Appendix 1

List of participants

Participants EFC WP15 meeting 7th September 2011 Stockholm (Sweden)

Name	Company	Country
Johan van Roij	Shell Global Solutions International B.V.	NETHERLANDS
Stefan Winnik	Exxon Mobil Chemical	SINGAPORE
Pascale Sotto-Vangeli	Outokumpu	SWEDEN
Claudia Lavarde	GE S&I	FRANCE
Martin Hofmeister	Bayernoil Raffineriegesellschaft mbH	GERMANY
Amélie Ferey	Technip	FRANCE
Grzegorz Sielski	Sandvik Poland	POLAND
Berit Bøgner Skogstad	Statoil ASA	NORWAY
Stein Brendryen	Statoil ASA	NORWAY
Sandra Le Manchet	Arcelor Mittal	FRANCE
Andres Rivero	Statoil ASA	NORWAY
Stine Hals Verstraelen	CB&I Lummus B.V.	NETHERLANDS
Arjen Reinders	CB&I Lummus B.V.	NETHERLANDS
Tiina Hakonen	Neste Oil Corporation	FINLAND
György Isaak	MOL Hungarian Oil & Gas Co	HUNGARY
Baldy Laszlo	Env. & Corr. Manager	HUNGARY
Attila Veres	Env. & Corr. Manager	HUNGARY
Johan Sentjens	Temati	NETHERLANDS
Robin D. Tems	Saudi Aramco	SAUDI ARABIA
Chretien Hermse	TNO	NETHERLANDS
Jonas Höwing	Sandvik	SWEDEN
Knut Tersmeden	Sandvik	SWEDEN
Brian Chambers	Honeywell	USA
Bert Wolfs	Sabic	NETHERLANDS
Peter Krull	Holborn Europa Raffinerie GMBH	GERMANY
John Houben	ExxonMobil Chemical Holland BV	NETHERLANDS
Cecilia Oddstig	GE Water and Process Rechnologies	UK
Giorgio Longoni	Tecnimont	ITALY
Mike Billingham	Intetech	UK
Fred Van Rodijnene	Sulzer Metco Europe GmbH	GERMANY
Stephen Brennom	Sulzer Chemtech USA	USA
Alessandro Demma	Guided Ultrasonics Ltd	UK
Hennie de Bruyn	Johnson Matthey Catalysts	UK
Francois Ropital	IFP Energies nouvelles	FRANCE

Appendix 2

EFC WP15 Activities

(Francois Ropital)

Welcome to the EFC Working Party Meeting

"Corrosion in Refinery" WP15

Stockholm 7 September 2011

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 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

EFC Working Parties

http://www.efcweb.org

• A task force on CO_2 Capture and Sequestration (CCS) is launched

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 Vice Chairman: Hennie de Bruyn

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

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

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

Eurocorr Conferences

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

Publications - Guidelines

Publications from WP15

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

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

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

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

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

•Future publications : suggestions ?

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

EFC Working Party 15 plan work 2011-2013

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

. Sessions with other EFC WP at Eurocorr (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
  List of "corrosion refinery" related courses on EFC website ?

Information :
Future conferences related to refinery corrosion

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

•11-15 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

CUI and coatings

(J. Sentjens - Temati)

C.U.I.

EFC working party 15

Johan Sentjens

Agenda

- CUI
  Don’t only talk about the ***C*** but also about the ***I***
- Life Cycle Engineering
- Inspection-detection
- Insulation Systems: “OPEN” versus “CLOSED”
- New development: Insulating Coatings

Temati in a nutshell

- Technical Insulation
- Insulation System Supplier
- CUI Solutions

Statement

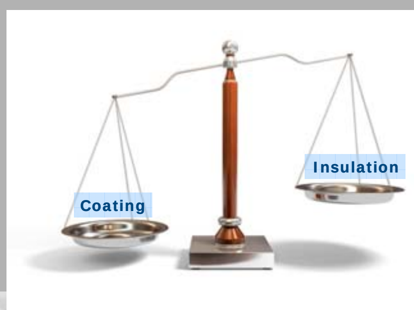
Insulation = Coating

=

Statement

Insulation = Coating

Form of protection



Statement

CUI is not a

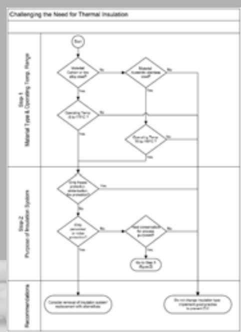
Technical Issue

but an

Organisation Issue

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

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

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

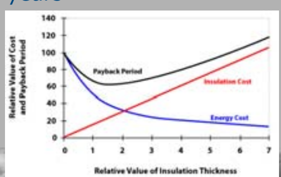
heat loss reduction **25%** when insulated sustainable.

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

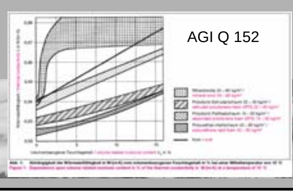
Return on investment?

Payback time 1 to 2 years

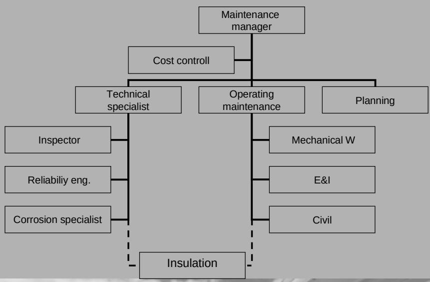


Food for Thought

- 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
  - ✓ TSA
  - ✓ Install new insulation

Same Insulation System ??

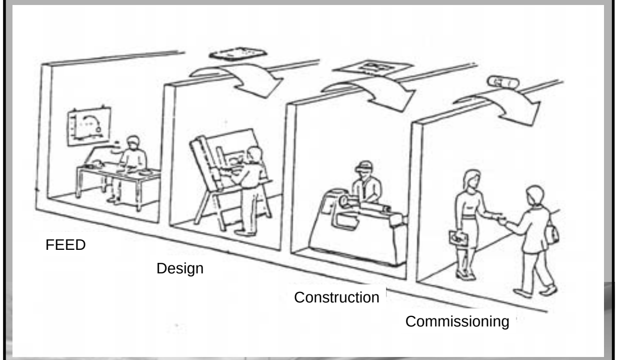
Can we learn from the past ?

Life Cycle Engineering

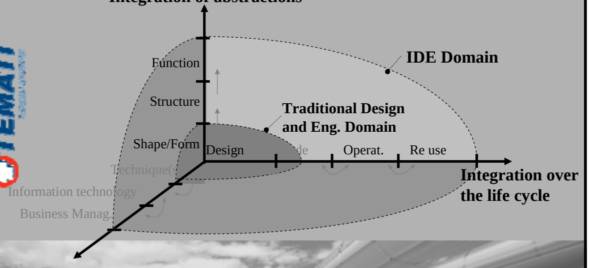
&

C.U.I

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



Integrated Design Engnieering



How to Prevent C.U.I.

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

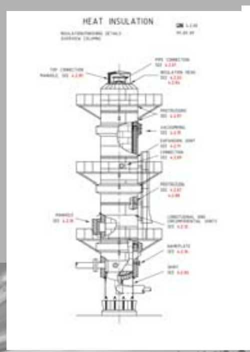
How to Prevent C.U.I.

Design “fit-for-purpose” insulation **SYSTEM**

CINI manual

Corrosion of carbon steel under insulation					
Process temperature	Category CUI risk	Recommended combination of systems to prevent CUI: Cyclic temperatures -20°C - 320°C		Insulation material	Finishing
Cyclic temperatures -20°C - 320°C	Extreme	TSA	- CINI 7.4.04	Closed cell structure + vapour barrier	Non metal finishing
> 601°C	Low			Open cell structure	Metal finishing
176°C - 600°C	Low	TSA	- CINI 7.4.04	Open cell structure	Metal finishing
		Paint system	- CINI 7.4.03 *		
51°C - 175°C	High	TSA	- CINI 7.4.04	Open cell structure	Metal finishing
		Paint system	- CINI 7.4.01/2	>Closed cell structure	Non metal finishing
				Non- contact insulation system	
-5°C - 50°C	Medium	TSA	- CINI 7.4.04	Closed cell structure + vapour barrier	Non metal finishing
		Paint system	- CINI 7.4.01		
< -5°C	Low	TSA	- CINI 7.4.04	Closed cell structure + vapour barrier	Non metal finishing
		Paint system	- CINI 7.4.01		
Corrosion of stainless steel under insulation (external stress chloride corrosion - ESCC)					
50°C - 175°C	High	TSA	- CINI 7.4.07	Open cell structure	Metal finishing
		Aluminum wrap	- CINI 7.4.06	Closed cell structure	Non metal finishing
		Paint system	- CINI 7.4.05	Closed cell structure	Non metal finishing

* in relation to the temperature range



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

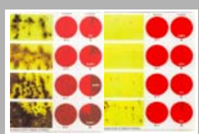
Finding C.U.I.

Inspection/Detection

- Direct
- Indirect

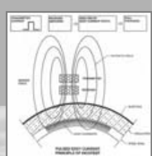
Finding C.U.I.

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



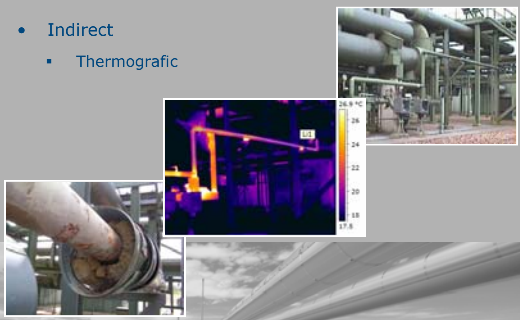
Finding C.U.I.

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



Finding C.U.I.

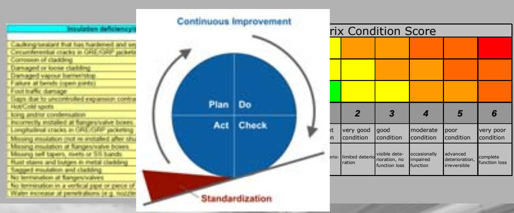
- Indirect
  - Thermografic



Why only inspect coating?

Quality

Insulation System



Insulation solutions for C.U.I.

Insulation Systems

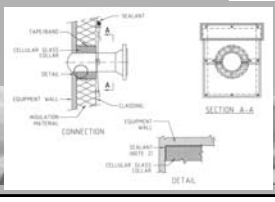
- "CLOSED" system
- "OPEN" system
- Non-Contact insulation

"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

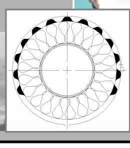
"OPEN" System

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

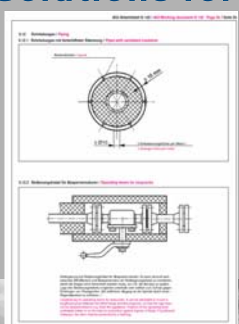
Solutions for C.U.I.

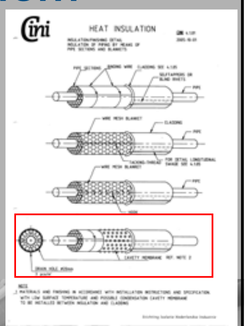
Aircavity Outside

- Temafol



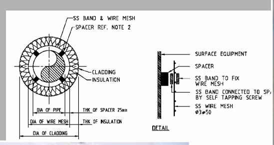
Solutions for C.U.I.





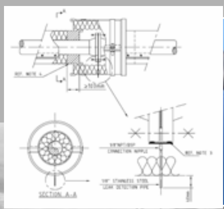
Non-Contact System

Aircavity Inside



Solutions for C.U.I.

- PMU Drain Plug
- Protectem® Flangebelt™



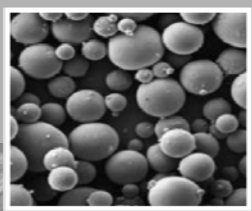
Insulation Solutions for C.U.I.

No insulation

- Personnel Protection
- Perforated sheet
- Wired mesh

New developments for C.U.I.

