Appendix 1

List of participants

Participants EFC WP15 hybrid meeting 1th September 2022

NAME	SURNAME	COMPANY	COUNTRY
Astudillo	Miguel	CEPSA	SPAIN
Bateman	Colin	Integrated Global Services	UK
Bour Beucler	Valerie	Nalco Water	FRANCE
Chacon	Paticia	CEPSA	SPAIN
Corradini	Raffaele	Techint Engineering Construction	ITALY
Daly	Simon	Safinah Group	UK
De Landtsheer	Gino	Borealis	BELGIUM
de Marco	Marco	Istituto Italiano della Saldatura	ITALY
Farina	Carlo	CEFIT Corrosion Consultant	ITALY
Galliot	Ludovic	TotalEnergies	FRANCE
Geraskin	Vitaly	Integrated Global Services	CZECH REPUBLIC
Gregoire	Vincent	Equinor	NORWAY
Gogulancea	Vlad	LUKOIL Neftochim Bourgas JSC	ROMANIA
Groysman	Alec	Israeli Corrosion Forum	ISRAEL
Hall	Iain	Integrated Global Services	USA
Hashemi	Farzad	Copsys Technologies	CANADA
Ismael	Sheila	Ineos	UK
Kirchheiner	Rolf	MTI	GERMANY
Kuhn	Michael	PPG Protective & Marine Coatings	UK
Leone	Antonino	Eni	ITALY
Maffert	Joerg	Dillinger Huttenwerke	GERMANY
Magel	Chris	PPG Protective & Marine Coatings	BELGIUM
Maguire	Michael	Currach Consulting Limited	CANADA
Makhoul	Roger	Spraying Systems MENA Co	UNITED ARAB EMIRATES
Miyashita	Junki	MODEC, Inc	BRAZIL
Monnot	Martin	Industeel	FRANCE
Nikolova	Nataliya	Bayernoil Raffineriegesellschaft mbH	GERMANY
Noordink	William	Corrosion Radar	NETHERLANDS
Norling	Rikard	RISE	SWEDEN
Rangel	Pedro	CEPSA	SPAIN
Rodriguez Jorv	Javier	CEPSA	SPAIN
Ropital	François	IFP Energies nouvelles	FRANCE
Santacruz	Beatriz	CEPSA	SPAIN
Schempp	Philipp	Shell Deutschland Oil GmbH	GERMANY
Sharma	Prafull	Corrosion RADAR	UK
Soltani	Askar	South Pars Gas Complex	IRAN
Surbled	Antoine	A.S – CORR CONSULT	FRANCE
Ulm	Philipp	Bayernoil Raffineriegesellschaft mbH	GERMANY
Tacq	Jeroen	SIRRIS	BELGIUM
Vosecký	Martin	Nalco Water	CZECH REPUBLIC
Wold	Kjell	Emerson	NORWAY
Yuhei	Suzuki	Nippon Steel Europe GmbH	GERMANY
Zhang	Jian-Zhong	SABIC	UK
Zlatnik	Ivan	MITSUI & Co Deutschland	CZECH REPUBLIC

Appendix 2

EFC WP15 Activities

(Francois Ropital)

EUROPEAN FEDERATION OF CORROSION

Welcome to the EFC Working Party Meeting

"Corrosion in Refinery and Petrochemistry" WP15

1 September 2022

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

EFC Working Party 15 « Corrosion in Refinery and Petrochemistry » Activities

Chairman: Francois Ropital Deputy Chairman: Johan Van Roij

Information Exchange – Forum for Technology

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

Sharing materials/ corrosion/ protection/ monitoring information by providers

Eurocorr Conferences : organization of refinery session and joint session with other WPs (2022 Berlin-Germany, 2023 Brussels-Belgium)

In 2022 the Refinery corrosion session took place on Wednesday 31 August.

In 2023 Eurocorr will take place from 27 to 31 August in Brussels

WP Meetings

One WP 15 working party meeting in Spring,

One meeting at Eurocorr in September in conjunction with the conference, this year it is on Thursday 1 September 2022 morning in Berlin (hybrid meeting)

Publications - Guidelines

Web site : https://efcweb.org/Scientific+Groups/WP15_+Corrosion+in+the+Refinery+and+Petrochemistry+Industry-p-38.html

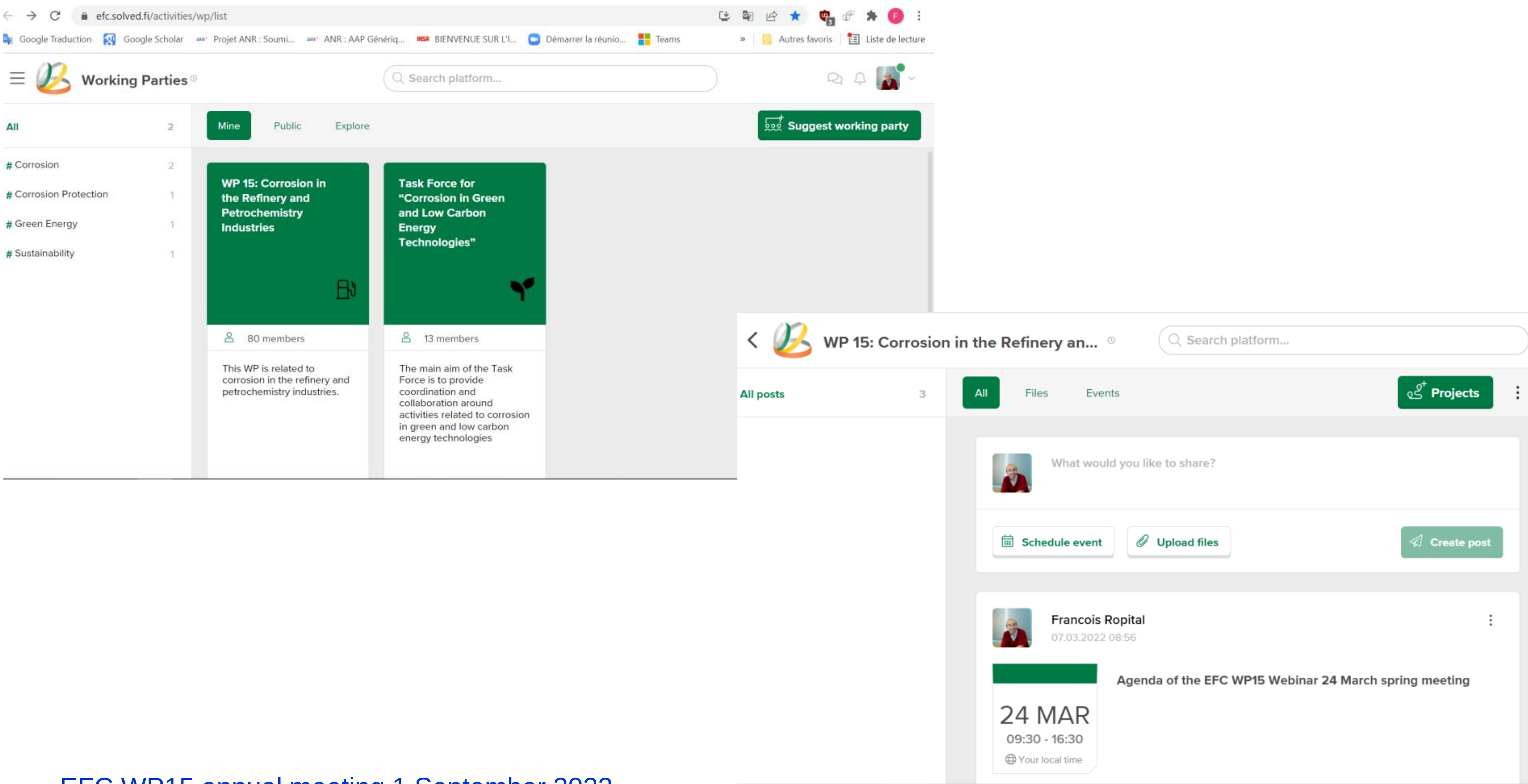
List of the WP15 spring meetings :

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)
14 April 2015	Leiden -NL (Nalco)
26 April 2016	Paris - France (Total)
13 April 2017	Frankfurt - Germany (EFC Head offices)
3 May 2018	Dalmine - Italy (Tenaris)
10 April 2019	Roma - Italy (Rina CSM)
23 March 2021	Zoom meeting
24 March 2022	Zoom meeting

EFC Hub Platform

A Web forum platform on the EFC Hub platform has been created

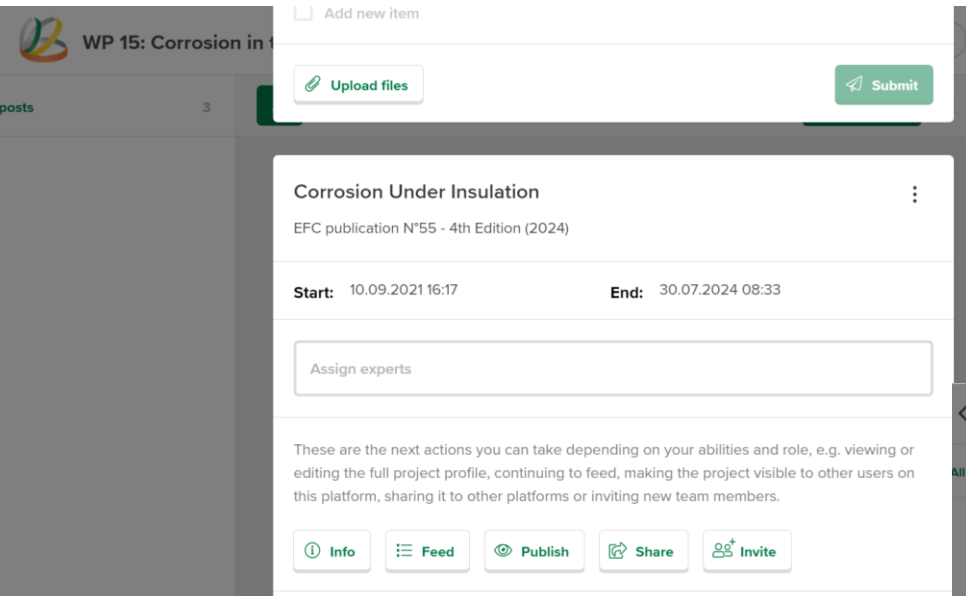
https://efc.solved.fi/activities/wp/list

