
  - ✓ Ultrasonic (IRIS)
  - ✓ Video probe



Visual inspection
(Ref. ex.1)





- Tube to tube-sheet joints
  - ✓ Good condition
- Inside tube
  - ✓ Unaffected
- Outside tube
  - ✓ Unaffected underneath the crude oil deposit that had formed
- Tubesheet (C-steel)
  - ✓ Some corrosion observed

Non destructive testing
(Ref. ex.1)

- **EC test**
  - ✓ **No defects detected for any of the 951 tubes**
- **Ultrasonic testing (IRIS)**
  - ✓ **None of 100 investigated tubes showed any decrease in nominal tube wall thickness**
- **Video Probe**
  - ✓ **Surfaces in general as new**
  - ✓ **A few minor localised spots with depth < 0,1 mm (below EC detection level) were found.**

CDU OH condensers
Reference example 2

Country	**Italy**			
Size	**25.4 x 1.65 x 6096 mm, 990 tubes (6 HE's - lower HE bank)**			
Service conditions	**Shell side :**	**Condensing hydrocarbon gases**		
		Temp.	**Inlet**	**167°C**
			Outlet	**134°C**
	Tube side :	**Crude Oil**		
		Temp.	**Inlet**	**32°C**
			Outlet	**112°C**
Previous experience	**Formerly tubed with C- steel in size 25.4 x 3.4 mm suffering severe general corrosion with service life shorter than 2 years**			
Sandvik SAF 2507	**First condenser installed in 1996 retubed after 9 years. Due to the good experience other 5 new bundles SAF 2507 were put in service in 2000 to complete the lower HE bank where most HCl condensation occurs.**			

CDU OH condensers
(Ref. ex.2)

SAF 2507 tubes after high pressure water cleaning

CS tie rods and baffle plates show significant corrosion attack

CDU OH condenser
C-steel tubes after 2-3 years service

C-steel tube bundle to be retubed

CDU OH condensers

Reference example 3

Country	Germany
Size	19.05 x 2.11 x 4880 mm , 1740 tubes per HX
Service conditions	Tube side : Crude Oil
	Shell side : Condensing hydrocarbon gases
Previous experience	Formerly using carbon steel. Corrosion problems gave a service life of no more than 2 years
Sandvik SAF 2507	Installed in beginning of 1997. When checked in 1999 still in perfect condition

SANDVIK

SAF 2507 in CDU OH condenser after 3 years service

s4

SAF 2507 tube bundle appearance before intermediate cleaning with pressurized water

SAF2507 benefits for CDU overhead condensers

- **Increased operational window**
  - ✓ Tolerate slight changes in operation of the unit
  - ✓ Tolerate upset condition experienced due to problems in control of chemical inhibition over time
  - ✓ Tolerate variation in used crude oil chemistry (impurity level)
  - ✓ Less sensitive to “human errors”
- **Less inspection and maintenance**
  - ✓ Pro-longed inspection intervals
  - ✓ Reduced costs and shorter stand-still periods
  - ✓ Better cleanability to remove salts or solid hydrocarbons during planned shutdowns
  - ✓ Higher initial cost but lower LCC compared to C-steel
- **Lower risk for undesired shut-downs**
  - ✓ High associated production losses, if occurring

Vacuum Distillation OH Condensers

Country	**UK**	
Size	**25.4 x 2.11 x 4622 mm**	
Service conditions	**Tube side :**	**Seawater** **Temp. inlet : ambient** **Temp outlet 40°C**
	Shell side :	**Hydrocarbon gases** **P = 2.3 bar with full vacuum** **Temp. inlet 240°C** **Temp outlet 100°C**
Previous experience	**Formerly tubed in Admirality brass with matching tubesheets but corrosion rates were high**	
Sandvik SAF 2507	**Tubing expanded into original tube-sheets and installed in 1994. Sacrificial Fe anodes installed to avoid galvanic corrosion.**	

