Appendix 1

Welcome and introduction

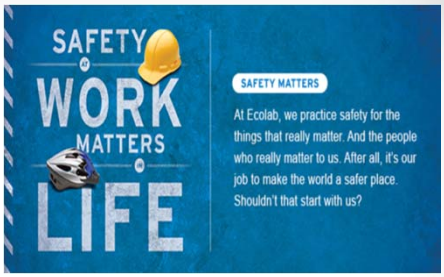
J. Chew (Nalco-Champion)

EFC WP15

Welcome

Jim Chew

VP Marketing & Business Development



NALCO Champion
An Ecolab Company

Taking Energy Further™ 2

WE ARE ECOLAB

Protecting People And What's Vital to Life




SAFE FOOD | CLEAN WATER | ABUNDANT ENERGY | HEALTHY ENVIRONMENT

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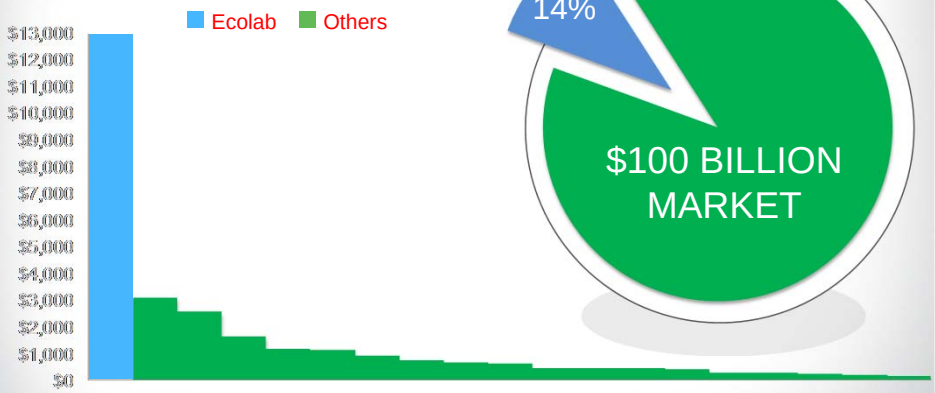
An Ecolab Company

Taking Energy Further™ 3

WELL POSITIONED



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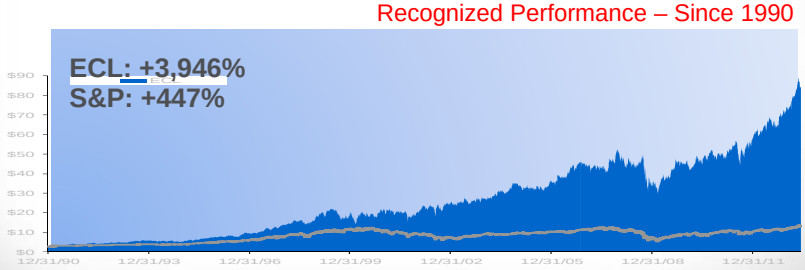
Taking Energy Further™ 4

ECOLAB
Financially Sustainable

Recognized Performance - 2013

Recognized Performance – Since 1990



5

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Taking Energy Further™ 5

ECOLAB
Our Values:

Reach shared goals.
Do what's right.
Challenge ourselves,
Work together.

2013 WORLD'S MOST ETHICAL COMPANIES WWW.ETHISPHERE.COM

Recognized for Doing Business the Right Way

Global Talent, Technology and **Share Leaders**

Chief Executive BEST COMPANIES FOR LEADERS 2013

NALCO Champion
An Ecolab Company

Taking Energy Further™ 6

Energy is core to Ecolab

ECOLAB®

Non Oil & Gas Sectors

- Food Service
- Hospitality
- Healthcare
- Buildings & Facilities
- Commercial Laundries
- Food & Beverage Processing
- Manufacturing
- Pulp & Paper
- Mining & Mineral Processing

Revenue: ~ $9.1B
36,000 employees

Oil & Gas Sector

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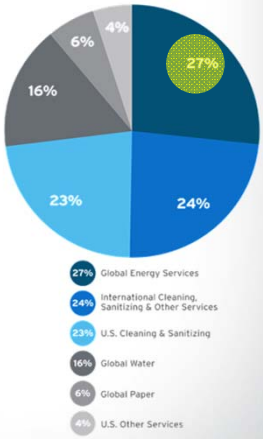
- WellChem Technologies
- Oilfield Chemicals
- Enhanced Oil Recovery
- Downstream

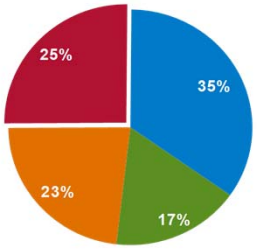
Revenue: ~ $3.5B
6700 employees



Energy is core to Ecolab

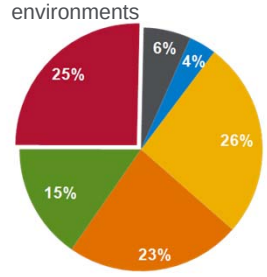
By Strategy

energy is a key component of Ecolab strategy to meet critical global needs



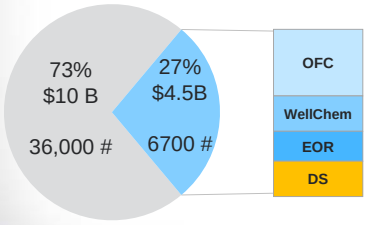
By Segment

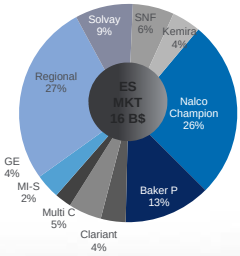
clean water, safe food, **abundant energy** & healthy environments

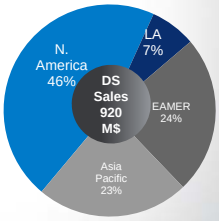


NALCO CHAMPION

Ecolab Legacy	WPS	Nalco Champion (ES)
Food Service	Food & Beverage Processing	WellChem Technologies
Hospitality	Manufacturing	Oilfield Chemicals
Healthcare	Pulp & Paper	Enhanced Oil Recovery
Buildings & Facilities	Mining & Mineral Processing	Downstream
Commercial Laundries		







NALCO Champion
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Downstream

2 Principle Market Segments
REFINING
PETROCHEMICALS

3 Offering Types
SERVICES
CHEMISTRY
EQUIP/AUTOMATION

$880 M MARKET LEADER preferred by customers to bring water and process solutions that deliver value to their dynamic operations

WE SOLVE THE OIL AND GAS INDUSTRY'S TOUGHEST CHALLENGES

4 Offering Platforms
WATER
REFINING PROCESS
PETCHEM PROCESS
FUEL ADDITIVES

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An Ecolab Company

OUR COMBINED RESOURCES

160+ countries

4,000+ field sales and service associates

47 manufacturing facilities

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An Ecolab Company

Unmatched, Diverse Global Presence

EHCP
Eastern Hemisphere Core Plant

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An Ecolab Company

19 GLOBAL ECOLAB TECHNOLOGY CENTERS

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An Ecolab Company

Taking Energy Further™ 13

Operation Excellence is the key corporate strategy our major customers

NALCO Champion
An Ecolab Company

Taking Energy Further™ 14

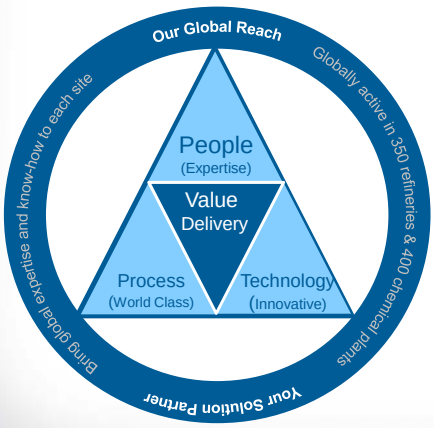
A Value Based Model

Everywhere it matters

- More than 80 years
- Over 2,000 experts
- 6 Continents

- Draw from daily experience in more than 350 refineries & 400 petrochemical plants

- Delivering unmatched expertise for Downstream with People, Processes Technology and Information



Exceptional **Service**

Proven Global **Processes**

+

Unique **Technology**

Global **Information**

Best Results, Lowest Total Cost

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An Ecolab Company

Taking Energy Further™ 15

The "window" to lost assets….

Homeowners stunned as 'Blunket Bobbies' climb through unlocked windows… to warn

A few facts

- Crimes of opportunity: Once a house is selected a burglar will spend less than 1 minute trying to get into it and less than 5 minuets inside
- Most entries occur on first floor
- Typical entry is at rear or side of house via open window or door

PCSOs climbed through windows to show how easy it is for thieves (file pic)

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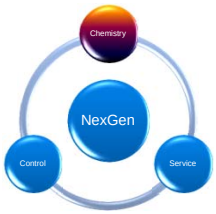
16

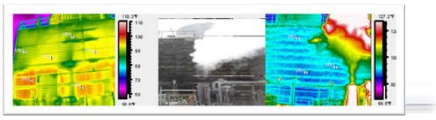
Wholistic Approach to Closing the Corrosion Window



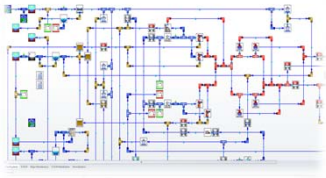
90/10

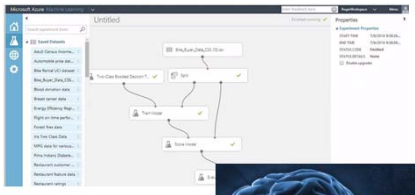
Ninety % of the corrosion damage occurs ten % of the time

"The Corrosion Window"



Advanced Services





Predictive Analytics

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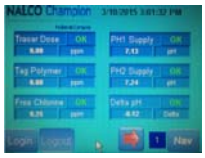
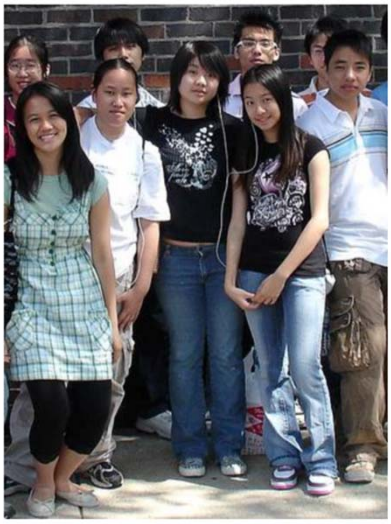


Automation

17

Things aren't always what they appear to be…



In reasoning, we assume when we take something for granted or accept an idea without sufficient proof of its truth or certainty.

What assumptions are apparent in the following story:

In Oakland, a gang of teens – some as young as 13 – were arrested in connection with sixty burglaries. All the teens were Asian Americans and the homes they robbed were all in Asian American neighborhoods. Two girls from the gang would knock at the doors. If someone came to the door, they would ask for someone who did not live there, then leave. If no one answered, the girls would signal to two boys who would go around to the back of the house and break in. The police said, "At times they would wave at neighbors, who would wave back."

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18

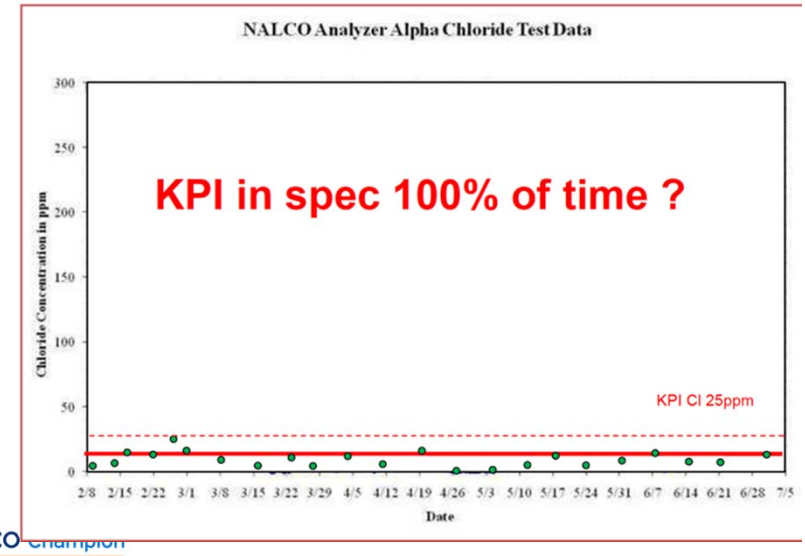
ONE TEAM EXECUTION

Keeping our promise to our customers

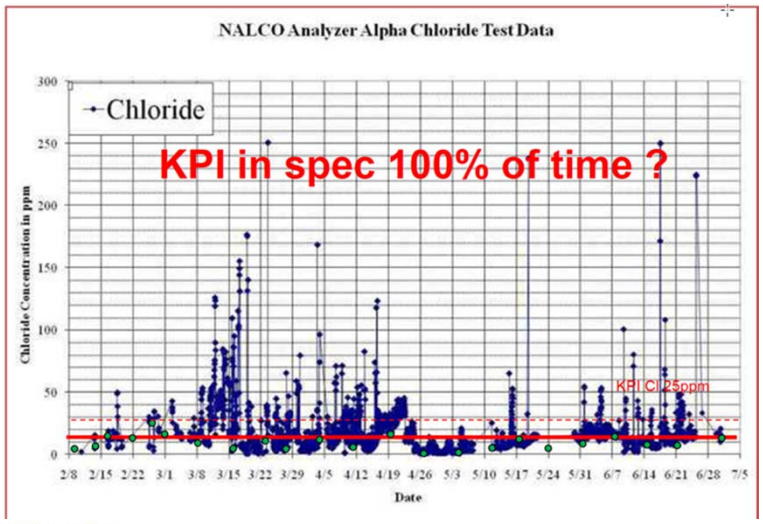
Identifying and solving problems …

… others may not see…as a Global Team

We appear to be in spec…



…not how it appeared to be when we got a closer look



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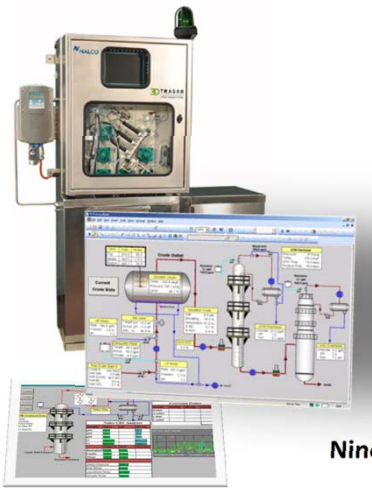
21

Refinery Crude Overhead Corrosion Control

3D TRASAR TECHNOLOGY for CRUDE OVERHEAD SYSTEMS



Traditional Monitoring & Control

- Wet chemistry
- Simulation programs
- Non Intrusive and Intrusive inspection
- Baseline feed of chemistry

Challenges with traditional methods

- Frequency
- Accuracy of testing
- Baseline chemistry dose either too high or too low resulting in costs and reliability concerns
- **NO or WEAK LINKAGE to RESULTS**

90/10

Ninety % of the corrosion damage occurs ten % of the time

"The Corrosion Window"

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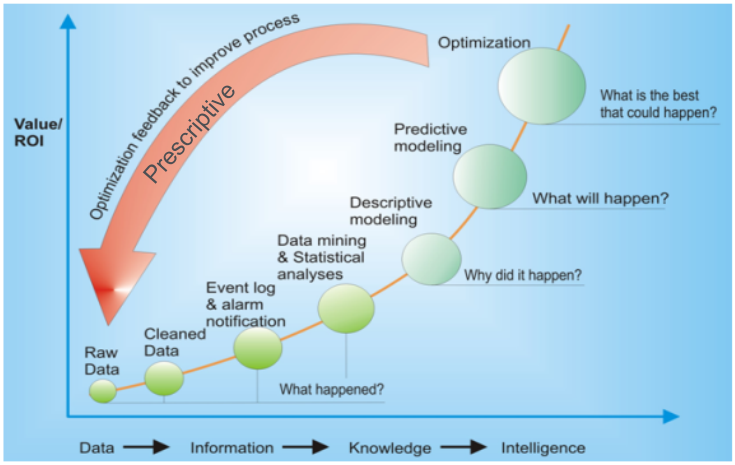
An Ecolab Company

22

The Prize: Predictability / Optimization

Refined Knowledge™ Project



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An Ecolab Company

Appendix 2

List of participants

Participants EFC WP15 meeting 14th April 2015 Leiden (The Netherlands)

Name	Surname	Company	Country
Angelova	Mariyana	LUKOIL Neftochim Bourgas JSC	RUSSIA
Bour Beucler	Valerie	Nalco Energy Services	FRANCE
Chew	Jim	Nalco	NETHERLANDS
Clarke	Kevin	Permasense Ltd	UK
De Landtsheer	Gino	Borealis	BELGIUM
Dees	James	Nalco	NETHERLANDS
Doublet	Sebastien	Air Liquide	FRANCE
Dufour	Jerome	Nalco	FRANCE
Escorza	Erick	Tenaris Dalmine	ITALY
Fenton	Stephen	Steve Fenton Consultants	UK
Goti	Raphael	Total Refining & Chemicals	FRANCE
Goudsmith	Eugene	Nalco	NETHERLANDS
Gouwen	Robert	Shell	NETHERLANDS
Groysman	Alec	Technion; Assoc.Chem. Eng	ISRAEL
Hall	Murray	Nalco	NETHERLANDS
Heisterkamp	Marco	BP Gelsenkirchen GmbH	GERMANY
Helle	Henk	CorrosionControl.Nu	NETHERLANDS
Hofmeister	Martin	Bayernoil Raffineriegesellschaft mbH	GERMANY
Holmes	Tracey	Special Metals	UK
Houben	John	ExxonMobil Chemical Holland BV	NETHERLANDS
Houlle	Patrice	Patrice Houlle Corrosion Service	FRANCE
Kiiski	Arto	Neste Jacobs Oy	FINLAND
Kolev	Nikolay	LUKOIL Neftochim Bourgas JSC	RUSSIA
Koller	Swen	Holborn Europa Raffinerie GMBH	GERMANY
Lenti	Roberta	SARLUX	ITALY
Loyan	Sophie	Total	FRANCE
Marcolin	Giacomo	Tenaris Dalmine	ITALY
Mata	Pedro	Nalco	NETHERLANDS
Meissner	Andreas	Salzgitter Mannesmann Precision GmbH	GERMANY
Niemi	Raisa	Neste Jacobs Oy	FINLAND
Pestic	Ivica	Shell	NETHERLANDS
Rehberg	Thomas	KAEFER Isoliertechnik GmbH & Co. KG	GERMANY
Renoldi	Fabrizio	SARLUX	ITALY
Ropital	François	IFP Energies nouvelles	FRANCE
Tabaud	Frederic	BP R&LT	NETHERLANDS
Thom-Kallen	Werne	BP Gelsenkirchen GmbH	GERMANY
Thornthwaite	Philip	Nalco	UK
Van Dooren	Piet	Borealis	BELGIUM
van Malsen	Johan	CB&I Nederland BV	NETHERLANDS
Van Rodijnene	Fred	Oerlikon metco	GERMANY
van Roij	Johan	Shell Global Solutions International B.V.	NETHERLANDS
Vosecký	Martin	Nalco	CZECH REPUBLIC
Yanes Guardado	Maria Jose	REPSOL	SPAIN

Appendix 3

EFC WP15 Activities

(F. Ropital)

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 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
- WP 22: Corrosion control in aerospace
- Task Force on Corrosion in CO_2 Capture Storage (CCS) applications

EFC Working Party 15 « Corrosion in Refinery » Activities

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

Chairman: Francois Ropital Deputy Chairman: Hennie de Bruyn

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

Information Exchange
Sharing of refinery materials /corrosion experiences by operating company representatives.

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

Eurocorr Conferences

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

Publications - Guidelines

EFC Working Party 15 « Corrosion in Refinery »

List of the WP15 spring meetings :

10 April 2003	Pernis - NL (Shell)
8-9 March 2004	Milan -Italy (ENI)
17-18 March 2005	Trondheim- Norway (Statoil)
31 March 2006	Porto Maghera - Italy (ENI)
26 April 2007	Paris - France (Total)
15 April 2008	Leiden -NL (Nalco)
23 April 2009	Vienna - Austria (Borealis)
22 June 2010	Budapest - Hungary (MOL)
14 April 2011	Paris - France (EFC Head offices)
26 April 2012	Amsterdam - NL (Shell)
9 April 2013	Paris - France (Total)
8 April 2014	Mechelen - Belgium (Borealis)

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 2014-2016

. Collaboration with Nace : exchange of minutes of meetings TEG 205X, …

. Sessions with other EFC WP at on which topics?
WP19 Polymer, WP1 Inhibitor W3 High Temperature
2016-Montpellier-France, 2017 Prague Czech Republic

• Update of publications
  - Amine unit corrosion in refineries

• New Publications: best practice guideline to avoid and characterize stress relaxation cracking ?

• Education – qualification – certification
List of "corrosion refinery" related courses on EFC website ?
Proposal of courses within Eurocorr ?

Eurocorr 2015

Graz 6-10 September 2015

Authors have been informed by mid April

Refinery corrosion session (Exact date not confirmed yet)

Annual WP15 working party meeting during Eurocorr
(Exact date not confirmed yet)

http://eurocorr2015.org/

7

Information :
Future conferences related to refinery corrosion

•6-10 September 2015
EUROCORR 2015 Graz Austria

•6-10 March 2016
Nace Conference 2016 Vancouver Canada

•May 2016
High Temperature Corrosion and Protection of Materials – Les Embiez France

•11-15 September 2016
EUROCORR 2016 Montpellier France

Look at the Website: www.efcweb.org/Events

Information : Training

•28-29 May 2015
Stress Corrosion Cracking Amsterdam (NL)
coordinate by S. Winnik
http://oilgas.flemingeurope.com/stress-corrosion-cracking-training

Appendix 4

Ageing Stress Relaxation Cracking

(A. Kiiski)

NESTEJACOBS

EFC WP15

Laiden 14.4.2015

ARTO KIISKI

NESTEJACOBS.COM

Neste Jacobs Oy

- Engineering company owned by Neste and Jacobs Engineering
- Group of 8 people working with materials
  - Material selections
  - Corrosion
  - Failure analysis (no lab)
  - Welding
  - NDT

Relaxation cracking of austenitic steels

- EFC WP15 2007 presentation by Hans Van Wortel
- Any new information after 2007
- Repairing of old welds ?
- Heat treatment temperatures of different materials: 347H, 800H
  - Higher temperatures than normal stabilization 900 - 920 C
- NDT of existing materials PT, UT?
- New material developed in JIP
  - In any standards
  - Any experience

RBI in refineries in Europe

- API 580 and API 581
- Qualitative and quantitative
- Any own systems
- Computer programs

Appendix 5

Ageing Stress Relaxation Cracking

Cracking in material 1.4919 – Relaxation cracking or other embrittlement phenomena

(M. Hofmeister)

Cracking in material 1.4910

Relaxation cracking
or other embrittlement phenomena?

EFC WP15

Spring Meeting 2015

Design data

- Material 1.4910 (X3CrNiMoN17-13-3)

C max. 0,04 **Cr** 16,00 – 18,00 **Ni** 12,00 – 14,00 **Mo** 2,00 – 3,00 **N** 0,10 – 0,18 **B** 0,0015 – 0,0050

- PWHT of vessel head: 1030°C, cooled in still air ?