- Insulating Coating
- Based on ceramic technology



Insulation Coating

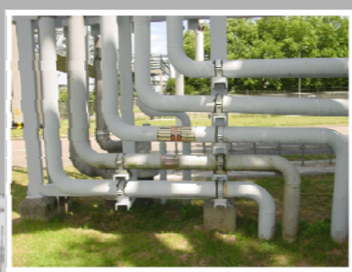
- Sprayable insulating coating
- Waterbased
- $T_{service}$ 180°C
- $\lambda \approx 0{,}05$ W/m.K

Field of application

- Personell Protection
- CUI: T < 175°C
- $T_{surface}$ < 65°C

Field of application

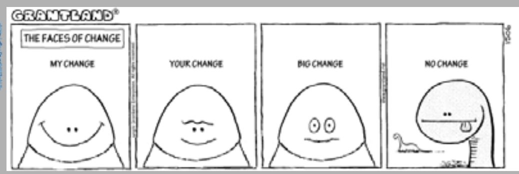
- Surface condensation

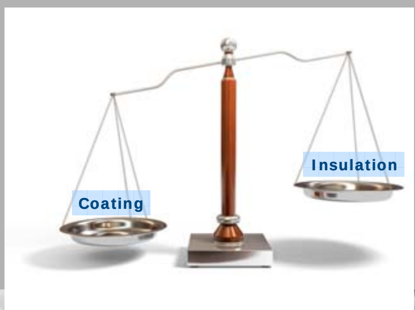


C.U.I. challanges

Knowhow & solutions are at hand

Change the mindset





Insulation Knowledge

Thank you for your attention

Johan Sentjens

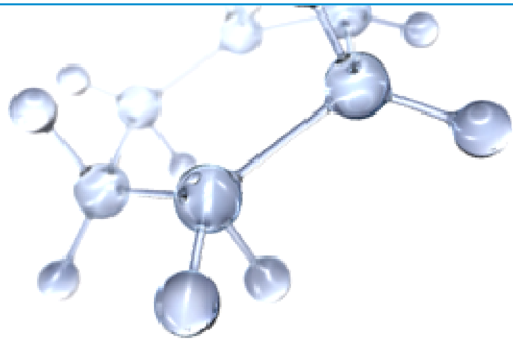
Appendix 4

TSA Implementation

Learnings from project deployment

(John Houben – ExxonMobil)

ExxonMobil Chemical



TSA Implementation

Learnings From Project Deployment

Corrosion 2011

John Houben, Stefan Winnik, Brian Fitzgerald

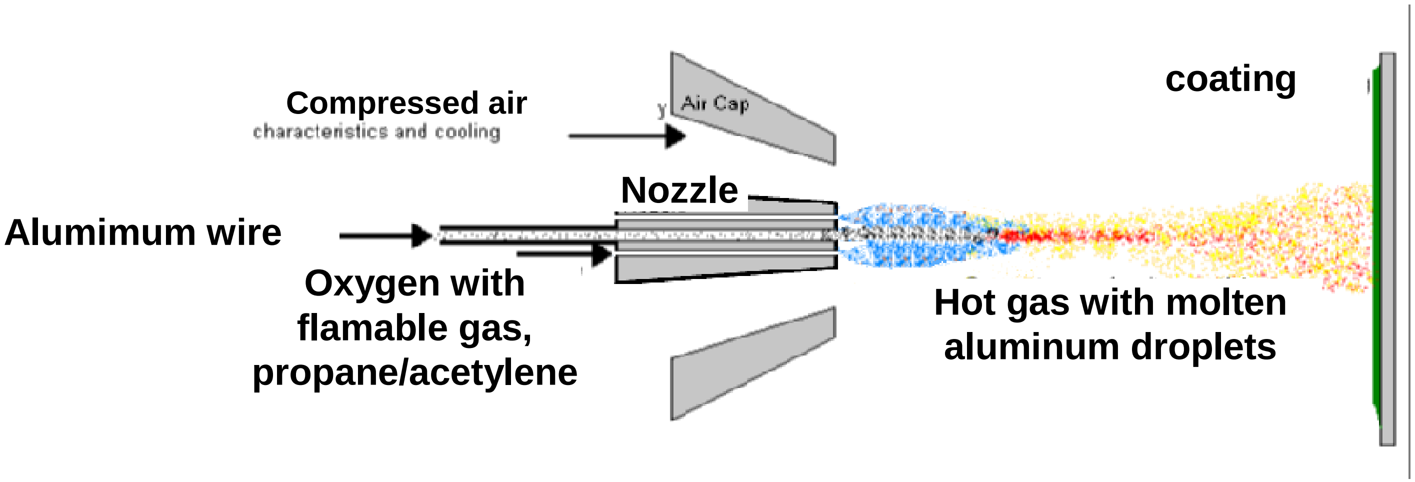
March 2011
2011CENGA 19

Overview

- Introduction to TSA
- TSA for CUI prevention
- TSA in the Petrochemical Industry
- Role of Materials Engineering – Project FEED
- Role of Materials Engineering – EPC Office
- Pressure Vessel Shop - TSA QC
- Piping Fab Shop TSA - QC
- Field Welds
- Supply Chain
- Summary

Introduction to TSA

- Thermal Spray Aluminum (TSA) is a thin 99+% metallic aluminum coating applied primarily with the following processes:
  - Flame spray, (shop and field), or
  - Electric Arc (shop, large surfaces in field)
- Most coating contractors have TSA capability in addition to the normal blasting and coating work
- The surface temperature of the substrate increases only slightly during application



ExxonMobil Chemical

TSA for CUI Prevention

- Corrosion Under Insulation (CUI) is a high maintenance cost item for fixed equipment
- Historically conventional coatings were used for CUI. These coatings have limited life. Also sub-standard coating systems were used
  - Epoxy or epoxy-phenolic coating are common for CUI. Most EP have upper temperature limit of 120^{o}C. High solids EP can go to 150^{o}C. If equipment temperature exceeds these limits, steam-out, regeneration, upsets these coatings fail
  - Inorganic Zinc (IOZ) is frequently used as shop primer. But multi-layer top coating system is needed for CUI protection, top coatings frequently “forgotten” in fieldwork
  - Cold Sprayed Aluminum (CSA) or coatings with aluminum flakes are no substitute for TSA
  - CUI has occurred under all insulation materials
- Field tests in the 80’s showed that TSA was best coating system for severe CUI conditions: sweating and cyclic service
- TSA coating with 250 micron thickness covers wide temperature range: -40^{o}C to 540^{o}C and long service life w/o maintenance. goal 30+ years

CUI after 8 years

CUI with Foam-Glass after 15 years

TSA in the Petrochemical Industry

- TSA is recognized as Best in Class for CUI prevention (EFC Publication # 55)
- ExxonMobil Chemical Company has widely deployed TSA for CUI prevention in maintenance and projects
- TSA is included in Industry Standards:
  - NACE RP 0198 includes TSA covering widest temperature and long service life
  - CINI 7.4.04 includes TSA for CUI
  - Protection up to 540ºC
  - EFC publication #55 lists TSA as first choice for CUI prevention
  - NORSOK M 501recommends TSA for insulated tanks, vessels and piping

60m high by 5m OD tower - TSA coated

ExxonMobil Chemical

Materials Engineering - Project FEED

- In FEED stage Materials Engineering (ME) selects coating systems based on atmospheric & service conditions, and company standards
- ME needs to make sure that FEED contractor is aware of company CUI prevention strategy. The importance of this topic needs to be highlighted to all engineering disciplines, early in project
- FEED contractor coating and vessel specialists need to be involved. CUI prevention starts in equipment design stage. General project engineers need guidance for this activity
- Keep systems simple; all CS equipment in CUI range shall be first TSA coated. Avoid multiple coating systems on one vessel: TSA first everything, than: fire-proofing EP top-coat, nozzles sealer
- Company and Industry specifications for TSA, Al-foil wrapping, Personnel Protection cages shall be referenced in FEED package and equipment datasheets
- FEED contractor does not need to re-invent TSA by writing new specifications for TSA, Al-foil wrapping, PP cages, etc
- Aluminum – foil wrapping of Stainless Steel piping needs to be included in insulation specification.
  - Select system materials and details not covered in company standards by requiring compliance with industry standards
  - Use TSA for stainless shop fabrication, sweating service, steam-traced system
  - Use Al-foil for field application, stainless steel piping

Do NOT create blind spaces

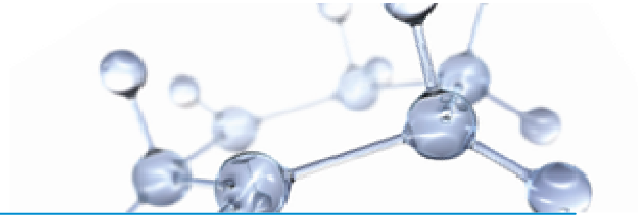
Do TSA complete vessel, supports, nozzles

ExxonMobil Chemical

Materials Engineering – EPC Office

- If EPC contractor has no project experienced with TSA coated equipment, increase support activity, provide detailed guidance
- Discuss with EPC requirements and specifications in FEED package:
  - ME needs to make sure that EPC contractor is aware of CUI prevention strategy. Importance of this topic needs to be highlighted to all disciplines - many times
  - Kick-off with EPC: coating, insulation, vessel, piping, QA/QC engineers, construction, etc.
  - Review typical vessel and piping " Standard Drawings" ; NACE RP 0198 gives guidance
    - Can all surfaces be grit blasted: support rings, support beams, skirt ID? If not, change details
    - No lifting lugs, use trunnions for insulated vessels, 10 mm stand-off for insulation support rings
    - Support welds shall be continuous and full. Avoid dead ends / blind corners
    - First CUI leaks are in small bore CS piping. Avoid field run and field coated CS small bore piping
    - Maximize shop prefab piping with shop TSA. Weld gussets on valve body & flange disk
  - EPC needs to make coating system spreadsheet, supported by detailed coating specification. Spreadsheet lists coating systems applicable to pressure vessels and piping, including field touch-ups and field welds
  - Company "coating specifications" may not be acceptable to use as "The Coating Specification"
  - Me shall review, with his process and equipment know-how, EPC's pressure vessel datasheets, equipment sketches to make sure that correct coating requirements and CUI friendly details are included. Can surface be grit blasted, no sharp corners, etc?
  - Use TSA for stainless shop fabrication, equipment in sweating service, steam-traced equipment. Use Al-foil for field application like stainless steel piping
  - Locate piping field welds at grade and group these together. For grit blasting and TSA pipe spacing in pipe rack at field welds shall be 0.3 m minimum. Model review suggested
  - Flanged valves do not need TSA coating

Pressure Vessel Shop - TSA QC



- ME shall attend Pre-award meeting and PIM of bulk PV's with TSA
  - Does PV manufacturer understand TSA application? No sharp corners, grit blasting, TSA, etc.
  - Does PV manufacturer or his in-house coating contractor have experience with TSA?
  - Does PV manufacturer have qualified (NACE) coating inspector on-hand?
  - Request at general PIM separate PIM for TSA   Overall: Provide guidance
- TSA coating is not more expensive in competitive bidding; costs about same as 2 layers EP
- For TSA extra PIM is needed when welding of PV is almost finished. At TSA PIM specific ITP for coating work shall be reviewed:
  - PIM presence: TSA shop supervisor, coating inspector, PV QC, ME, EPC project eng
  - Go over TSA specification. No sealer needed under insulation. Who does inspections? ITP points:
    - Check if surface can be grit blasted, walk down pressure vessels to check this in shop
    - Is grease and oil present from machining (flanges), MPE, LPE, UT, who removes this?
    - Grit blasting medium, angular sharp profile needed, no grit-shot mixtures
    - Are sharp corners rounded to 3 mm radius
    - Check surface profile: 75 micron
    - Check ventilation for preventing dust from blasting & electric arc application contaminates surface
    - When are TSA test plates made, witness by coating inspector? TSA equipment shall function without wire feeding or spray problems. Both electric arc and flame-spray equipment & operator qualification
    - Agree on TSA method and QC for TSA application inside vessel skirts, supports, bolt holes and bolting
    - TSA operator shall perform in-process thickness measurements, 250 micron required on all places
    - QC inspector shall witness & document final TSA thickness measurements and water spray test Equipment that fails water spray shall not be seal coated or shipped from shop
    - It is acceptable to do TSA before hydro test
- Every surface that can be grit blasted can be TSA coated, no excuse for using wet coatings replacing TSA for repairs, difficult to reach areas