Hydrotreating process flow diagram

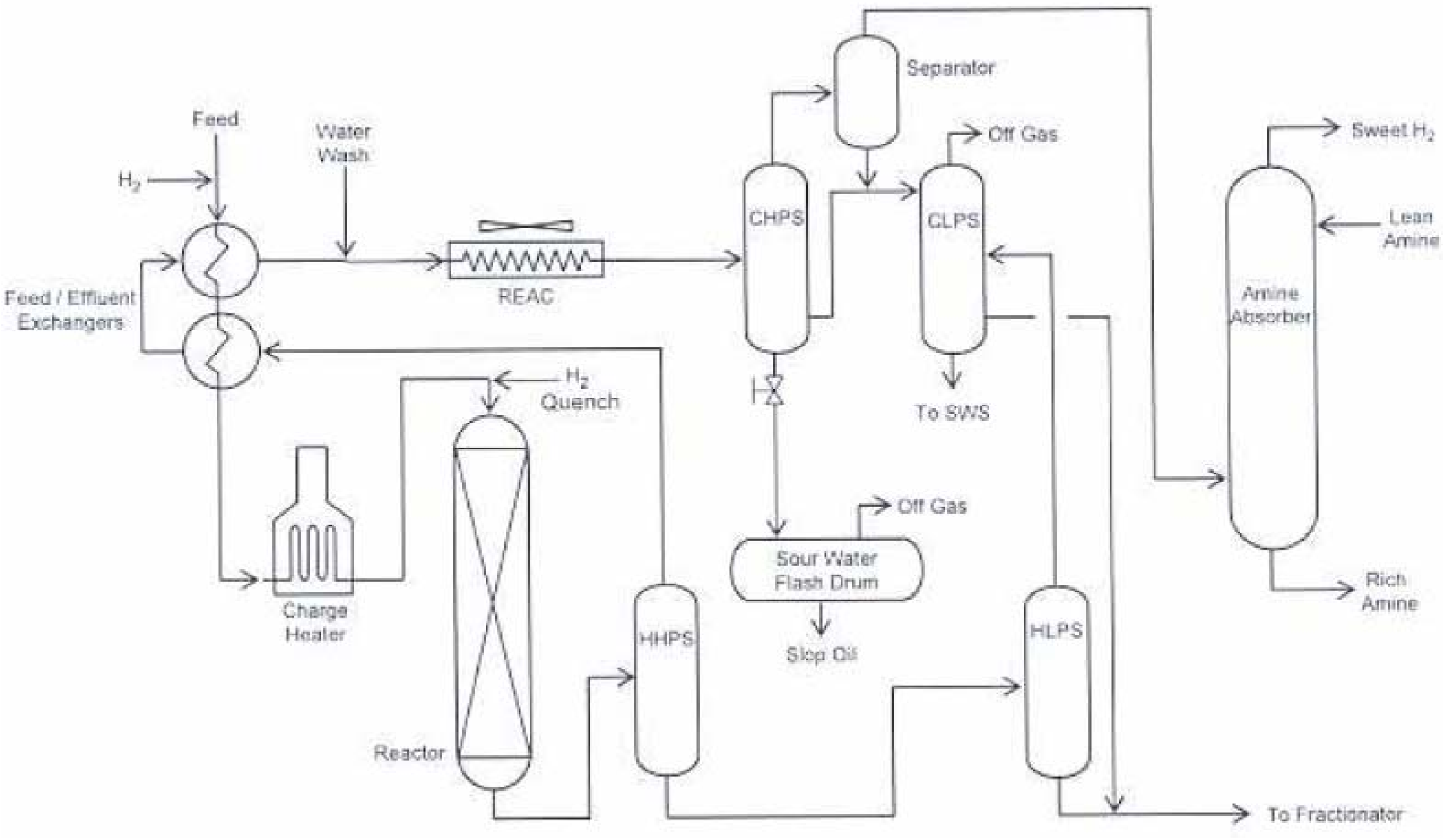
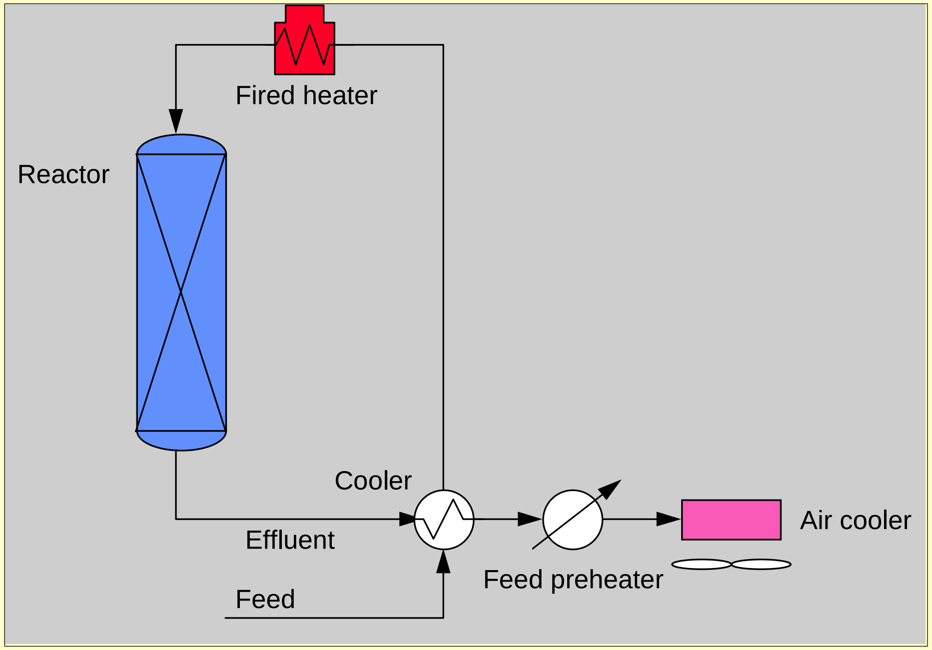


FIGURE 4 – Hydrotreating process flow diagram.

Hydrodesulphurisation (HDS)



Specific Problems

Chlorides
- SCC
Ammonium bisulphides
- Erosion, Under-Deposit
Polythionic Acid
-Intergranular Corrosion
-(SCC)

Feed/Effluent Exchanger
TP 321, TP 347
SAF 2205

Reactor Effluent Air Cooler
SAF 2205, SAN 28
Alloy 825,

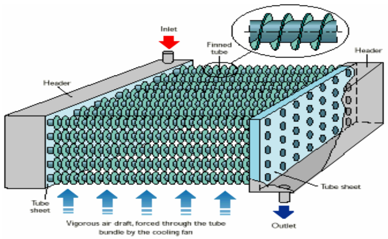
HDS Feed / Effluent HX

Country	Singapore	
Size	19.05 x 2.11,mm	
Service conditions	Tube side :	Reactor effluent containing traces of chlorides P = 2.9 MPa Temp. inlet 345°C Temp. outlet 230°C
	Shell side :	Feed (light virgin naptha) P = 3.3 MPa Temp. inlet 135°C Temp. outlet 315°C

Previous experience : AISI grade 321 failed due to Chloride Stress Corrosion Cracking