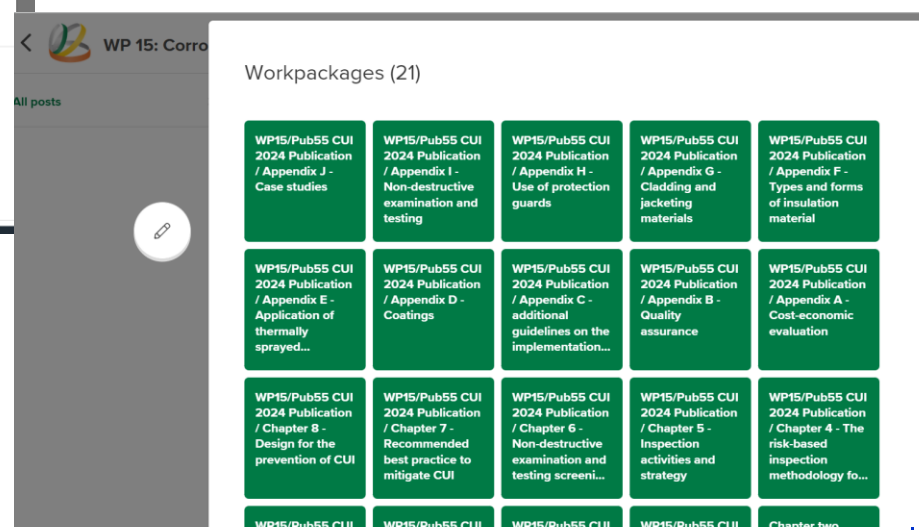


EFC Hub Platform: CUI Project

EFC CUI Web forum platform:

https://efc.solved.fi/activities/wp/feed/ef91a569-219e-444b-90f8-69c26945cdf7





Publications from WP15 – Forum Platform

•EFC Guideline n° 55 Corrosion Under Insulation Editor: Gino de Landtsheer
The 3rd revision is available

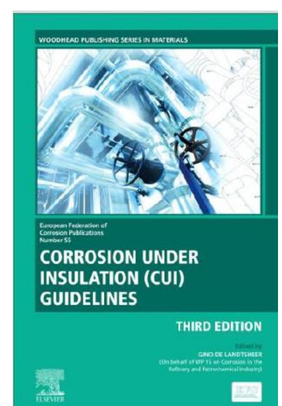
https://www.elsevier.com/books/corrosion-under-insulation-cui-guidelines/de-landtsheer/978-0-12-823332-0

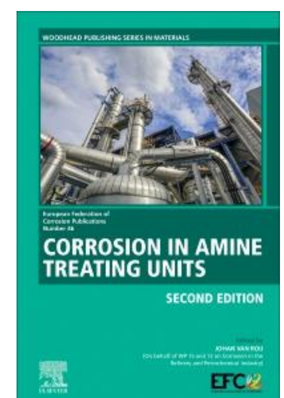
•EFC Guideline n° 46 revision on corrosion in amine units Editor: Johan van Roij
is now available

https://www.elsevier.com/books/corrosion-in-amine-treating-units/van-roij/978-0-323-91549-6

• Best practice guideline on corrosion in sea water cooling systems (joint document WP9 Marine Corrosion and WP15)
In progress by a task force

Thank you to all the contributors for their work





Advancement of the guideline on corrosion on sea water cooling systems

Chapter	Title	Chapter Leader	Chapter contributor
1	Introduction	Valerie Bour-Beucler	Jean-Nicolas Cordier
2	Heat exchanger systems	Valerie Bour-Beucler	Jean-Nicolas Cordier
3	Sea water environment	Valerie Bour-Beucler	Corrodys
4	Forms of corrosion	Valerie Bour-Beucler	Antoine Surbled
5	Biocide treatments	Valerie Bour-Beucler	Philippe Bleriot
6	Inhibitors	Philippe Bleriot	
8	Materials	Antoine Surbled	
8.1	Carbon steel		Antoine Surbled
8.2	Stainless steels		Dominique Thierry Jonas Howing
8.3	Nickel alloys		Dominique Thierry Angela Philipp
8.4	Copper alloys		Dominique Thierry
8.5	Aluminium, Titanium alloys		Antoine Surbled
8.7	Concrete		Antoine Surbled
9	Corrosion protection	Jian-Zhong Zhang	
9.1	*Material selection to avoid galvanic coupling*		*Jian-Zhong Zhang*
9.2	*Coatings*		*Jian-Zhong Zhang*
9.3	*Cathodic protection*		*Nicolas Larche Dominique Thierry*
10	Maintenance and tube cleaning	Valerie Beucler	Jian-Zhong Zhang Antoine Surbled
11	Control monitoring inspection	Antoine Surbled	

Thank you to all the contributors for their work

Joining EFC WP15 activities

If you are not on the list of WP15 members and you want to join you can

- Fill the EFC Friend form: https://efcweb.org/friendsform.html

- Or send an email to francois.ropital@ifpen.fr

EFC Web site :https://efcweb.org/

EFC Hub Platform : https://efc.solved.fi/activities/wp/list

Information :
Future conferences related to refinery corrosion

CUI Workshop: New HSE Shared Research project on Corrosion Under Insulation - can you contribute to this important research?
15 September 2022 in Buxton, UK
https://solutions.hse.gov.uk/news_items/corrosion-under-insulation

19-23 March 2023
CORROSION 2023 AMPP Denver

27-31 August 2023
EUROCORR 2023 Brussels Belgium

1-4 September 2024
EUROCORR 2024 Paris France

Look at the Website: https://efcweb.org/Events.html

Appendix 3

CRA Upgrades of process vessels by high velocity thermal spray (HVTS) cladding – Asset conversion for renewable fuel processing

(Vitaly Geraskin)

CRA UPGRADES OF PROCESS VESSELS
BY HIGH VELOCITY THERMAL SPRAY CLADDING

ASSET CONVERSION FOR RENEWABLE FUEL PROCESSING

IAIN HALL, MATTHEW MACWATTERS

United States Canada Europe Kazakhstan Japan Middle East South Africa

igs

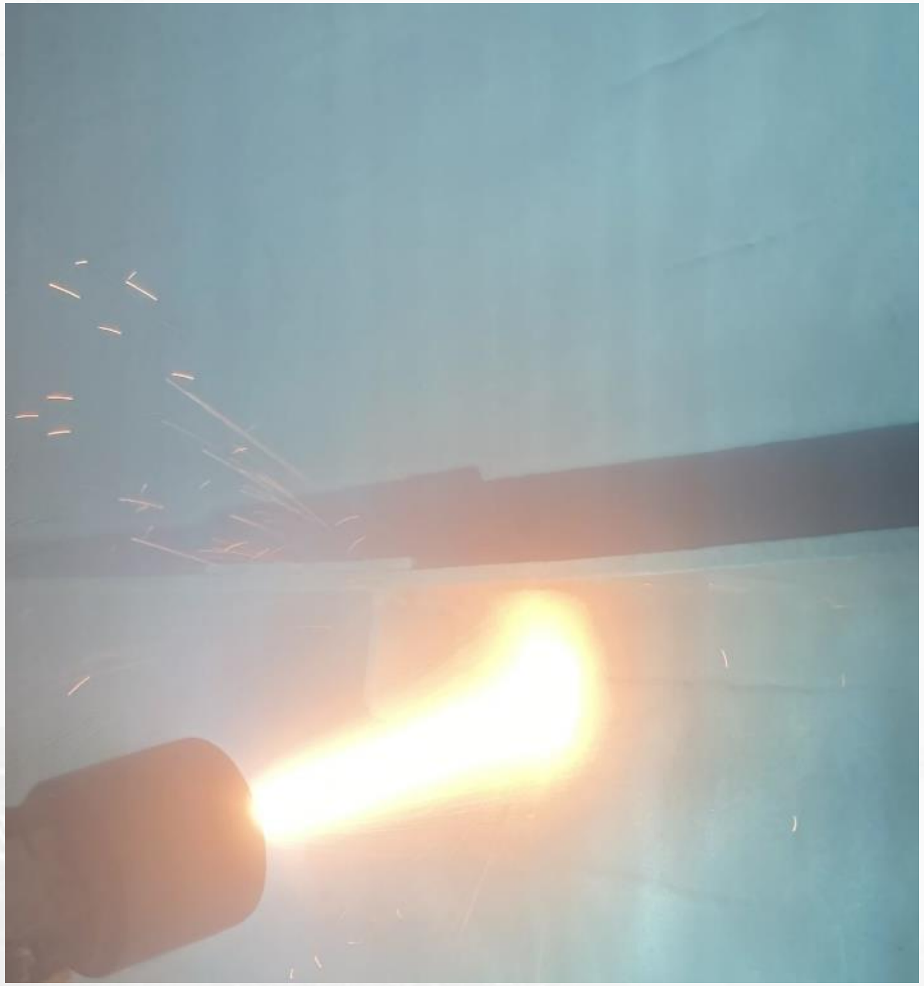
PRESENTATION CONTENT:

- **THERMAL SPRAY TECHNOLOGY FOR VESSELS**
- RENEWABLE FUEL APPLICATION
- MATERIAL PERFORMANCE QUALIFICATION
- CASE STUDY
- Q AND A

Alternatives considered for shell DM mitigation

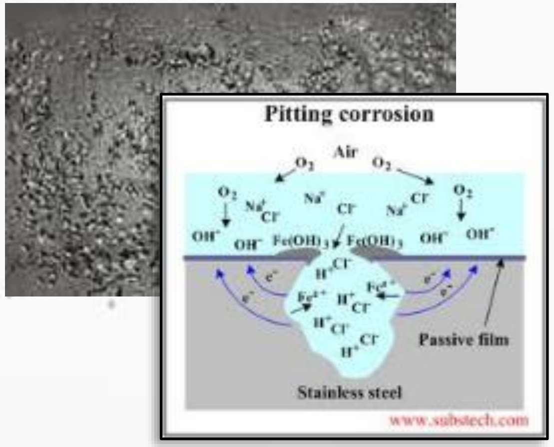
- Vessel replacement / higher alloy shell
  - New design solution
  - Time and cost prohibitive
- Vessel overlay with CRA using weld overlay
  - Slow and more expensive process
  - Introduction of stress and damage risk in preexisting WO
  - possible PWHT/Bake out need
- Shell cladding with High Velocity Thermal Spray Alloy
  - Rapid application of NiCrMoNb alloy
  - lowest alloy up cost
  - no distortion / risk to existing CRA

High Velocity Thermal Spray
Vessel Cladding

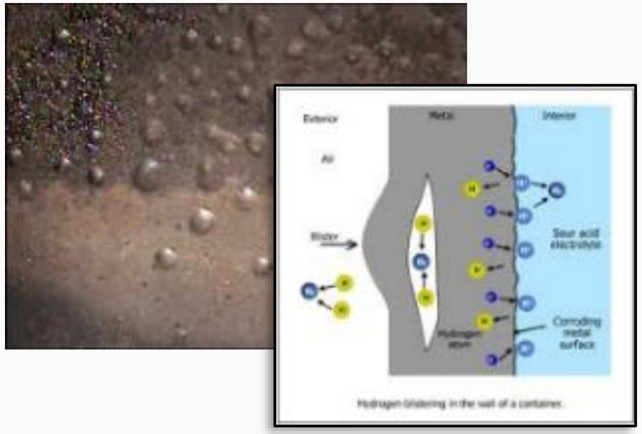


Commonly addressed corrosion mechanisms:

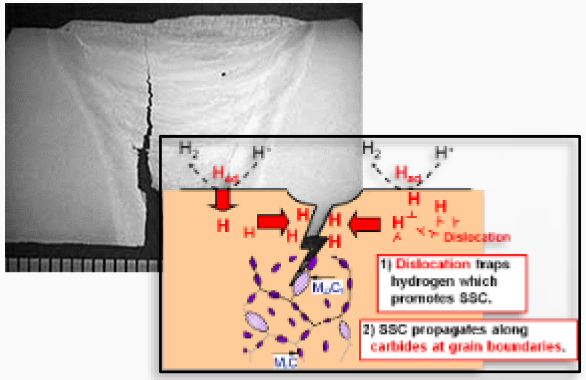
Pitting Corrosion:



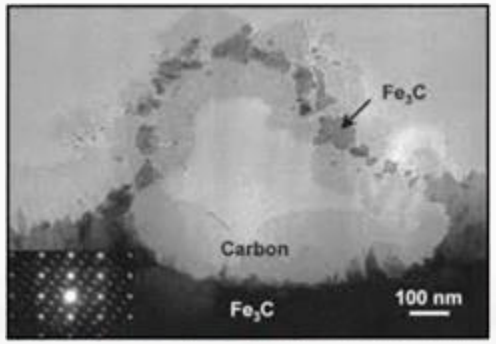
Hydrogen Blistering and Cracking:



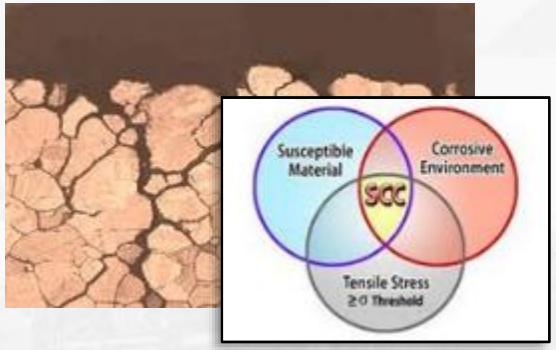
Sulfide Stress Cracking:



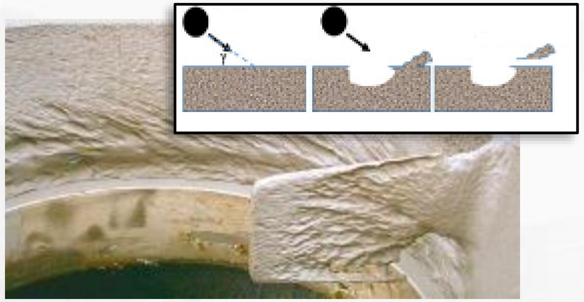
Metaldusting:



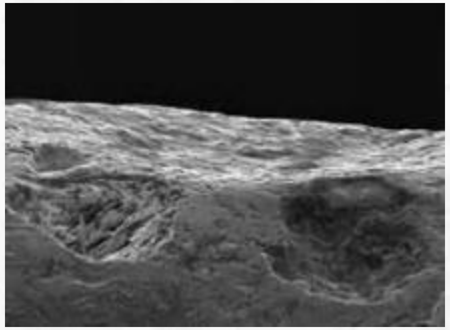
Stress Corrosion Cracking (SCC):



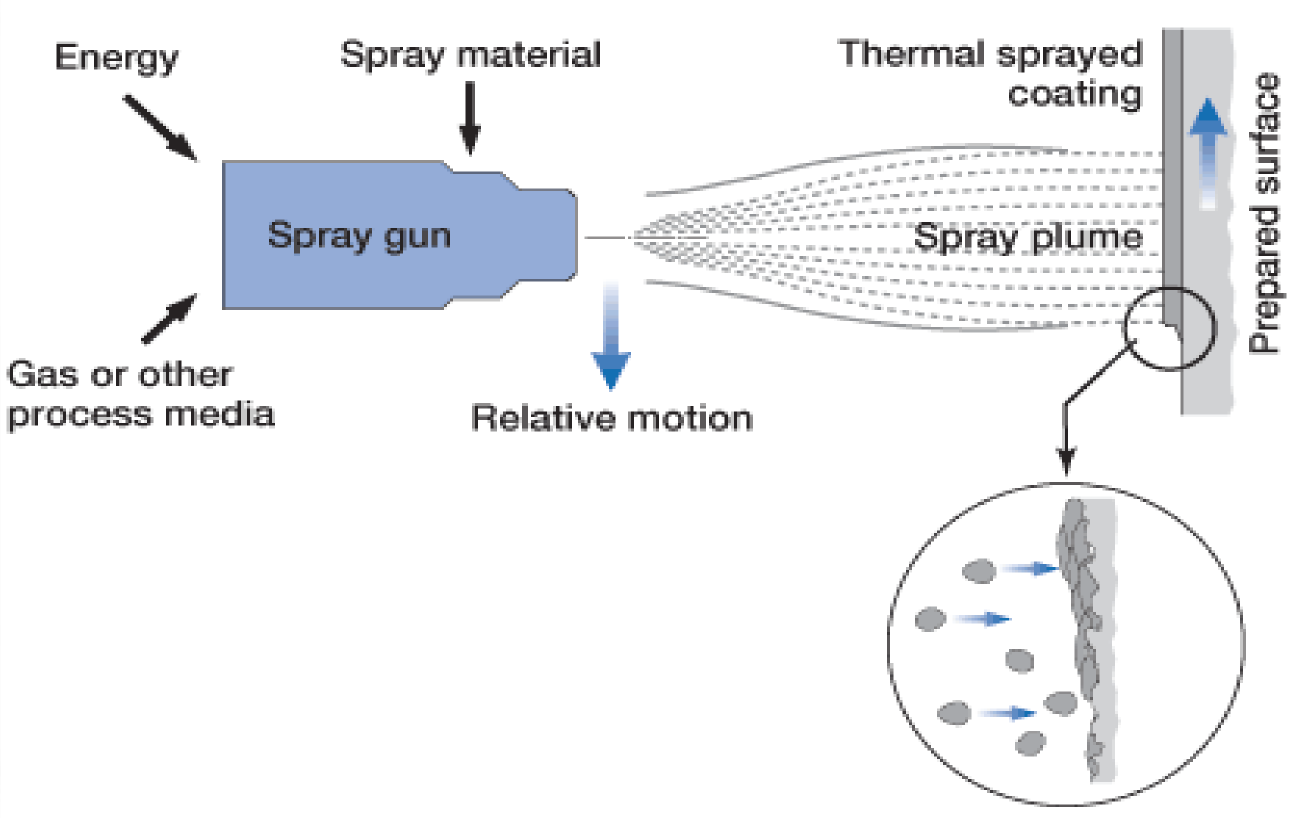
Wear and Erosion:



Sulfidation (Gaseous and dew point):



Employing Thermal Spray to Upgrade the surface alloy

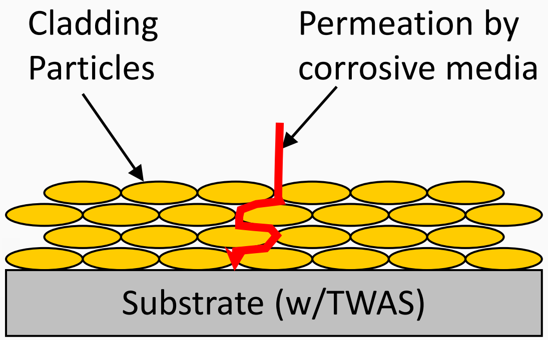


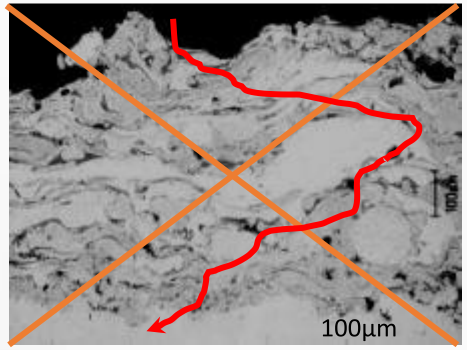
- Atomized molten particles propelled by a carrier gas
- They impact the prepared substrate and freeze into individual splats
- Used to apply a wide range of materials onto a surface quickly and cost effectively.
- Mechanical & Chemical bond, no heat affected zone (HAZ)

High Velocity Process - Refined microstructure and chemistry:

Twin wire Arc Spray (TSA Only)

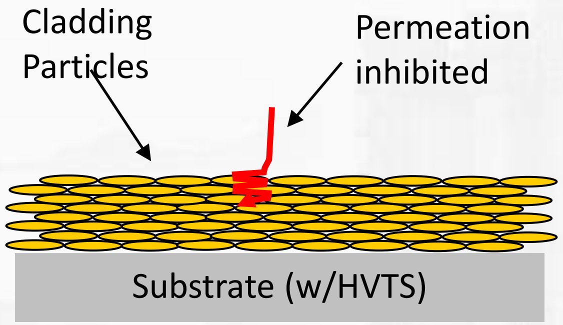
- Low Velocity System (sub-sonic)
- High oxide content
- Lower bond strength
- Interconnected oxides & porosity

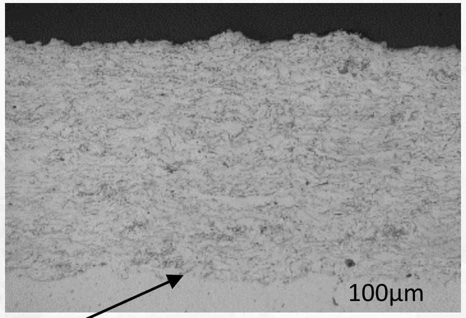




IGS High Velocity Thermal Spray (HVTS)

- Atomized wire in a super-sonic gas stream
- Alloy modification minimizes in-flight oxidation to acceptable levels during spraying
- Purposefully engineered to produce a low residual stress cladding