- Working temperature 500°-530°C, design 590°C
- Temperature excursions possible up to design temperature
- Working pressure 2,5 barg (→low stress)

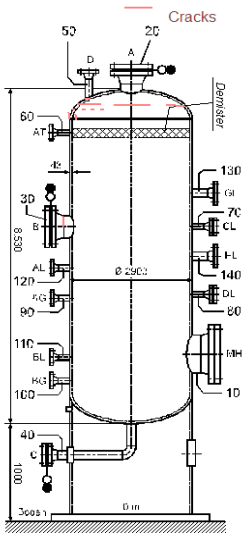
- Hydrocarbon vapours

- Vessel life until first cracks (detected) 11 years

Stress

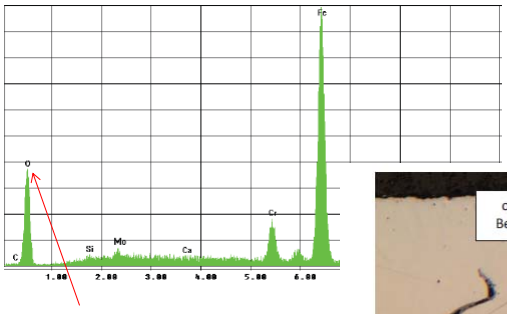
- Low stress factor from internal pressure
- Historical external loads not known, „reserves“ from internal pressure
- Residual stresses from head forming, welding
- Secondary stresses from start-up procedures (high dT/dt) possible

Cracks – Location



Typical crack depth: 2-20mm, outer surface

Crack in Knuckle Area of Vessel Head



Scale: Oxides

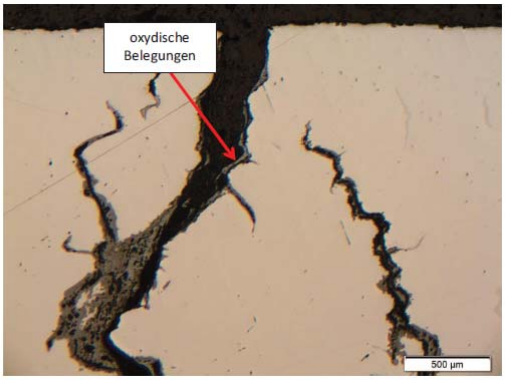


Bild 15: Metallographischer Schliff (ungeätzt): Riss Außenseite 50x

Folie 5
21.04.2015
M. Hofmeister

Datei:

Secondary cracks

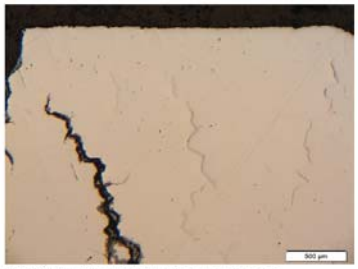


Bild 17: Metallographischer Schliff (ungeätzt): Nebenrisse Stelle 1, 50x

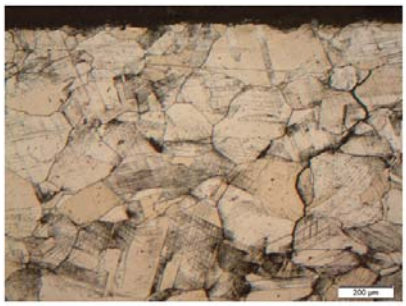


Bild 21: Metallographischer Schliff (präparativ geätzt): Gefüge Außenseite, 100x

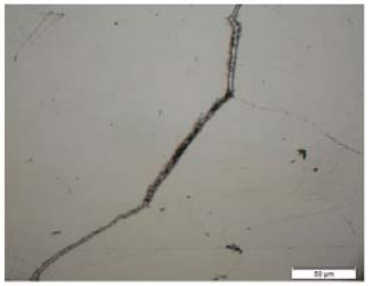


Bild 25: Metallographischer Schliff (präparativ geätzt): Belegungen der Korngrenzen, 500x

Folie 6
21.04.2015
M. Hofmeister

Datei:

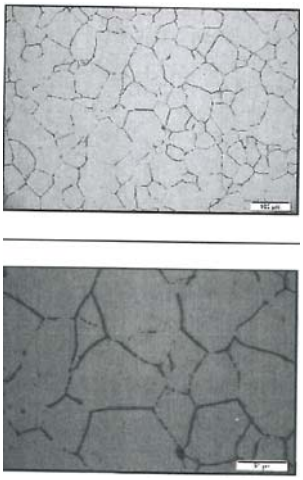
Stress relaxation cracking

- ?

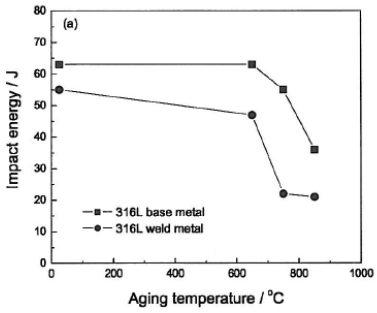
- 1.4910 largely free of precipitations and immune to stress relaxation cracking according to TNO report, typical time period until damage is 1-2 years
- solution annealing recommended if cold working exceeds 15% (relevant at knuckle area)
- working temperature to low for this damage mechanism (according to experience)
- carbide precipitation at grain boundaries, no signs of fine distribution of carbides inside grains giving extra hardness of grains and low strength at boundaries

- Control of Relaxation Cracking in Austenitic High Temperature Components, H. van Wortel, NACE 07423

Sensitization



C-content 0,02-0,04%
Replicas 2011
No fracture mechanical tests
Cleavage fracture – CVN ? Influence of coarse grain?



Effect of Aging on the Toughness of Austenitic and Duplex Stainless Steel Weldments

Omyma Hassan Ibrahim[1], Ibrahim Soliman Ibrahim[2] and Tarek Ahmed Fouad Khalifa[3]
1) Metallurgy Dept., Nuclear Research Centre, Atomic Energy Authority, Egypt
2) Nuclear Safety Centre, Atomic Energy Authority, Egypt
3) Shoubra Faculty of Engineering, Benha University, Egypt
[Manuscript received August 31, 2009, in revised form February 26, 2011]

Appendix 6

Ageing – Temper embrittlement

Condition assessment of powerformer piping system

(S. Koller)

PFR-piping system
Condition assessment

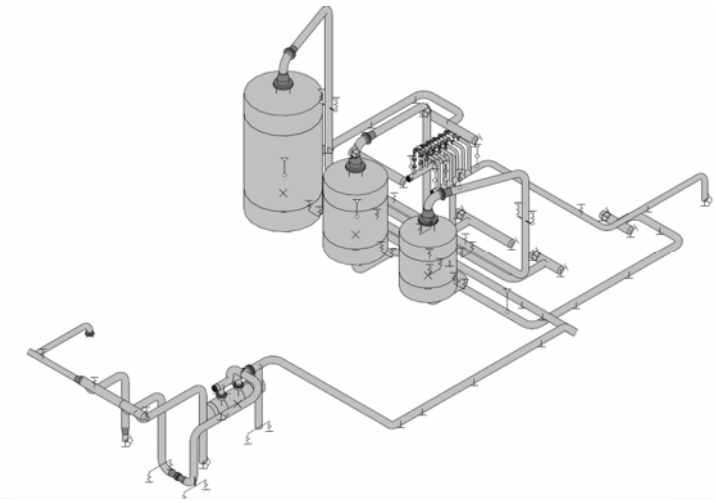
HOLBORN EUROPA RAFFINERIE GMBH

Name: Swen Koller
Position: Senior Inspector

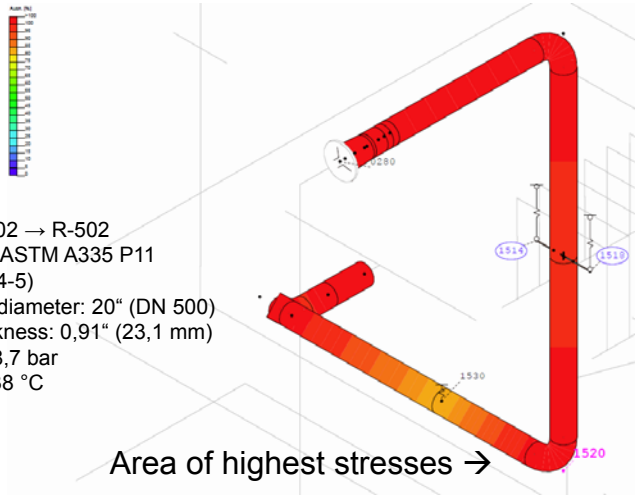
Phone: +49 40 7663 - 1405
Email: skoller@holborn.de

1. Overview
2. Test results
3. Measures taken

Overview of the PFR-piping systems



Stress analysis according to EN 13480

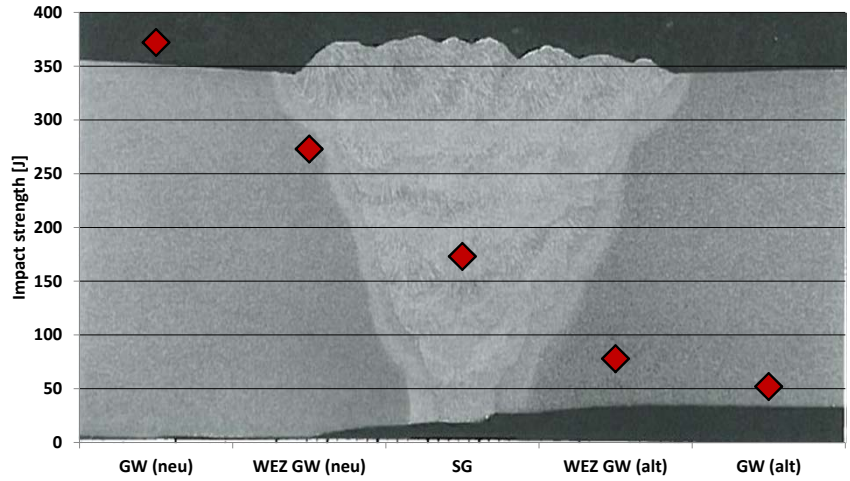


PFR-F-502 → R-502
Material: ASTM A335 P11
(13CrMo4-5)
Nominal diameter: 20“ (DN 500)
Wall thickness: 0,91“ (23,1 mm)
Pmax: 38,7 bar
Tmax: 538 °C

Test-Coupons

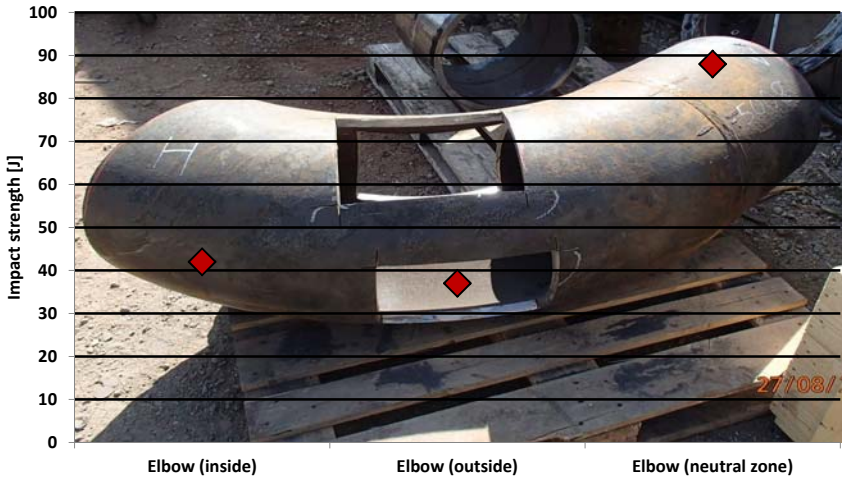
production weld test

Production weld test



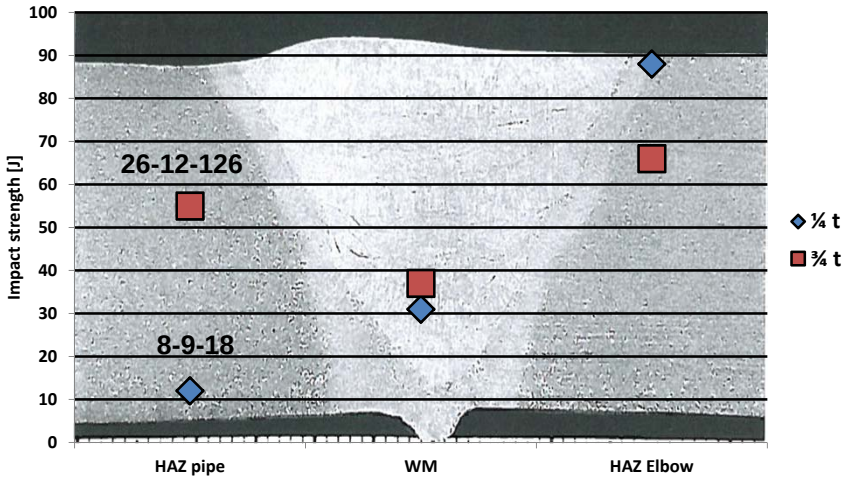
Test-Coupons

Elbow (old)

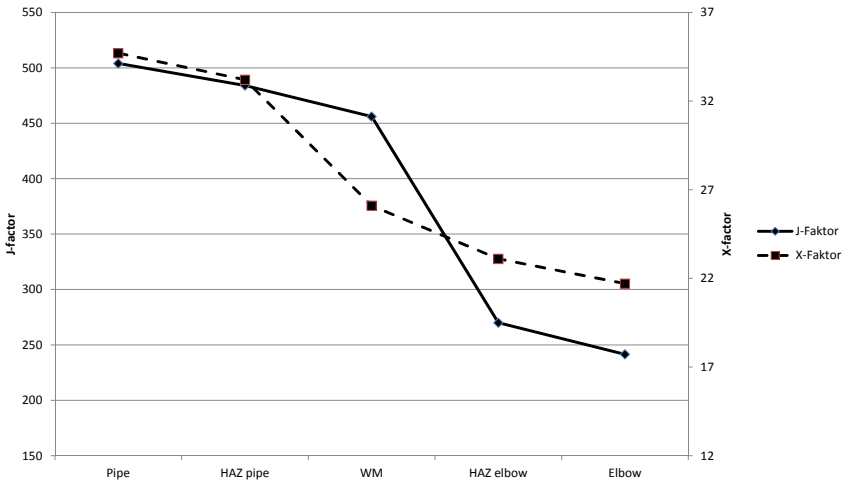


Test-Coupons

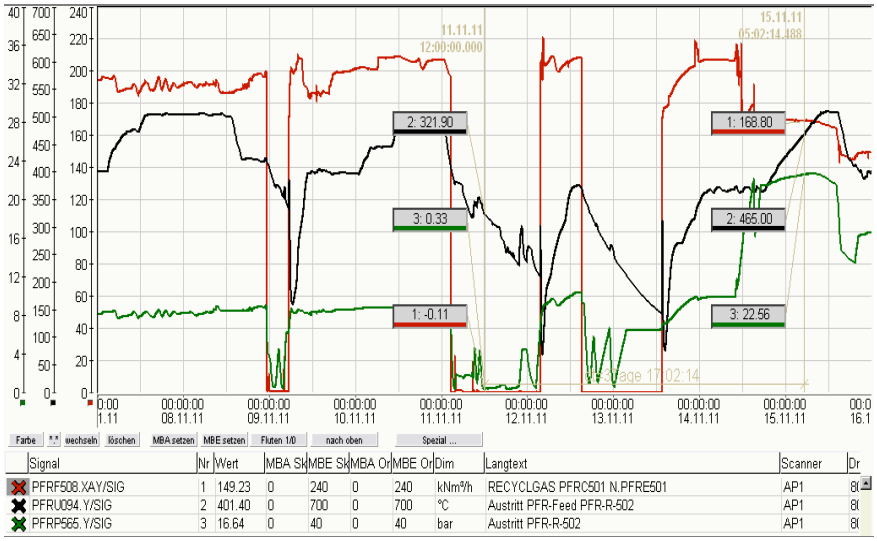
Old weld seam pipe to elbow



Watanabe (J)- and Bruscato (X)-factor

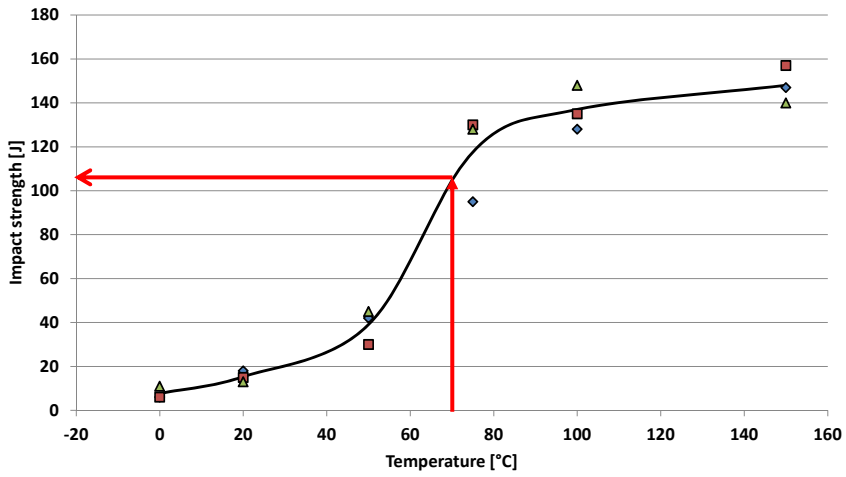


Service parameter (regeneration)



Signal	Nr	Wert	MBA Sk	MBE Sk	MBA Or	MBE Or	Dim	Langtext	Scanner	Dr
PFRF508.XAY/SIG	1	149.23	0	240	0	240	kNm³/h	RECYCLGAS PFRC501 N.PFRE501	AP1	8(
PFRU094.Y/SIG	2	401.40	0	700	0	700	°C	Austritt PFR-Feed PFR-R-502	AP1	8(
PFRP565.Y/SIG	3	16.64	0	40	0	40	bar	Austritt PFR-R-502	AP1	8(

A_V-T-courve (HEZ old pipe)



Measures

- Comprehensive maintenance and renewal of the pipe support system for minimizing stresses arising during service
- Optimising the shut-down and start-up process considering the stress conditions
- NDT (MT and UT) on selected welding seams directly before the start-up

Appendix 7

Unexpected stainless steel cracking in high temperature service

(F. Tabaud)

Unexpected cracking in SS316 piping in high temperature service.

Frédéric Tabaud – BP R&LT
Principal Engineer Materials and Corrosion

Introduction

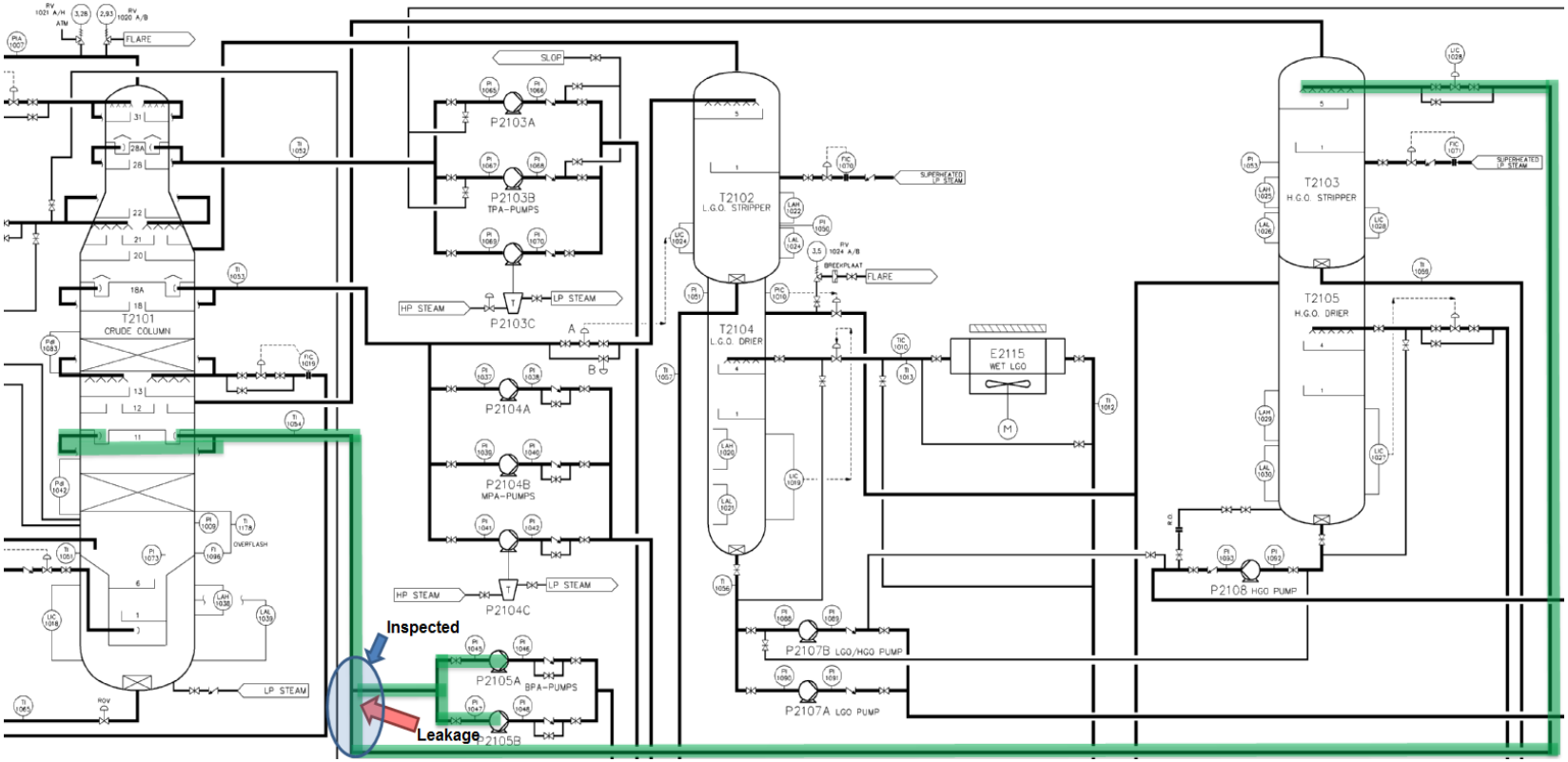
Presentation of a failure case:

- Where it happened
- What was observed
- Inspection results
- Failure analysis

Cause of failure: Discussion and Questions

- Already seen?
- Any input?

Where - Crude Unit ,Heavy Gasoil (HGO)

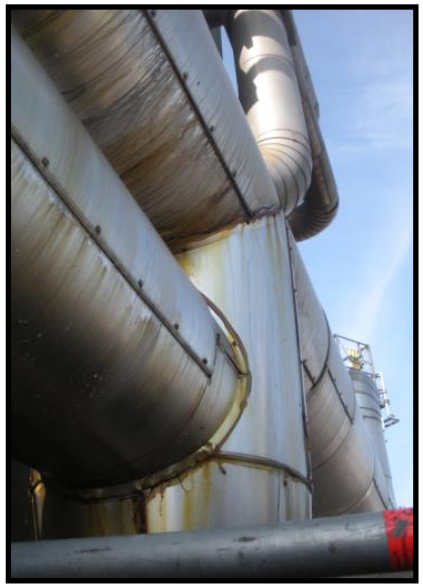


A leak was discovered on the HGO/BPA draw off line.
Unit was taken out of service without incident.