Sandvik 3RE60 — 7 years service recorded. No further update

HDS Reactor Effluent Air Cooler

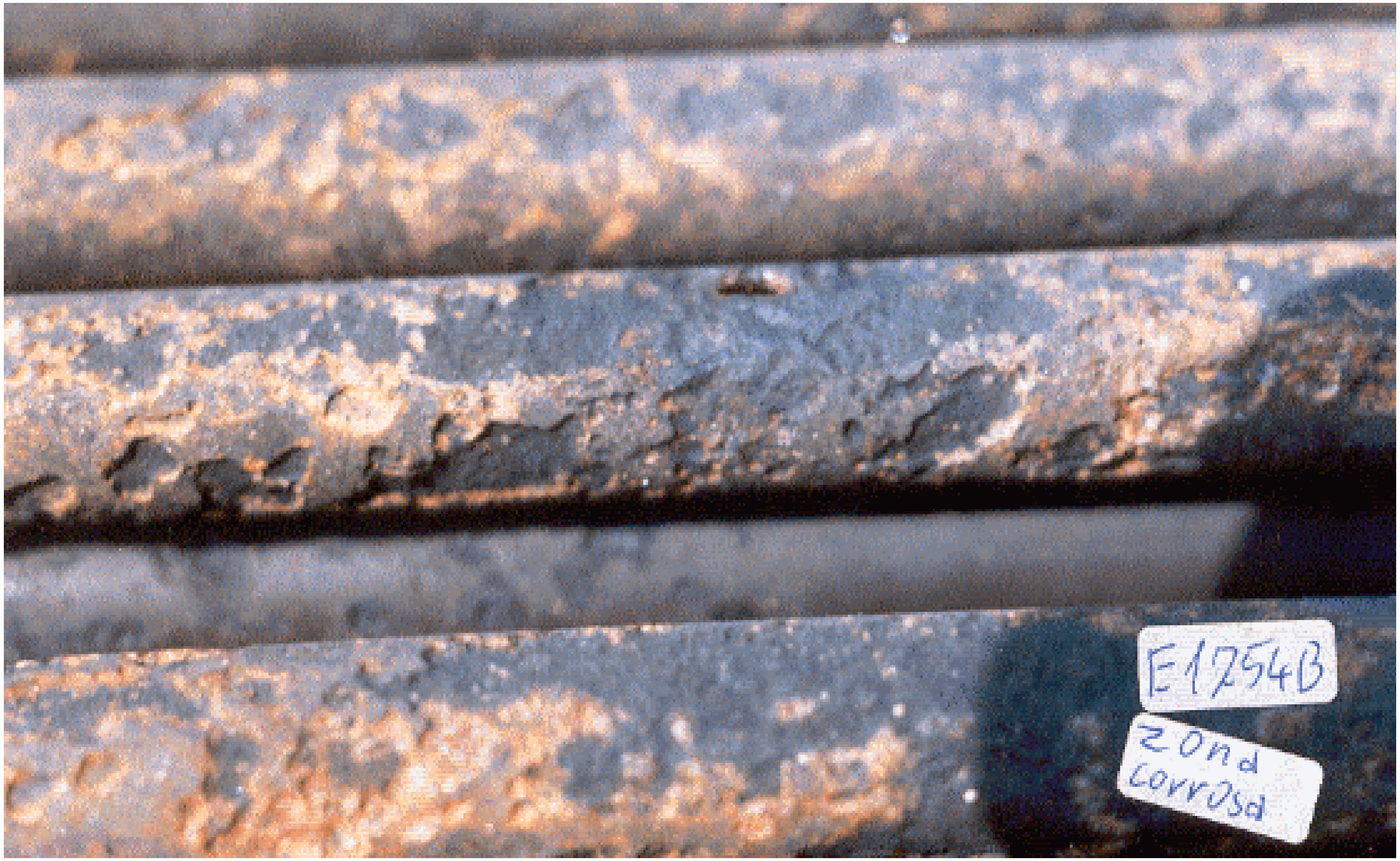


Country	**UK**	
Size	**25.4 x 2.11 x 9271mm**	
Service conditions	**Tube side :**	**Kerosine with approx. 10,000ppm H_2S** **Temp. inlet 160°C** **Temp. outlet 40°C**
	Shell side :	**Air** **Temp. ambient**

Previous experience — **Formerly tubed in C-steel which were replaced every 18 months due to under-deposit corrosion in the presence of ammonium compounds. A water wash system was considered but even distribution could not be guaranteed.**

Sandvik SAF 2205 — **Tubing had extended surface finning applied and was installed in 1995. Units in service for > 4 years with no evidence of corrosion.**