Piping Fab Shop - TSA QC

- ME should attend PIM for bulk piping & TSA PIM
- Be critical that piping crew does not re-engineering the TSA spec
- Maximize shop TSA application, go over pipe support details, gussets, full welds, no dead-spaces or pockets. TSA welded supports
- Small bore piping shall also be shop TSA coated, avoid field-run and field coated small bore piping
- Piping contractor needs to radius to 3mm sharp edges and remove slag, spatter, welding wire etc.
- Grit-blasting of piping is more critical, convex shape requires higher skills for obtaining good 75 micron sharp surface profile, all around pipe
- Both electric arc (large diameter piping, watch dust) and flame-spray can be used; later reduces overspray on small diameter piping
- TSA can be applied before hydrotest
- Keep 10-25 mm TSA free from bevels field welds
- Water-spray test is key QC test
- Pipe coatings are often damaged in handling. With TSA scratches and nicks do not need repair
- Nylon lifting bands, rubber wraps around chains, plenty of wood in shop, trucks and lay-down yards prevent damage
- In the unusual event TSA needs repair watch for touch-up with IOZ or sealer by paint brus QC check point
- TSA coated pipe shall not be wrapped in plastic

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Piping Field Welds – TSA QC

- If engineering work is done correctly field welds can be TSA coated with out problems:
  - Maximize shop TSA work
  - Are field welds located at grade and grouped together in pipe-rack?
  - Are pipes spaced 0.3 m min for grit blasting and TSA in pipe-rack?
  - Has TSA contractor experience with TSA'ing field welds?
  - All vents and drains should already be TSA coated in shop
- Discuss in detail field TSA with Project Safety group
  - Take them to the TSA shop and preview the field grit blasting and field flame-spray application
  - Safety concerns for field TSA with flame spray is similar to grinding & welding
  - Safety procedures, with realistic hazard evaluation, are essential
  - Consider garnet or vacuum-blasting tools for surface preparation to minimize dust of surface preparation   Do not use "standard grit-blasting kettle and compressors. Bristle blaster for remote welds
- EPC contractor shall have dedicated TSA field supervisor, that coordinates the field weld TSA activity with all skills:
  - Scaffolding, weather sheeting (tent) if needed
  - Field weld completion, do not let these rust
  - If needed NDT, (hydrotest can be done after TSA)
  - Surface preparation, can be on hot weld; followed immediately by TSA application
  - TSA QC, layer thickness (often too thick) and "dull chisel" test
- Visually inspect complete pipe spool for damage on field and shop TSA before TSA crew moves to next TSA station

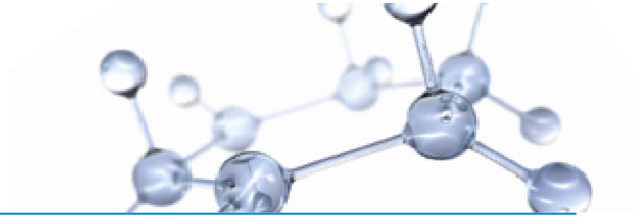
ExxonMobil Chemical

Supply Chain

- Many fabricators and TSA contractors are available worldwide
- TSA is nothing new: India, South Korea, Malaysia, Italy, France, UK, Benelux, Singapore, USA, regions all delivered TSA coated equipment for projects
- On site, TSA frequently is done by existing painting contractors. Has proven to be very good approach
- EPC's can be bottleneck, if not familiar with TSA. Increase ME support
- TEC of new shop fabricated equipment with TSA is similar to 2 layer epoxy-phenolic coating if supplier has experience with TSA
- No extra cost, no longer delivery time. Worldwide projects have proven this already
- Supply chain is making quick progress on TSA application, investing in people and TSA equipment
- TSA spray equipment suppliers are available to assist TSA contractors or existing painting contractors with TSA applicator training, equipment lease Turn key field TSA application service for "remote" locations are available from some equipment suppliers

Shop TSA of Tower:
60 m high x 5m OD.
Notice stand-off insulation support rings - shell

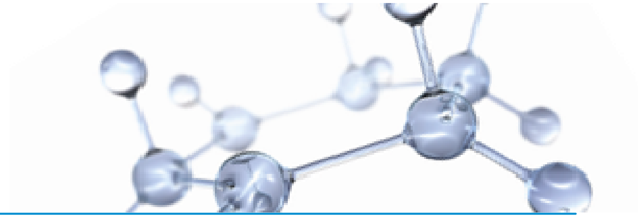
Summary



- Plant reliability is improved and maintenance cost is reduces by implementation of CUI prevention strategy in projects, good value for your money
- TSA is Best in Class for CUI prevention
  - Guidance by knowledgeable ME's is effective in helping EPCs and the supply chain quickly climb the learning curve
  - TSA is nothing new, know-how for projects is available
  - TSA is cost competitive with two layer epoxy-phenolic coating
  - Large multi M$ projects have shown that TSA is widely available Experience and supply chain is growing WW
  - ExxonMobil spends 10% of the maintenance budget on CUI inspections and repairs. This bad actor can be reduced by implementing CUI prevention in projects
- Critical for success is hands-on ME support and project understanding of the importance of the CUI Prevention Strategy
- Implementing a CUI Prevention Strategy after project start-up is 10X more expensive than the EPC stage

100 ton vessel with TSA lifted in place

Copyright



Appendix 5

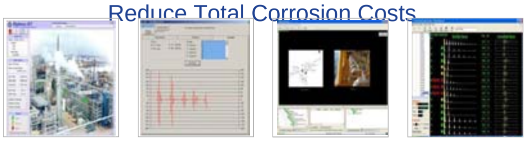
Rightrax Corrosion Monitoring

(C. Laverde- GE Energy Services)

GE Energy- Sensing & Inspection Technologies

Rightrax Corrosion Monitoring

Reduce Total Corrosion Costs



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Why Rightrax is used

Aging

•Most assets are old
•60% of the worlds pipelines are more than 40y old
•these factors increase inspection requirements

Cost

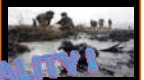
•Inspections are expensive
•Corrosion abatement is expensive
•Loss of production is the biggest cost factor

Safety

•HSE is expensive
•Safety comes first
•Remote monitoring reduces access to dangerous sites

Image

•If accidents happen the company image is damaged
•Multi million dollar fines could be imposed



AND IMPROVED DATA QUALITY !

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Where Rightrax is used

Access

•Build scaffolding
•Remove insulation
•Bury pipelines

Hazards

•Chemical areas
•High temperature areas
•Radiations
•High altitude installations
•Explosions

Remote

•Offshore facilities
•Desert facilities
•Jungle facilities
•Artic facilities

Process

• Corrosion
• Erosion

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Product versions

Flexible array (LT)

•Both manual and automatic version
•Flexible array with 14 individual transducer elements
•Bonded 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

Advantages:
•Non intrusive, easy installation
•Array coverage area = 12X200mm

High temperature (HT)

•Both manual and automatic version
•Single point transducer
•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 for ATEX IS for use in zone 1

Advantages:
•Non intrusive, easy installation
•Process related events due to high resolution

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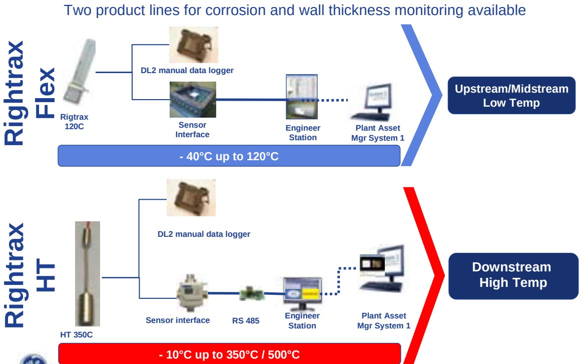
Online Corrosion Monitoring

Two product lines for corrosion and wall thickness monitoring available



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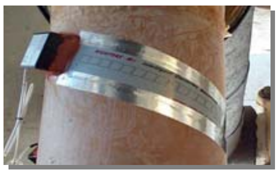
Non Intrusive sensors



Sensors are simply bonded or are clamped onto the inspection area

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Sensor Placement Possibilities

Place Sensor **HERE**

Connect and take Measurements **HERE**

Remote access to corrosion data, eliminating, excavations, erect scaffolding, remove insulation or shut down plants.

Excavations

Rope access

Remove Insulations

Scaffoldings

Cost of gaining access to the pipe for measurement is high, Hazard to personnel…

Getting personnel to & from inspection sites

Long & unsafe trips

Personnel to support NDT service

Working in hostile locations, hazardous areas

HT System

Rightrax HT – The System

Consists of four basic elements:
- The HT350x ultrasonic high temperature sensor
- The CMX-HT sensor interface (CMX X 4 Sensors, 32 CMX X Syster
- The Node Interface and IS Barriers
- Data acquisition and data analysis software

Core element the HT-350x sensor

GE Proprietary Information
For Internal Use Only

<350/500°C

The HT350x Sensor, Key Features

•Single element sensor

•Intrinsically safe certification

•Thickness range 3 mm - 19 mm

•Temperature range -20°C up to 350°C/500°C

•5 m cable length to CMX-HT sensor interface

•Suitable for pipe diameters of 3” up to 24” with standard clamping design

  •Customization for larger diameters

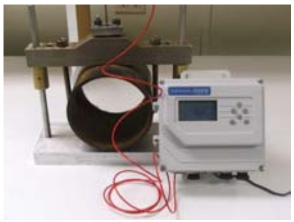
•Nominal operating frequency of 5MHz

•Coupling is achieved through gold foil

The CMX-HT node

•**Intrinsically safe sensor interface box**

•**Supports up to 4 HT350x sensors**



•Connect to the system node interface using a RS485 cable

•Each sensors returns

  •Time of flight interface echo

  •Time of flight back wall echo

  •Ascan

•Driven by the CMX data acquisition software

•Does not store data

Data Acquisition & Data Analysis Software

Provides:

• Thickness temperature-corrected

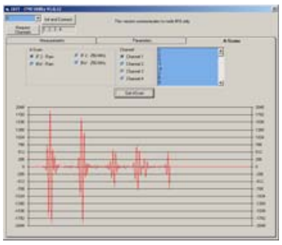
• Alarms for thickness levels and corrosion rates

• Minimum/Maximum/Average thickness

• Short term and long term corrosion rates

• Maximum corrosion rates

• A-scans to verify signal accuracy



All values can be exported to third party systems by industry standard OPC, Modbus, or in CSV data file format

Data Acquisition & Data Analysis Software

Screen displays tailored to suit specific requirements.

• Global view, showing sensor locations

• Local view, showing site locat

• Node views

• A-scan

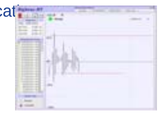
• Trend plot

• Alarm lists

• Tabulated data

• Diagnostics overview

Global View



AScan View

Local View Example

Node View Example

Integration to Plant Asset Management Systems

Interface with any asset management systems and with

Bently Nevada System 1, enables

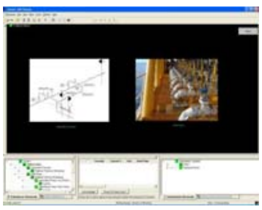
the **time stamped correlation**

of absolute wall **thickness**

and corrosion rates **to critical process variables**

such as temperature, pressure, flow,

crude quality, and chemical injection.