50 MPa bond strength
No heat affected zone (HAZ)

How to create a barrier…

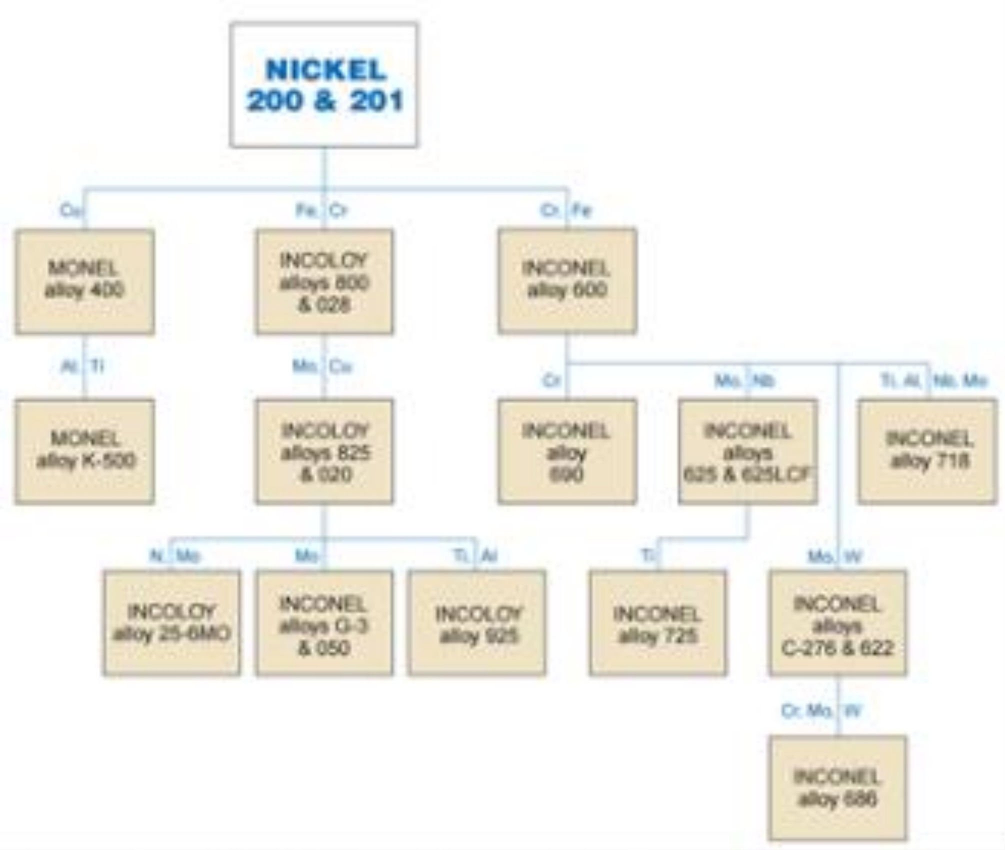
Alloy selection and modification:

Alloy Modification

- NiCrMo alloys provide a good basis for material selection, typically suitable for wide pH ranges in sour and high chloride environments.

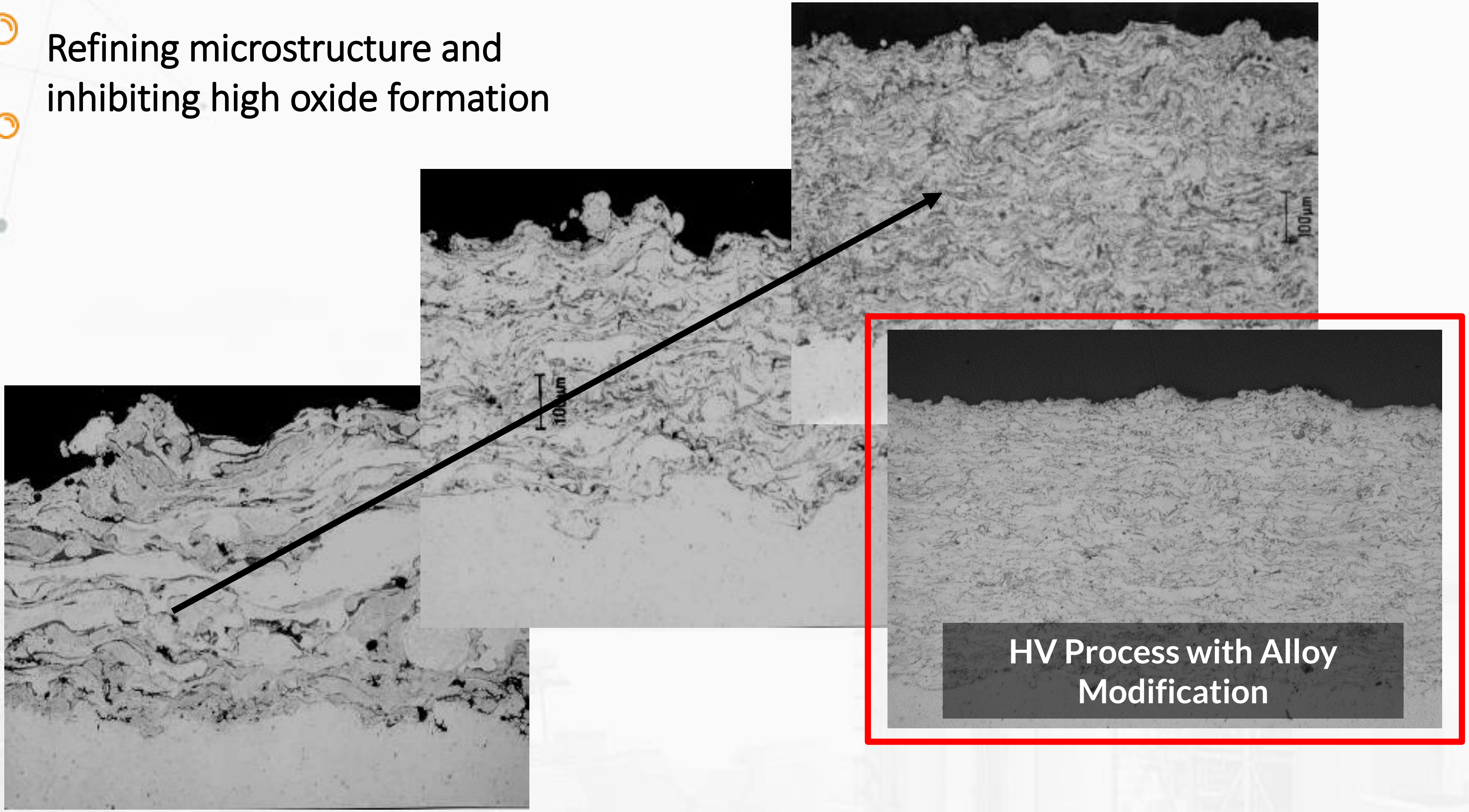
- Higher Cr alloys are preferred for higher temperature service. They have high pitting resistance equivalent numbers (PREN = Cr + 3.3(Mo +0.5W) + 16N), high TAN tolerance as well sulfidation resistance.

- For thermal spray applications, however, as in welding, additional alloy modifications are required to address process oxidation, stress, and tolerance to field application conditions. This ensures the as-applied cladding performs as would be expected from the bulk material properties.



Progression in Metal Cladding application technology…

Refining microstructure and
inhibiting high oxide formation



PRESENTATION CONTENT:

- THERMAL SPRAY TECHNOLOGY FOR VESSELS
- RENEWABLE FUEL APPLICATION
- MATERIAL PERFORMANCE QUALIFICATION
- CASE STUDY
- Q AND A

Renewable Diesel/Biofuels Applications

- Numerous refineries are converting all or part of the facility to renewable fuel to meet market demands for renewable fuel, significantly in the air transportation sector.
- Repurposed equipment is faced with challenges due to new corrodents and damage mechanisms.
- Previous equipment design and/or mitigation strategies may no longer be sufficient to deal with any combination of Free Fatty Acid (FFA), Naphthenic Acid, Carbonic Acid, Chlorides etc. in effluent and associated streams.
- Mitigation strategies must account for differences between old/new DMs, includes both base material and cladding. Depending on process conditions, 3XX SS alloy overlays may not be resilient enough for more aggressive service conditions.
- Cladding materials based on known alloy tolerance (NiCrMo/W/XX), have been further developed for thermal spray application to provide corrosion resistance for renewable fuel processing.

Damage Mechanism Concerns in Petroleum vs. Renewables vs. Co-processing

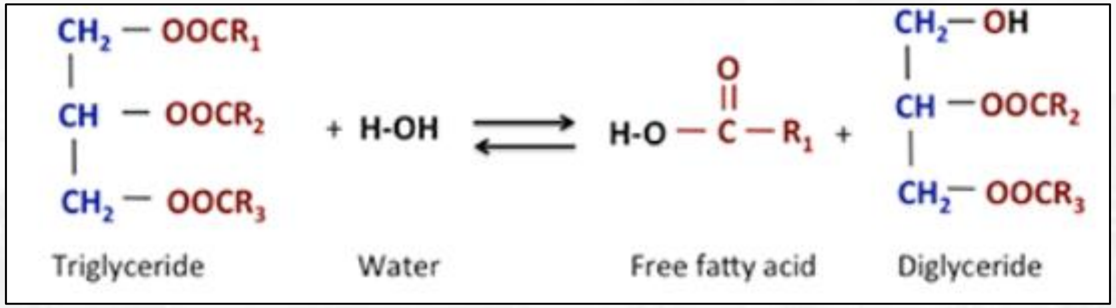
100% Petroleum	100% Renewables	Co-processing
• Sulfur is the major concern in the feed along with lower amounts of naphthenic acids and nitrogen • H_2/H_2S corrosion dominates in the hot section of the unit • Sulfur-to-TAN (Total Acid Number) ratios can be leveraged to control corrosion of some materials • TAN numbers in 0-3 range • As the effluent cools, NH_4Cl and NH_4HS and wet H_2S damage can occur	• Fatty Acids are the major concern in the feed, resulting in Free Fatty Acid (FFA) corrosion • Pretreatment of feeds may be necessary to remove catalyst poisons and extend run length • Pretreating and lipid degradation can increase acid content; acids convert to CO_2 and water in the reactor • TAN numbers are frequently in • 100 – 170 range, sulfur content may be low. Chloride levels can be elevated. • As effluent cools, CO_2 corrosion (carbonic acid corrosion) can occur.	• Depending on the blend, H_2/H_2S corrosion and fatty acid corrosion could occur in hot sections of the feed • Pyrolysis requires higher processing temperatures • In the effluent, alkaline aqueous species help to mitigate CO_2 corrosion • Wet H_2S damage and salting (from chloride contamination) are still relevant mechanisms

Background: Corrosion Concerns

- **Biofuel Conversion Process:** Triglycerides (fats, oils, greases, etc.) converted to fatty acid methyl esters (FAME) via transesterification

$$\underset{\text{Triglyceride}}{C_{57}H_{104}O_6} + \underset{\text{Methanol}}{3CH_3OH} \xrightarrow[\text{Catalyst}]{} \underset{\text{FAME}}{3C_{19}H_{36}O_2} + \underset{\text{Glycerol}}{C_3H_8O_3} \quad (1)$$