NH_4HS corrosion on a effluent HDS kerosine HEx



C-steel tubes

Corrosion resistance to NH_4HS

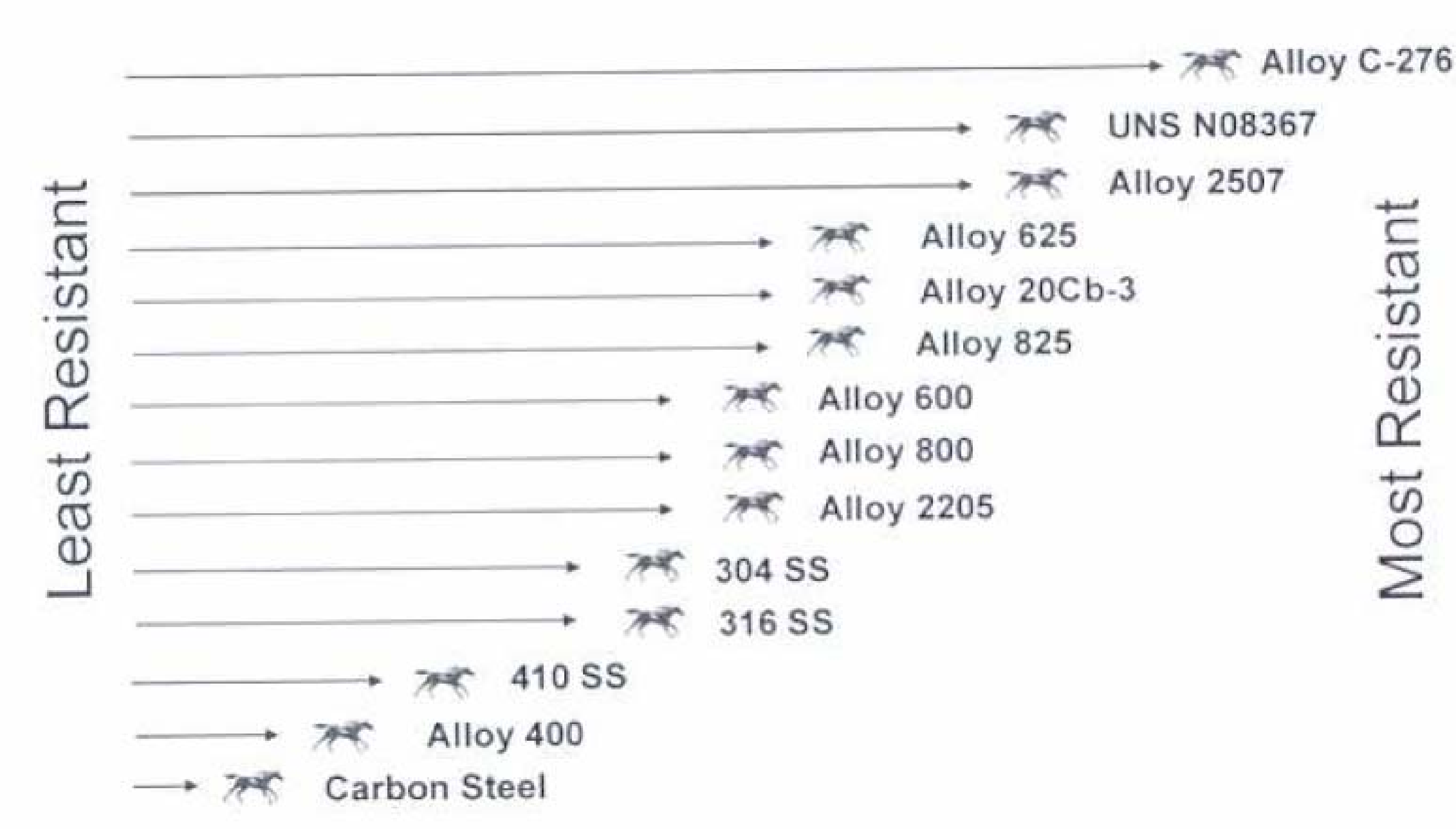
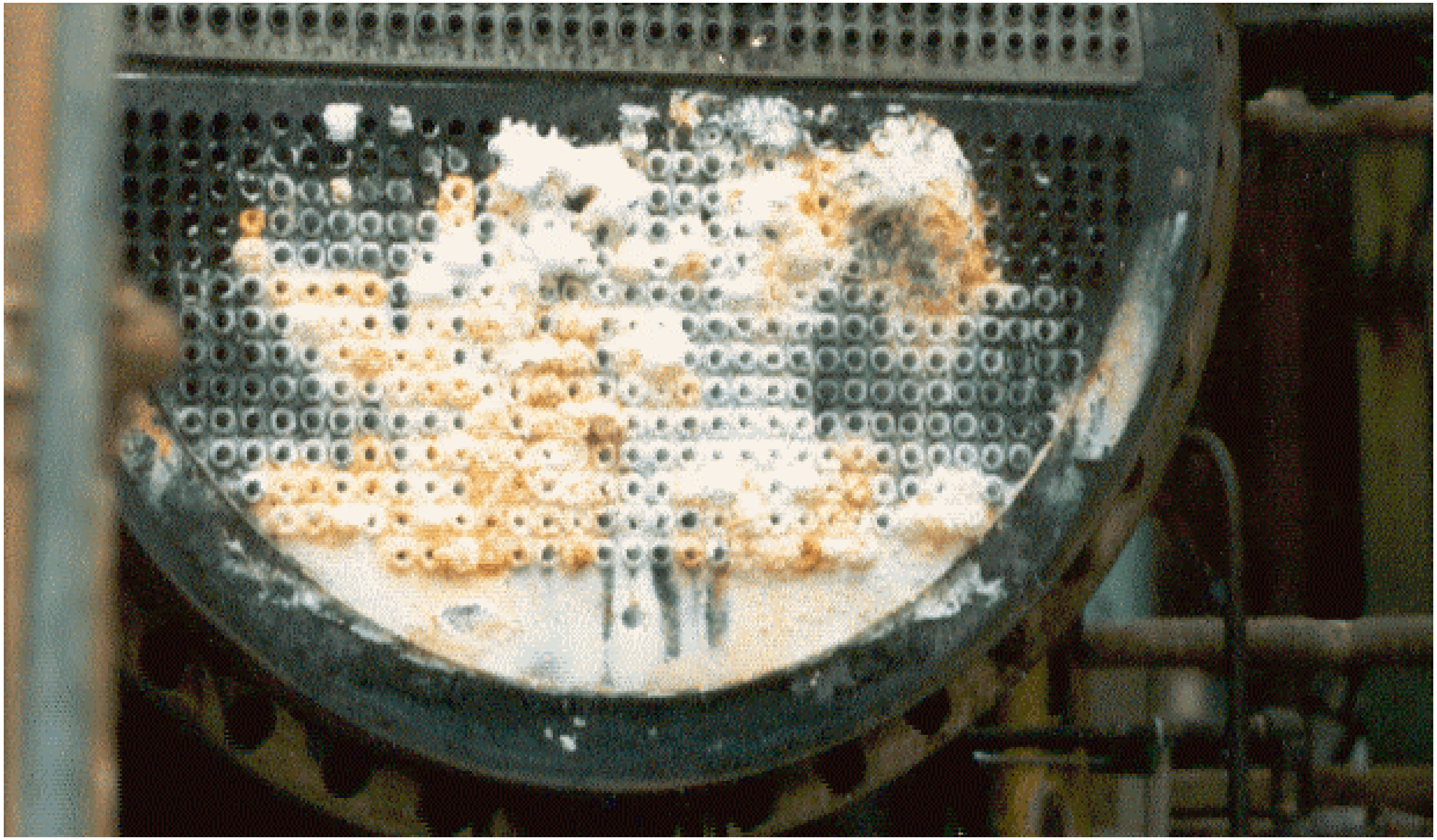