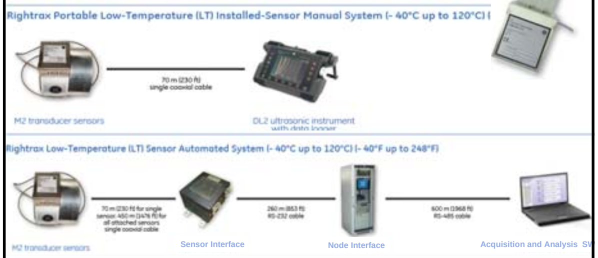


LT System

Rightrax LT – The System

Consists of four basic elements:

- The Multi element sensor: 14 sensors elements
- The Sensor Interface (1 sensor interface X 10 sensors; 2 Sensors inte
- The Node interface
- Data acquisition and data analysis software



The M2 Sensor, Key Features

- Multi element sensor: 14 sensors elements
- 12mm by 200mm inspection coverage
- Thickness **range <u>5 mm <> 100 mm</u>**
- Temperature range **<u>-40°C / 120°C</u>**
- Self Calibrating, programmable identification, Built in Temperature chip
- Suitable for pipe **<u>diameters of 6"</u>** and above

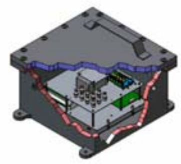
Functionality DL2

- DL2Works with **M2** Rightrax sensors
- **Store up to 100 complete M2 measurements**
- **View M2 sensor elements in live mode**
- Ease of use, unskilled personnel
- **Connect to PC with RS232 to download measurements**
  - Using the complementary software packet WinHostp
- Carry case, battery charger and cables included

The ATMS Data Logger

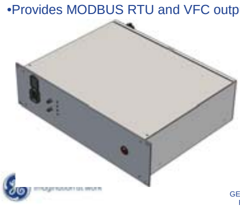
(<u>A</u>utomated <u>T</u>hickness <u>M</u>easurement <u>S</u>ystem)

- Flaw detector with intelligent Decision making software
- **<u>Makes direct measurements in millimeters</u>**
  - Software converts to inches
- **<u>Built-in 10 way multiplexer to connect 10 M2 sensors</u>**
- **<u>Connect to LD2 line driver with multi-core cable</u>**
  - <u>Providing Serial RS232 connectivity with the PC</u>

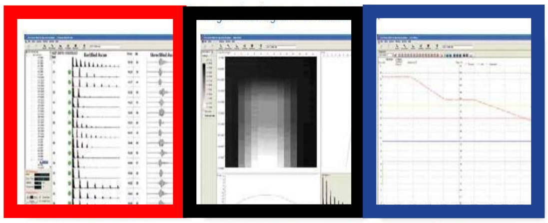


The LD2 Line driver

- Powers the data logger with **<u>24 Volts DC</u>**
- **<u>Provides RS232 communication between the ATMS data logger and the PC</u>**
- Is placed within the control room or other nominated safe area
- Is fitted with a Single Board Computer (SBC) which is used to manage the operation of the system using proprietary software pre installed.
- Can be supplied in a 19" rack mount enclosure
- Can be supplied in wall mounted cabinet for installation outside safe areas
- Provides MODBUS RTU and VFC outputs



Rightrax LT Reporting & Analysis Views



A-scan View Showing individual measurements	Map View and B-scan View Showing Overall	Trend View Showing Overall Corrosion Rates

Rightrax Solutions Matrix

Hazardous area rating	Transducer type	Transducer frequency and diameter	Max no. of transducers/ system	Transducer temperature range in/ max	Operational measurement range min/max)	Resolution / accuracy	Maximum cable distance "A"	Maximum cable distance "B	Maximum cable distance "C"	Interface / protocol
None	M2 Pad 14 elements	8.0 MHz measurement area 200 mm x 12 mm	14 elements Unlimited DL storage 100 sensors	-40˚C to 120˚C (-40˚F to 248˚F)	5 mm - 100 mm (0.197 in - 3.937 in)	+/- 0. 1 mm (+/- 0.004 in)	70 m (230 ft) (single coaxial cable)	NA	NA	NA
ATEX Ex-proof	M2 Pad 14 elements	8.0 MHz measurement area 200 mm x 12 mm	10 M2 (14-elements) 2 Sensor interfaces	-40˚C to 120˚C (-40˚F to 248˚F)	5 mm - 100 mm (0.197 in - 3.937 in)	+/- 0.1 mm (+/- 0.008 in)	70 m (230 ft) max for single sensor. 450 m (1476 ft) max for all attached sensors (single coaxial cable)	260 m (853 ft) (RS-232)	600 m (1968 ft) (RS-485)	MODBUS SCADA System 1 3rd Party
Intrinsically safe	Single-element delay-line sensor	5 MHz x single point	128 transducers 32 CMX X 4sensors	-20˚C to 350˚C (-40˚F to 662˚F)	3 mm - 17 mm (0.118 in - 0.669 in)	+/- 0.0025 mm (+/- 9.8x10-5 in)	5 m (16.4 feet)	600 m (1968 ft) (RS-485)	600 m (1968 ft) (RS-485 or Ethernet)	MODBUS SCADA System 1 OPC 3rd Party

Value Proposition– Online Corrosion reliable data

Improve Productivity :

- **Plant uptime is maximized**
- **Support to process opportunity crude**:
  Wall-thickness data taken at selected critical points can help support chemical injection systems to effectively manage corrosion rates.

Value Proposition– Online Corrosion reliable data

Decrease inspection cost

Provides wall-thickness data on-line without the need to erect scaffolding, remove insulation or excavations.

Reduce inspection cost

Value Proposition– Online Corrosion reliable data

Improve plant safety

Prevent failure and unscheduled shutdowns

or accidents are very costly

- Environmental damage
- Loss of production
- Large fines
- Repair cost
- Damage of reputation & image

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Appendix Slides

References

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Downstream – recent project summary

Customer	Project and region	Description
TOTAL	Vacuum distillation unit, fluid: Vacuum Residue; France	HT Manual System: 4 sensors, Pipe Operating Temp is 350 °C, Material Pipe: alloy steel 5Cr-0.5Mo Pipe diameter is 219mm (8"), Wall thickness is 8.18mm.
BP Texas city	Refinery USA	Performance trial for HT sensors and system
ExxonMobil	Refinery USA	Performance trial for HT sensors and system
OXY Oman	Refinery OMAN	Manual System: 2 LT sensors, 2 HT sensors

Solvay Belgium

•**Application:** gas liquid mixture HCL, DCE, VC, PVC facility

•**Main Concern:** Avoid all human error factors

•**Rightrax Solution:**

–Rightrax HT Full Automatic System

–Fluid: gas liquid mixture HCL, DCE, VC

–Max temp: 165°C,

–Max thickness: 9.5mm

–Material: 904L

–Pipe diameter: 11.8 inches

•**Main advantages provided by the Rightrax:**

–Increasing safety

–Reliable data due to the same point being monitored with no errors as all human error factors have been removed,

RIGHTRAX – GE Water

Oxydental Mukhaizna Oman/ GE Water

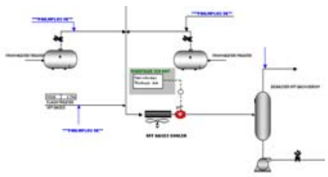
Wet Sour Gas Lines

Manual System

2 HT sensors Wet Sour Gas condensers outlet

2 LT sensor Wet Gases, Moisture, Dew Point

Wet Sour Gas Treater
Filming inhibitor efficiency control



ERG ISAB SUD refinery in Italy/ GE Water

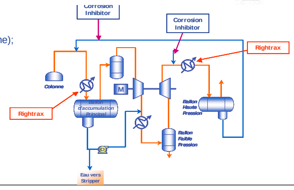
FCC Unit (Fluid Catalytic cracker unit),

in the overhead of Main Column (compression zone);

Manual System

4 HT sensors

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



Current Customers

bp, TOTAL, Shell, Saudi Aramco, Technip, AMOCO, ExxonMobil, Syncrude, Phillips 66 ConocoPhillips, GASCO, Chevron, PETROBRAS, Esso Imperial Oil

RIGHTRAX WORK HISTORY

SAGA PETROLEUM 1996

CORROSION MONITORING ON SOUR GAS SCRUBBERS ON SNOORE TLP OFFSHORE NORWAY.

SHELL SCOTLAND 1996

CORROSION MONITORING ON HEAT EXCHANGER ST FERGUS SCOTLAND. (Set of Gas processing plants)

SHELL HOLLAND 1996

MONITORING ON 40mm FINFAN COOLER END PLATES SHELL PERNIS. Refinery

SHELL HOLLAND 1997

CORROSION MONITORING TO COOLING TOWER M1's HARD WIRED BACK TO CONTROL ROOM WITH DATA AUTOMATICALLY DOWNLOADED TO A PC EVERY 8 HOURS.

SHELL BRUNEI 1997

FLOWLINE MONITORING

BROWN & ROOT 1997

WELLHEAD MONITORING ON **SANGU PLATFORM BANGLADESH** & DUPLEX RISERS FOR SAND EROSION.

SAUDI ARAMCO 1997

MONITORING ON REFINERY PROCESS PIPEWORK **SAUDI ARABIA.**

RIGHTRAX WORK HISTORY

BP COLOMBIA 1998

3 OFF SUBTERRANEAN CORROSION MONITORING STATIONS. 10 OFF M1 UNITS AT EACH SITE WITH DATA TX TO THE CENTRAL PROCESSING FACILITY USING THE FLIGHT REFUELLING DATA TRANSMISSION SYSTEM.

BP/OIS 1998

MONITORING OF PROCESS PIPEWORK ON BP ANDREW OFFSHORE NORTH SEA.

BROWN & ROOT OCTOBER 1998

OBAIYED GFDP (EGYPT).

PHILLIPS OCTOBER 1998

DUPLEX BENDS JUDY PLATFORM SAND EROSION

BEB ERDGAS GERMANY NOVEMBER 1998

EXTERNAL PIPELINE CORROSION MONITORING

BP ALASKA NOVEMBER 1998

PROCESS PIPEWORK MONITORING (PRUDHOE BAY).

BROWN & ROOT DECEMBER 1998

AMERADA HESS LTD (SOUTH ARNE) SEA WATER INJECTION LINES

RIGHTRAX WORK HISTORY

BROWN & ROOT DECEMBER 1998

EASINGTON CATCHMENT AREA PROJECT.

SAGA PETROLEUM FEBRUARY 1999

EROSION MONITORING ON RISER MANIFOLDS ON **VARG WHP** PROJECT.

SYNCRUDE (CANADA) APRIL 1999

PIPEWORK CORROSION MONITORING 24".

SHELL PERNIS MAY 1999

CORROSION MONITORING TO PROCESS PIPEWORK.

SYNCRUDE CANADA MAY 1999

PROCESS PIPEWORK CORROSION MONITORING.

BP WYTCH FARM JUNE 1999

FLOWLINE MONITORING (WELD ROOT EROSION).

ELF PETROLEUM (NIGERIA) AUGUST 1999

FOWLINE MONITORING TO CRITICAL BENDS

RIGHTRAX WORK HISTORY

ARCO ALASKA SEPTEMBER 1999

REMOTE FLOWLINE CORROSION MONITORING USING THERMO- ELECTRIC GENERATION AND RF TX DUMPING TO CONTROL ROOM DATABASE.

TOTAL SEPTEMBER 1999

UPHEAVEL PIPELINE AT TATUN INDONESIA. CORROSION MONITORING ON FLOWLINE BENDS.

CONOCO UK LTD THEDDLETHORPE GAS TERMINAL NOVEMBER 1999

GAS FLOWLINE MONITORING.

ELF PETROLEUM (BRUNEI) NOVEMBER 1999

UNMANNED OFFSHORE 18" RISER MONITORING TO INCLUDE ONSHORE FLOWLINE MONITORING.

IVG (GERMANY) JANUARY 2000

MONITORING TO 24" SALT WATER & FRESH WATER INJECTION LINES.

CACT (CHINA) MAY 2000

OFF SHORE RISER MONITORING (EROSION).

SYNCRUDE (CANADA) JUNE 2000

CORROSION MONITORING TO PROCESS PIPEWORK.

RIGHTRAX WORK HISTORY

BP ARGENTINA AUGUST 2000

6" FLOWLINE MONITORING (SAN PEDRITO PIPELINE).

RUGBY CEMENT LTD UK DECEMBER 2000

60KM 24" SLURRY LINE PITTING CORROSION MONITORING.(6 AREA'S)

CONOCO UK LTD THEDDLETHORPE JANUARY 2001

CORROSION MONITORING ON 80MTR C-108 COOLING TOWER 100DEG C

IOC INDIA JANUARY 2001

CORROSION MONITORING ON 42" OIL SUPPLY LINES BEFORE AND AFTER CORROSION INHIBITOR INJECTION.

BP HOTON

PLATFORM APRIL 2001. FULLY AUTOMATED CORROSION MONITORING SYSTEM ON MANIFOLDS 4 EXPORT LINES (DATA TRANSFER VIA CONTROL SYSTEM TO ONSHORE CONTROL CENTRE

IVG (GERMANY) JULY 2001

CORROSION MONITORING ON 42" FRESH WATER PIPELINE AFTER DAMAGE TO PIPE HAD DISLODGED CONCRETE LINING.

EPMI (MALAYSIA) AUGUST 2001

CORROSION MONITORING OF 15 SIES ON ASSORTED VESSELS.MANUAL DATA COLLECTION.

RIGHTRAX WORK HISTORY

HALLIBURTON SINGAPORE (SHELL EA PROJECT) SEPTEMBER 2001

CORROSION MONITORING ON KNOCKOUT DRUMS FOR SHELL **FPSO PROJECT (NIGERIA)** AUTOMATED SYSTEM COLLECTING DATA IN CONTROL ROOM.

BP HOTON UK UPGRADE JANUARY 2002

UPGRADE OF SYSTEM TO INCLUDE MONITORING ON GAS COOLERS AND DATA TRANSFER VIA ETHERNET SYSTEM TO SHORE.