What was found

HGO/BPA piping:

- SS316, installed in 2008
- 340^{0}C / 3 bar (Ops) - *405^{0}C / 4.5 bar (Des)*
- Insulated, traced, “frequent” stops since new piping commissioning
  - **Cl^- SCC suspected**



BPA system with insulation

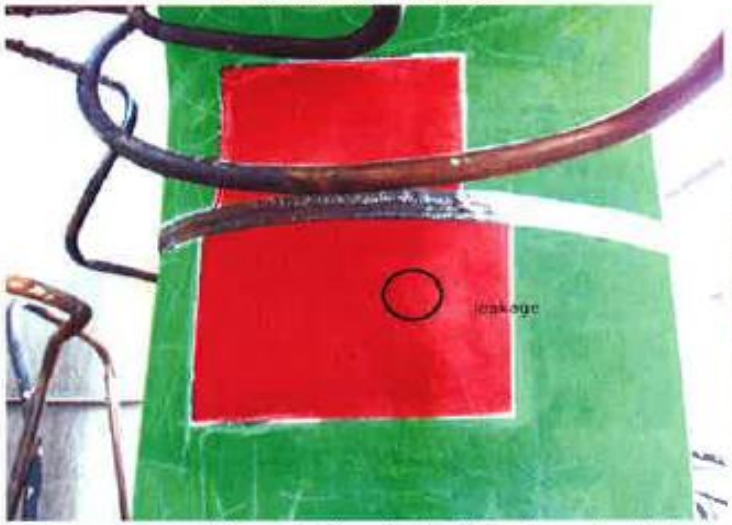
Steam leakage BPA system

Crack on the BPA line

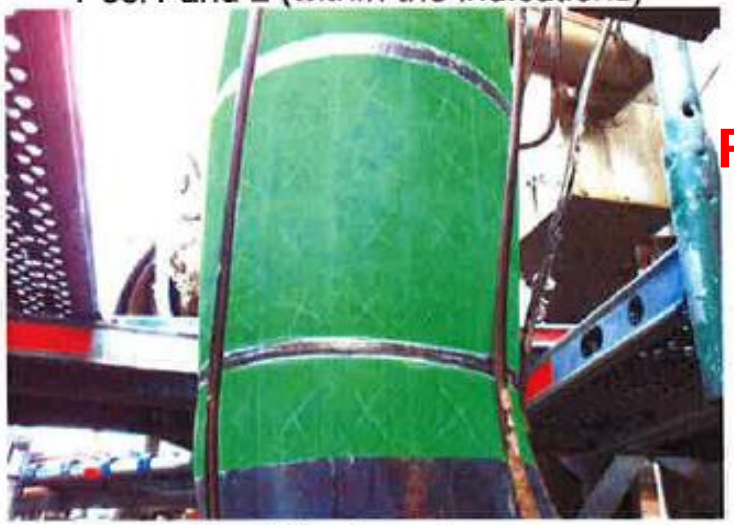
Inspection results

Pos.1 and Pos.2

Pos.1 and 2 (within the indications)



Pos.1 and Pos.2 (both indication-fields)



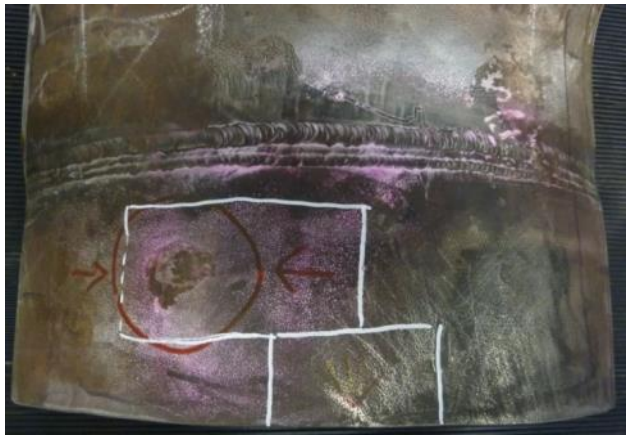
Pos.3 (reducer)

Forged T-pieces fully inspected by eddy-current:

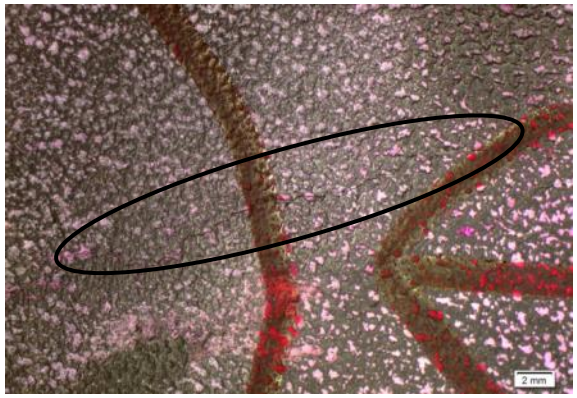
Green – inspected and no deviations found

Red – inspected and deviations found

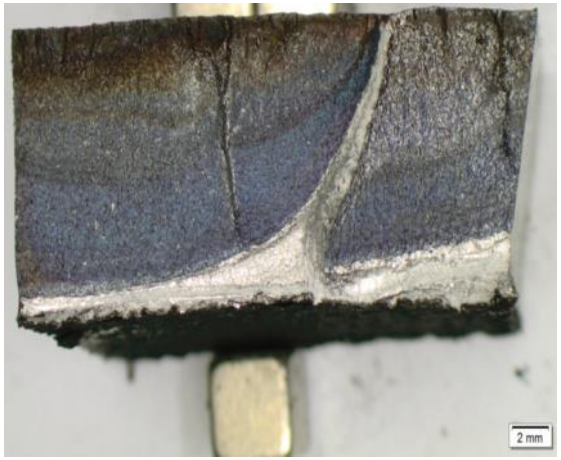
Failure analysis – Macros
(Element Material Technology BV)



Locations of the prepared cross sections (1 and 2) and the section with the bent open fracture surface (3).

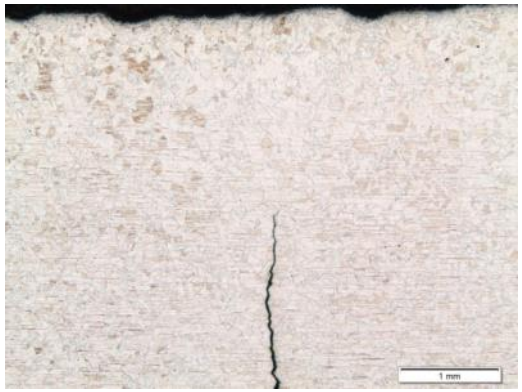


Two jagged cracks ran in transverse direction, with the larger one responsible for the leakage.
Magnification: ~10x

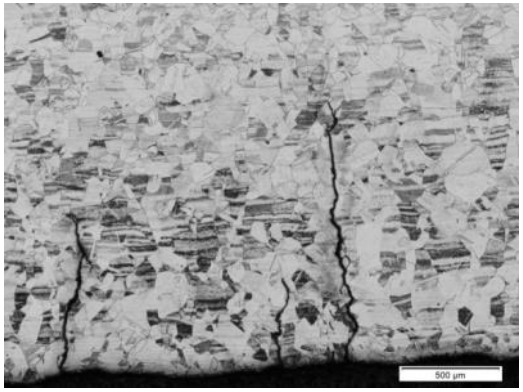


The revealed crack surface showed distinct beach marks and discolorations due to oxidization.

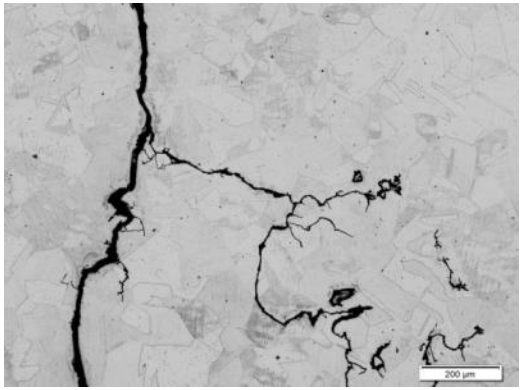
Failure analysis – Micros
(Element Material Technology BV)



Cross section had one dominant crack almost running through the thickness of the pipe wall.
Magnification: ~ 25x
Etchant: 10% oxalic acid



The cracks had a jagged appearance with hardly any branching. They stood open, had blunt tips and were partially filled with oxides.
Magnification: ~ 50x
Etchant: 10% oxalic acid



The cracks in cross section 2 were slightly branched and had irregularly shaped sub-cracks.
Magnification: ~ 100x
Etchant: 10% oxalic acid

Failure analysis – Conclusions *(Element Material Technology BV)*

- The cracking resulting in the failure was caused by fatigue, most likely mechanical or thermal fatigue.
- Some minor stress corrosion cracks were observed, but the characteristics of the main crack make a primary mechanism of Cl-SCC highly unlikely.
- Only superficial corrosion was observed on both the outer and inner pipe wall, but with no direct relation to the failure mechanism.

Unexpected cracking - Discussion

The **cracking** resulting in the failure **was caused by** fatigue, most likely **mechanical or thermal fatigue**.

- No evidence of applied/residual mechanical stresses (piping stress calculation and supports checked).

- What could be the source of the thermal stresses?

Unexpected cracking - Discussion

- Piping is insulated (350^{0}C Op T) and traced (LP steam @ 140^{0}C)
  - On austenitic stainless steel, thermal fatigue if ΔT >120^{0}C
  - If impinging tracing steam “cools” the process piping, the resulting ΔT could be in excess of 200^{0}C
  - Where are the cycles originating from?

- Any other idea?

Unexpected cracking - Questions

Cracking of the main process piping was most likely due to thermal fatigue

Questions:

- What caused the thermal fatigue?
- Can leaking steam lead to such failure?
- Any input from the attendance?
- Was this been seen before?
- How many company use electrical tracing or alternative methods in critical service?

Appendix 10

Failure cases

Failure of a low alloy carbon steel steam line by caustic stress corrosion cracking

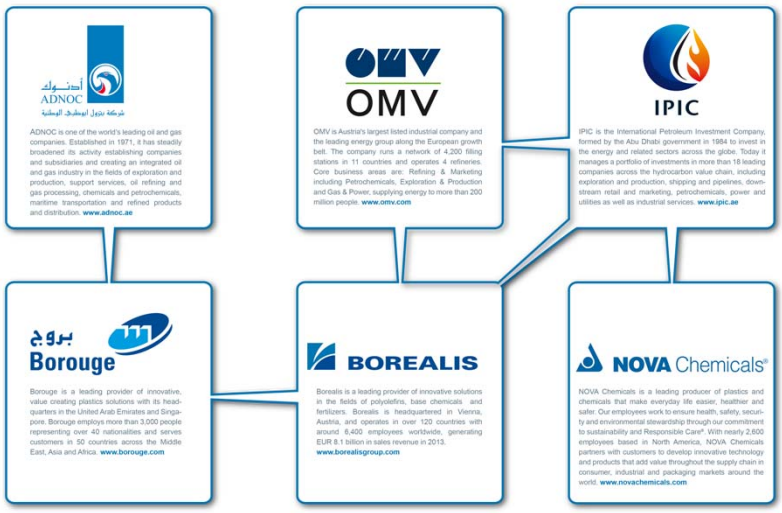
(P. van Dooren)

Stress Corrosion Cracking in Steam Line

Piet Van Dooren
Borealis

EFC – WP 15
Spring Meeting,
Leiden, 14 April 2015

A solid ownership structure provides a reliable foundation for the future …



… and enables us to advance innovative ideas all over the world

Borealis Group Locations

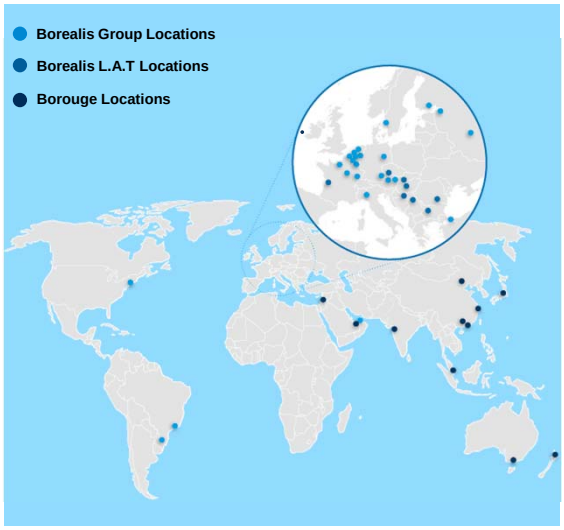
Customer Service Centres / Representative Offices: Abu Dhabi (UAE), Austria, Brazil, Belgium, Finland, Romania, Russia, Turkey, United States
Production Plants: Austria, Belgium, Brazil, France, Finland, Germany, Italy, Sweden, The Netherlands, United States
Innovation Centres: Austria, Finland, Sweden
Head Office: Austria

Borealis L.A.T Locations

Austria, Bulgaria, Croatia, Czech Republic, France, Hungary, Romania, Serbia, Slovakia

Borouge Locations

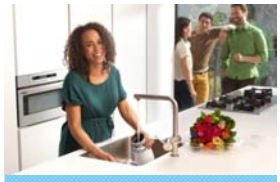
Sales Offices / Representative Offices: Abu Dhabi (UAE), Auckland, Beijing, Beirut, Guangzhou, Hong Kong, Melbourne, Mumbai, Shanghai, Singapore, Tokyo
Production Plants: Ruwais, Abu Dhabi (UAE); China
Logistics Hubs: Abu Dhabi (UAE), China, Singapore
Head Offices: Abu Dhabi (UAE), Singapore



Borealis provides pioneering solutions in three business areas

Borealis Polyolefins

Borealis works closely with its customers and industry partners to provide innovative and value-creating plastics solutions that increase end-product safety, reduce weight, lower costs and enable integration of parts.



Borealis Base Chemicals

Borealis continues to develop its profitable Base Chemicals business building on unique feedstock technology, logistics and integration strengths.

Borealis Fertilizers

By the end of 2014, Borealis will supply more than five million tonnes of fertilizers and technical nitrogen products per year via its Borealis L.A.T. distribution network.

Borealis is the leading fertilizer company in Central and South East Europe with strong ambitions for further growth.

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Situation

- Ammonia plant
- Steam line :
  - Steam feed to steam turbines
  - Superheated steam 37 bar / 435°C
  - Installed 1969
  - Insulated
  - Steam line situated between superheater and turbines : line cannot be isolated from rest of installation without stopping the plant

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Incident : Leak in Steam Line

- Important leak detected in steam line :
  - Located at weld of eccentric reducer 14” – 8” to pipe 8” / Crack visible over 25% of circumference
  - Risk Analysis to install temporary clamp (leak box) : considered not safe ! (risk of total line failure during installation of heavy leak box) :
    - ➔ “***if we can’t do it safe, we don’t do it at all***”
- Plant stopped : Cold stop !
- Pipe + reducer replaced
- RCFA – Root Cause Failure Investigation
- ➔ good decision to stop plant : after investigation it became clear that consequence could have been much worse than a steam leak …

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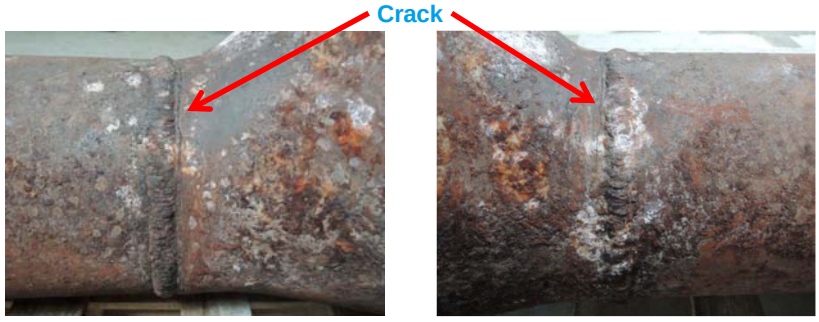
Eccentric Reducer 14” x 8” welded to 8” pipe

Mat. = 15Mo3

WT = 8,5 mm



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Eccentric Reducer 14” x 8” welded to 8” pipe

Outside :
Crack follows Heat Affected Zone

Inside :
Crack does not meet weld root
(despite weld root imperfections)

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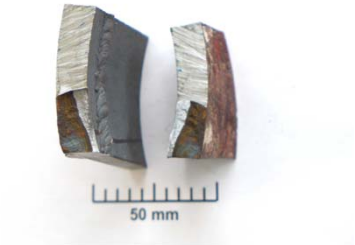
Crack initiation found to be starting from OUTSIDE



↑ = crack propagation

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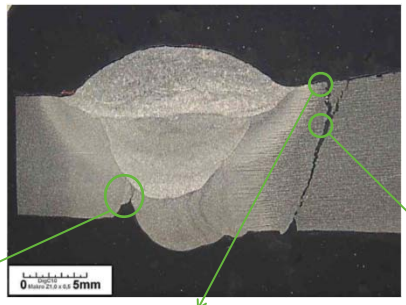
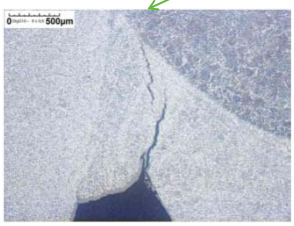
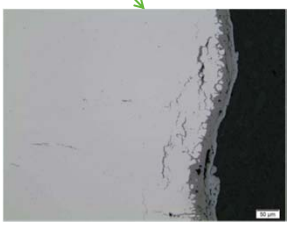
Intergranular Cracks from outside to inside

Crack initiation at weld root imperfections, but no crack propagation



Intergranular cracks, with many branches, propagated from outside through thickness, without plastic deformation





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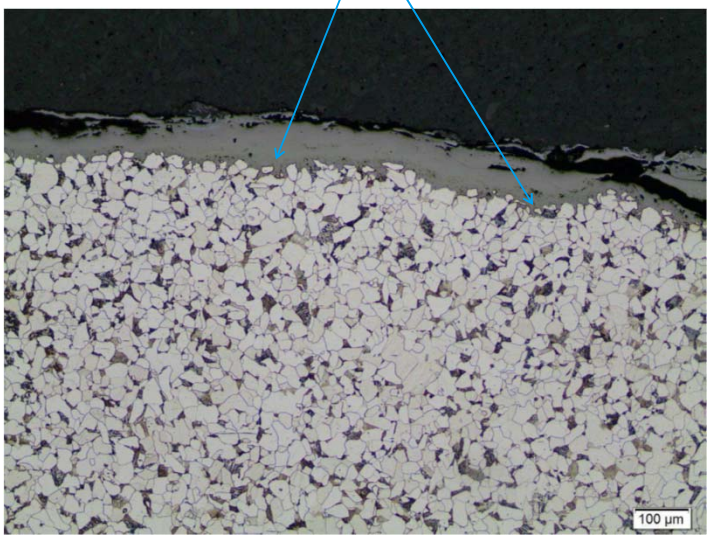
Intergranular Corrosion attack observed



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Damage Mechanism

- Damage mechanism ? :
  - Material properties (pipe + reducer) tested and OK :
    - Mechanical (tensile, impact, …)
    - Chemical
    - Metallographic
  - Sound welds (except for some root imperfections, but without influence on damage)
  - Temperature too high for ‘normal’ CUI
  - Pure corrosion can be excluded
  - Pure mechanical failure (forced overload, fatigue, …) can be excluded
  - No residual stresses from construction expected : > 40 years at 435°C
  - Observed defects typical for Stress Corrosion Cracking

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Damage Mechanism

- Suspected failure scenario :
  - Chemical attack on outside, causing superficial intergranular corrosion
  - Sharp notches introduced by intergranular corrosion
  - Cracks initiated by Stress Corrosion Cracking :
    - At position with design-related higher stress : ➔ reducer !
    - At moment of higher extrinsic stress applied : ➔ re-operation sequences

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Corrosive Attack ?

- Deposits on outer surface analysed :
  - Dark areas : mainly iron oxides
  - White deposits analyzed with EDX :
    - P, S, K and Ca : from former fertilizer plant ? (closed 2000)
    - Mg, Al, Si and Ca : from insulation material ?
      - mineral wool fibres
      - former CalciumSilicate based insulation ? (unknown)
- ➔ corrosive combination of moisture (leaking through insulation weather protection), insulation materials and fertilizers (calciumsilicate, calciumnitrate, N, P, K, …) may have led to a caustic environment :
  - ➔ Caustic Stress Corrosion Cracking Under Insulation

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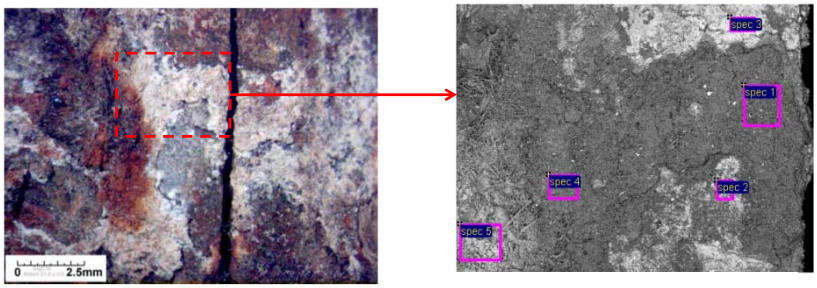
EDX investigation ‘surface deposits’



Spectrum	Chemical Composition [Weight-%]											
	O	Mg	Al	Si	P	S	K	Ca	Mn	Fe	Cu	Mo
„spec 1“	55.04	3.71	4.49	14.21	1.55	0.52	1.91	14.36		4.21		
„spec 2“	46.03	0.92	0.6	3.6	0.56		0.67	15.92		30.67		1.03
„spec 3“	31.48			0.89			0.52	2.44	0.92	62.12	1.63	
„spec 4“	55.45	2.94	1.55	4.68	5.04	0.96	1.11	26.34		1.93		
„spec 5“	44.74	1.32	1.54	5.63	1.57		1.12	7.61		36.46		

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Next actions

- Investigate other areas with ‘stress concentration points’ in the steam line (elbow, reducers, tees, supports, …) at next opportunities :
  - Visual examination
    - Also look for ‘white deposits’
  - PT or MT
  - Replica’s (metallographic examination)

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Questions ?

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Appendix 11

Failures – why they occur and how to prevent them

(A. Groysman)

Failures – why they occur and how to prevent them? Are They Inevitable?

Alec Groysman

Technion, Haifa

Israel Society of Chemical Engineers & Chemists, Tel Aviv

EFC Working Party 15

Leiden, The Netherlands

14 April, 2015

It is impossible to finish crimes in any society. Crime is natural to all societies at all times (Movie "Gentlemen – Comrades").

Like human being depends on inner and outer factors, the functional service of metallic equipment depends on a metal (inner factors) and the environment and conditions (outer factors).

Corrosion is an inevitable process in accordance with the 2nd law of thermodynamics.

Our task is to maintain service functions of metallic constructions during the economic life period, usually 15-25 years.

700 Oil Refineries over the world

155 in Europe

Fast aging of refinery equipment and wide variation in crude oil type → high corrosion risk.

Wood MH, Vetere Arellano AL, Van Wijk L, Corrosion-Related Accidents in Petroleum Refineries (2013) JRC Scientific and Policy Reports, European Commission EUR 26331 EN, Institute for the Protection and Security of the Citizen, Italy

Important analysis of 99 corrosion-related accidents occurring in refineries over the last 50 years (1962-2012)

Corrosion failure is responsible for one of five major refinery accidents that have occurred in European countries since 2000.

Half of the accidents had very high consequences on the environment, economics of the refinery, and surrounding community.