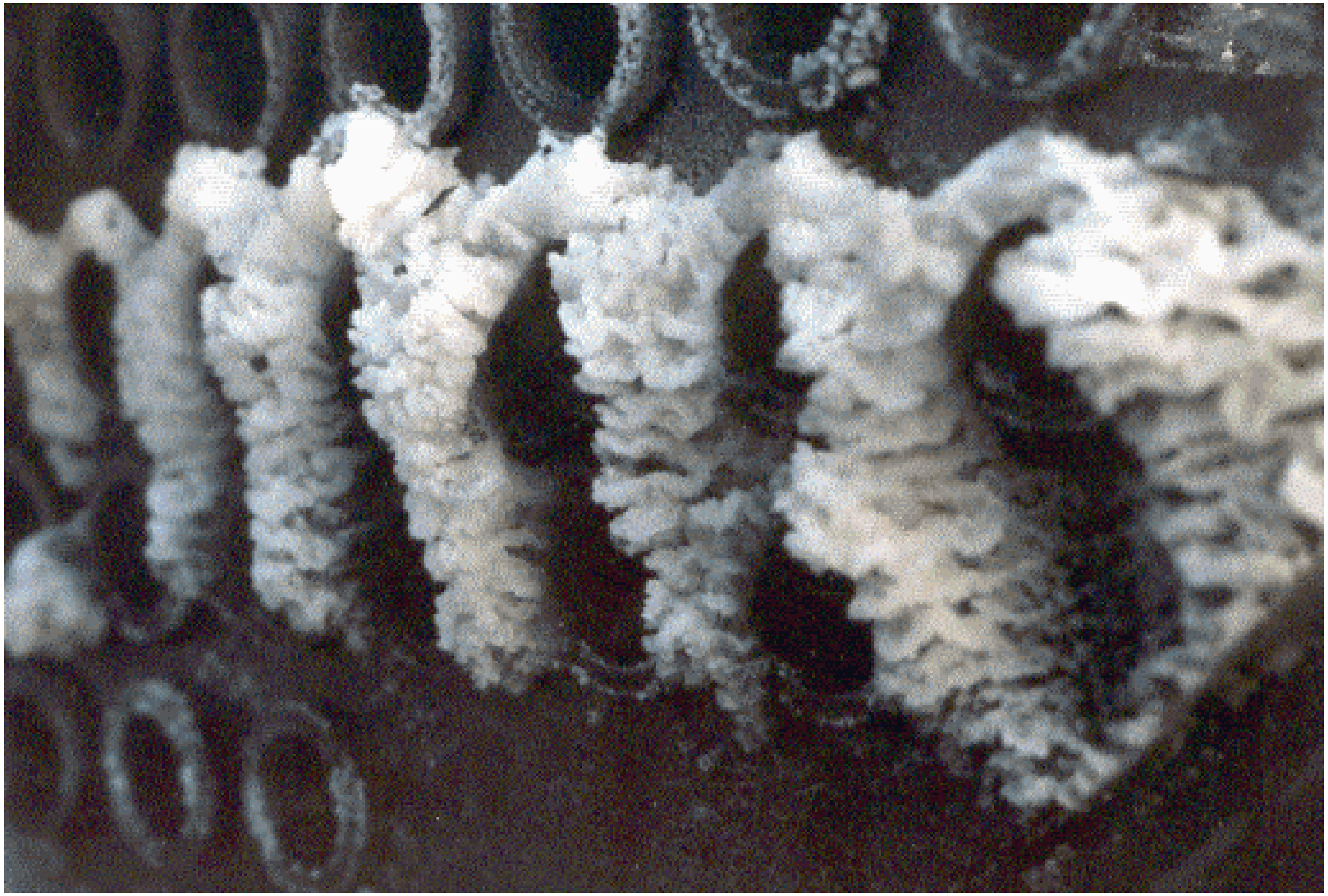
FIGURE 4 – Material Resistance to NH_4HS Corrosion

Reference: R.J Hovath,M.S.Cayard,R.D.Kane – Prediction and Assessment of NH4HS corrosion under refinery sour water service conditions – Paper No.06576 -2006