PHILLIPS JADE UK PLATFORM MARCH 2002

HIGH PRESSURE MANIFOLD MONITORING WITH OPERATING TEMPERATURES UP TO 130 DEGREES C

BP JUNO PROJECT APRIL 2002

UPGRADE TO RISER MONITORING SYSTEM ON DUPLEX BENDS

SAUDI ARAMCO MAY 2002

CORROSION MONITORING ON PIPING SYSTEMS ON HIGH TEMPERATUREGAS PLANT

SHELL BRUNEI JUNE 2002

SUBTERRAIN FLOWLINE MONITORING WITH DATA RETRIEVAL ABOVE GROUND.

AERA CALIFORNIA JULY 2002

CORROSION MONITORING ON SELECTED PITTED AREAS ON OVERGROUND PIPELINE.

RIGHTRAX WORK HISTORY

PHILLIPS PETROLEUM AUG 2002

UPGRADE TO HIGH TEMPERATURE MANIFOLD MONITORING 130 DEG C

SHELL BRUNEI SEPT 2002

FULLY AUTOMATED MONITORING SYSTEM ON THE CHAMPION OFFSHORE PROJECT WITH DATA RETRIEVAL VIA SBC AND TRANSMISSION TO SHORE VIA MODBUS.

SAUDI ARAMCO OCTOBER 2002.

PROCESS PIPEWORK MONITORING ON HIGH LEVEL LAGGED PIPE ON ROAD CROSSING AREAS IN REFINERY.

SHELL BRUNEI (TECHNIP) JANUARY 2003.

EROSION MONITORING ON EGDP1 (EGRET PROJECT) EXPORT LINE TO AMPG6, WITH ONLINE DATA COLLECTION AT SHORE BASE.

BP HOTON UPGRADE APRIL 2003.

UPGRADE OF EXSISTING SYSTEM TO INCLUDE MORE SENSORS TO AUTOMATED DATA COLLECTION MODULE

SHELL BRUNEI MAY 2003.

AUTOMATED SYSTEM ON THE CHAMPION CPCB-7 PROJECT DATA RETRIEVAL VIA ETHERNET TO SHORE.

CONOCO / PHILLIPS UK MAY 2003.

EXISTING MANUAL SYSTEM UPGRADED TO FULLY AUTOMATED ON LINE DATA COLLECTION MODULE WITH DATA TRANSMISSION TO SHORE VIE CUTOMERS ETHERNET NETWORK

RIGHTRAX WORK HISTORY

SHELL BRUNEI TECHNIP AUGUST 2003.

EROSION MONITORING ON AMPG-6 OFFSHORE PLATFORM MONITORING EXPORT LINE FROM EGRET, WITH ONSHORE DATA COLLECTION.

SHELL ST FERGUS, SCOTLAND NOV 2003.

SUPPLY OF A PORTABLE DL1 AND M1 SENSORS FOR ONSHORE FLOWLINE INSTALLATION.

SHELL BRUNEI CHAMPION WELL JKT 2 (CWWJ-2) APRIL 2004

WELL FLOWLINES, PRODUCTION HEADERS AND EXPORT LINE SEROSION MONITORING

SHELL BRUNEI CHAMPION WELL JKT 3 (CWWJ-3) APRIL 2004

WELL FLOWLINE EROSION MONITORING

SYNCRUDE (CANADA) AUGUST 2004

CORROSION / EROSION MONITORING ON PROCESS PIPEWORK

BP SHAR DENIZ KASHAGAN (IICORR) SEPTEMBER 2004

CORROSION MONITORING ON VESSELS FOT THE SANGACHAL TERMINAL EXPANSION PROJECT

CONOCOPHILLIPS UK JUDY PLATFORM NOVEMBER 2004

EXPANSION TO CORROSION / EROSION ON MULTIPHASE PIPEWORK MONITORING

RIGHTRAX WORK HISTORY

TOTAL-FINA-ELF DALIA FPSO TOPSIDES ANGOLA (TECHNIP) DECEMBER 2004

A FULLY AUTOMATED ON-LINE FLOWLINE MONITORING SYSTEM WITH ALARMS TO THE ICSS.

MSE ENG FOR SHELL BRUNEI CHAMPION WEST PHASE III DECEMBER 2004

FULLY AUTOMATED PROCESS PIPEWORK MONITORING SYSTEM WITH DATA RETRIVAL ONSHORE VIA ETHERNET.

PROSAFE (SINGAPORE) FPSO ESPOIR COTE D'VOIRE JULY 2005

20 CORROSION / EROSION MONITORING POINTS ON FPSO PROCESS PIPEWORK

SHELL BRUNEI (MSE) CHAMPION FACP-04 AUGUST 2005

AUTOMATED EROSION MONITORING SYSTEM WITH DATARETRIVAL TO ONSHORE CORROSION OFFICE

PETROBRAS (BRAZIL) FEBUARY 2006

MANUAL SYSTEM FOR MONITORING CRUDE OIL LINE WITH HIGH WATER CUT AT ONSHORE FACILITY.

TOTAL INDONESIA (Sisi Nubi) SEPTEMBER 2006

RISER EROSION MONITORING ON 3 OFFSHORE UNMANNED PLATFORM, DATA RETRIVAL TO CLIENTS PCS SYSTEM

SYNCRUDE CANADA NOVEMBER 2006

CORROSION / EROSION MONITORING ON PROCESS PIPEWORK

RIGHTRAX WORK HISTORY

IMPRO TECHNOLOGIES USA (BP Pipelines) DECEMBER 2006

SUBTERRANEAN MONITORING ON REMOTE PIPELINES

ROSE CORROSION EYGPT(BP SAQQARA PROJECT) APRIL2007

OIL TRANSPORT LINE MONITORING

TOTAL AKPO PROJECT Nigeria (FPSO) JUNE 2007

RISER EROSION MONITORING

SAUDI ARAMCO SAUDI ARABIA JULY 2007

PROCESS PIPEWORK MONITORING

PETROBRAS BRAZIL AUGUST 2007

PROCESS PIPEWORK MONITORING

GASCO UAE SEPTEMBER 2007

PROCESS PIPEWORK MONITORING

WELLWISE UK JANUARY 2008

DRILLING PIPEWORK TRIALS

RIGHTRAX WORK HISTORY

Jetec TOTAL INDONESIA (Peciko Phase 6) FEBUARY 2008

RISER EROSION MONITORING ON 6 OFFSHORE UNMANNED PLATFORM DATA RETRIVAL TO CLIENTS PCS SYSTEM

GE OIL & GAS ITALY MARCH 2008

FLOWLINE MONITORING KASHAGAN PROJECT

TAL AUSTRIA MAY 2008

TRANS ALPINE PIPELINE MONITORING 40"

SYNCRUDE CANADA MAY 2008

PROCESS PIPEWORK MONITORING

IMPRO USA JULY 2008

8" &10" PIPELINE MONITORING

TAL AUSTRIA SEPTEMBER 2008

TRANS ALPINE PIPELINE MONITORING 40"

CHEVERON USA SEPTEMBER 2008

PROCESS PIPEWORK TRIALS.

RIGHTRAX WORK HISTORY

Saudi Aramco Rastanura

3 HT sensor with a 1 CMX and a system controller in a safe area; Sour gas application

Shell Hamburg

1 HT sensor with DL2 Crude Line

Oxydental Oman

2 HT sensors Wet Sour Gas

Solvay Belgium

4 HT sensors full automatic system, PVC application: gas liquid mixture HCL, DCE, VC

BP Texas City

3 HT sensors Crude Line

Conoco PhillipsBayway NJ

5 HT sensors Crude Line

ExxonMobil Baytown

1 HT sensors Crude Line

YPF Argentina

9 CMX, 19 HT transducers, control system and Cimplicity software.

Total Donges

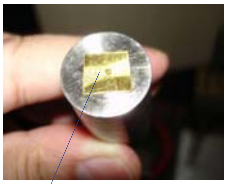
4 HT Sensors, fluid Vacuum Residue

Petrobras

Distillation unit at RPBC - Cubatao Refinery. The main products are: Jet fuel, Formula 1 fuel, coke for export

High Temperature Sensor

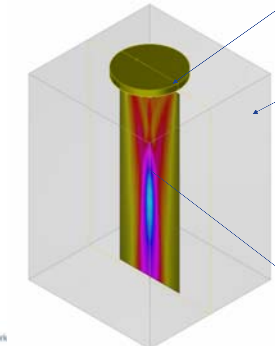
Probe Setup



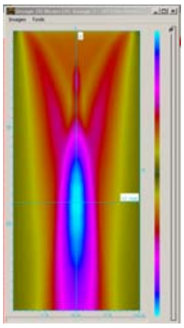
2 mil Gold foil

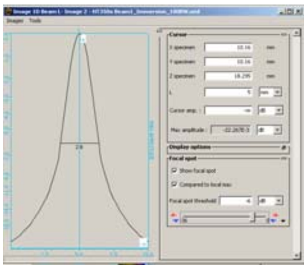
Coupling mark about 3mm wide

CIVA model



Acoustic beam in the delay



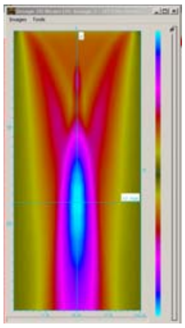


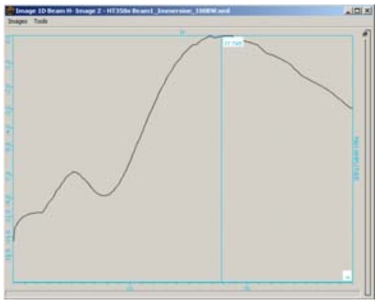
Beam profile at the delay tip or probe/pipe IF

3 dB width = 1.9 mm

6 dB width = 2.8 mm

Axial Acoustic beam- Near field



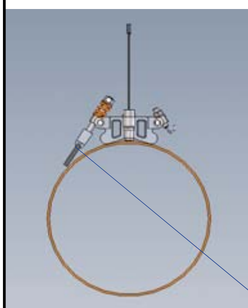


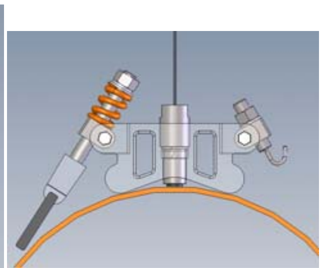
Near field about the same as delay length .7"

High Temperature Clamping Systems

The HT Sensor Clamp

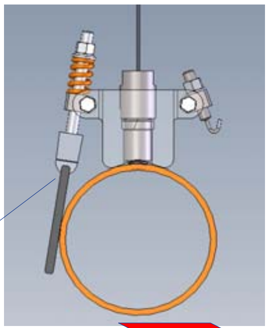
Large pipes: 8"-30"





The HT Sensor Clamp

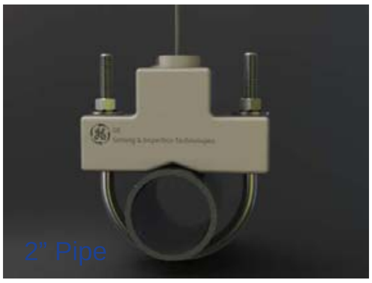
Small pipes: 3”-8”