Significant corrosion failures occur because:
- the hazard was not identified;
- the hazard was ignored.

***Failure** is the state or condition of not meeting a desirable or intended objective.*

***Failure** is a sudden cessation of functioning, or a lack or deficiency of a desirable quality.*

*Will corrosion always be finished by **failure**?*
*Can we predict **failure**?*

Critical chloride (Cl^-) concentrations in water for stainless steels (without pitting corrosion), 25°C

Stainless steel	Critical Cl^- concentration, ppm	Reference
304	180	White RA and Ehmke EF (1991)
	500	Dillon CP (1995)
316	500	White RA and Ehmke EF (1991)
	3,000	Dillon CP (1995)

Can anybody predict the corrosion rate of MIC?

Why corrosion failures occur?

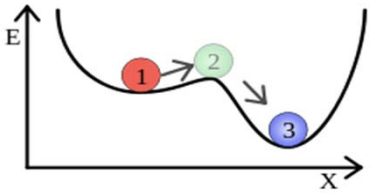
1. Corrosion phenomena - stochastic processes.
2. Corrosion phenomena depend on inner and outer factors.
3. Anti-corrosion protective measures do not guarantee 100% protection and prevention from failure.
4. On-line corrosion monitoring methods do not reflect real state of the metal-environment system.
5. Standards, codes, and specifications related to corrosion issue are not effectively used at oil refineries.

Why are corrosion failures inevitable?

1. Thermodynamic possibility of corrosion.

$4Fe_{(s)} + 6H_2O_{(l)} + 3O_{2(g)} \leftrightarrow 4Fe(OH)_{3(s)}$ ΔG^o_{298} = - 1397.2 kJ/mol

$Fe_{(s)} + 2H_2O_{(l)} \leftrightarrow Fe(OH)_{2(s)} + H_{2(g)}$ ΔG^o_{298} = - 15.7 kJ/mol



Difference between stable (1 and 3) and 'metastable' (2) state.
E – energy of a system.
X – the direction of the reaction.

There are no satisfactory kinetic models.

2. Corrosion Management. Human factor.

Many corrosion failures are caused by reasons unrelated to corrosion engineering, but mismanagement and wrong policy in corrosion control and monitoring.

Inadequate inspection and control, documentation, communication, collaboration and performance requirements for corrosion protection and monitoring.

Humans are responsible in 65-85% of corrosion cases.

Staff does not report about thirty per cent of cases.

Causes of humans` mistakes:

- *Lack of knowledge.*
- *Insufficient control and supervision.*
- *Lack of incentives to improve situation.*
- *Wrong operation.*
- *Incorrect design.*

Only penalties and financial incentives can change situation in decrease of corrosion failures.

3. Legislation in the field of corrosion management

To establish penalties for the lack of anti-corrosive preventive actions and corrosion monitoring.

4. Education and Knowledge Transfer

75% of all corrosion failures happen because of insufficient information, communication, interaction, and knowledge.

How to prevent (decrease) failures?

1. ***Searching of ways how stochastic corrosion processes result in failure.***

2. Forcing managers to establish penalties and incentives.

Legislation in the field of corrosion management !

3. We should change relationship of society to corrosion like relationship to ecology was changed; show the influence of corrosion failures on safety, health of people, and pollutions.

Materials are published in books:

Corrosion in Systems for Transportation and Storage of Petroleum Products and Biofuels, Springer, 2014

Corrosion for Everybody, Springer, 2010

Corrosion Problems and Solutions in Oil Refining and Petroleum Industry, Springer, 2016 (be published)

Appendix 12

Monitoring of crude unit overhead corrosion through improved monitoring and on line control

(P. Thornthwaite)

NALCO Champion

An Ecolab Company

Mitigation of Crude Unit Overhead Corrosion through Improved Monitoring & Online Control

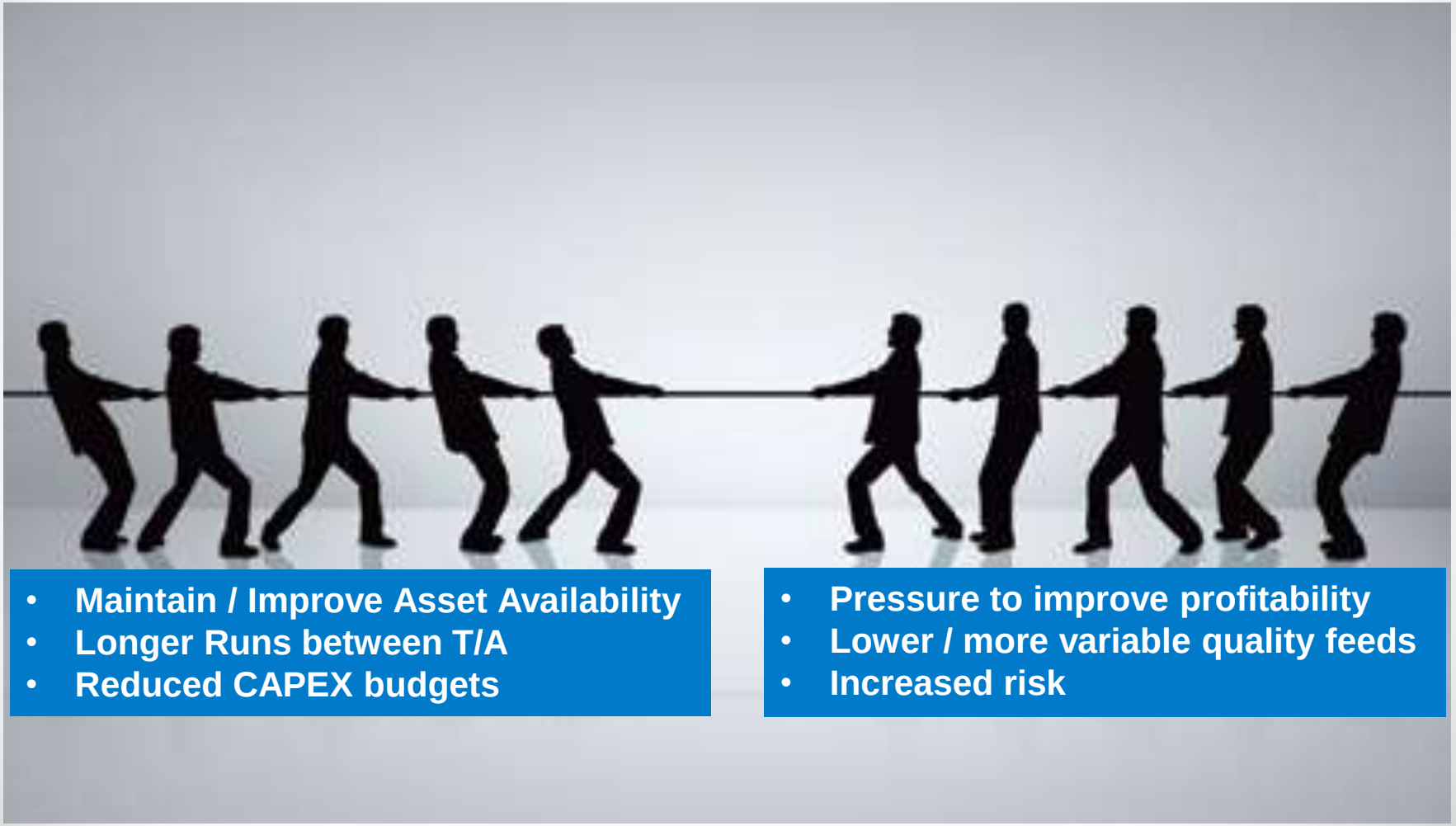
EFC Spring Meeting 14 April 2015

Leiden, The Netherlands

Philip Thornthwaite

Nalco Champion, Northwich, UK

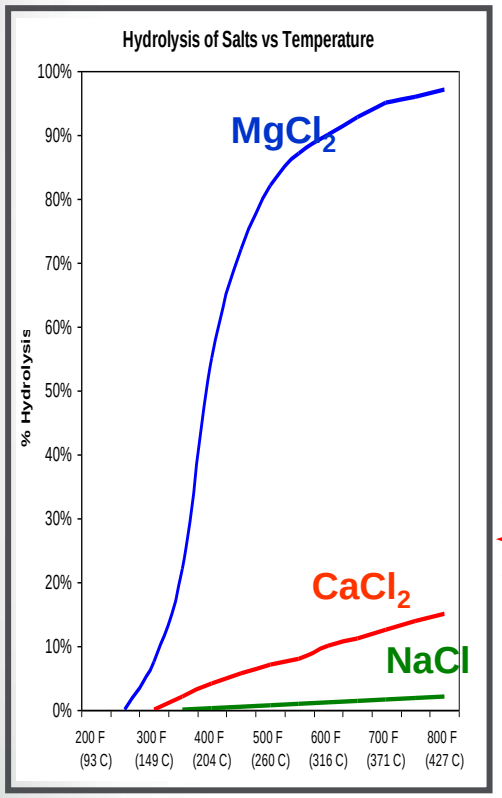
Challenges Facing the Refining Industry

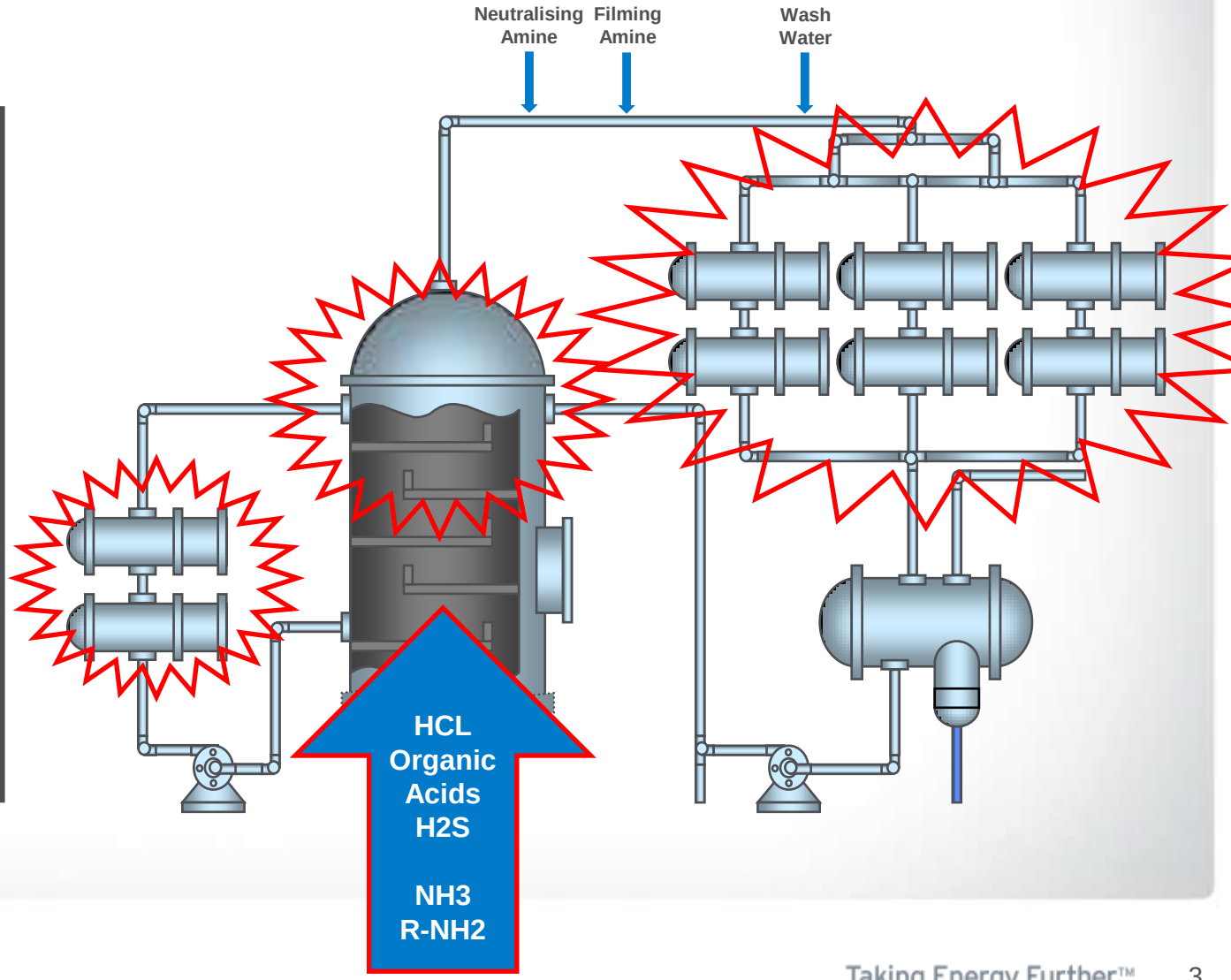


- Maintain / Improve Asset Availability
- Longer Runs between T/A
- Reduced CAPEX budgets

- Pressure to improve profitability
- Lower / more variable quality feeds
- Increased risk

The Problem


Hydrolysis of Salts vs Temperature
% Hydrolysis
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
MgCl2
CaCl2
NaCl
200 F (93 C)
300 F (149 C)
400 F (204 C)
500 F (260 C)
600 F (316 C)
700 F (371 C)
800 F (427 C)


Neutralising Amine
Filming Amine
Wash Water
HCL
Organic Acids
H2S
NH3
R-NH2

Problems with Existing Corrosion Control Programs

- In today's refinery, crude diet changes every 1-2 days
- Traditional Approach to Crude Column Monitoring
  - Service Provider 2 per week
  - Operators daily
  - Grab samples, Chlorides, Iron, pH
  - Reacting to data and alarms

Are you flying blind?

- Does this provide the expected results:
  - Crude Unit overhead leaks?
  - Unplanned downtime?
  - Increased maintenance and operating costs?
  - Margin leakage?

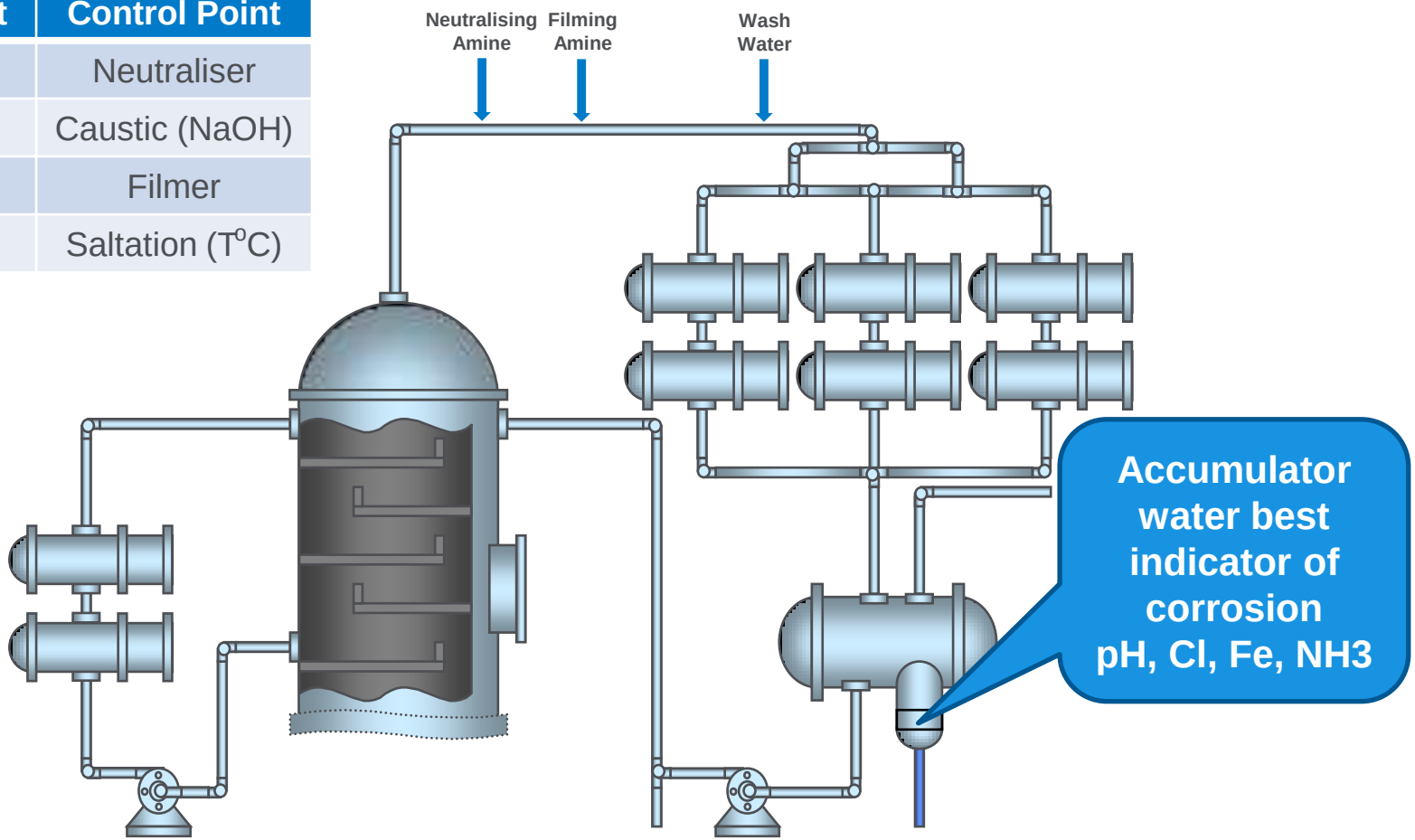
- Process Safety?
- Reliability?
- Maintenance & Operating Cost?
- Margin Capture and Product Qualities

The Solution

- Can not eliminate feedstock variability
  - Opportunistic approach to feedstock selection = $$ to refiners
- Operational variability is a factor
- What can we impact? - Frequency of measurement
  - Increased volume of data allows clearer operational picture
  - Statistically significant data set
  - Potential to catch unit variation
  - Little time lag in results

The Concept

Measurement	Control Point
pH	Neutraliser
Cl	Caustic (NaOH)
Fe	Filmer
NH_3	Saltation (T^oC)



Data must be real time, accurate, & frequent

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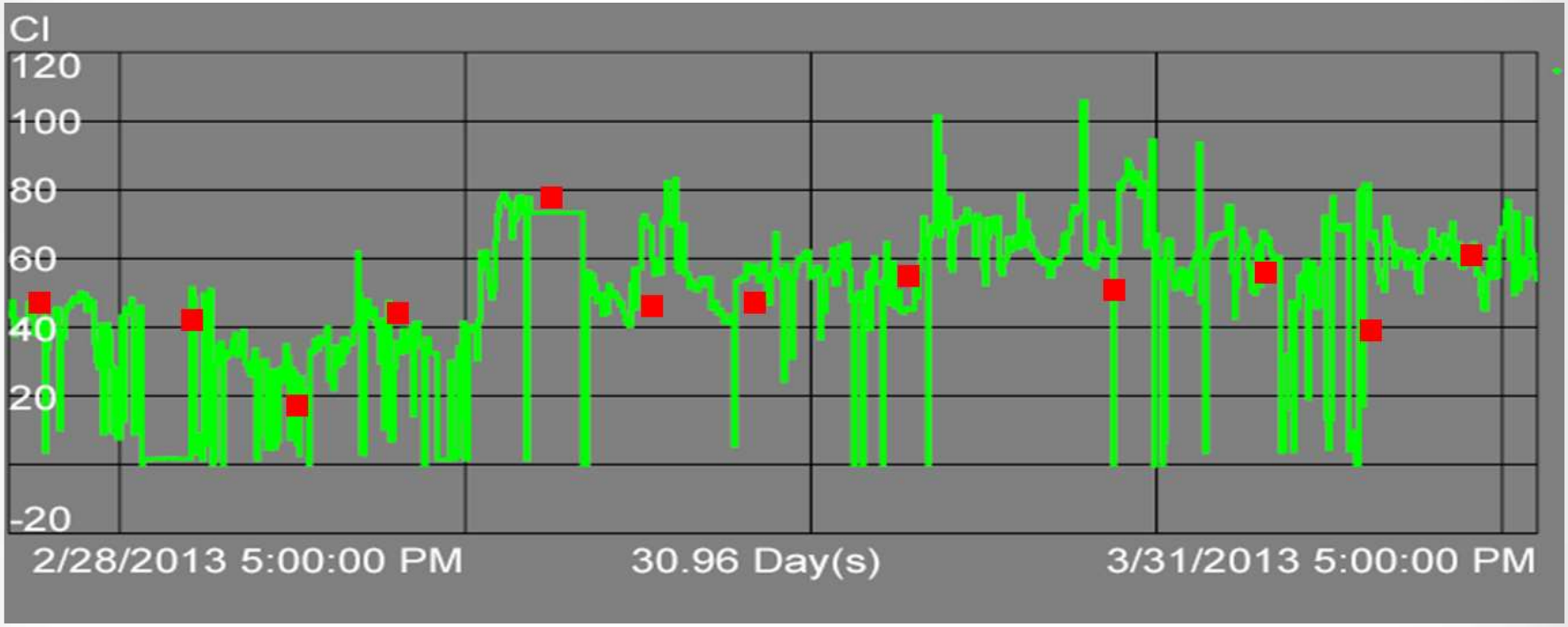
An Ecolab Company

Nalco Champion Solution
3D Trasar for Crude Overhead Systems

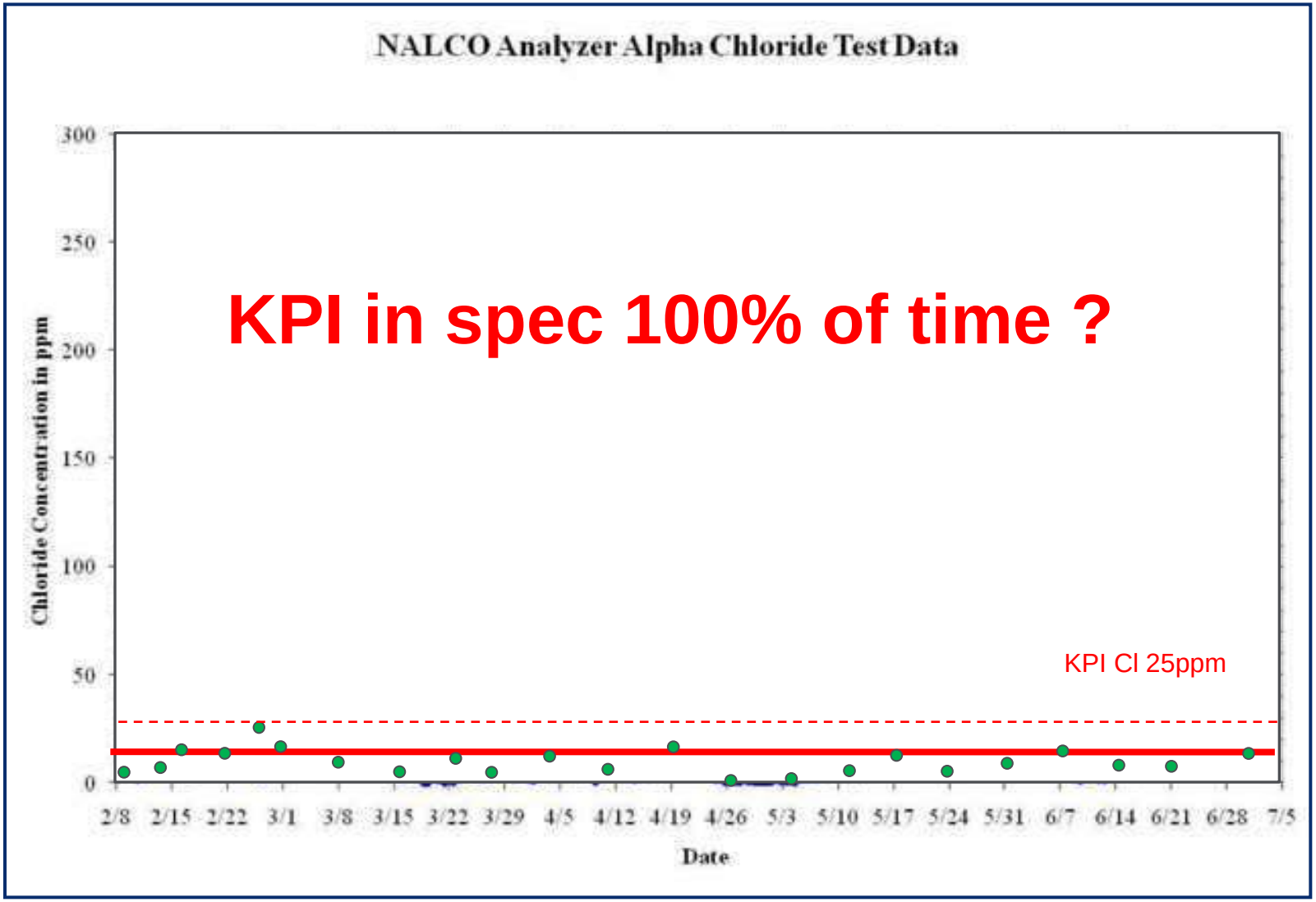
- Field Laboratory 24/7/365
  - Continuous pH
  - Chloride, Iron and NH_3 hourly
- P&ID controller
  - Neutraliser
  - Filmer
  - Caustic
- Data export to DCS & historian
  - Alarming of key operational limits
- Add on phase modelling software & corrosion measurement devices