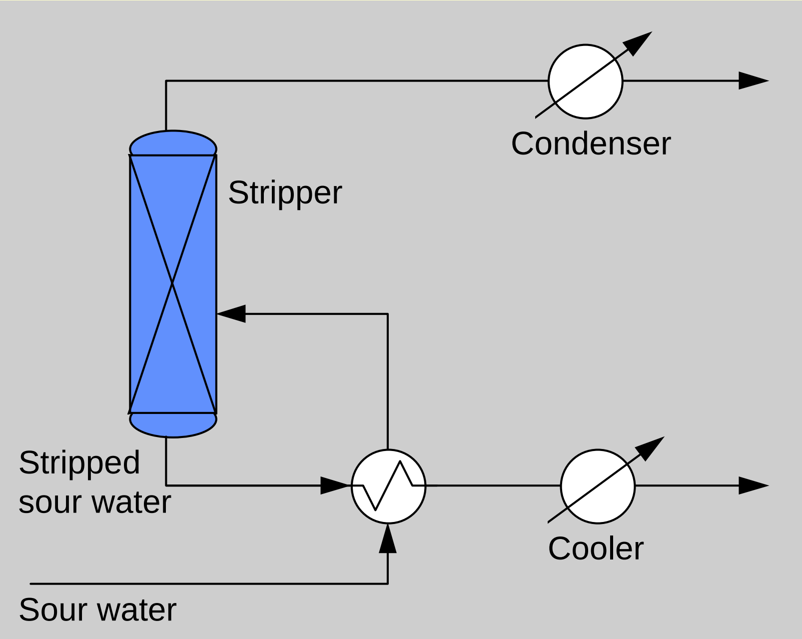
NH_4Cl deposits on a HDS gasoline heat exchanger



NH_4Cl deposits on a HDS kerosine heat exchanger



Sour Water Stripping



Specific Problems

Chlorides, H_2S, NH_4, CO_2
- General corrosion
- Pitting, SCC

* ***Sour water feed/bottom HX***
* ***Stripper OH condenser***
* ***Air coolers***

Materials: SAF 2205 → SAF 2507 (PRE 42,5)

Sour Water Feed / Bottom HX

Country	UK
Size	19.05 x 1.65 mm in U- bent form
Service conditions	
Tube side :	Sour water feed, 180 ppm Cl^-, 3000 ppm NH_3, 7000 ppm H_2S Temp. inlet 60 °C , Temp. outlet 80 °C P- 2.1 bar , pH 6.9
Shell side :	Stripper column bottoms 180 ppm Cl^-, 100 ppm NH_3 140 ppb H_2S Temp. inlet 120 °C , Temp. outlet 100 °C P 2.3 bar, pH 6.7

Previous experience: New system implemented to meet EEC standards.

Sandvik SAF 2205 Was chosen for resistance to chlorides in the cooling water and H_2S on the shell side. When inspected after > 4 years, still in excellent condition.

Sour Water Stripper - Condenser

Country UK

Size / Quantity 19.05 x 1.65 mm in U-bent form

Service conditions

Tube side : Cooling water from closed loop system
300 ppm Cl^-
Temp. inlet 23°C
Temp. outlet 28°C

Shell side : Condensing gas
8.17% NH_3
6.9% H_2S
Temp. 115°C
pH 8.1

Previous experience: New system implemented to meet EEC standards

Sandvik SAF 2507 SAF2507 chosen for resistance to Cl^- and higher levels of H_2S. Good performance

Sour gas cleaning - Condenser

Country	Canada
Size	25.4 x 1.65 mm, in U-bent form
Service conditions:	Tube side : Steam
	Shell side : Amines containing CO_2, cyanides, polysulphides, NH_3 and H_2
Previous experience:	C-steel failed. Testing undertaken where 304 showed pitting and SCC and SAF grades gave good results
Sandvik SAF2205	Delivered in April 1997 as U-tubes with the inner rows heat treated.

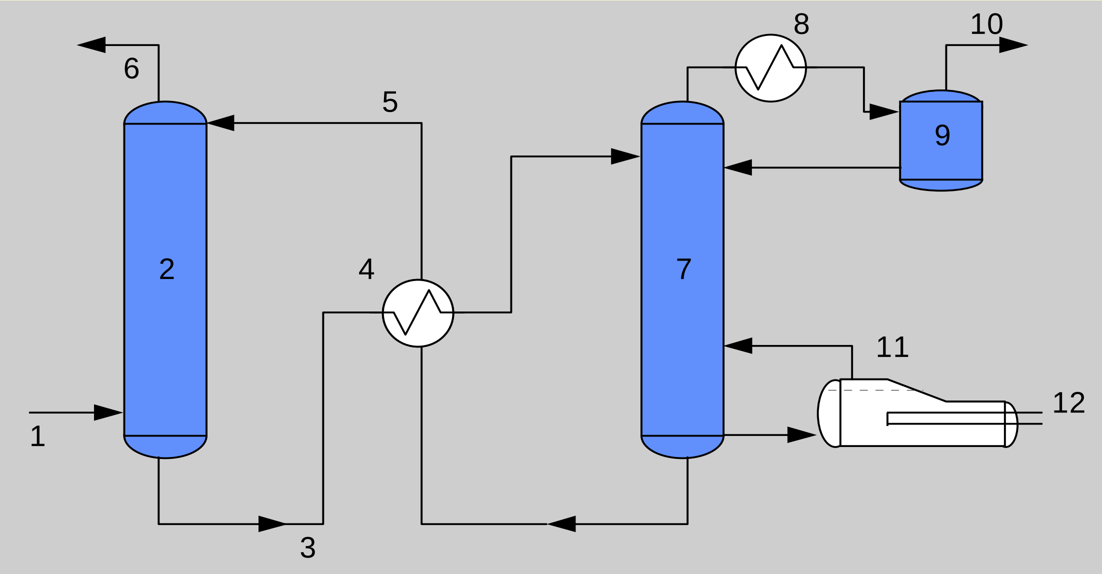
Sour water treatment

Country	Italy
Size	19.05 x 2.11 x 4877 mm, 870 tubes (E45 A/B/C)
Service conditions	Shell side : Water from desalter+water from sour water stripper (NH_3, CN^-, Cl^-) Design temp. 140°C Tube side : Refinery cooling water with 6000 ppm chlorides. Design temp. 155°C
Previous experience:	Formerly tubed with Cu-Ni 70-30, but severe corrosion occurred after sour water additions on the shell side
Sandvik SAF 2507	Replacement of the tube bundle carried out in 2002. In service since, with good result.