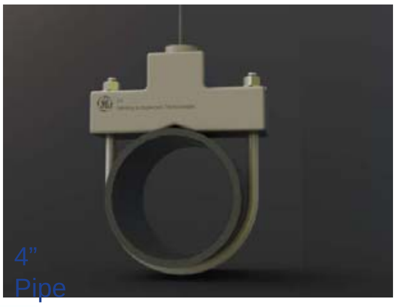
SS Chain

<660°F

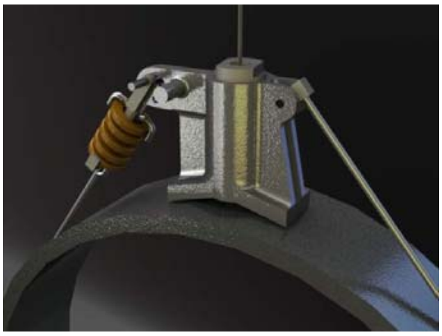
Small HT Piping Clamps



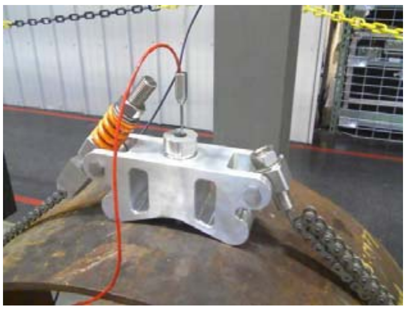
Small HT Piping Clamps



Adjustable HT Clamping Systems



Chain Clamp system on actual 30” pipe



Chain Clamp mounted on 24” crude line

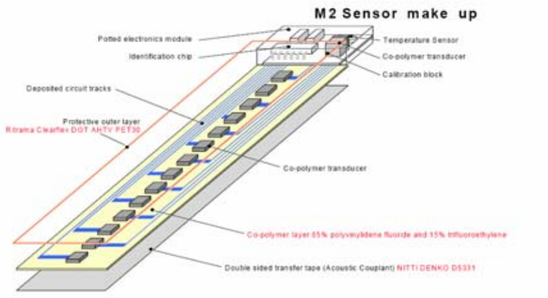
Four (4 ea.) Chain Clamps mounted on actual 24”crude line

imagination at work

61 /
GE Title or job number /
9/27/2011

Low Temperature Sensor

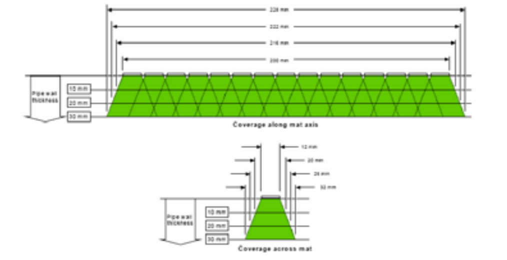
The M2 Sensor, Schematics



imagination at work

63 /
GE Title or job number /
9/27/2011

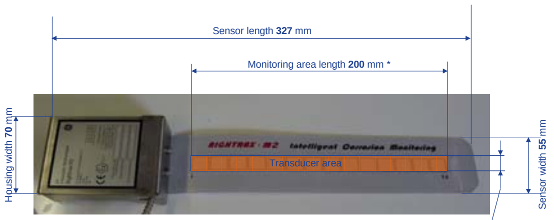
Rightrax Intelligent Monitoring SENSOR COVERAGE
(Beam Spread)



imagination at work

64 /
or job number /
9/27/2011

The M2 Sensor, Inspection Area



Physical dimensions, main housing: 83x70x35mm, flexible strip: 244x55 mm

Monitoring area width 12 mm *

imagination at work

65 /
GE Title or job number /
9/27/2011

Mid Stream Application

Pipelines were designed to transport dry gas, but will now transport wet gas so the client has decided to monitor both lines at their most vulnerable point i.e. the lowest point on the lines due to the possibility of moisture causing corrosion

Pipeline excavation

2 off Rightrax M2 Sensors were f itted at the locations as instructed on site located from the 3 O Clock to 9 O Clock position on both pipelines

Sensor Installed

DL2 Data Collection

Both Sensors wrapped in Pipeline coating prior to soil reinstatement

Soil Reinstatement

18 Mtr Extension Cable wired back to Data collection post

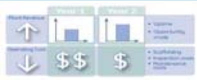
Data Collection

The Value Chain - Your Choice

The Transfer Function

Wall thickness Loss = Crude Quality +Chemical Inhibitors+ Operating Temp+ Ageing Assets+Fluid Dynamics

Improve Safety and Reduce Inspection Costs



Safety = less labor+less scaffolding+automation+ less risk+defined damage mechanisms

Improve Environmental Health & Safety & Revenue

EHS $

EHS & Revenue = reduce unscheduled shutdowns+loss of capital equipment+hazards to personnel+ pollution to the environment+increase revenue

Appendix 6

Acid gas unit treatment corrosion

Survey of WP15 to update EFC n°46 guideline

Update of EFC guideline n°46
Amine unit corrosion in refineries

Update of EFC guideline n°46
Amine unit corrosion in refineries

Revision of EFC46 "Amine units corrosion"
Some feed backs from the enquiry

Survey of industrial units:

1 MDEA unit (H_2S, NH_3, CO_2) without any specific corrosion problems

1 MDEA unit (H_2S, NH_3, CO_2) with :

- Leakage at reverse flow chamber of regenerator overhead air cooler – two times; affected material CS; mechanism Erosion/Erosion-Corrosion; remedy action change the metallurgy of tubes from CS to SS X8CrNiTi 18-10.
- Damage of the reflux pump casing of regenerator, affected material SS X20Cr13, mechanism Erosion/Erosion-Corrosion

1 proposal for a chapter on non intrusive on line monitoring:

1 comment on treatment, monitoring, control parameters for overhead

Appendix 7

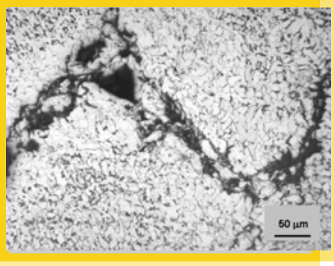
High Temperature Hydrogen Attack

Failure of a Dissimilar Metal Weld in a Texas Tower Heat Exchanger of a Platformer Unit.

(J. Van Roij Shell Global Solutions)

High Temperature Hydrogen Attack

Failure of a Dissimilar Metal Weld in a Texas Tower Heat Exchanger of a Platformer Unit.



European Federation of Corrosion WP15 "Corrosion in Refinery" Annual Meeting

Johan van Roij
Senior Materials & Corrosion Engineer

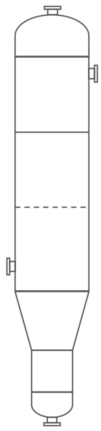
Outline

- What happened?
- Heat Exchanger Design
- Field Inspection
- Metallography
- What is HTHA?
- Contributing Factors
- Conclusion & Key Learning

HE - Design

Design Temperatures

Outlet channel	520 °C
Upper shell	543 °C
Main shell	400 °C
Lower shell Cone Reduced shell Inlet Channel	288 °C



Construction Materials

ASTM A-387
Grade 12 Class 1
(1 Cr ½ Mo steel)

ASTM A-285
Grade C
(carbon steel)

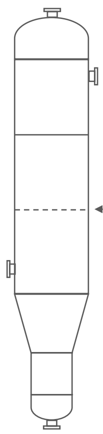
HE - Design

Design Code: BS 5500 ed. '76

Welding QC: BS 4870 Part 1 - 1981

Design Press: 3.81 MPa (552.6 psi)

PWHT Details

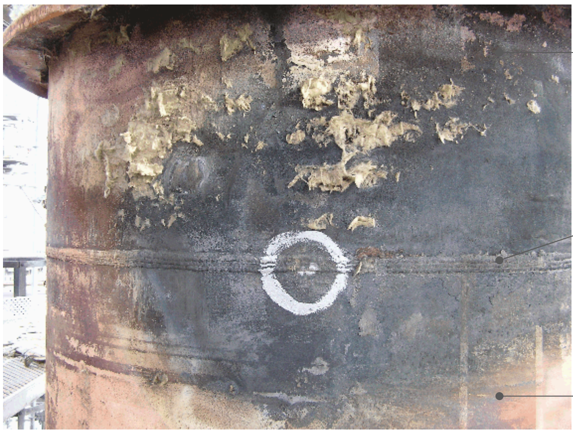


Upper Section
680 ºC, 4h 10m
Furnace

Dissimilar Metal Weld (DMW) /
Closure weld
620 ºC, 2h
Induction (local)

Lower Section
620 ºC, 2h
Furnace

Field Inspection



ASTM A-387
Grade 12 Class 1
(1 Cr ½ Mo steel)

DMW / Closure weld
(carbon steel)

ASTM A-285
Grade C
(carbon steel)

Field Inspection

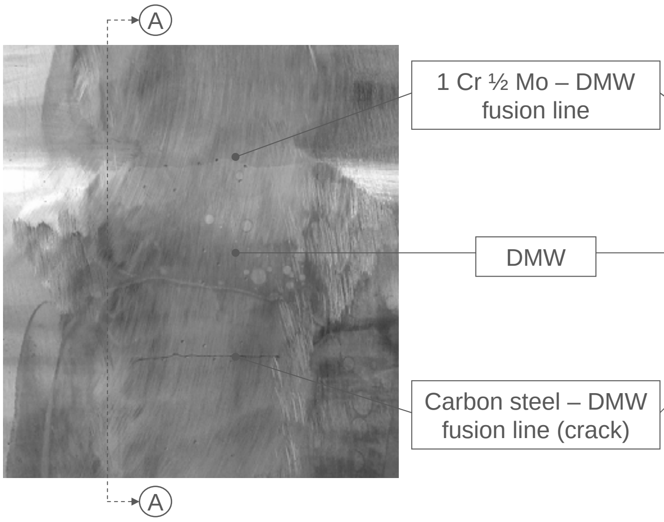
Small leak found at fusion line between DMW and carbon steel base metal.

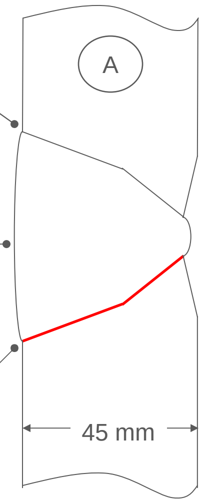
ASTM A-387
Grade 12 Class 1
(1 Cr ½ Mo steel)

DMW / Closure weld
(carbon steel)

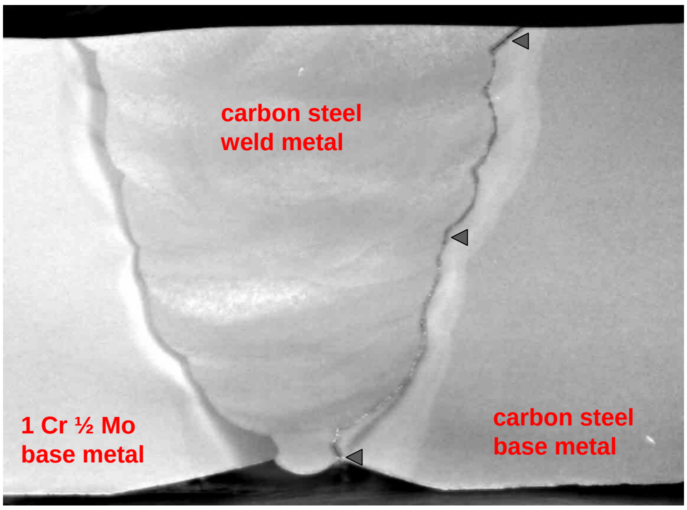
ASTM A-285
Grade C
(carbon steel)

Field Inspection



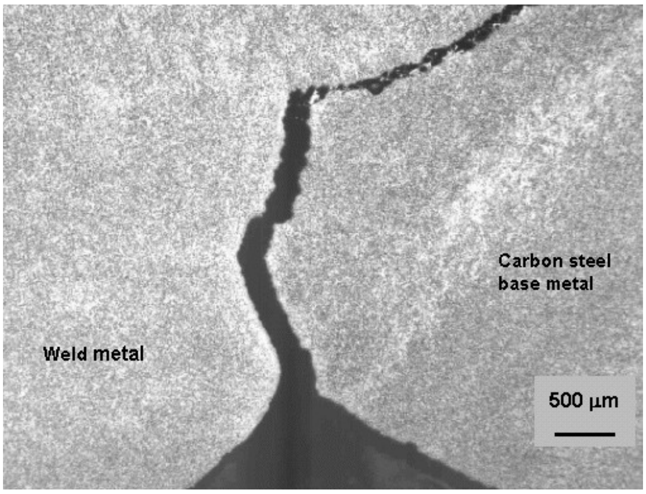


Metallography



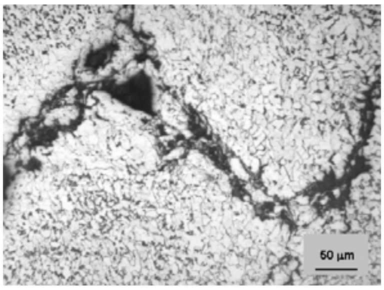
Crack precisely follows the fusion line on the carbon steel side of the dissimilar metal weld (DMW) (arrows).

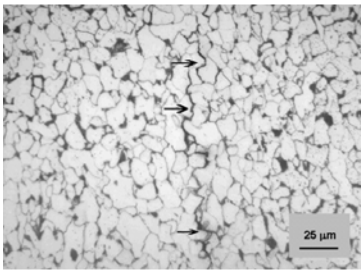
Metallography



Cracks started in the notch between the weld and base metal, then propagated along the fusion line.

Metallography





Local decarburization and fissuring in steel around main crack.

This is typical of localized High Temperature Hydrogen Attack (HTHA).

Inter-granular nature of the cracks can be seen in this image.

This is typical of localized HTHA.

What is High Temperature Hydrogen Attack (HTHA)?

Definition: Irreversible degradation of the mechanical properties of steel
by high temperature reaction of absorbed hydrogen with carbon in the steel, resulting in decarburisation and internal fissuring.