- Corrosion concerns include organic acid + free fatty acid (FFA) corrosion, high temperatures and pressures, and contamination (chlorides)



FFA formation due to a high-water content

PRESENTATION CONTENT:

- THERMAL SPRAY TECHNOLOGY FOR VESSELS
- RENEWABLE FUEL APPLICATION
- MATERIAL PERFORMANCE QUALIFICATION
- CASE STUDY
- Q AND A

Performance Qualification Tests:

Elevated temperature/pressure exposure and thermal cycling

- 2 litre, C22 Autoclave testing:
  - Pressure 2000psi (14MPa)
  - Temperature 650F (340C)
  - Coupon rotation at 50rpm

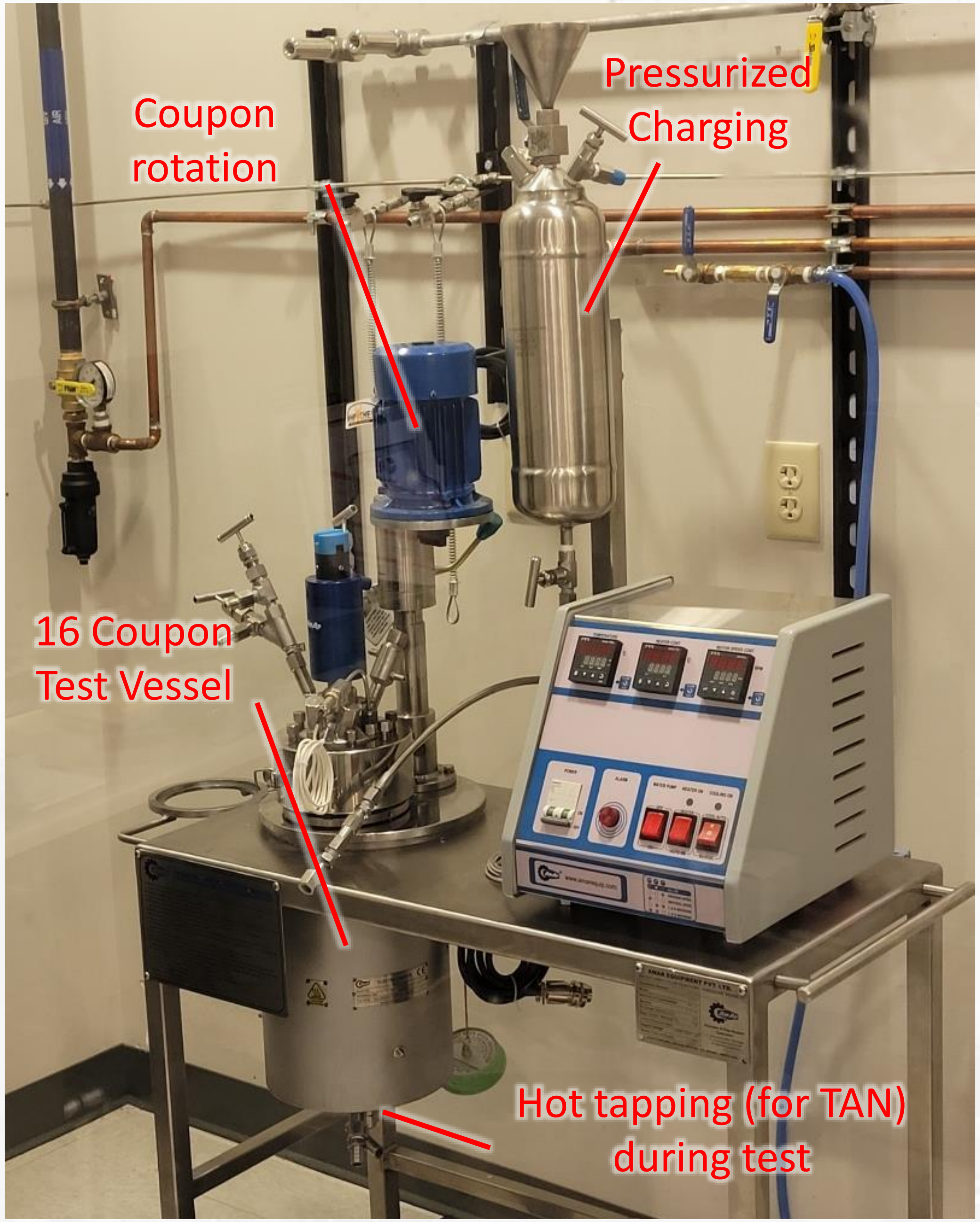
- Feedstocks evaluated,
  - Virgin Soybean (TAN 0, 0 Cl)
  - EU and US producers for retrofit/upgrades.
  - *Brown grease/plant-based oils*
  - *Initial assays*

    *TAN 130-175 mg KOH/g (*ASTM D664)

    Halides (Cl) 0 to 100 mg/kg

- 16 Materials:
  - Wrought alloy SS347, 2.25Cr, 625
  - Weld Overlay 625
  - IGS HVTS alloys

Weight Loss/SEM Evaluation



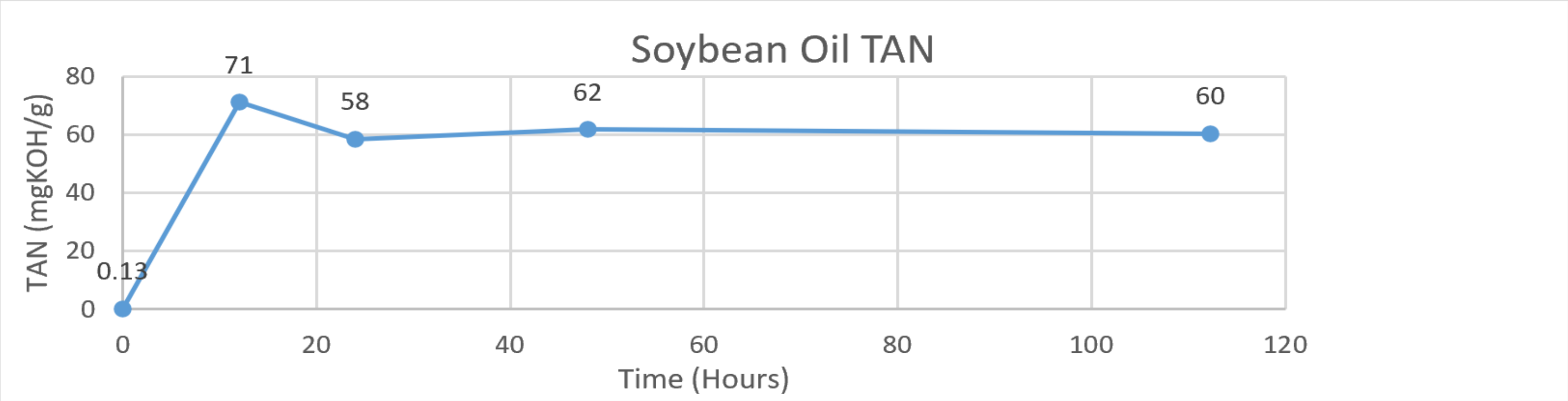
Feedstock Characteristics (FAME)

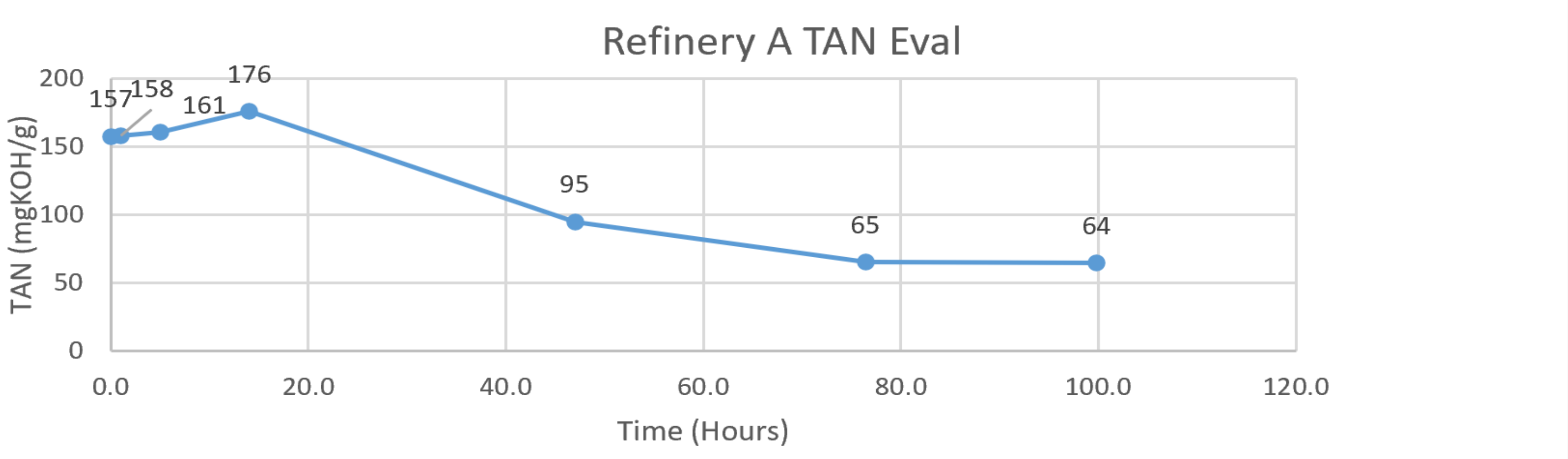
- Lab-scale esterification and FAME analysis performed on feedstocks
- Refinery A** feedstock is likely plant based; Refinery B** feedstock is likely blended, animal fats
- Linoleic Acids are especially corrosive for SS, and Oleic acids are among the most corrosive for CS alloys