Fluid Catalytic Crackin (FCC) condensing section

Country	Italy
Size	20 x 1,5 x 6100 mm 1200 tubes (E209 A/B/C) 20 x 1,25 x 4880 mm 942 tubes (E209 D/E)
Service conditions	Shell side : first stage condensate (water and hydrocarbons) from FCC plant (UOP) sulphides 3000-4000 ppm, NH_3 4000-5000 ppm, Chlorides 10-20 ppm, pH 8-9 Temp: inlet 80°C/out 30°C Tube side : chlorinated seawater Temp. inlet 25°C /outlet 30°C
Previous experience:	HX tubed formerly with Al-brass and Cu-Ni 70-30, but severe SCC occurred due to NH3 and sulphides
Sandvik SAF 2507	Replacement of first tube bundle carried out in 1997. Today 5 HX's in service since 2001 with good result.

Gas cleaning (Amine unit)



Specific Problems

Chlorides
-SCC
-Amines (MEA, MDEA)
- general corrosion, SCC

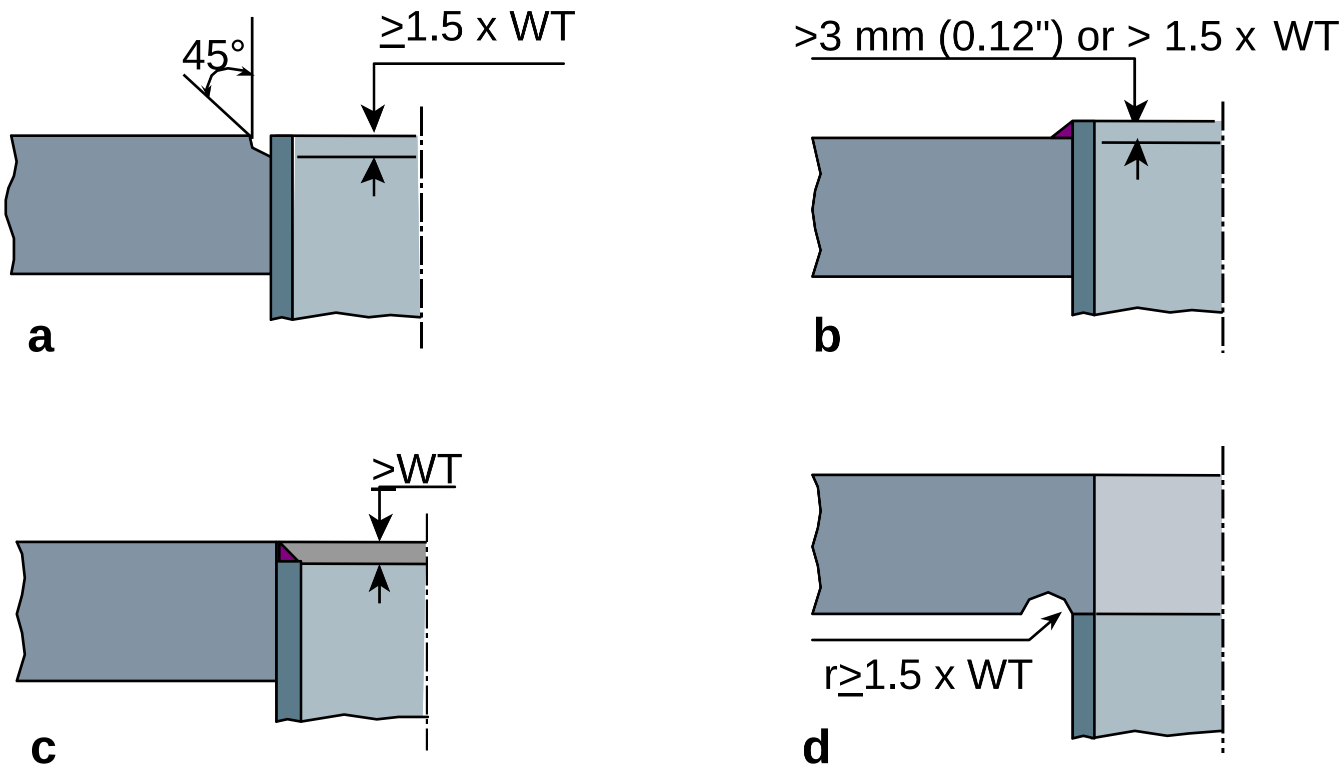
Rich/Lean amine HX
Reboiler
Condenser

SAF 2205, SAF2507

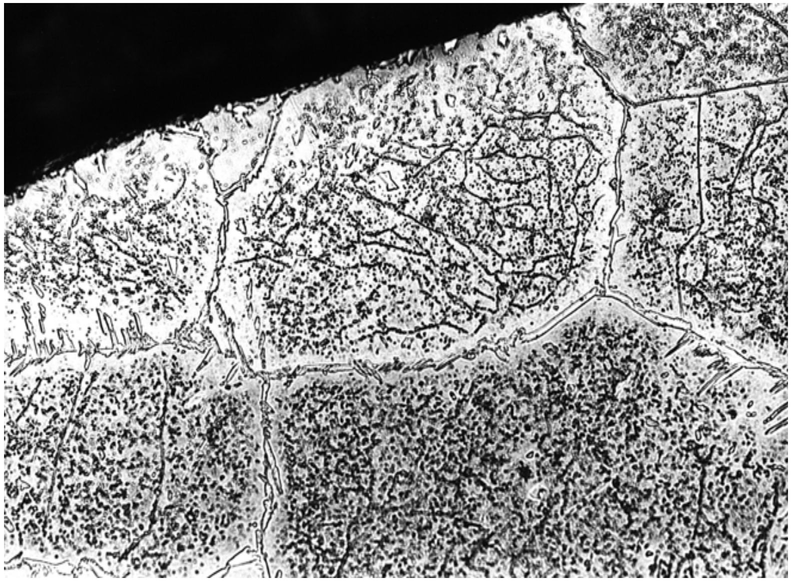
NH_4HS corrosion in a amine unit reboiler

C-steel tubes

Tube to tube-sheet welding of stainless steels. Joint preparation

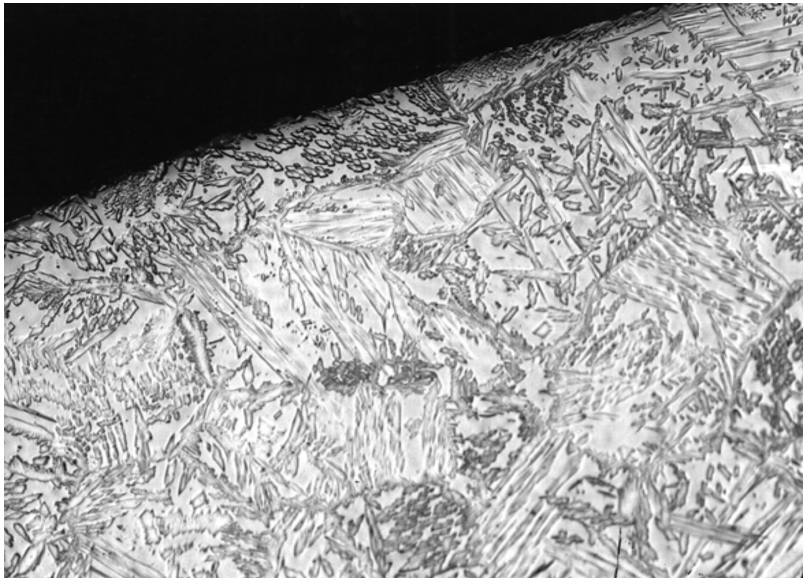


Effect of shielding gas on duplex T/TS welds



Shielding gas: Ar

Excessive ferrite

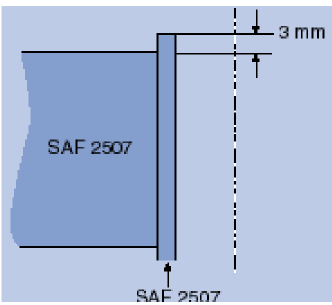


Shielding gas: Ar + **2-3% N_2**

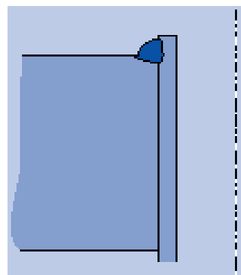
Good ferrite / austenite balance

Welding of SAF 2507 tubes to SAF 2507 tube-sheet

Joint preparation



Weld pass sequence



Base metal

Form:	**Tube**	**tube sheet**
Material specification:	**UNS S32750**	**UNS S32750**
Trade name:	**SAF 2507**	**SAF 2507**
Dimension, mm:	**19.05 x 1.65**	**t = 40**

Filler metal

Trade name:	Sandvik 25.10.4.L
Dimension, mm:	Ø 1.6

Welding technique