3D Trasar for Crude Overhead Systems



Analytical Technique	Number of Tests in 30 Days
Manual (typical)	12
Automation	744

3D Trasar for Crude Overhead Systems



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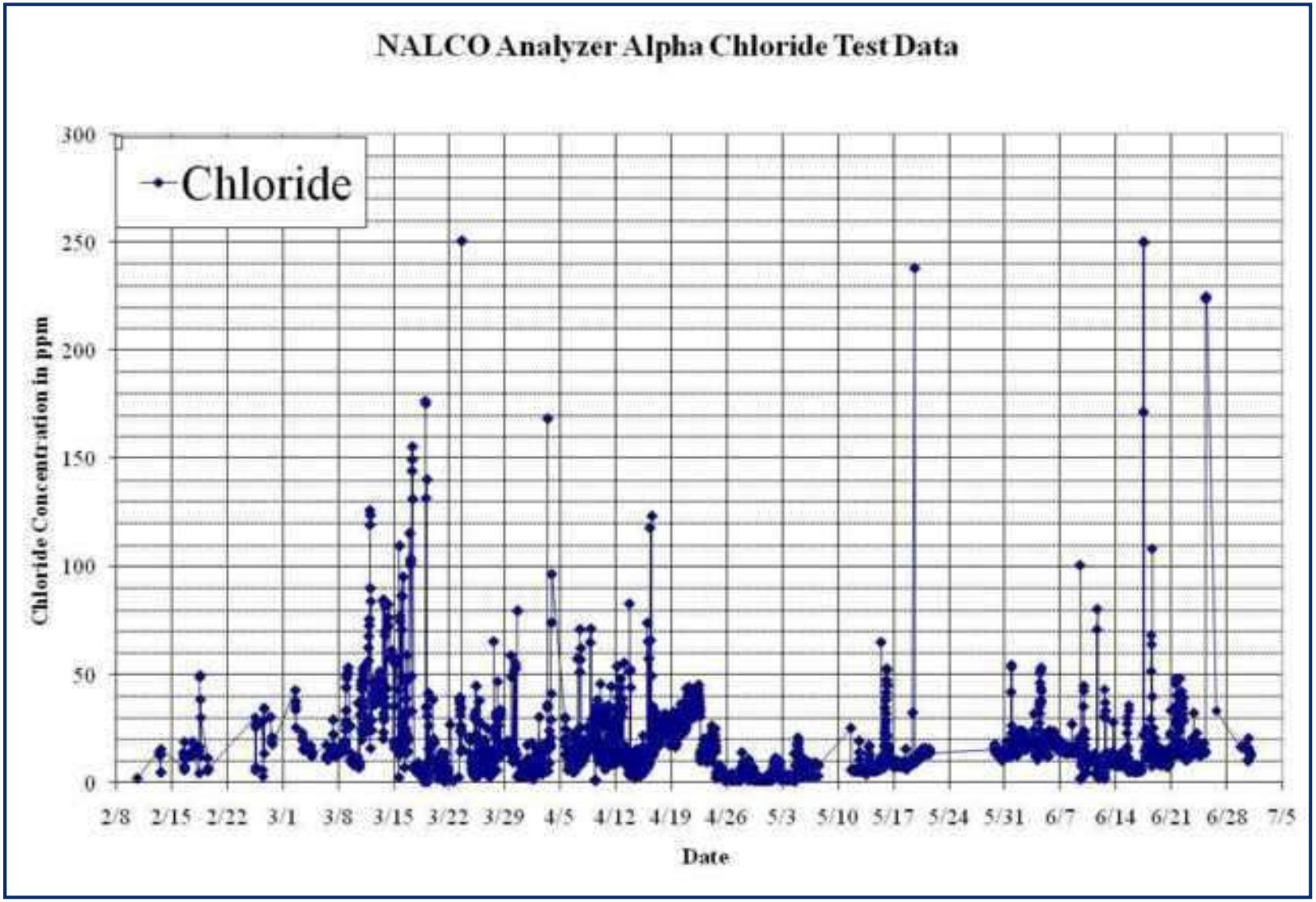
3D Trasar for Crude Overhead Systems



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Comparison

Lagging Indicators

- Traditional Approach
  - 2x per week vendor
  - Operators daily
  - Grab samples
    - Chlorides
    - Iron
    - pH
    - NH_3
  - Snapshots
  - Reacting to data and alarms

Leading Indicators

- Crude Unit Automation
  - Sample pH tested every 5 minutes
  - Sample Cl, Fe & NH_3 tested every hour
  - Data resides on DCS/server
  - Operating Limits set
  - Vendor Notifications
  - Proactive – use of trends to recognize potential events
  - Take measures to bring process back within safe limits

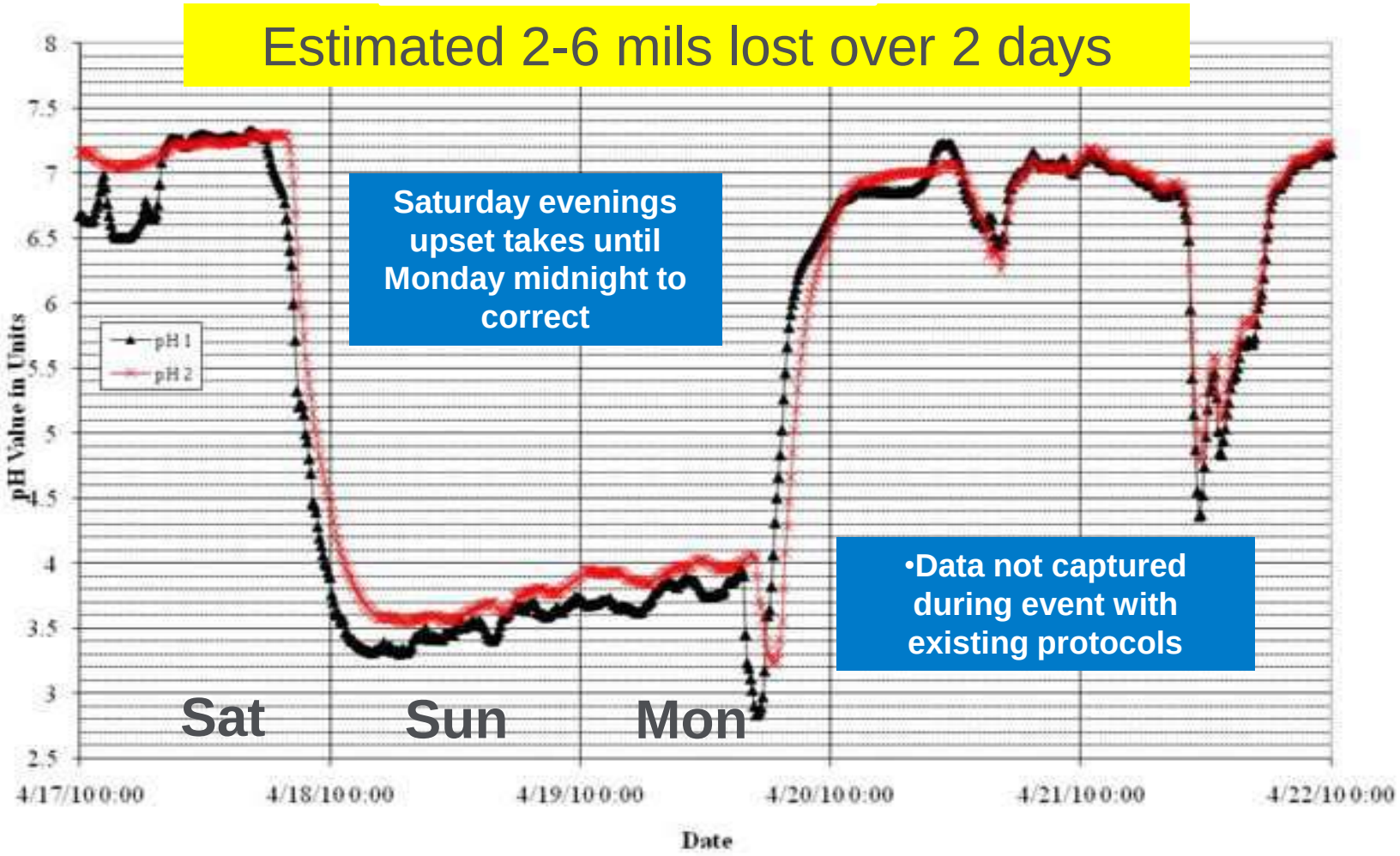
3DTrasar for Crude Unit Overhead Systems

FIELD EXAMPLES

NALCO Champion
An Ecolab Company

Weekend Upset

One years worth of corrosion occurred in one 2-day upset

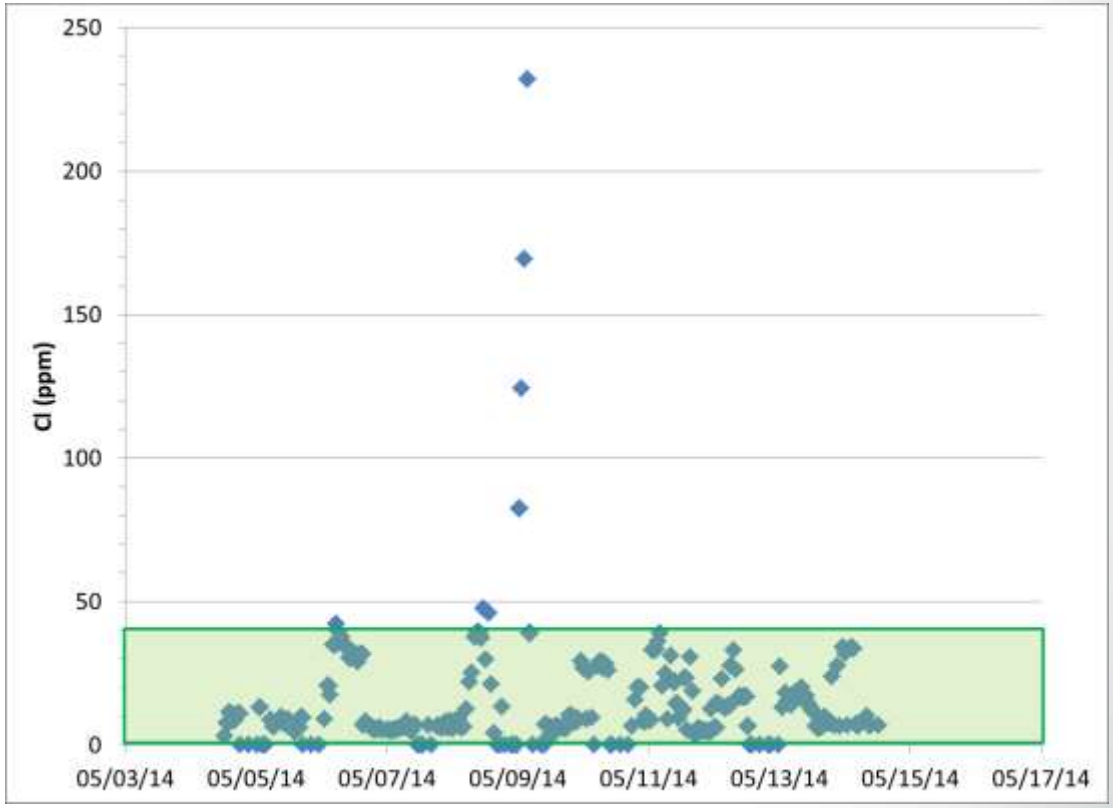


NA

An Ecolab Company

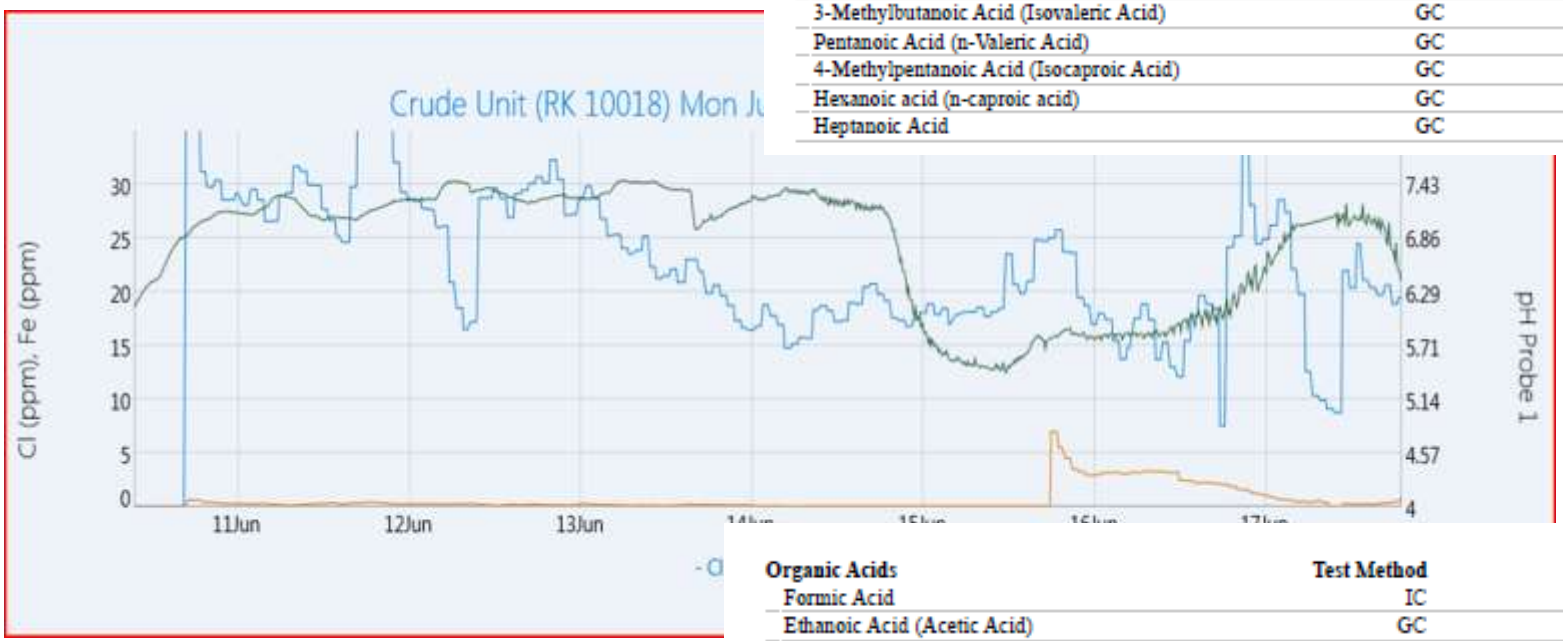
Midnight Watchman

- Received a high chloride alarm at 12:50 am on 5/9
- Operations quickly made adjustments for caustic injection after notified.
- Caustic pump injection adjusted when notified of high chloride excursion.



New Crude Impact

Organic Acids	Test Method	Filtered
Formic Acid	IC	<10 mg/L
Ethanoic Acid (Acetic Acid)	GC	65 mg/L
Propanoic Acid (Propionic Acid)	GC	60 mg/L
2-Methylpropanoic Acid (Isobutyric Acid)	GC	35 mg/L
Butanoic Acid (n-Butyric Acid)	GC	50 mg/L
3-Methylbutanoic Acid (Isovaleric Acid)	GC	170 mg/L
Pentanoic Acid (n-Valeric Acid)	GC	75 mg/L
4-Methylpentanoic Acid (Isocaproic Acid)	GC	<10 mg/L
Hexanoic acid (n-caproic acid)	GC	30 mg/L
Heptanoic Acid	GC	90 mg/L



Organic Acids	Test Method	Filtered
Formic Acid	IC	<10 mg/L
Ethanoic Acid (Acetic Acid)	GC	90 mg/L
Propanoic Acid (Propionic Acid)	GC	85 mg/L
2-Methylpropanoic Acid (Isobutyric Acid)	GC	40 mg/L
Butanoic Acid (n-Butyric Acid)	GC	70 mg/L
3-Methylbutanoic Acid (Isovaleric Acid)	GC	310 mg/L
Pentanoic Acid (n-Valeric Acid)	GC	75 mg/L
4-Methylpentanoic Acid (Isocaproic Acid)	GC	<10 mg/L
Hexanoic acid (n-caproic acid)	GC	15 mg/L
Heptanoic Acid	GC	160 mg/L

- No desalter issues with norm during this time
- Hot Drum chloride results rer
- pH drop due to organic acid not chloride

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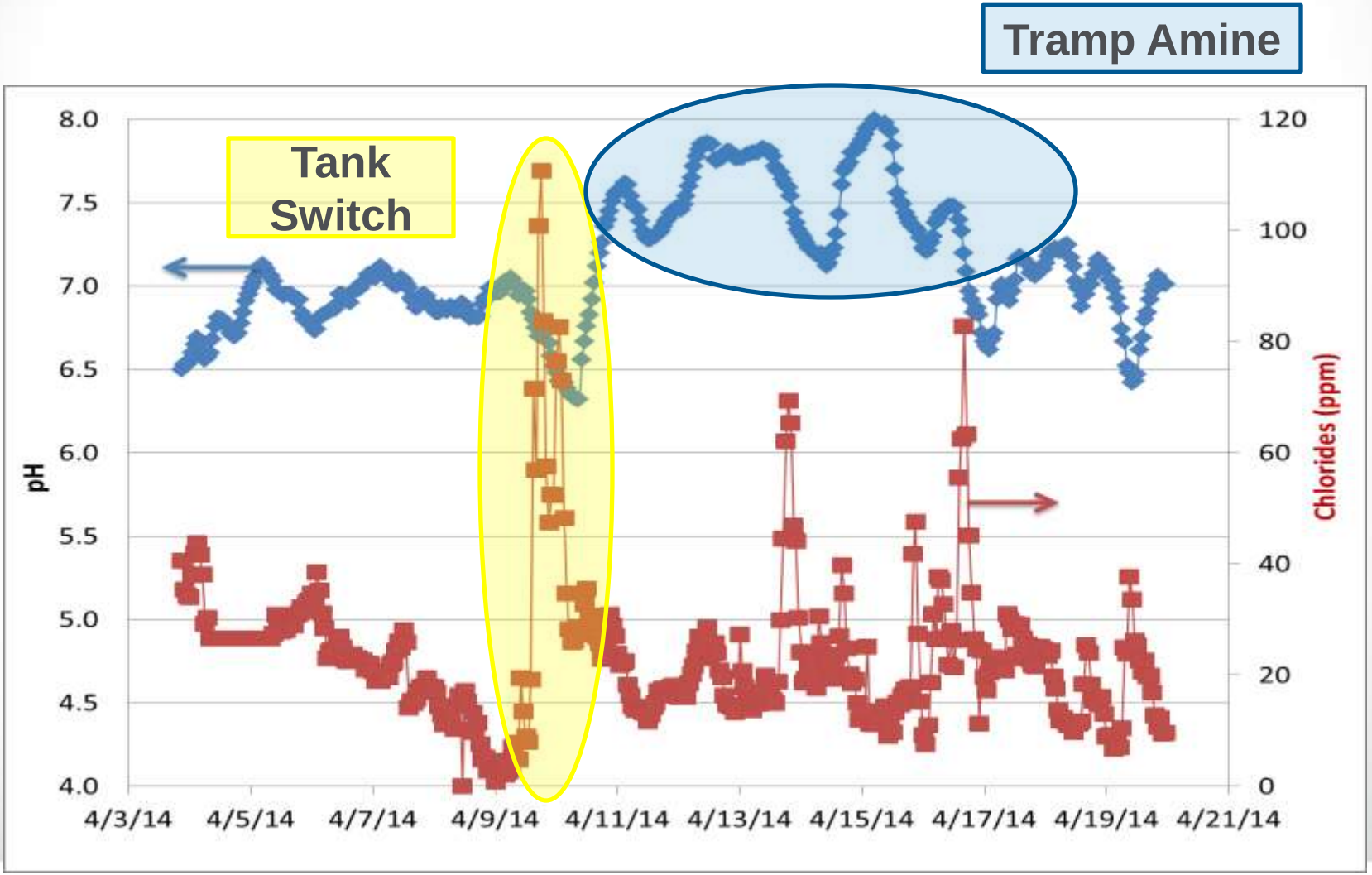
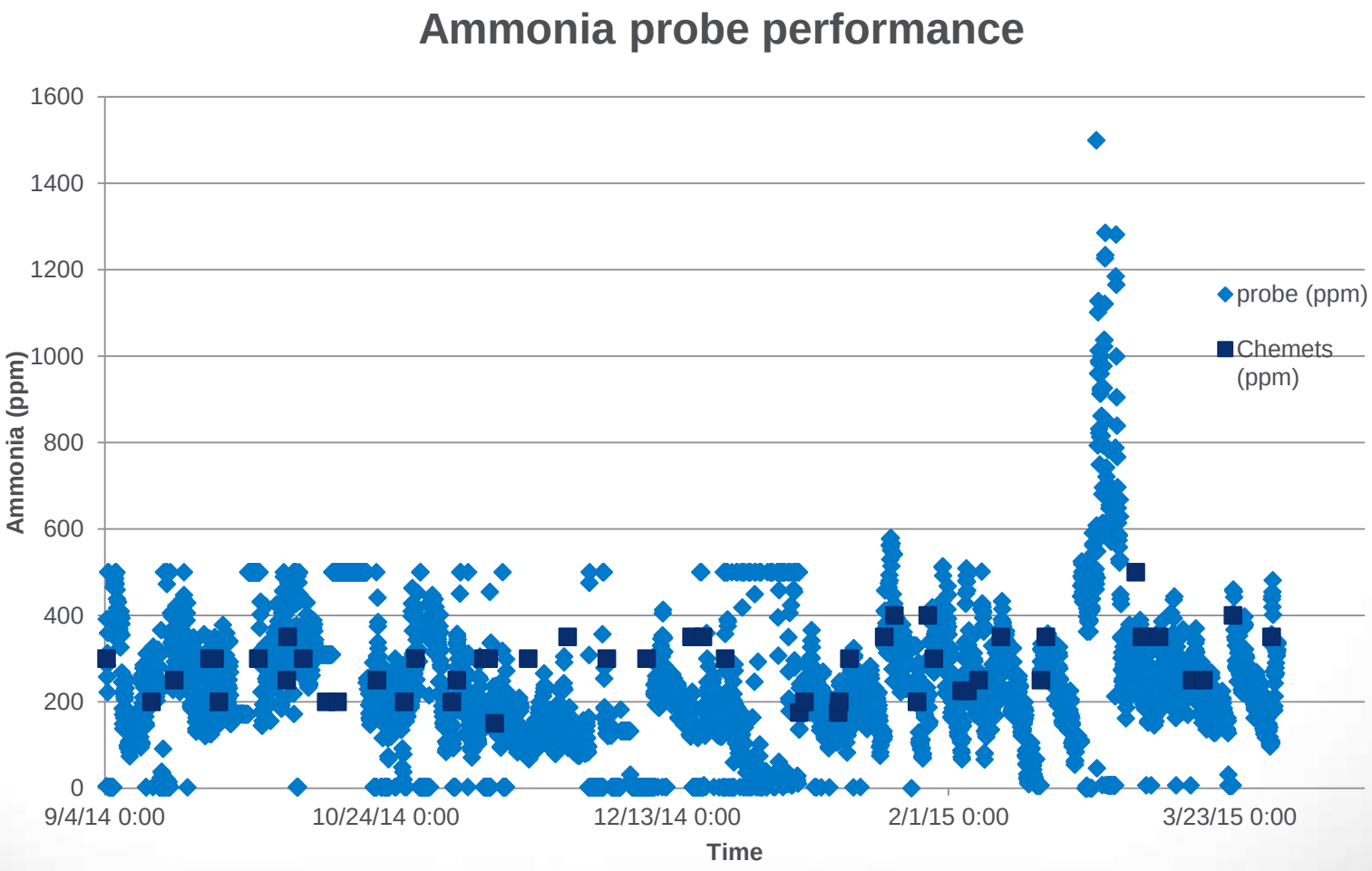
Crude Tank Switch & Crude w/ Tramp Amines