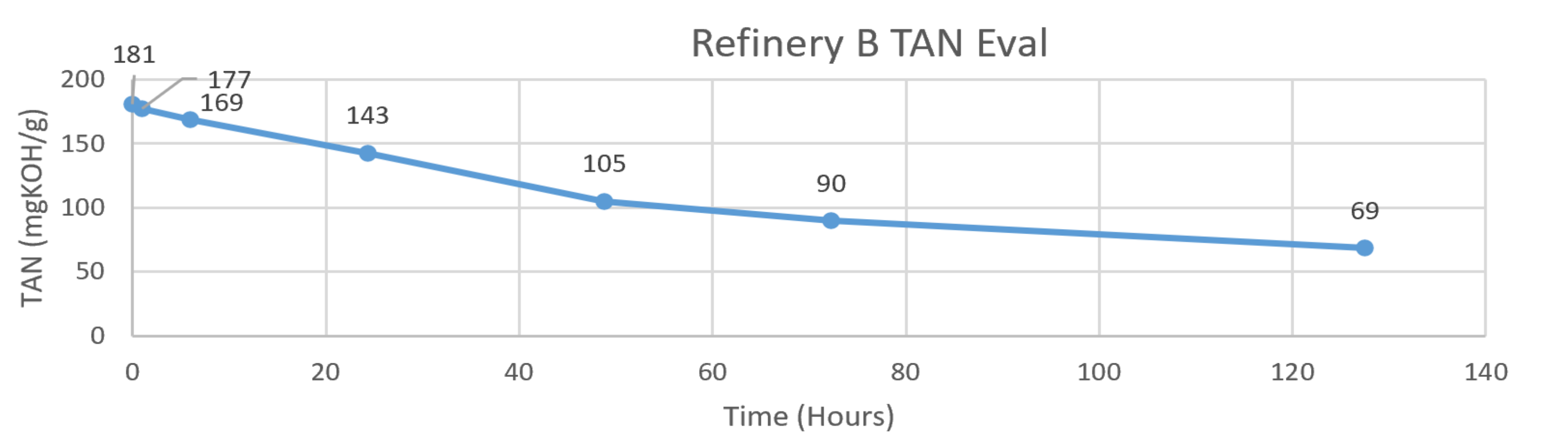
Compound	C-Number	Commercial Soybean Oil	Refinery A Feedstock	Refinery B Feedstock
Methyl Palmitate	C16	37%	20-30%	10-20%
Methyl Stearate	C18	3%	0%	0-10%
Methyl Oleate/Elaidate	C18:1 cis/trans9	42%	30-40%	20%
Methyl Linoleate	C18:2 cis/trans9,12	13%	10-20%	50-60%
Methyl Linolenate	C18:3 cis6-9-12	0%	0-10%	0-10%

****Exact compositional information redacted**

TAN Assessment
(ASTM D664)



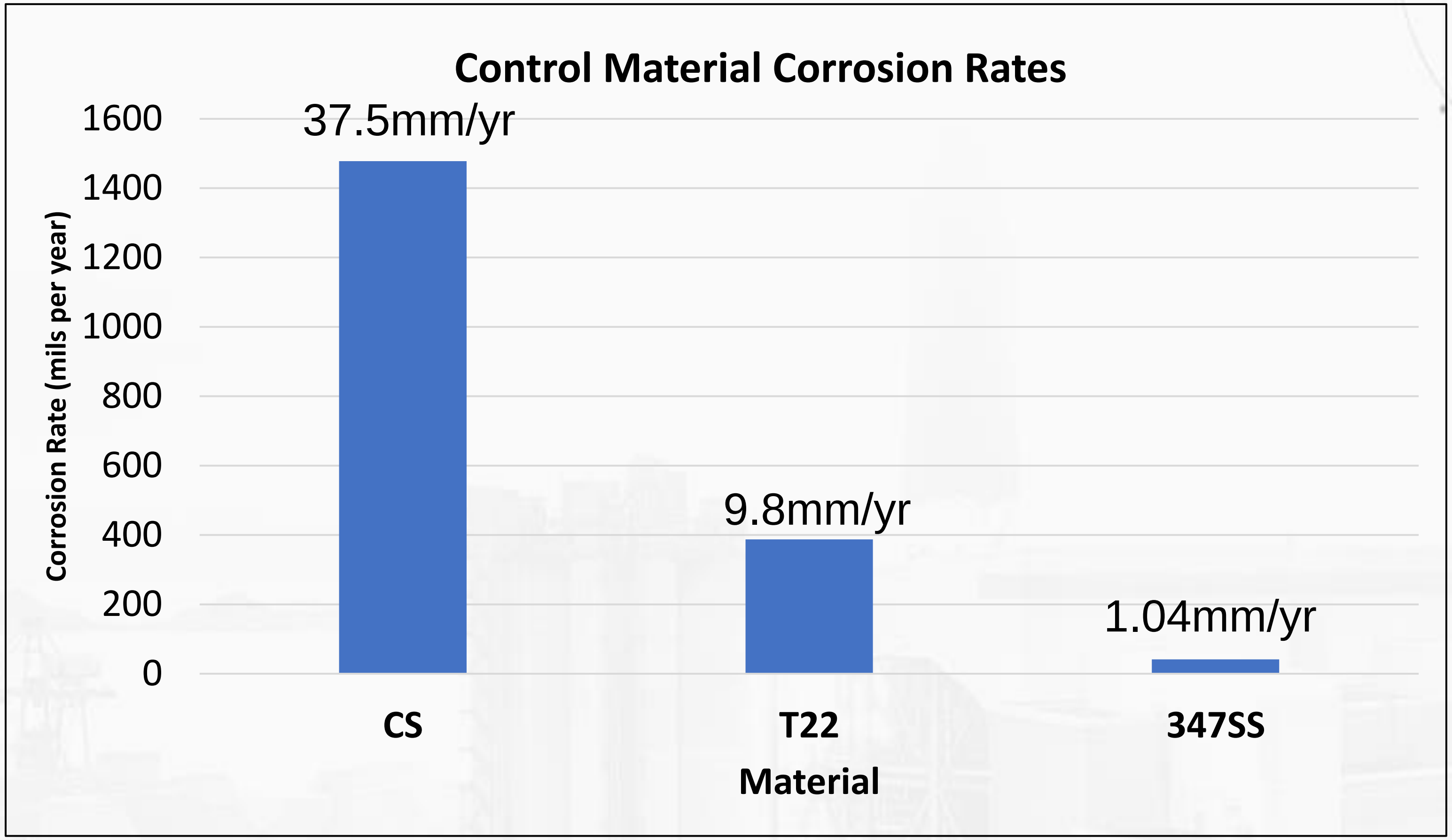




Test Results – Soy Oil

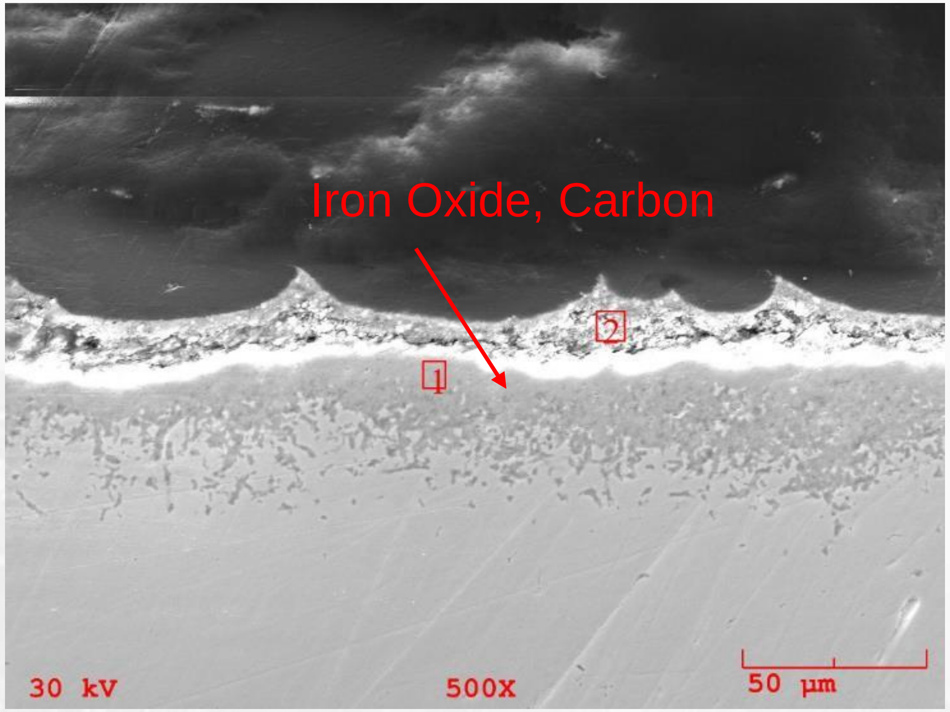
- Coupon thickness loss was determined and converted to annualized thickness loss

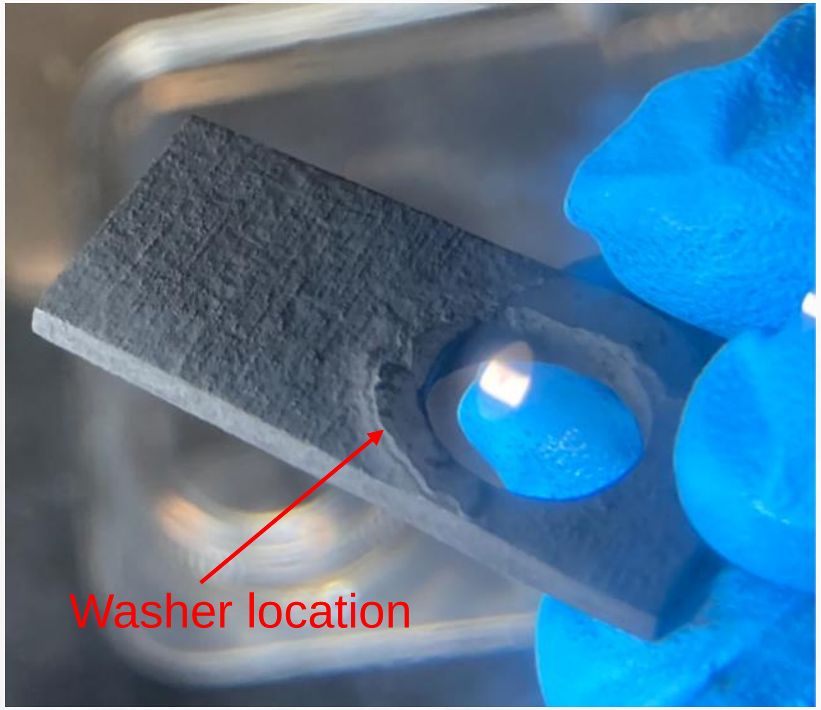
- SEM imaging and EDS used to identify corrosion product