Process:	TIG (GTAW)
String or weave:	Stringer beads
Initial/Interpass cleaning:	Degrease joint area
Post weld cleaning:	Stainless steel brush and/or pickling paste
Preheat:	None
Post weld heat treatment:	None
Shielding gas:	Ar 97% N_2 3%
Flow rate, l/min:	10

Welding conditions

Pass No.	Welding process	Filler Designation	Size, mm	Current Polarity	Range, A	Voltage Range, V	Travel speed, mm/min	Heat input kJ/mm
1	TIG	25.10.4.L	1.6	DC-	60-100	10-11	40-110	0.2-1.5

SAF2507 cost considerations

- Higher initial cost but lower Life-Cycle Cost compared to C-steel
- More cost effective grade compared to other special stainless steels
- Simple and well functioning chemical control systems can be used => No large investments for advanced systems necessary
- Less demand for large new investments on desalting and/or water-wash equipment

Conclusions

- **Duplex and Superduplex stainless steels are ideal and cost effective for use in refinery heat exchanger applications:**
  - ✓ **Excellent corrosion resistance towards refinery process fluids and chloride containing cooling waters**
  - ✓ **High mechanical strength and erosion resistance**
  - ✓ **Low thermal expansion and high fabrication compatibility with refinery traditional materials**
  - ✓ **A constanty increasing use and awareness on duplex stainless steels among HX fabricators**

SAF2205, SAF2507 and SAF2707HD

- ✓ **A family of grades enabling optimum materials selection**
- ✓ **SAF2507 is today readily available grade in all product forms**
- ✓ **SAF2707HD, a new high PRE (49) hyper-duplex steel for refinery severe acidic & under-deposit corrosion conditions**

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