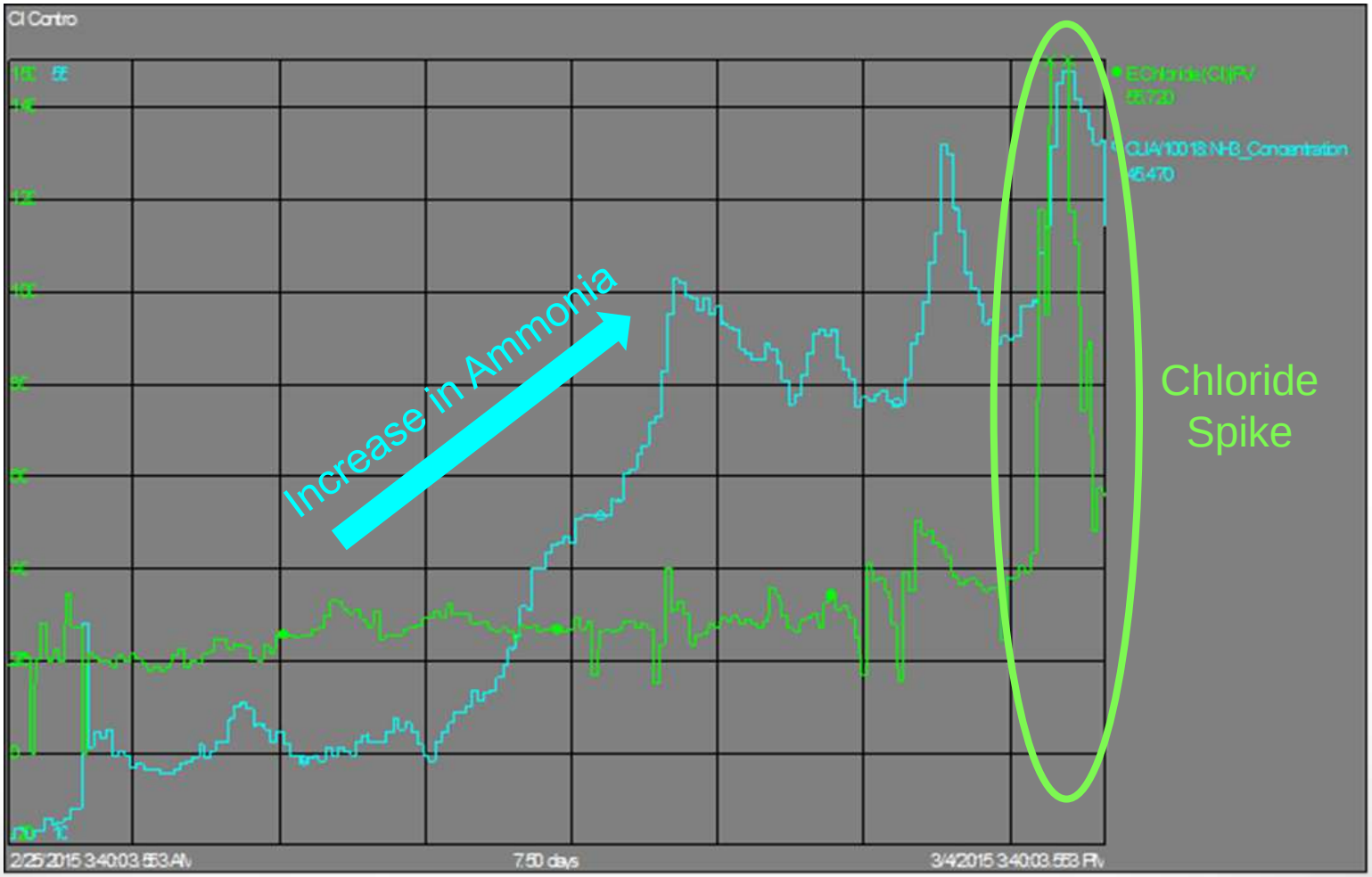


3DTCOS Analyzer Results- Ammonia



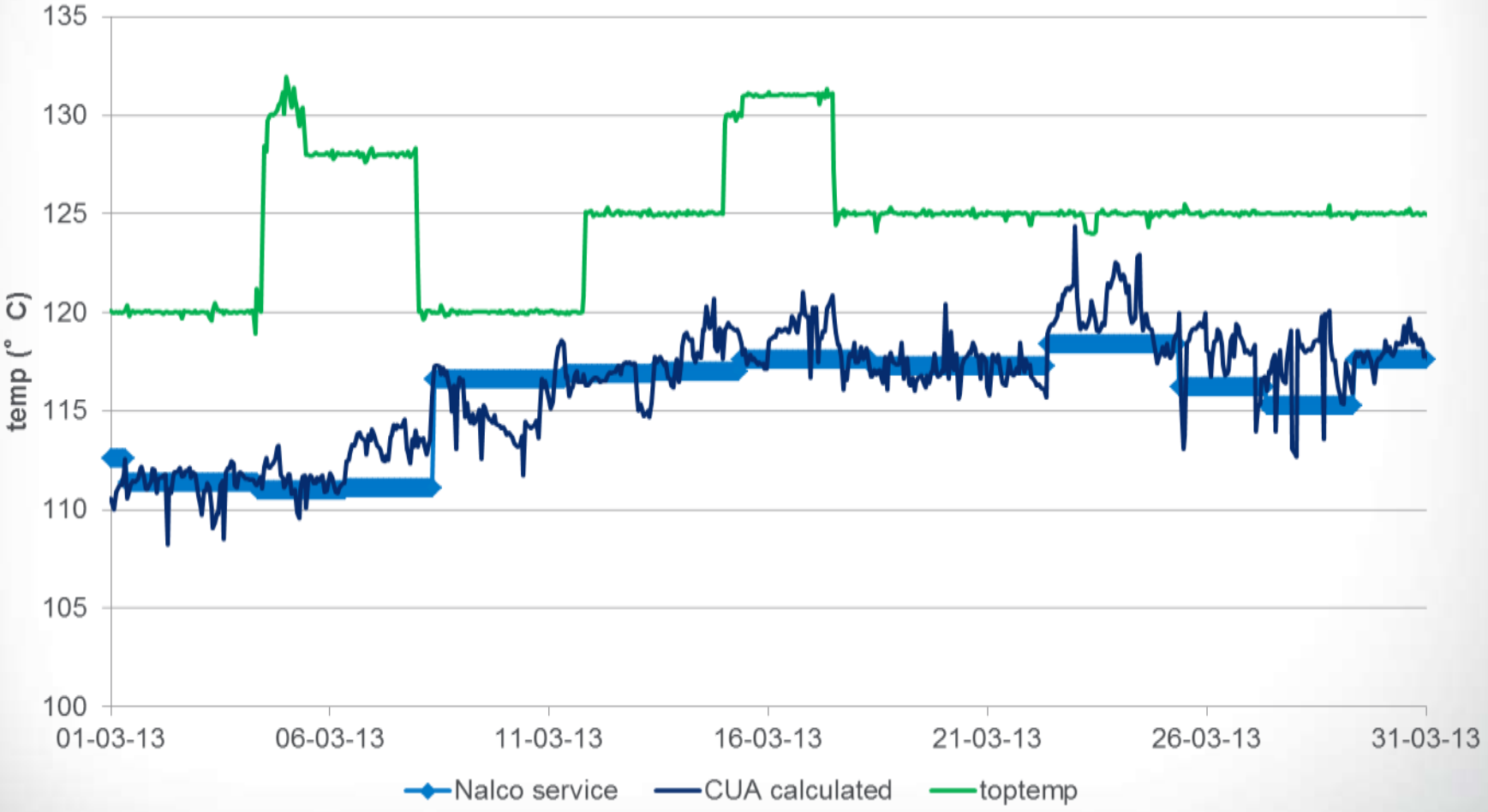
Increase in the potential for ammonium chloride salt formation

3DTCOS Analyzer Results- Ammonia

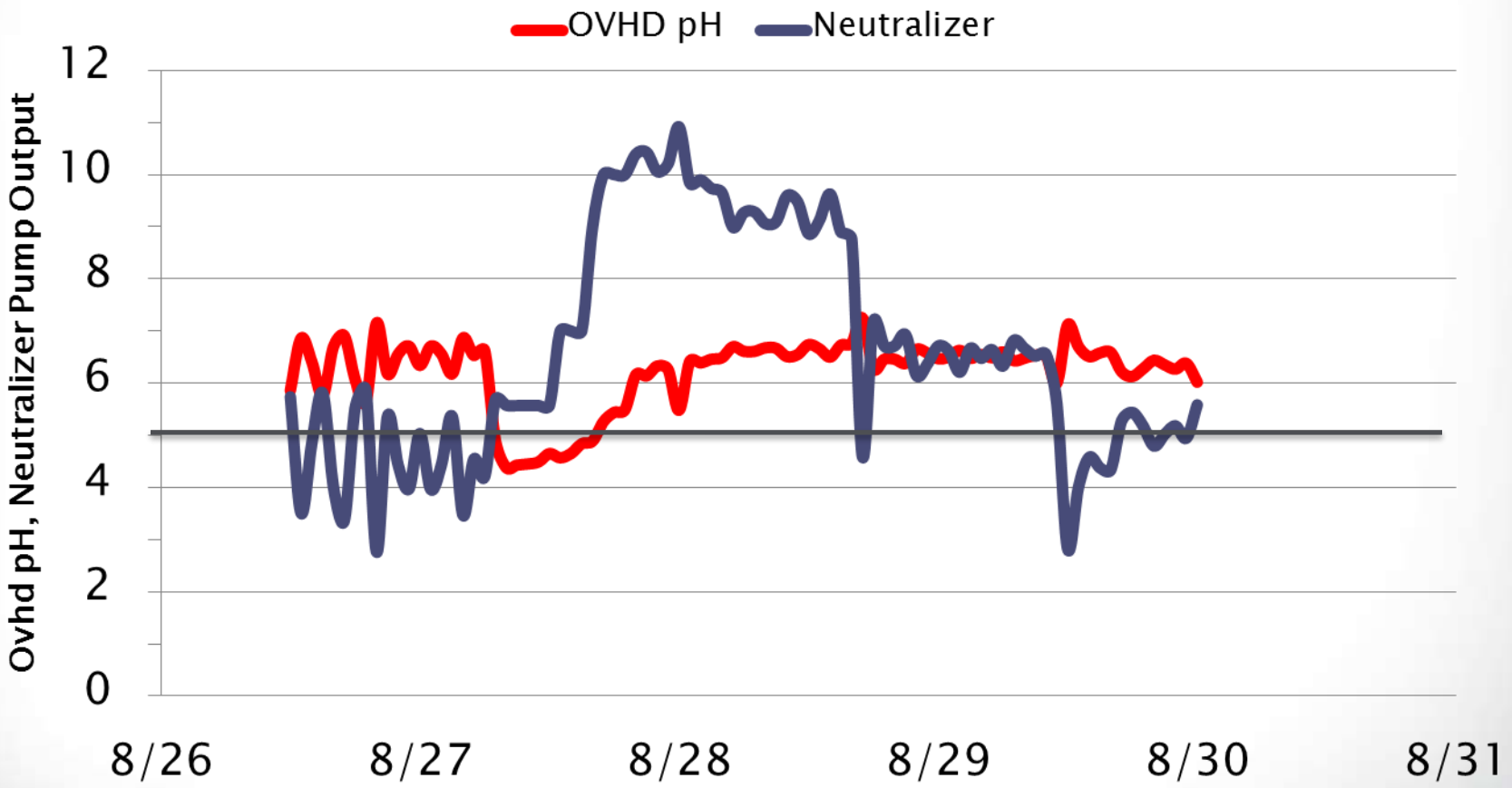


Increase in the potential for ammonium chloride salt formation

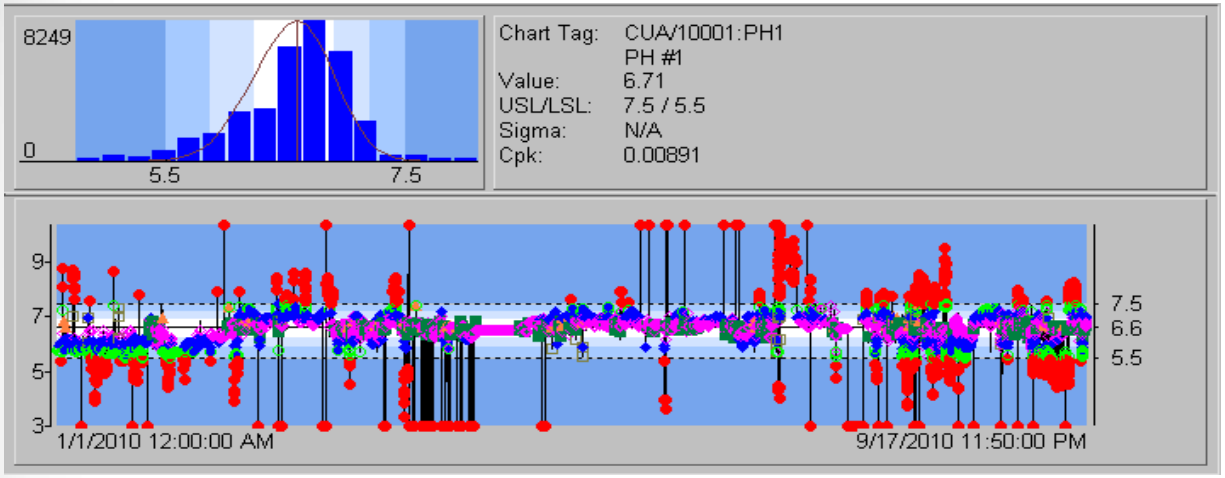
Online Calculation of NH_4Cl Salt Temps



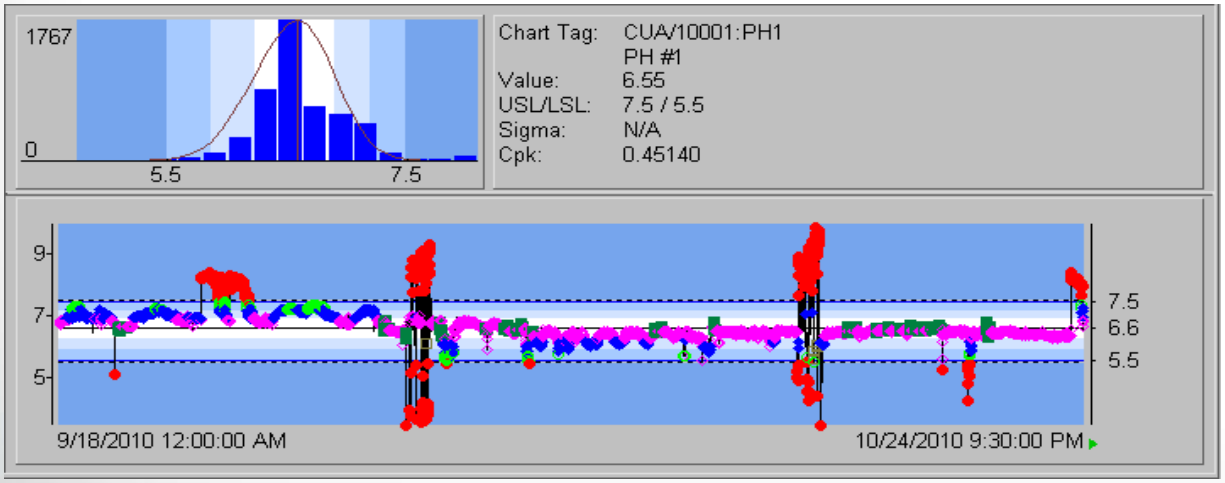
Tank Switch (in Control Mode)



Control Mode



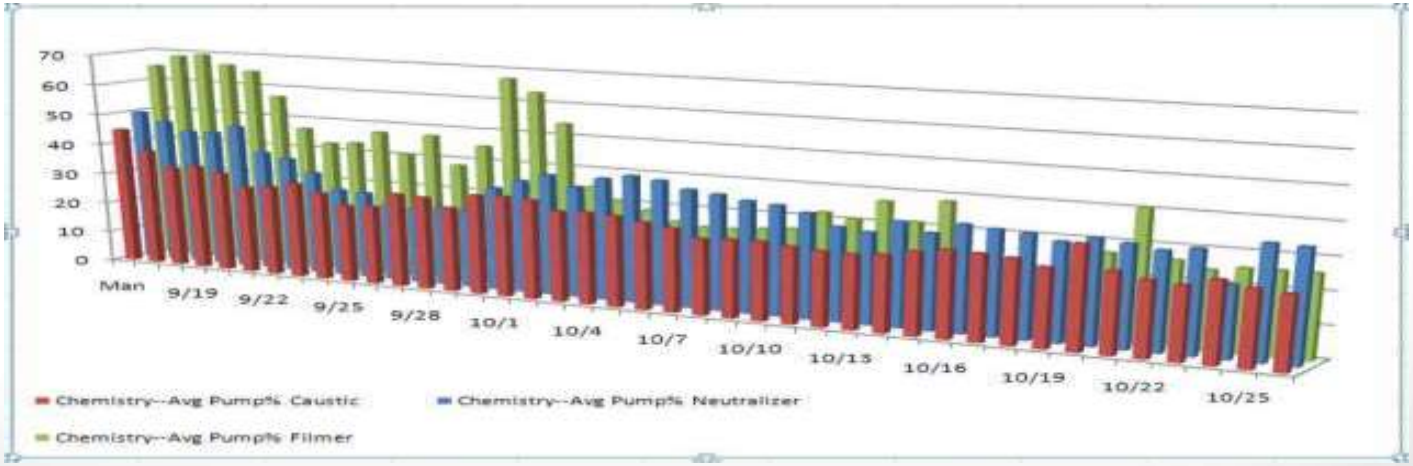
BEFORE



AFTER

Control Mode – Impact on Chemistry

Additive	Before pump setting %	After pump setting %	% Savings
Caustic (NaOH)	45	27	39
Neutralizer	50	34	32
Filmer	65	37	42

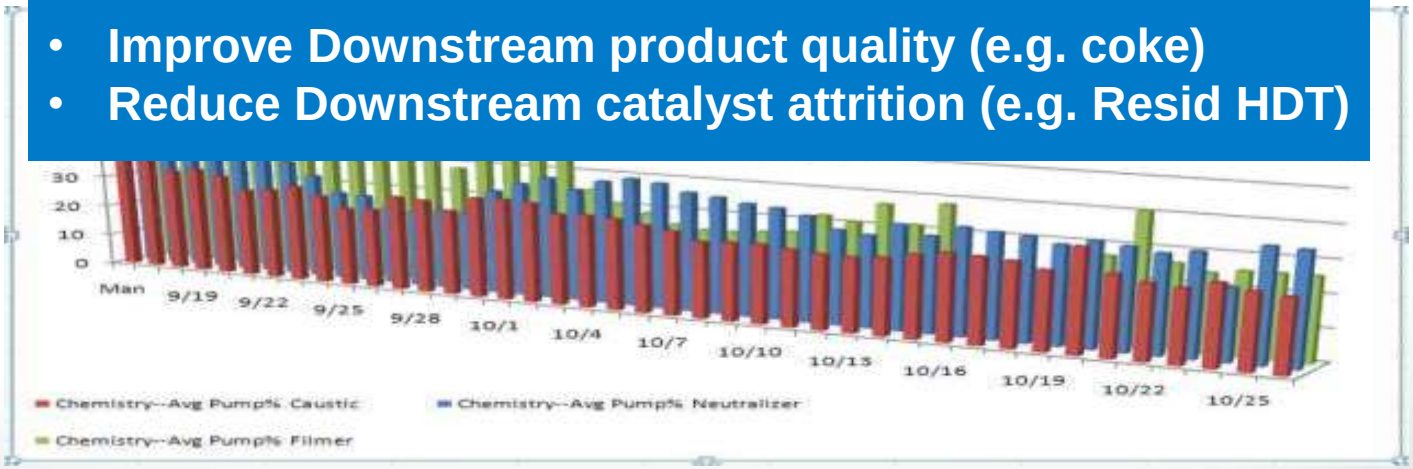


Control Mode – Impact on Chemistry

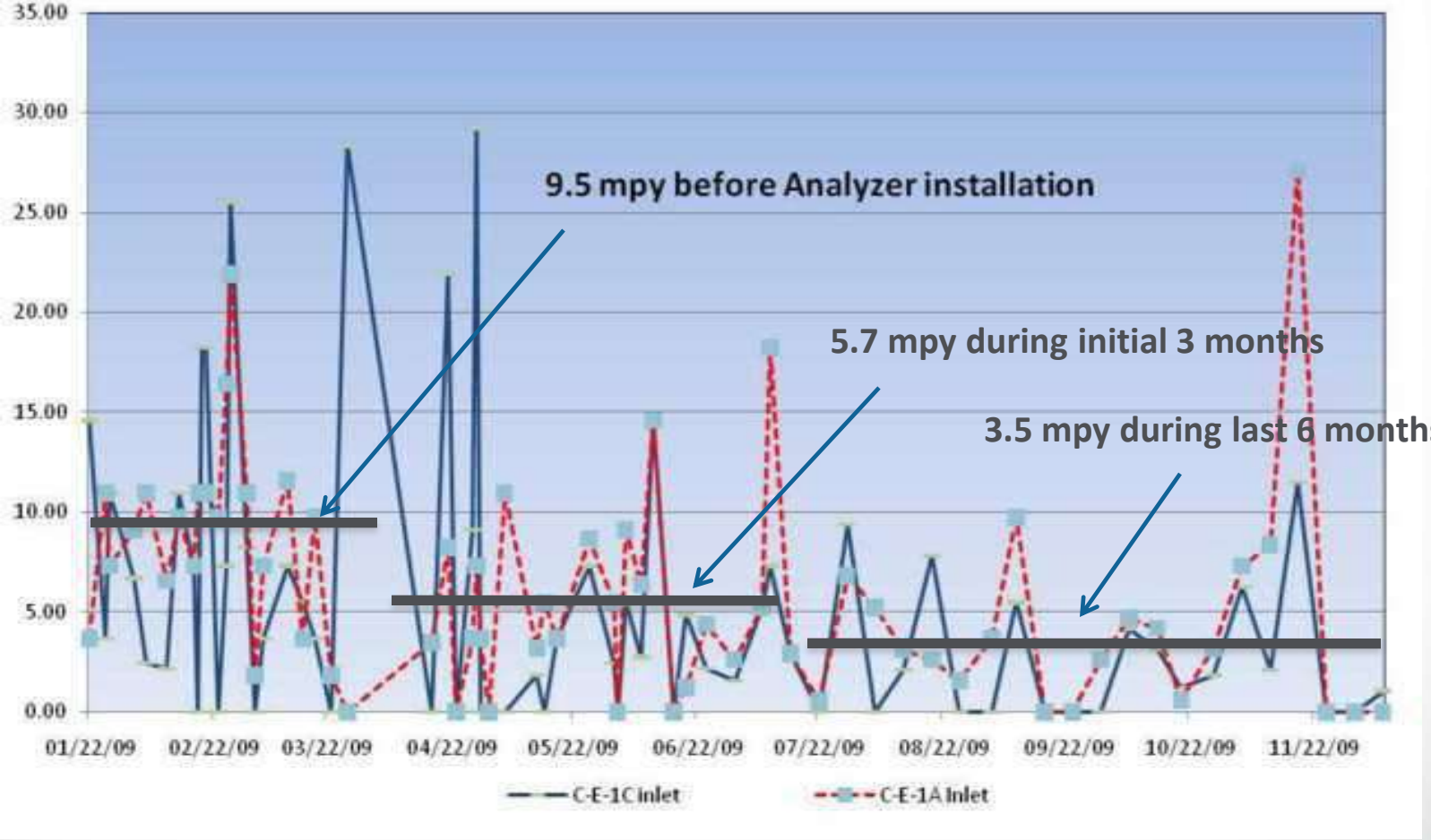
Additive	Before pump setting %	After pump setting %	% Savings
Caustic (NaOH)	45	27	39