Test Results – Carbon Steel

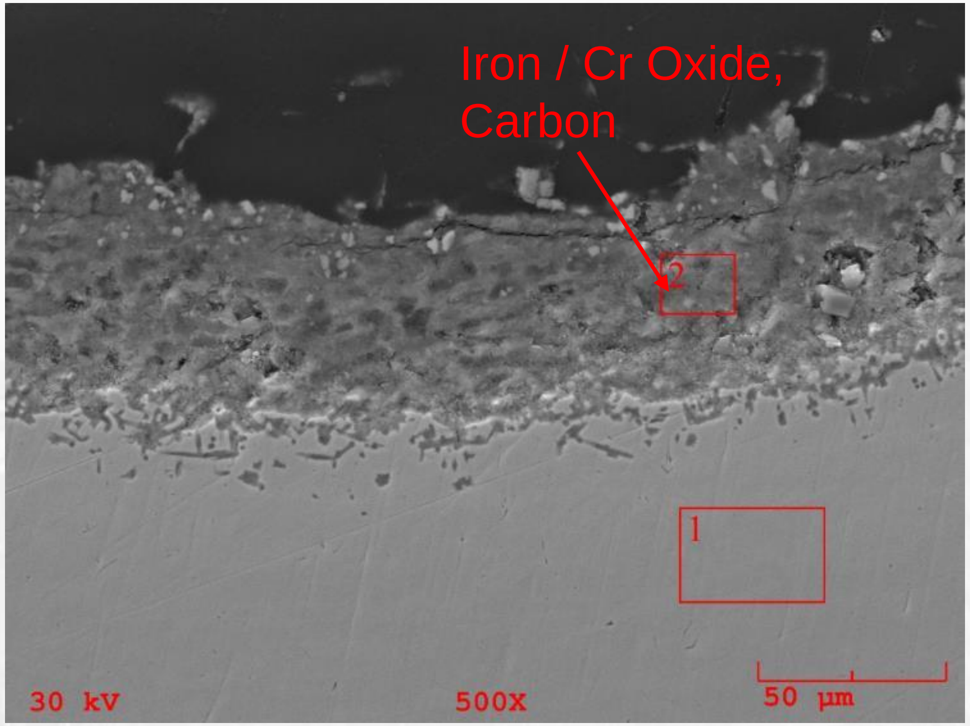
- Significant corrosion deposits and thickness loss – striations from rotation
- Annualized corrosion rate (Approx.) – **37.5 mm per year**





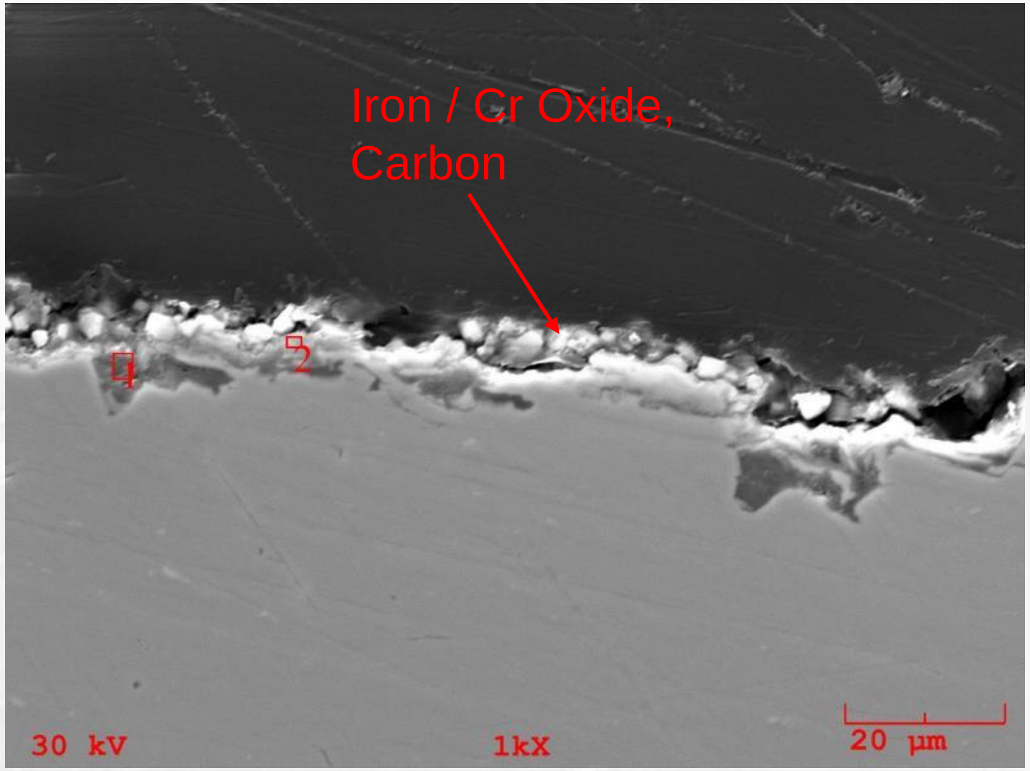
Test Results – (2.25Cr1Mo)

- Significant corrosion deposits and thickness loss
- Annualized corrosion rate (Approx.) – **9.8mm per year**



Test Results – 347SS (18.5Cr11Ni)

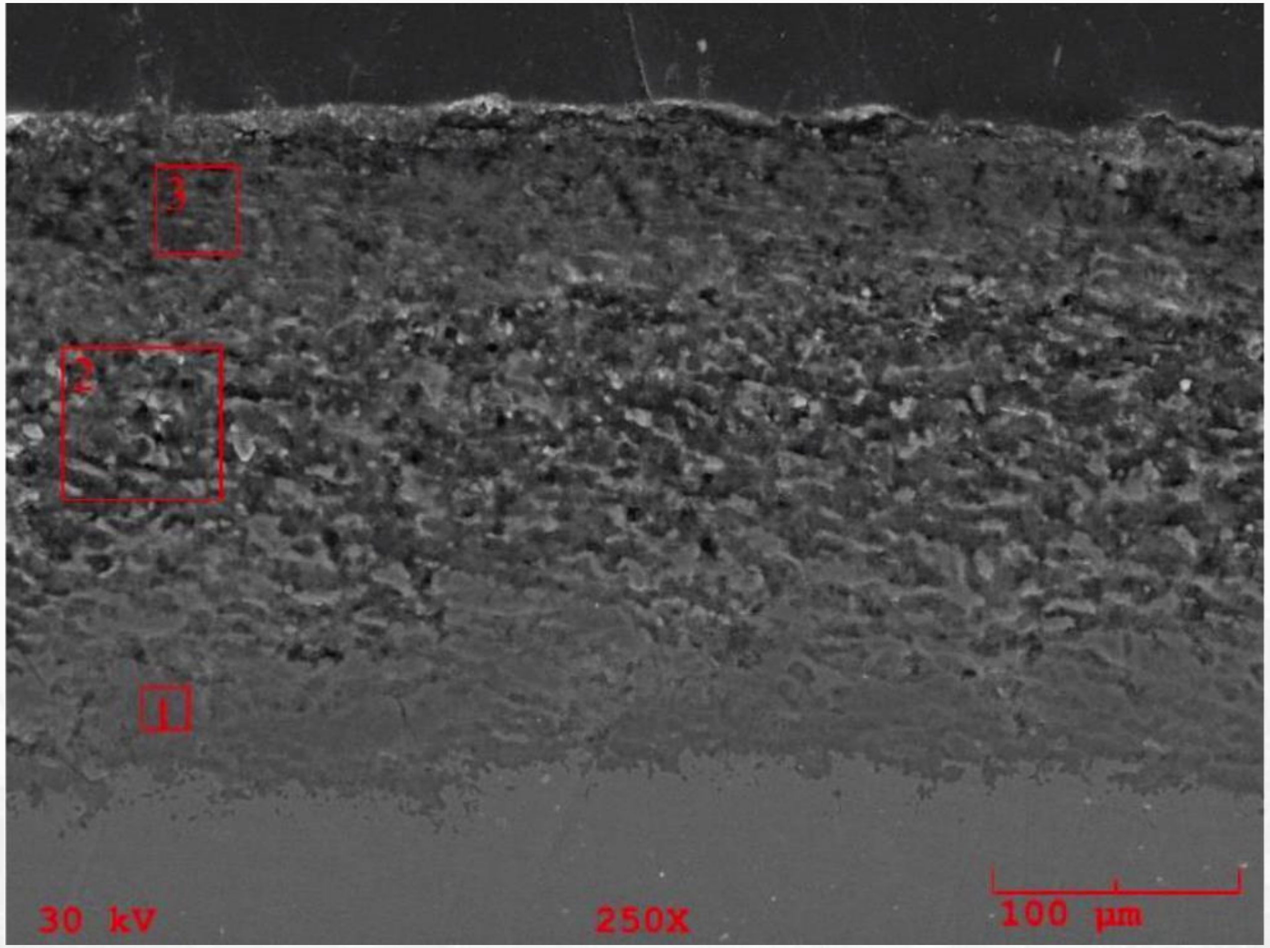
- Relatively minor corrosion deposits and thickness loss
- Annualized corrosion rate (Approx.) – **1.04mm per year**