- Above approx. 7 bar H_2 and 230 °C
- Atomic hydrogen diffuses into steel
- Reaction with carbides in the steel:

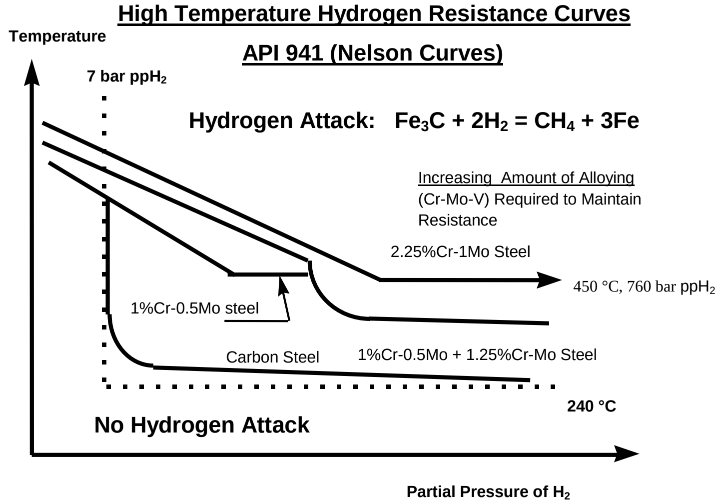
$$Fe_3C + 2H_2 \longrightarrow 3Fe + CH_4$$

- Main Variables:
  - H_2 Partial Pressure
  - Temperature
  - Exposure Time
  - Steel Chemistry
- Design Basis: "Nelson Curves" (API - RP 941)

HTHA – Nelson Curves

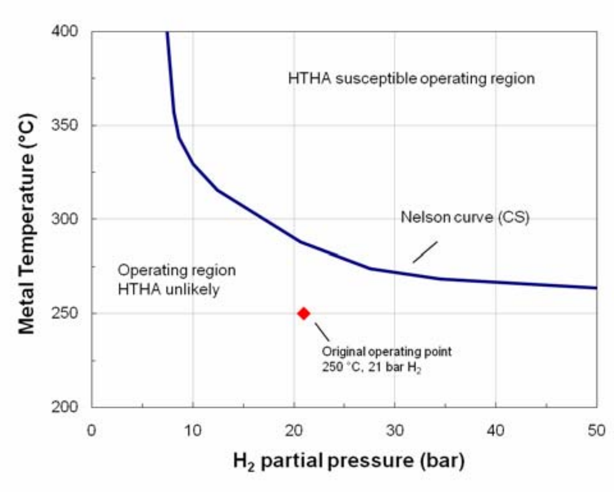
High Temperature Hydrogen Resistance Curves

API 941 (Nelson Curves)



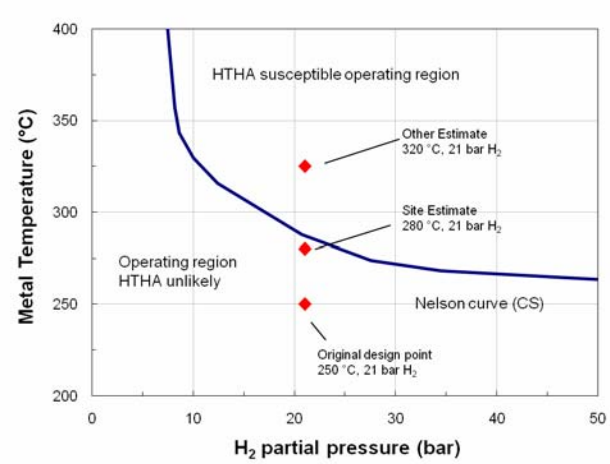
API 941: *"Because the Nelson curves are based largely upon empirical experience, an operating company may choose to add a safety margin, below the relevant curve, when selecting steels".*

Design



The original design basis operating temperature for the dissimilar metal weld (DMW) was 250 °C and an assumed H_2 partial pressure of 21 bar. This is about 40 °C below the CS Nelson curve.

Fouling Caused Increase in Temperature



Tube-side fouling increases the temperature of reactor effluent, which causes an upward shift in the temperature profile of the shell.

Site estimate results in operation within 5 °C of the CS Nelson curve.

Other estimate results in operation 32 °C above the curve.

API 941: *"Because the Nelson curves are based largely upon empirical experience, an operating company may choose to add a safety margin, below the relevant curve, when selecting steels".*

Conclusions

- Primary causal factor in this failure was local HTHA of the fusion line between Dissimilar Metal Weld (DMW) and CS base metal due to operation above the Nelson curve.

- The fusion line was more susceptible than weld metal or base metal due to its relatively low strength and the high reactivity of grain boundary carbides

- Stress concentration effect of DMW design and pre-existing weld defects explains the location and timing of the failure.

Key Learning

- Current design guidelines recommend the equipment to operate ~15 °C and ~1.7 bar below the appropriate Nelson curve versus *ON* the Nelson curve as was practiced in the past. Hence old equipment operating under similar conditions may be at similar risk.

- Crack formation due to HTHA is known to accelerate in areas of high stress. Due to its design and construction, the dissimilar metal weld closure joint had two types of stress concentrators at the fusion line (notch and weld defects).

Appendix 8

Carbon Steel Degradation in High Temperature Hydrogen Service – API Alert

AMERICAN PETROLEUM INSTITUTE

Carbon Steel Degradation in High Temperature Hydrogen Service

Industry Alert

The purpose of this alert is to inform you that there have been several reports of cracking - related issues with carbon steel piping and equipment in high temperature, high pressure hydroprocessing service at operating conditions where carbon steel was previously thought to be resistant to high temperature hydrogen attack (HTHA). One published report of such incidents can be found in the paper PVP2010-25455, Proceedings of the 2010 ASME Pressure Vessels and Piping Conference, July 18-22, 2010, Bellevue, WA.

API RP 941, *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants*, 7th Edition, 2008, Figure 1, shows the operating limits for steels in hydrogen service to avoid decarburization and fissuring from HTHA. One curve on that graph is for carbon steel. At temperatures and hydrogen partial pressures below the curve, HTHA is not expected to occur in carbon steel.

Prior to these recent reports, the only reported failures of carbon steel below the API RP 941, Figure 1 curve were in cases of exceptionally high stress, as discussed in Sections 5.2 and 5.3 of API RP 941. All of the new reports of HTHA involve carbon steel equipment that was not postweld heat treated. Past research summarized in API TR 941, *The Technical Basis Document for API RP 941*, states that non-postweld heat treated welds not only retain high residual welding stresses but also have lower carbide stability in the weld heat affected zone that further increases HTHA susceptibility. The API RP 941 Task Group of the API Subcommittee on Corrosion and Materials is now in the early stages of collecting and verifying data and information to determine if the recommended practice might need to be altered as a result of this new information.

API is notifying all refining operating companies of this new issue should owner-operators decide to alter their inspection plans or risk assessments for carbon steel piping and equipment, especially if not postweld heat treated and/or highly stressed, and particularly in hydroprocessing services. Section 6 of API RP 941 provides recommended practices for inspection of equipment that may be susceptible to HTHA.

If any of your operating sites have experienced unexpected cracking issues associated with carbon steel equipment that may be due to HTHA, please bring those to the attention of API by participating in the Corrosion and Materials Subcommittee and the RP 941 Task Group. The form found in Annex F of API RP 941, *Datasheet for Reporting High Temperature Hydrogen Attack (HTHA) of Carbon and Low-alloy Steels*, provides a recommended format for internal company data collection.

For information on API's Refining Standards and the API RP 941 Task Group please contact David Soffrin, Manager, Downstream Standards, at soffrind@api.org.

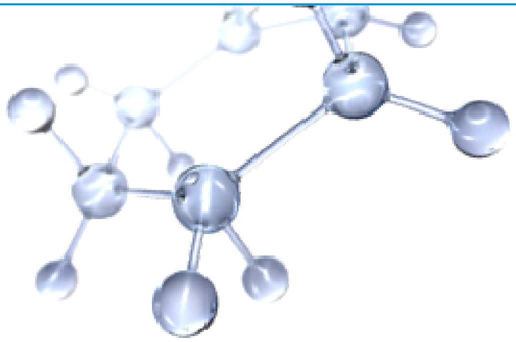
Appendix 9

Lean Duplex Stainless Steel Upgrades for

Critical Cooling Water Heat Exchangers

(John Houben – ExxonMobil)

Lean Duplex Stainless Steel Upgrades for Critical Cooling Water Heat Exchangers



Corrosion 2011

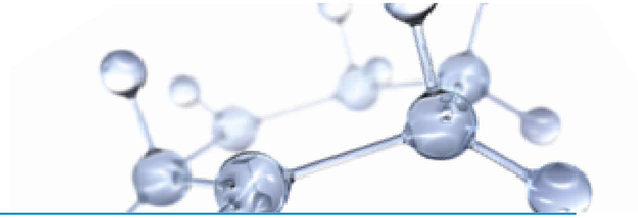
Brian Fitzgerald & John Houben

March 2011
2011CENGA 16

Agenda

- Background / Case for Action
- Maintenance Example
- Exchanger Upgrade Options
- Economic Evaluation of LDSS vs Carbon Steel (CS) Exchanger Bundles
- Conclusions

Background / Case for Action

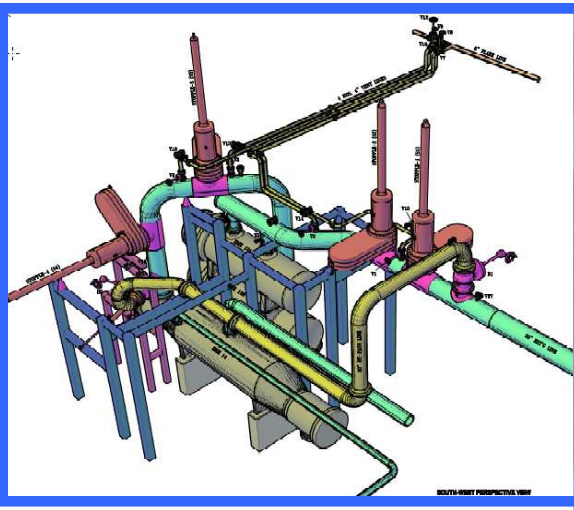


- **Background**
  + Mitigation of Cooling Water (CW) and/or process-side corrosion required for all CW exchangers
  + Upgrading exchangers from CS to austenitic SS has potential risk of SCC

- **Incentives for upgrading critical exchanger metallurgy include:**
  + Improves reliability and effectively eliminates process safety risk of leaking exchanger mitigation
  + Enables extended runs between T/As
  + Improves environmental performance
  + Moves us closer to goal of “maintenance / inspection free” equipment

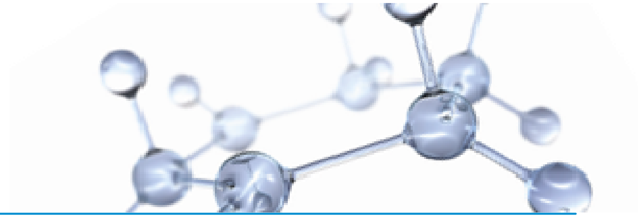
- **Premature exchanger failures result in significant financial losses / cost**
  + Critical exchanger leaks can cost millions of dollars in lost production and maintenance expense
  + Repairs require extensive engineering and planning to manage associated Process Safety risk

Critical Exchanger Leak Example



- **Process Gas Compressor intercooler exchangers leak**
  + Forced choice of a shut-down or a hot tap / stopple
  + Significant organizational disruption and engineering to manage
  + Stopple is essentially putting a valve in a live process line
- **Key hot tap and stopple "fun facts"**
  + Each 30" hot tap was followed by 30" stopple
  + Each stopple set is 12.5 tons and ~ 22 feet long
  + Hot tap set up is 10.7 tons and approximately 17 feet long
  + Total lost production was $ 2-4 M
  + Total mechanical cost was $ 2-3 M

Lean Duplex Stainless Steel

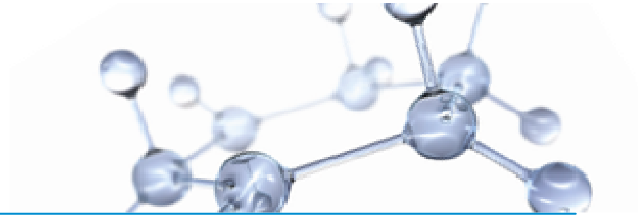


Alloy	UNS	Cr	Ni	Mo	Mn	N	Yield MPa
304L	S30400	18.1	8.3	---	1.0	---	170
316L	S31603	17.2	10.1	2.1	1.0	---	170
2205	S32205	22	5.7	3.1	1.0	0.18	450
SAF2304	**S32304**	**23**	**4.8**	**0.3**	**1.0**	**0.10**	**400**
LDX2101	**S32101**	**21.5**	**1.5**	**0.3**	**5**	**0.22**	**450**
AL 2003	**S32003**	**21.6**	**3.8**	**1.8**	**1.3**	**0.18**	**450**
AL 201 HP	S20100	16.3	4.5	--	7.1	0.07	310
AISI 430	S43000	16.3	0.3	--	0.5	0.05	310