Reduction if Caustic injection will also reduce Na levels in the residue streams, which will:

- **Improve Downstream product quality (e.g. coke)**
- **Reduce Downstream catalyst attrition (e.g. Resid HDT)**



Impact of Continuous Monitoring on Corrosion



Conclusions

- 3DTCOS fills in the gaps on monitoring
  - On the job 24/7 (pH, Fe, Cl, and soon NH3)
  - Communicates out of compliance situations immediately
- 3DTCOS improves equipment reliability and can prevent unplanned shut downs by allowing the refiner to be reactive to:
  - Equipment failures such as caustic pump
  - Desalter upsets
  - Crude changes
  - Unforeseen impacts of opportunity crudes (completion fluids, well work-overs, etc)
  - Detect tramp amines & allows mitigation strategies to be effective

Conclusions

- 3DTCOS closes the loop on chemical control allowing the refiner to significantly improve reliability by reacting in near real-time to challenging conditions

- 3DTCOS makes it possible to process more opportunity crudes; improve crude slate flexibility & adjust operating parameters to maximize profit

THANK YOU FOR YOUR TIME

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An Ecolab Company

Appendix 13

On line integrity monitoring systems: applications for cooling water systems, internal corrosion in acid gas treatment units

(K. Clarke)

permasense®

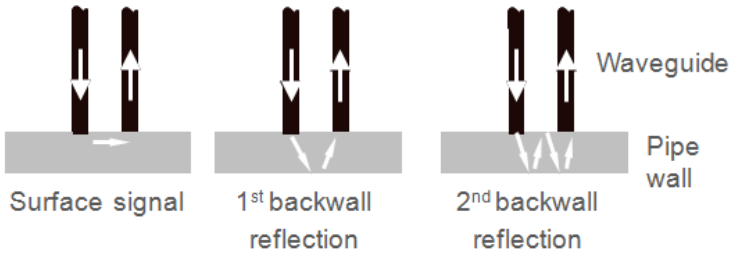
Experts in remote monitoring solutions

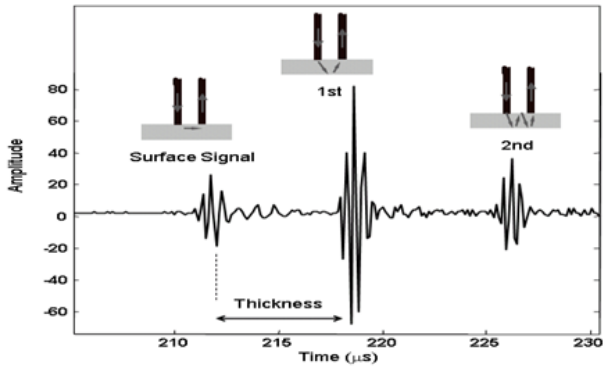
New Technology developments enhance accuracy and responsiveness of permanently installed ultrasonic sensors

Kevin Clarke
Chief Revenue Officer
April 14th 2015

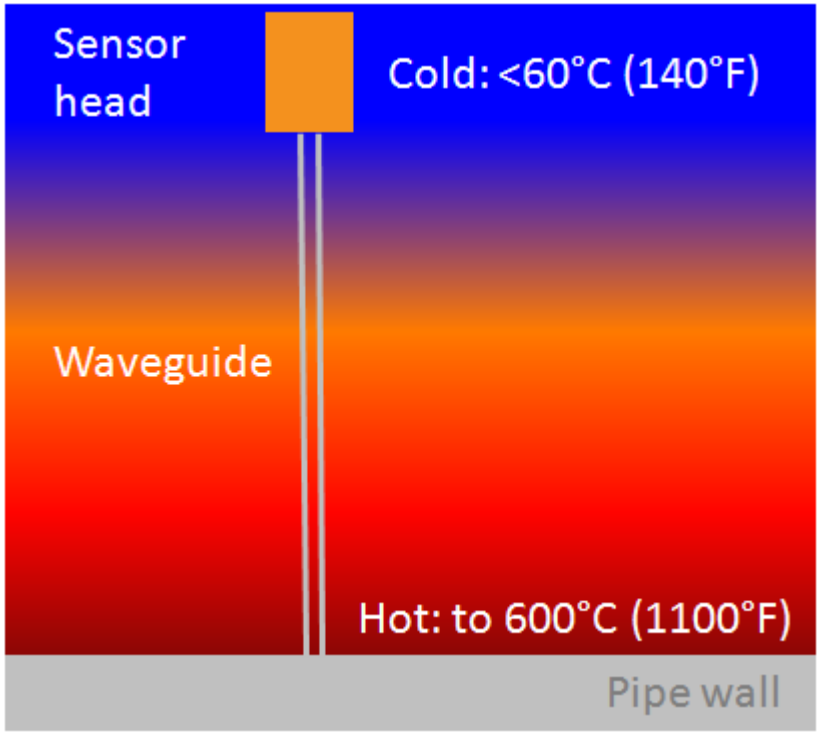
Permasense Technology
Overview

- Based on well-proven ultrasound technology, with a twist – the waveguide concept





Typical signal and wave path from the Permasense WT100 sensor



- Designed for a wide range of process temperature applications
  - -185˚C / -350˚F to +600˚C / +1100˚F

Permasense Technology

Overview

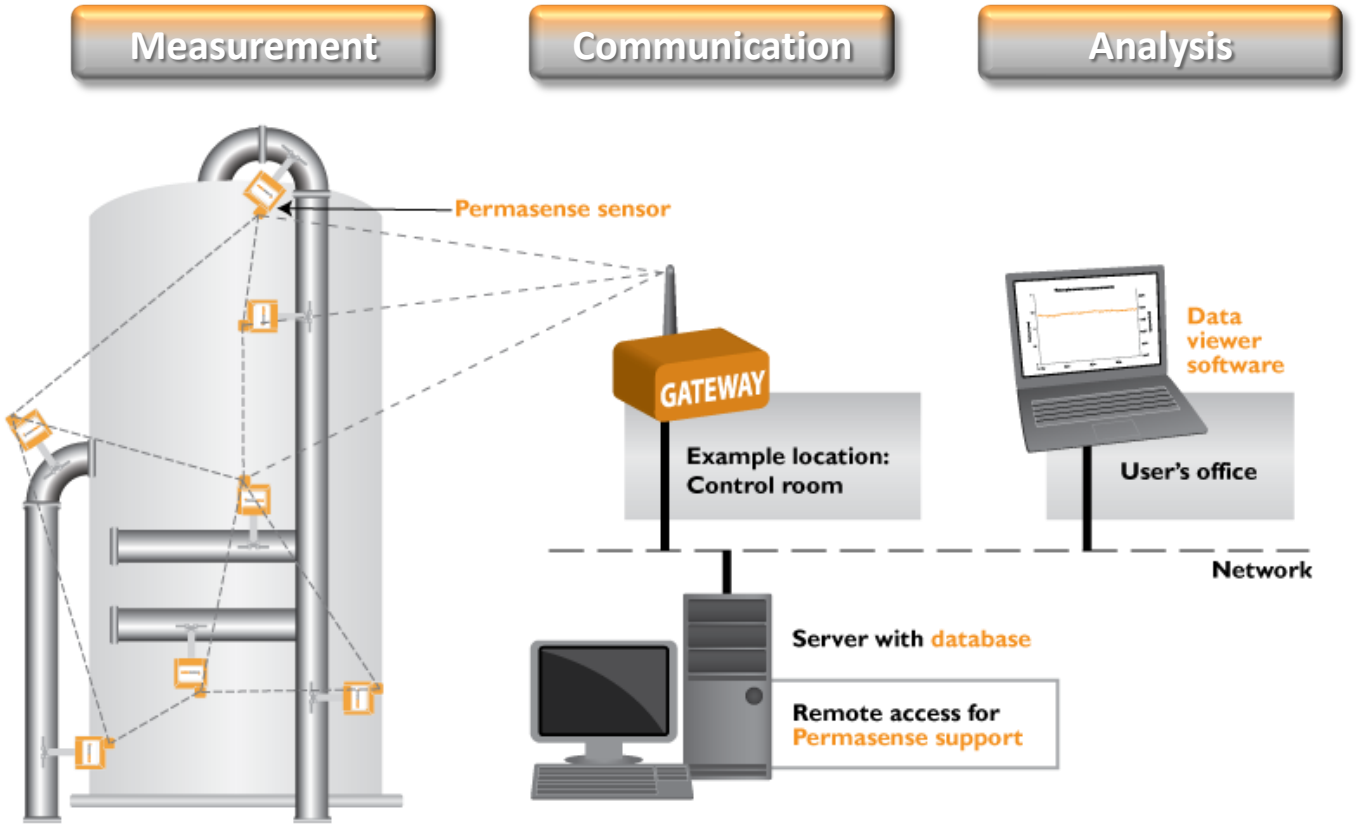
- Non-intrusive, no/low maintenance
- Wireless – simple, robust and low cost installation
- Measurement every 12 hours (can be adjusted)
- Has been applied to most metallurgies found in refineries & petrochemical plants
- Extended battery life, 2½ -9 years depending on sensor/battery model and wireless mesh density
- Mounted on welded studs, clamps, magnetic or epoxy saddles
- Installation off-line or during normal operations
- Can be installed through thick insulation
- Proven in all of BP's refineries world-wide
- Growing sensor population across all of the Oil & Gas Majors
  - 10,000th sensor shipped in March 2015
  - 10,000,000th measurement made in January 2015

Technology Overview

Complete system – sensors to software

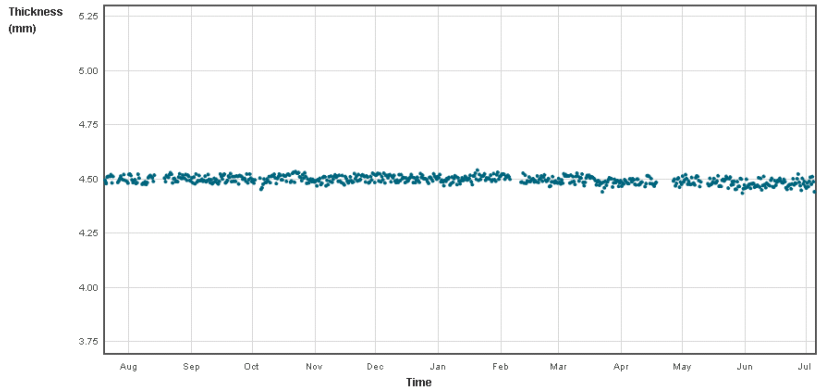
Data-to-Desk

Short-range system

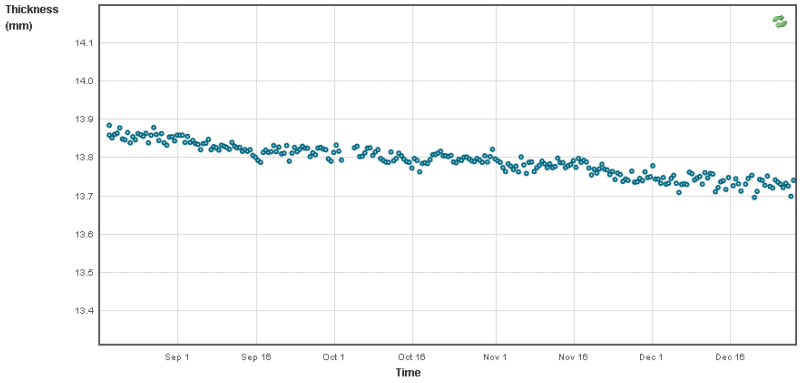


System Outputs

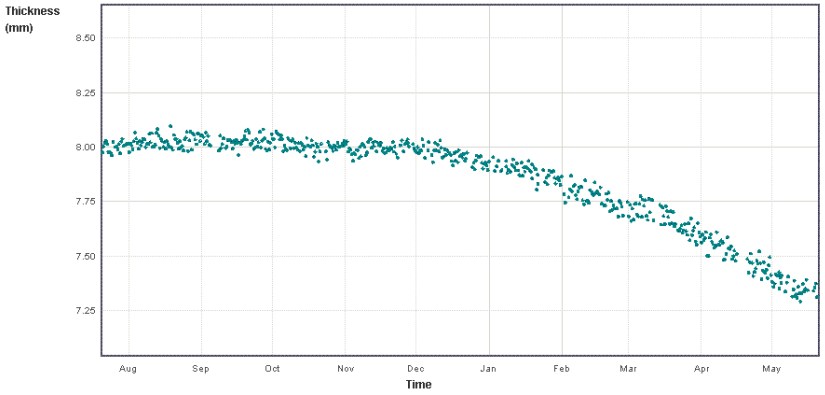
Trend identification with confidence - Impact of process, feedstock, solid erosion & inhibitor changes can be identified, tracked and optimised



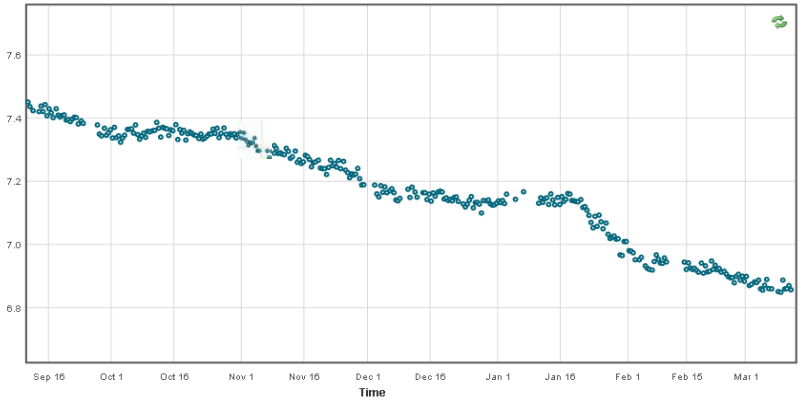
No visible trend on UT measured thicknesses in the period - no corrosion / erosion activity



Visible downward trend in UT measured thickness over time. Constant rate of metal loss



No trend on the UT measured data from August-November. From December sustained metal loss



Variable rate of metal loss - due to crude slate variations

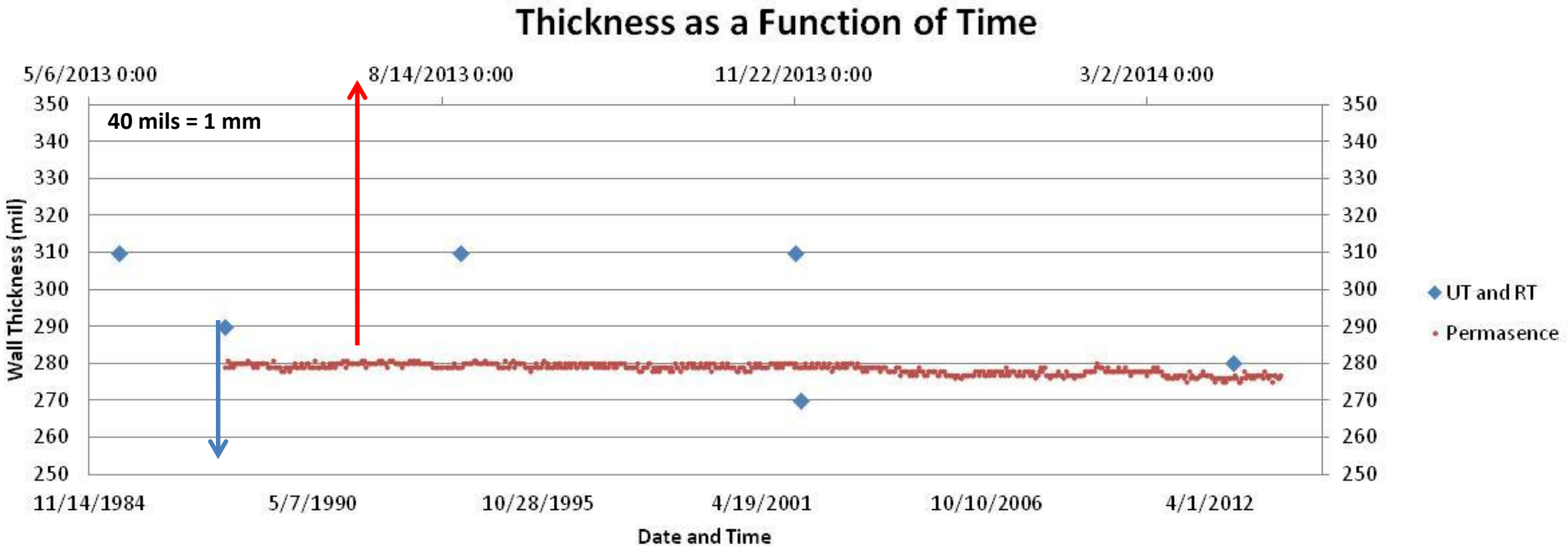
Drivers for deployment of continuous wall thickness measurement sensors

permasense®

Experts in remote monitoring solutions

Latest Technology Enhancements

Accuracy versus Manual Ultrasound



- Clearly a major advance in accuracy versus manual ultrasound
  - Better repeatability and reproducibility

Manual

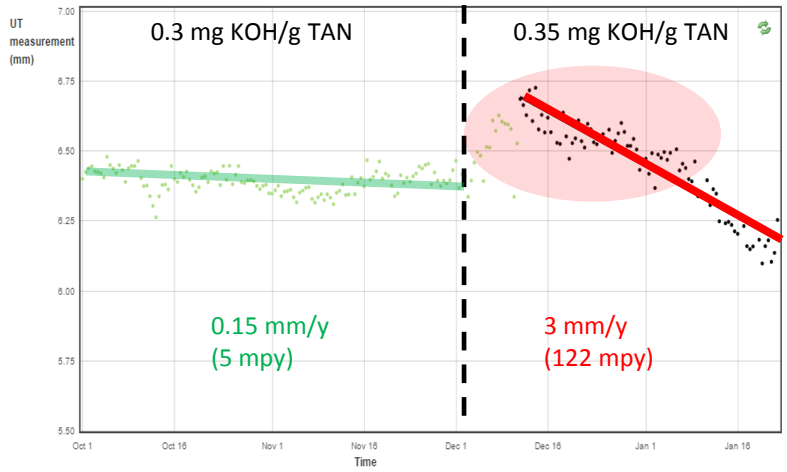
- Single measurement accuracy is 0.5 to 1 mm
- Years between measurements

Permasense

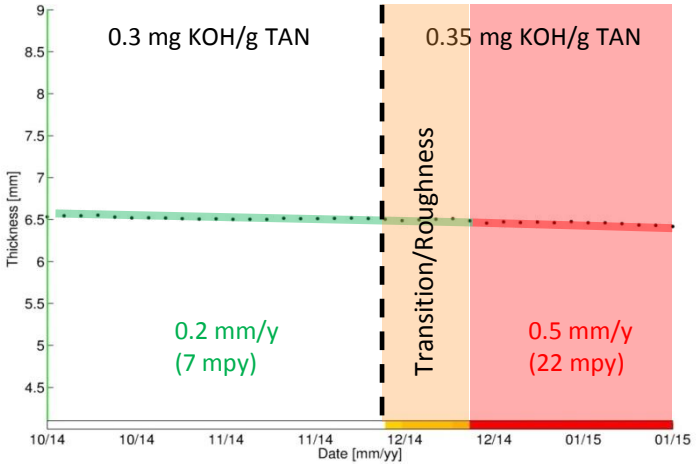
- Single measurement +/- 0.1 mm
- After 50 measurements, with statistical advantage +/- 50 microns
- Measurements every 12 hours; catch onset of corrosion events within a few days