- **Intermediate Tanks – In service**
  - + Organic acids settle out in CS tanks; service life <5 yr; coating fail
  - + 316 SS Tanks @ 160K$; 2101 Tanks @ 110K$

- **Heat Exchangers, Fresh Cooling Water – Current Upgrade Targets**
  - + Critical CS HE with life < 8-15 yr life
  - + Margin loss for bundle switch 1000K$ plus
  - + Mechanical costs (hot tap & stopple) 1000K$ plus
  - + Environmental reportable

Upgrade & Alternatives



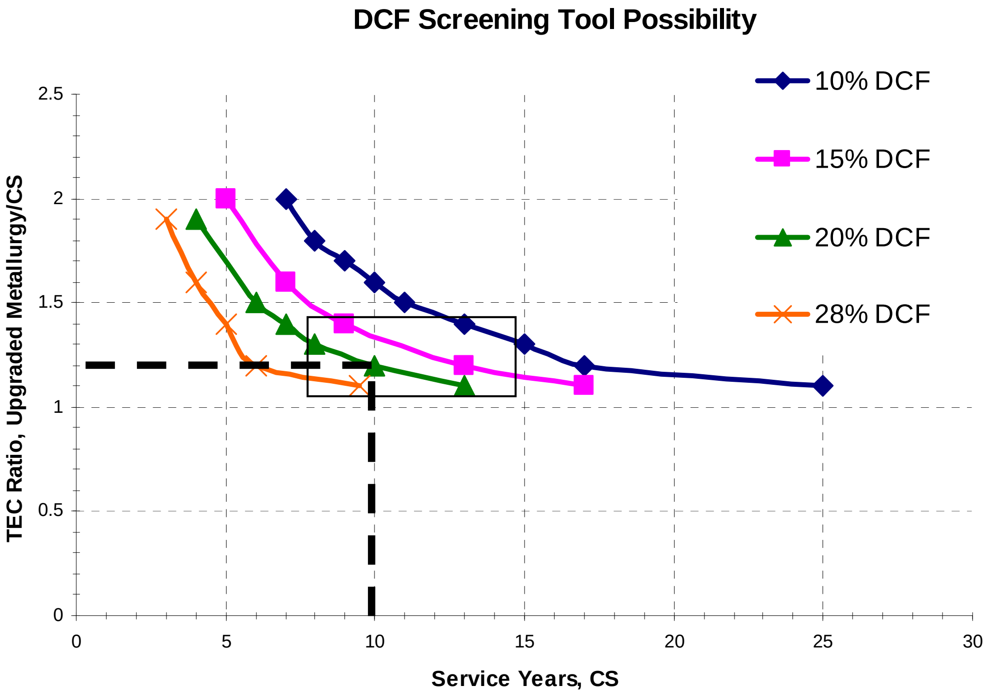
- **Opportunity Identified**
  - + Lean Duplex SS (LDSS) tube bundles commercially available ***with welded tubing at ~ 1.2 to 1.4 times cost of CS tube bundles***
- **Scope of Evaluation**
  - + Critical exchangers in **fresh recirculating CW service**
    - + No spare exchanger
    - + No bypass
    - + Leak will cause business disruption or safety, health or environmental incident / report
  - + Compare LDSS tube upgrade versus other carbon steel tubes and alternatives including installation of spare exchangers and bypasses

Exchanger Upgrade Options

LDSS Study – Representative Critical Bundle Options			
Tube Material Options	**Description**	**Cost (TEC)**	**TEC Ratio**
Carbon Steel	**CS tubes & tubesheet w/ welded TS joint**	115 k$	Base
Lean Duplex	**1. Upgrade tubes w/ welded TS joints**	140 k$	1.2
	2. Upgrade tubes w/ welded TS joints and baffles / ties / etc.	160 k$	1.4
	3. Upgrade tubes, baffles / ties / etc, and tubesheet w/ welded TS joints	195 k$	1.7

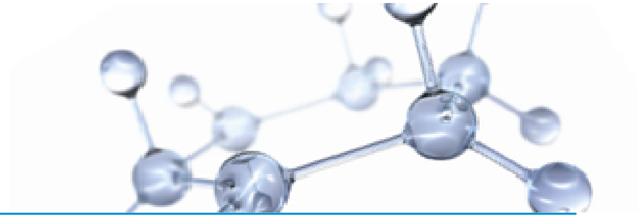
- Upgrading tubes alone is a significant improvement, but baffles / etc. remain “weak link” if the shell side is corrosive
- Upgrading baffles / ties / etc to SS along with tubes should effectively extend bundle life “indefinitely”
- Upgrading tubesheet to SS is costly and not req’d based on 2205 duplex experience
- Other tube upgrade options (coated tubes, admiralty, 2205 duplex) are more costly
- Spare exchangers and bypasses are more costly

Economic Evaluation of LDSS vs CS Exchanger Bundles



- DCF Screening example based on initial bundle replacement cost only
- Additional credits for mechanical costs and lost production costs can be taken. For example, every 1000K$ of mechanical or lost production costs in year 9 (of 10 year run) at 20% DCF adds 194K$ to the carbon steel TEC

Conclusions

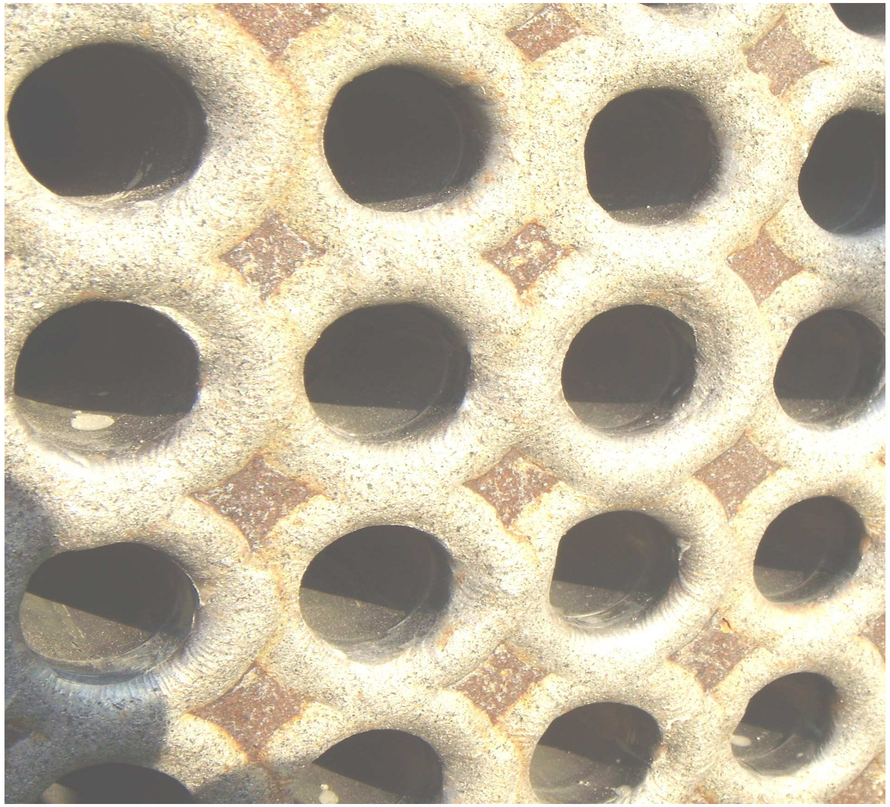


- CS bundles remain a viable option for non-critical heat exchangers
- Upgrades expected to generate 15-30+% DCF for critical CW exchangers

Attachments – CS TS with 2205 DSS tubes
CTW Tube Side 6 years Service

Attachments – CS TS with 2205 DSS tubes

CTW Tube Side



ExxonMobil Chemical

Attachments – CS TS with 2205 DSS tubes
CTW Shell Side 15 years Service

Attachments – CS TS with DSS tubes
Hydrocarbon Service

Attachments – CS TS with LDSS tubes

TS Mock Up Test

Tubesheet after rolling

Manometer 75 bar

Sealweld

Copyright

Appendix 10

Stress Relaxation Cracking Recent Project Experience

(Hennie de Bruyn – Johnson Matthey)

Stress Relaxation Cracking
Recent Project Experience

Hennie de Bruyn
Head of Metallurgy
Process Technologies

Katalco Activate your potential

Johnson Matthey Catalysts

Preventing Stress Relaxation Cracking

- New catalyst production plant
  - Location: Kanpur, India
  - High temperature equipment; hydrogen & other gas environments
  - Cyclic service up to 700°C
  - Austenitic stainless steel type 304H selected for most high temperature equipment
  - Potential for stress relaxation cracking identified during early project stages
  - TNO input for PWHT/ageing heat treatment procedure
- Manufacturer Resistance
  - PWHT requirements for 304H became an obstacle with EPC and equipment manufacturers
  - Some vessel manufacturers in India declined to quote because of PWHT requirements
  - Most would not guarantee the design (ASME Sec. VIII Div. 1) because of PWHT
  - Requalification of all welding procedures (PWHT is essential variable)
  - Acceptance only after lengthy explanations of stress relaxation cracking

Katalco Activate your potential

Johnson Matthey Catalysts

Preventing Stress Relaxation Cracking

- Practical Considerations
  - Finding a large enough heat treatment furnace
  - Supporting a reactor and other equipment inside the heat treatment furnace
  - Avoiding thermal stresses in the equipment
  - Some equipment (for example heat exchangers) too complex to heat treat; do not want to heat treat bellows, etc.
  - Ensuring even temperature distribution during PWHT
  - Heating rate: large furnaces can only maintain 40 – 50°C/hr (well below TNO recommendations) – uncertainty
  - Cooling down: getting equipment out of the furnace quick enough

- Welding
  - Base material properties well above minimum requirements (ASTM A240 gr. 304H)
  - Mechanical properties after PWHT still above minimum requirements

Preventing Stress Relaxation Cracking

- Open questions
  - Long-term effect of ageing heat treatment of creep properties of the material?
    - Big uncertainty!
    - How can we establish this?

  - Can stress relaxation cracking be avoided in another way (avoid PWHT)?
    - Grain size control of the base material; additional costs; not sure this is sufficient
    - Ni-content of the alloy; additional costs; might be prohibitive; unaffordable

  - Is PWHT (ageing) sufficient?
    - Testing of production test plate at TNO
    - Very little information on PWHT conditions available in public domain
    - Urgent need for an open guideline; EFC WP15 has been discussing this since 2007
    - What is the status of Total/Cefracor work on this subject?

Katalco Activate your potential
Johnson Matthey Catalysts

Appendix 11

New JIP on Stress Relaxation Cracking

(Chretien Hermse - TNO)

Stress relaxation cracking

September 22nd discussion at TNO

TNO | Knowledge for business

Chrétien Hermse

Hans van der Veer

H. van Wortel, NACE 2007, Nashville, USA, paper 07423

Stress relaxation cracking: a new project?

- Several JIPs between 1995 and 2000
- Susceptibility test
- Prevention strategy using PWHT
- Recommended practice in 2000

Stress relaxation cracking under control

Nevertheless:

- Several requests from industry!

Stress relaxation cracking: new questions

- Effect of PWHT on creep life time
  - Can creep reduction factors be avoided?
- SRC susceptibility of new alloys not in the previous JIP
  - Supplement to existing recommended practice
- Alternative remediation strategies
  - PWHT is inconvenient, are alternatives thinkable?
- Dissimilar welds
- Determination of the effect of wall thickness
- …

Is this a real problem?

Discussion meeting

- September 22nd discussion meeting at TNO in Apeldoorn, Netherlands
- Draft proposal available for discussion
- Several engineering companies, material and welding consumable suppliers, and end users will attend
- Other interested industrial partners are also welcome

- Please send an email to chretien.hermse@tno.nl to register

Stress relaxation cracking

- Temperature range 500-700 degrees Celsius
- Mechanical form of degradation
- Sensitivity test available, remediation and repair strategy developed: TNO recommended practice (H. van Wortel, RC-00-43)
- Most materials susceptible, good suppliers give information about appropriate treatment to prevent SRC