Applications
Case Study – Naphthenic Acid Corrosion Monitoring

Envelope Peak

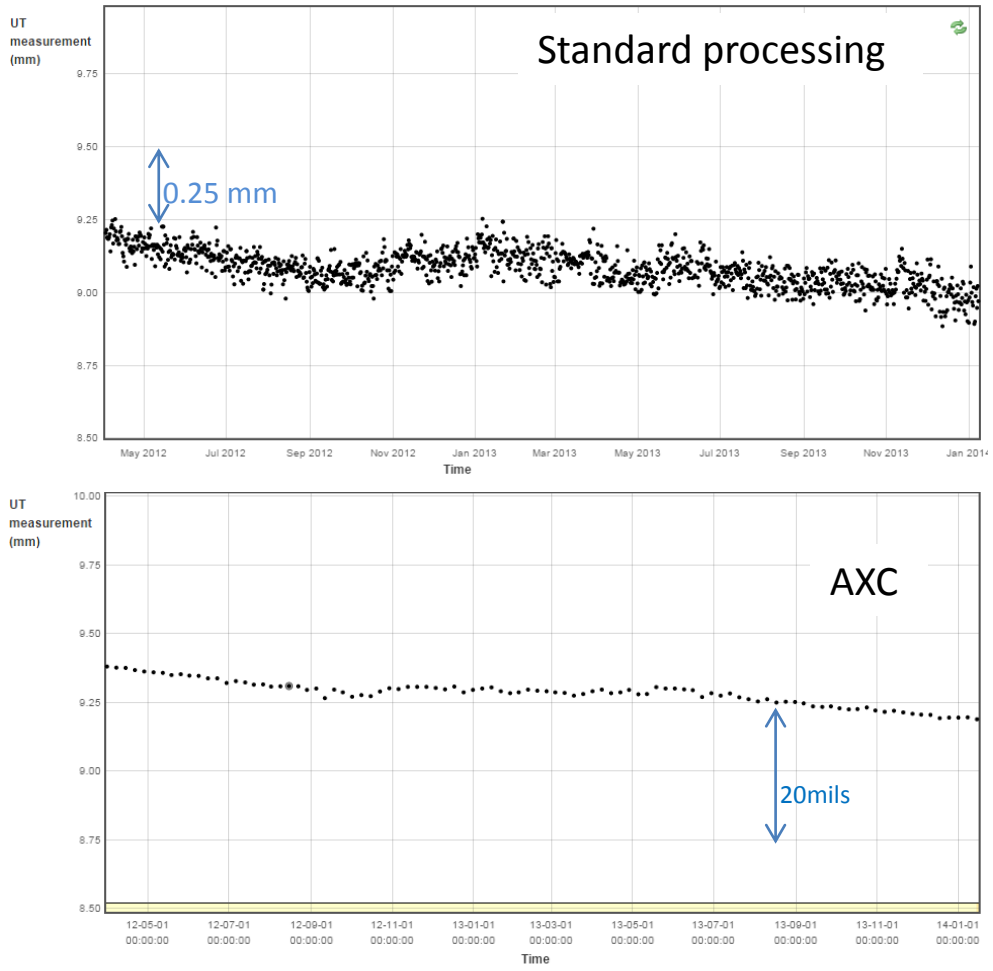


Adaptive Cross Correlation, AXC®

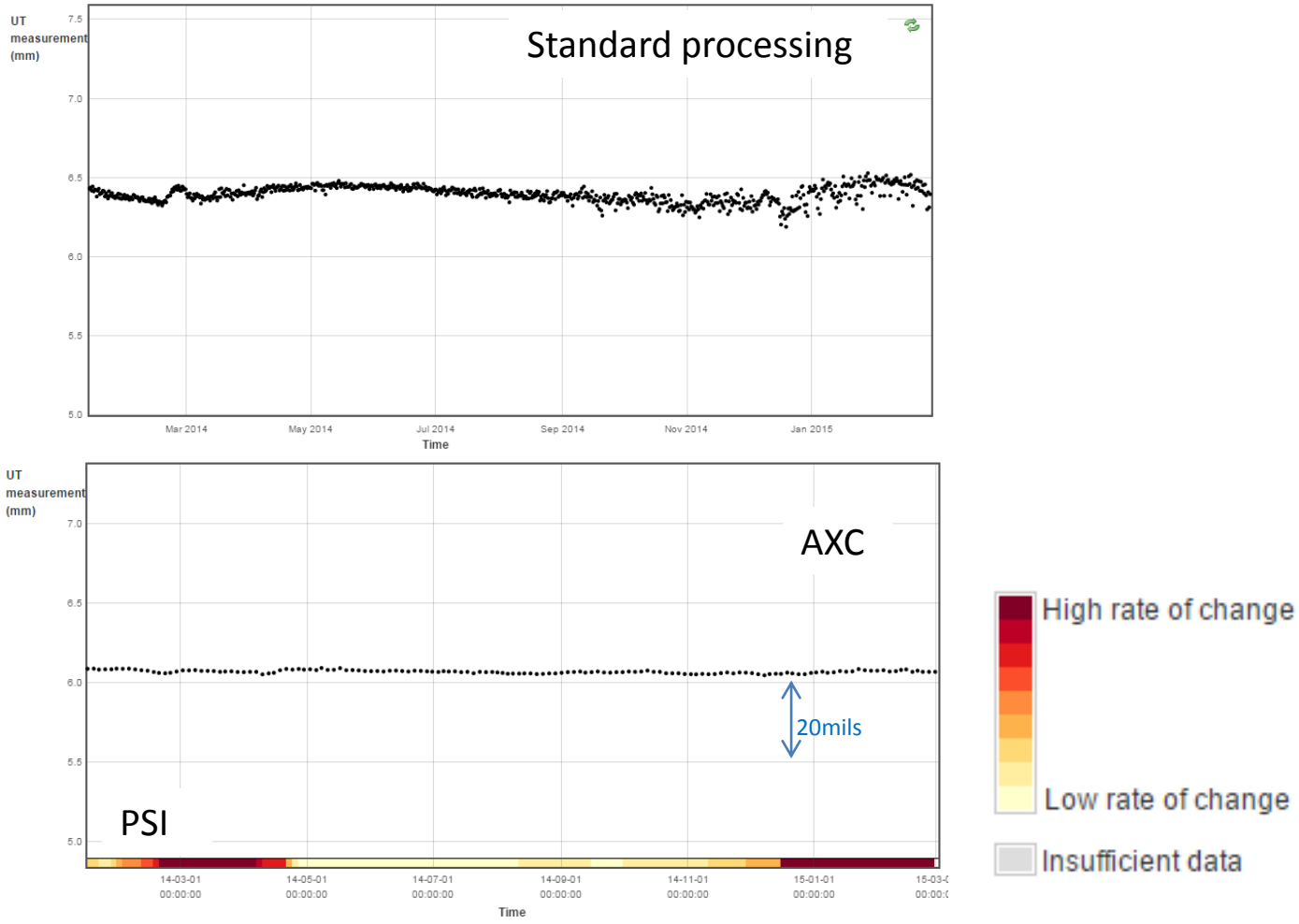


- Traditional method used by <u>all</u> ultrasonic methods is confused by backwall roughness, a key feature of naphthenic acid corrosion, characterised by an apparent increase in thickness
- Actual wall thickness is not clear for ~ 1 month
- Calculated rate when trend established is exaggerated
- Good agreement of corrosion rate before roughness begins (AXC® method less noisy)
- AXC® makes use of the change of waveform shape to improve detection of the first echo and the reliability of ‘time-of-flight’ determinations
- PSI® colour bar keeps the valuable information about the onset of roughness/pitting

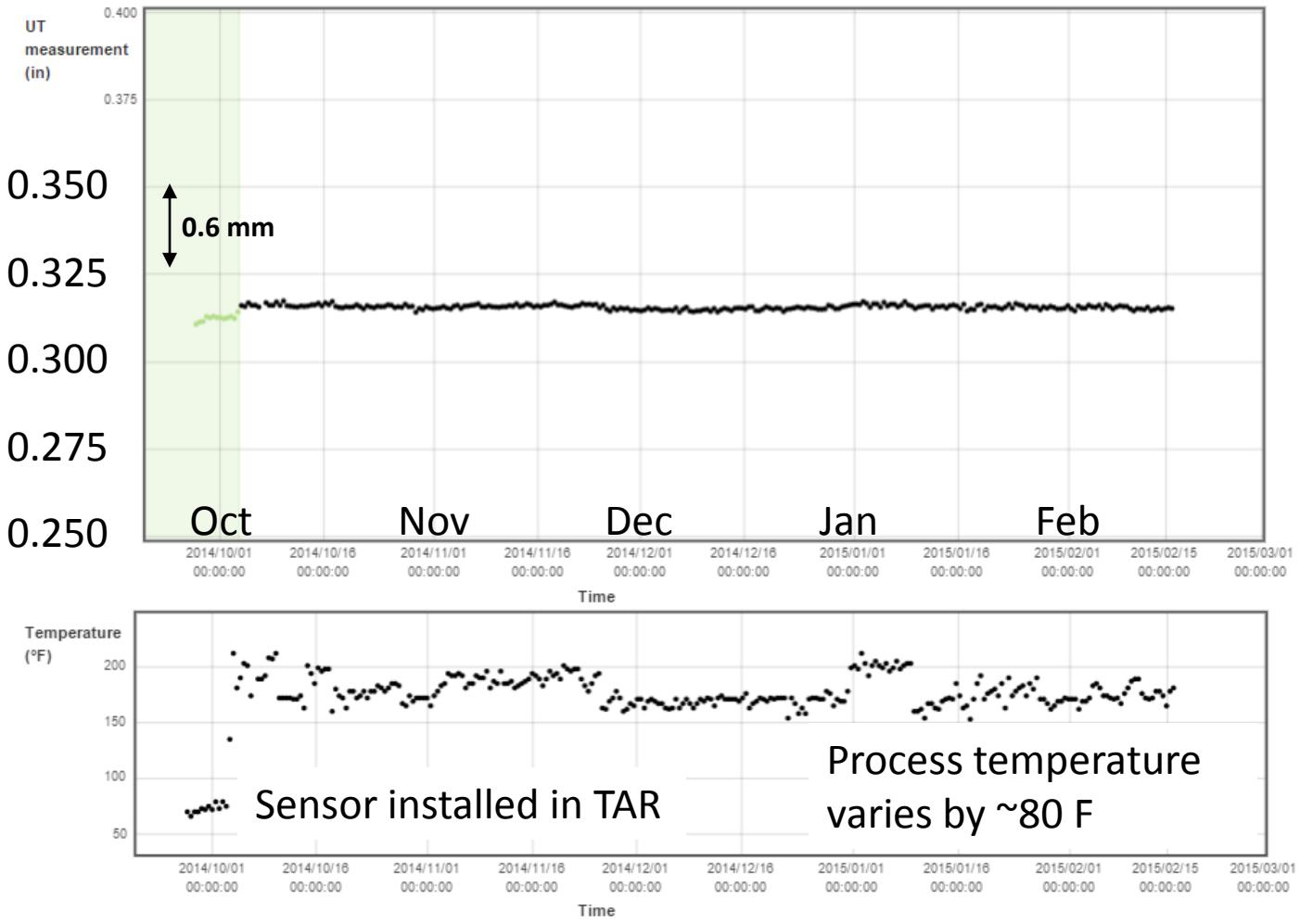
Enhanced signal processing: AXC has less noise than standard processing



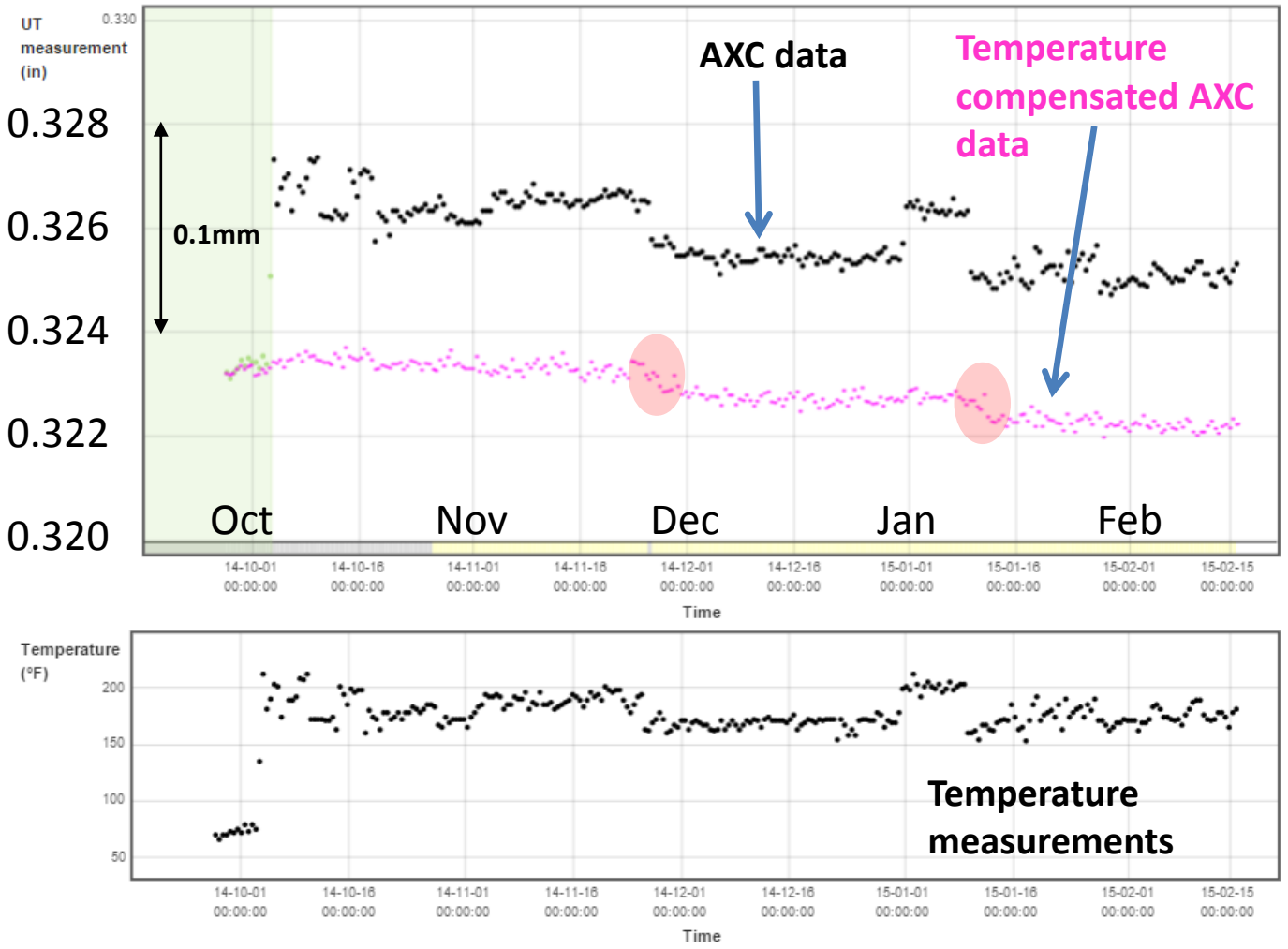
Enhanced signal processing: PSI detects changes in internal surface morphology



Standard measurements and temperature measurements (WT210 sensor)



AXC & temperature compensation further ease data interpretation

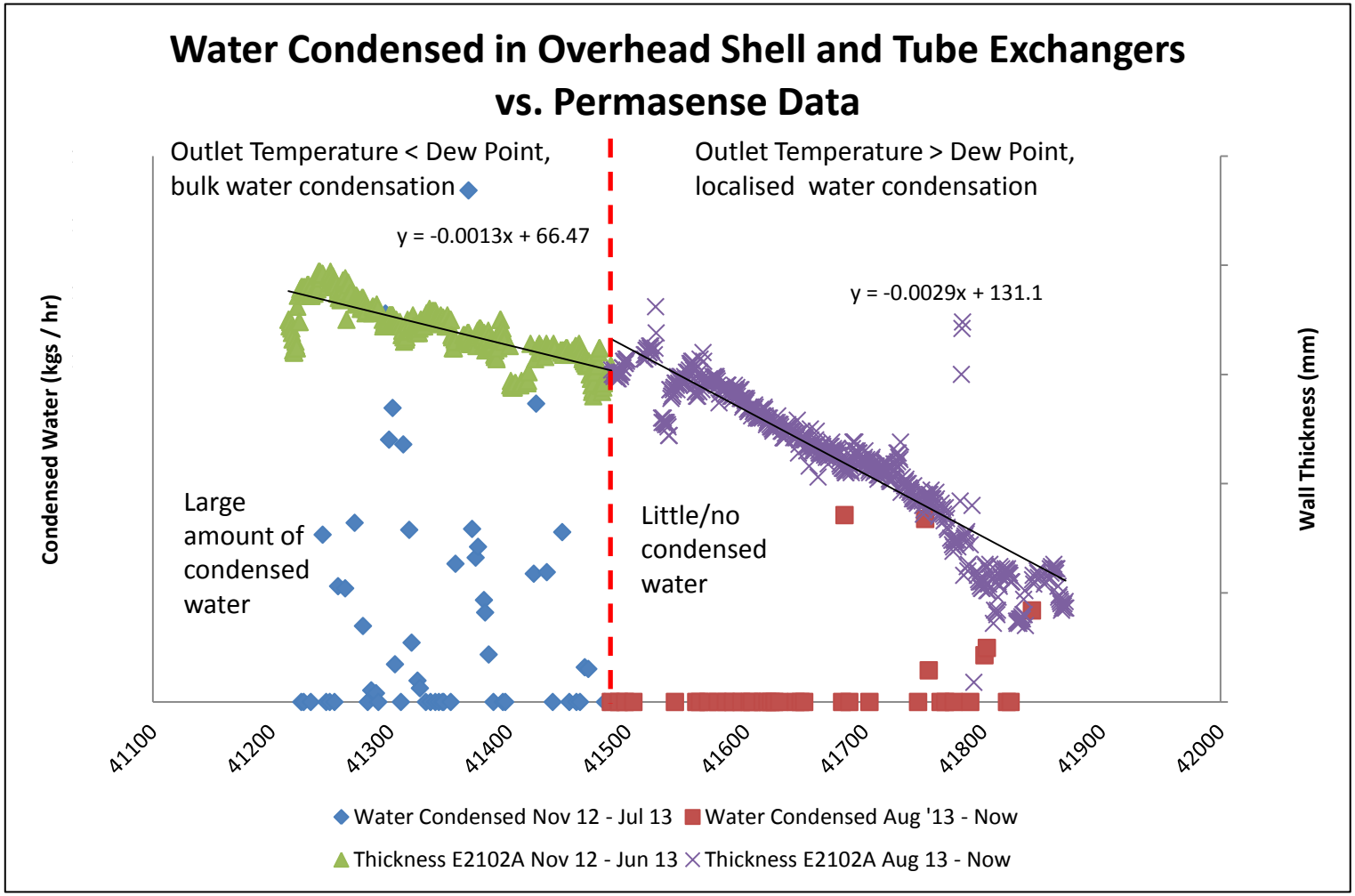


permasense®

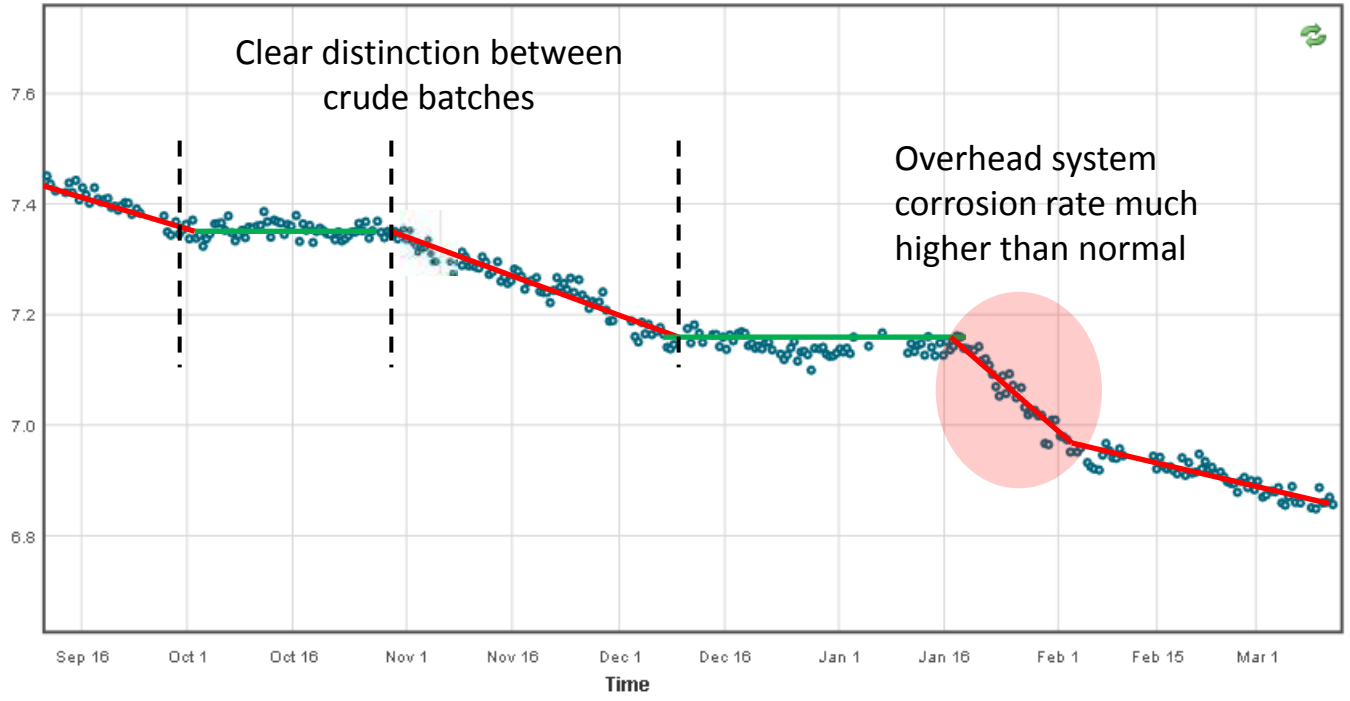
Experts in remote monitoring solutions

Case Studies

Applications
Case Study – CDU Overheads Dewpoint Monitoring



Applications
Case Study – CDU Overheads Organic Acid corrosion



- Continuous wall thickness monitoring enabled correlation of corrosion rate with crude slate
- Sensors in CDU overheads showed higher corrosion rate than expected for a particular batch of crude; no correlation with overhead inorganic chlorides
- Prompted refinery to investigate presence of organic acids from that crude batch, which was confirmed by detailed lab analysis

System Benefits
Continuous high-quality data enables…

- Confidence in asset management
  - Early identification of corrosion / erosion activity
  - Understanding of causes – correlation with process condition changes
  - Better forecasting of attainment of retirement thickness
  - Data is ‘real’, accurate and current
- Optimisation of prevention / mitigation strategies
  - Correlation of trends with inhibition strategy
- Insight into impact of feedstock decisions
  - Rapid feedback with changes in crude slate
- Cost-effective, safe measurement
  - No cost of repeat measurements
  - No shutdown for measurement
  - No personnel exposure to high-risk or hostile locations
- Makes Integrity issues more easily understood by the non-expert
  - A common ‘language’ for problem solving of integrity-related issues

Summary

- Operators using permanently installed continuous corrosion monitoring systems have a more ***accurate*** and ***timely*** understanding of the corrosion rates occurring within their facility
- Latest developments give accuracy and responsiveness on a par with high sensitivity intrusive probes
- Often installed as part of a safety or operational risk management programme
- Data is available at your desk and provides valuable ***insight*** into the effect of changing operations on corrosion/erosion rates
- Data supports more effective risk-based decision making about:
  - Feedstock changes
  - Chemical inhibition strategy
  - Shutdown timing
  - Metallurgical upgrading
- System is ***changing*** the way that Operations/Process Management consider integrity management in operational decision making
- System enables enhanced inspection strategies, where access is costly, dangerous or physically restricted
- Wireless data transmission facilitates ***cost effective*** and ***rapid*** installation in difficult working environments

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Experts in remote monitoring solutions

Contact:
Kevin Clarke
Email: kevin.clarke@permasense.com
Tel: +44 7740 761466

Century House
100 Station Road
Horsham
Surrey
RH13 5UZ, UK
Tel: +44 20 3002 3672