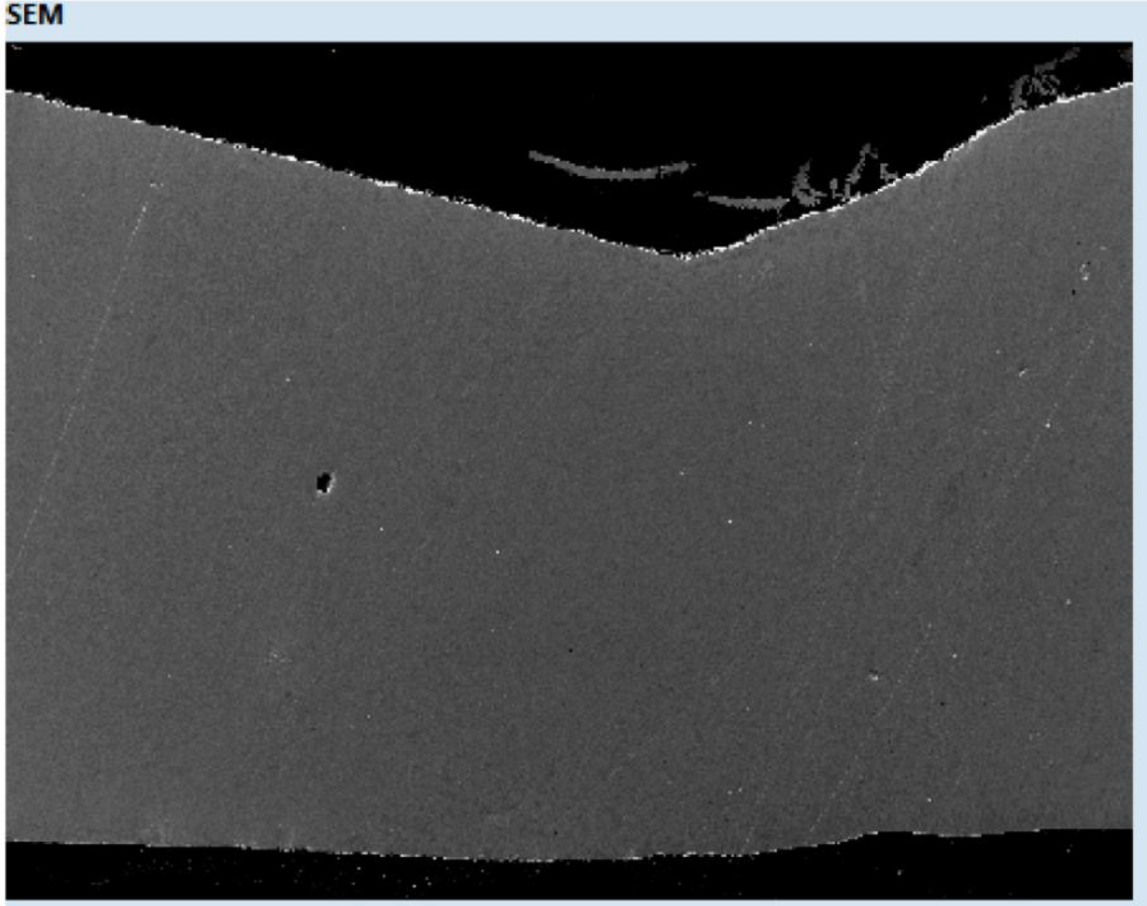
Test Results – Refinery Feedstocks

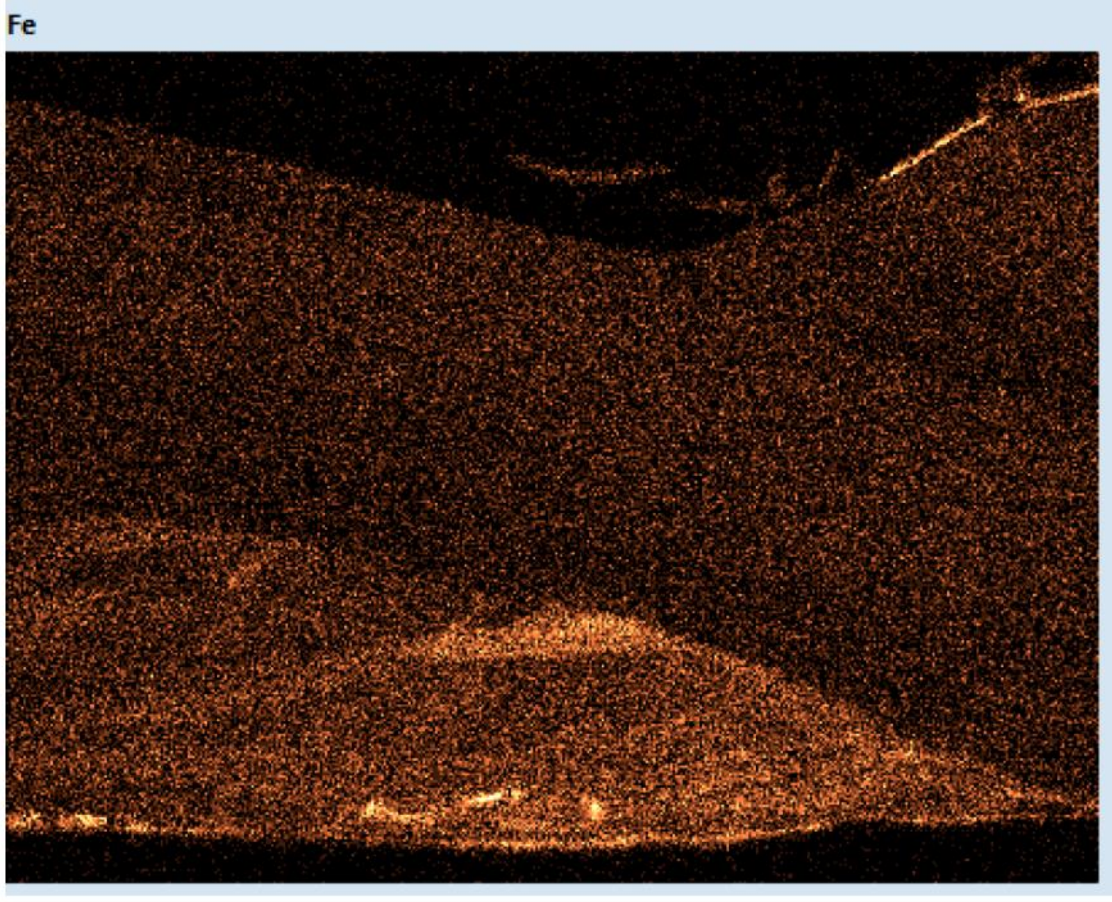
Type	Material	Refinery A Corrosion rate mm/yr	Refinery B Corrosion rate mm/yr	Notes
Wrought Alloy	347 SS	-2.73	-3.56	Uniform / general corrosion
	2.25Cr -1Mo	-19.05	-14.44	Major corrosion - uneven / pitting (local corrosion rate is probably higher)
	HVTS Alloy (Modified NiCrMoXX)	0.10	0.10	Look Untouched - Weight gain is probably feedstock residue / insignificant
	625 WO	-2.26	-2.80	Corrosion primarily on the underside of the WO (Iron dilution weakened material??)
Carbon Steel Clad	HVTS Alloys	0.03	-0.07	Look Untouched - Weight gain/change maybe feedstock residue / insignificant
	HVTS Alloys	0.13	0.07	
	HVTS Alloys	0.18	0.10	
	HVTS Alloys	0.09	0.01	
	HVTS Alloys	0.09	0.02	
347SS Clad	HVTS Alloys	0.63	0.25	Possible weight gain
	HVTS Alloys	1.11	0.27	
	HVTS Alloys		0.02	Look Untouched - Weight gain is probably feedstock residue / insignificant

Test Results – Used oil feed – (2.25Cr1Mo)

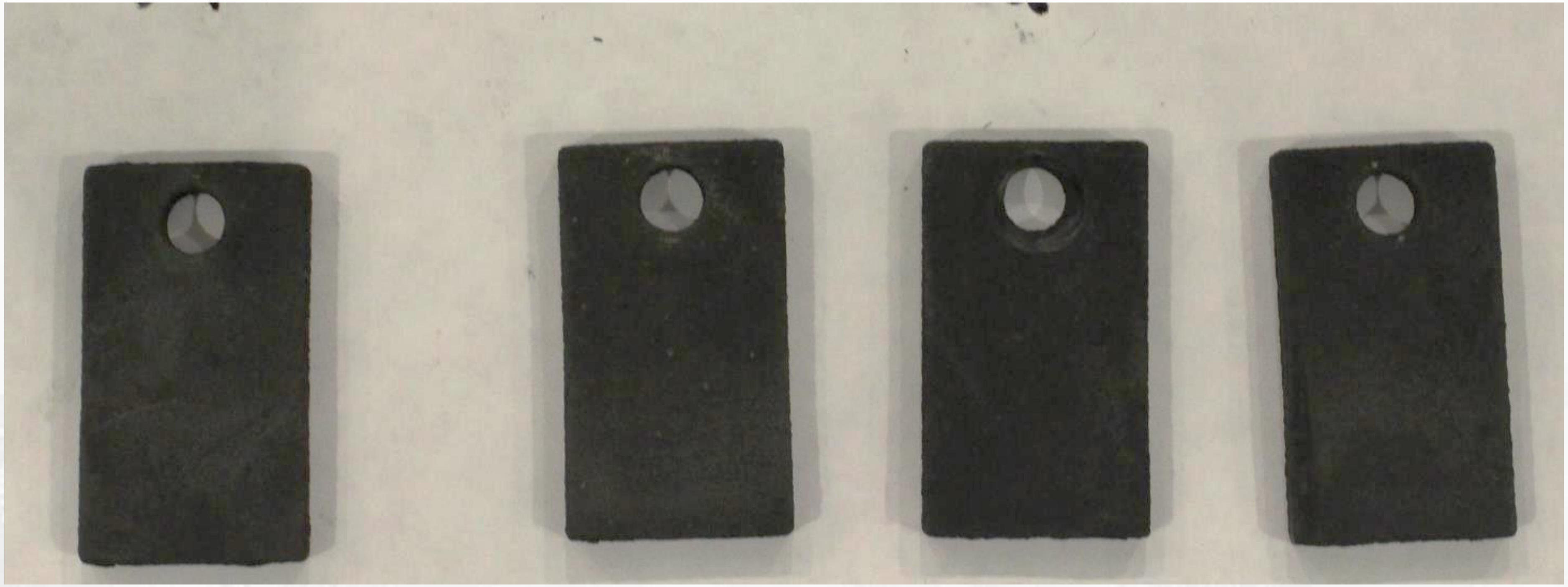


Test Results – Used oil feed – (625 Overlay)



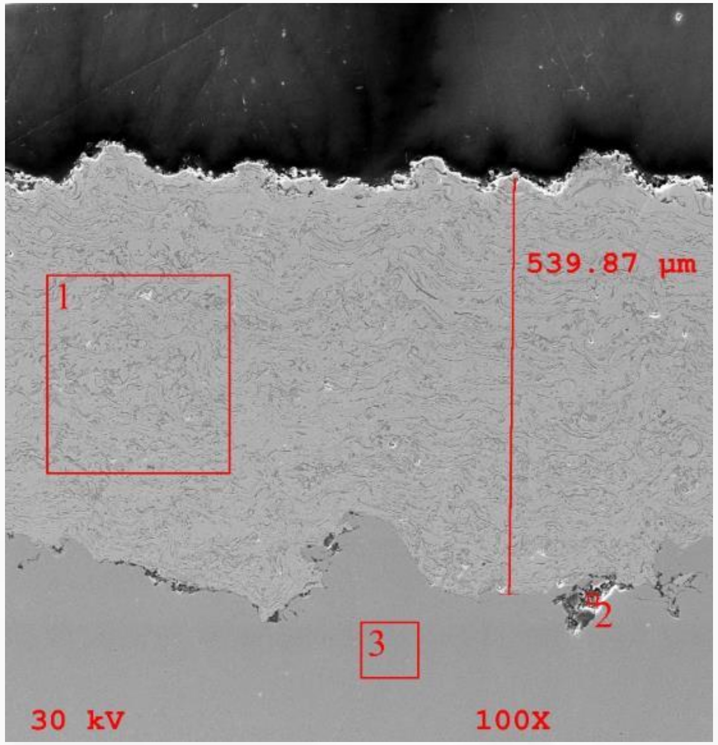


Test Results – HVTS Systems



After Exposure

Test Result – HVTS Alloy



- No corrosive media penetration – substrate protected
- Negligible HVTS thickness loss / attack

PRESENTATION CONTENT:

- THERMAL SPRAY TECHNOLOGY FOR VESSELS
- RENEWABLE FUEL APPLICATION
- MATERIAL PERFORMANCE QUALIFICATION
- CASE STUDY
- Q AND A

Conclusion and Q/A

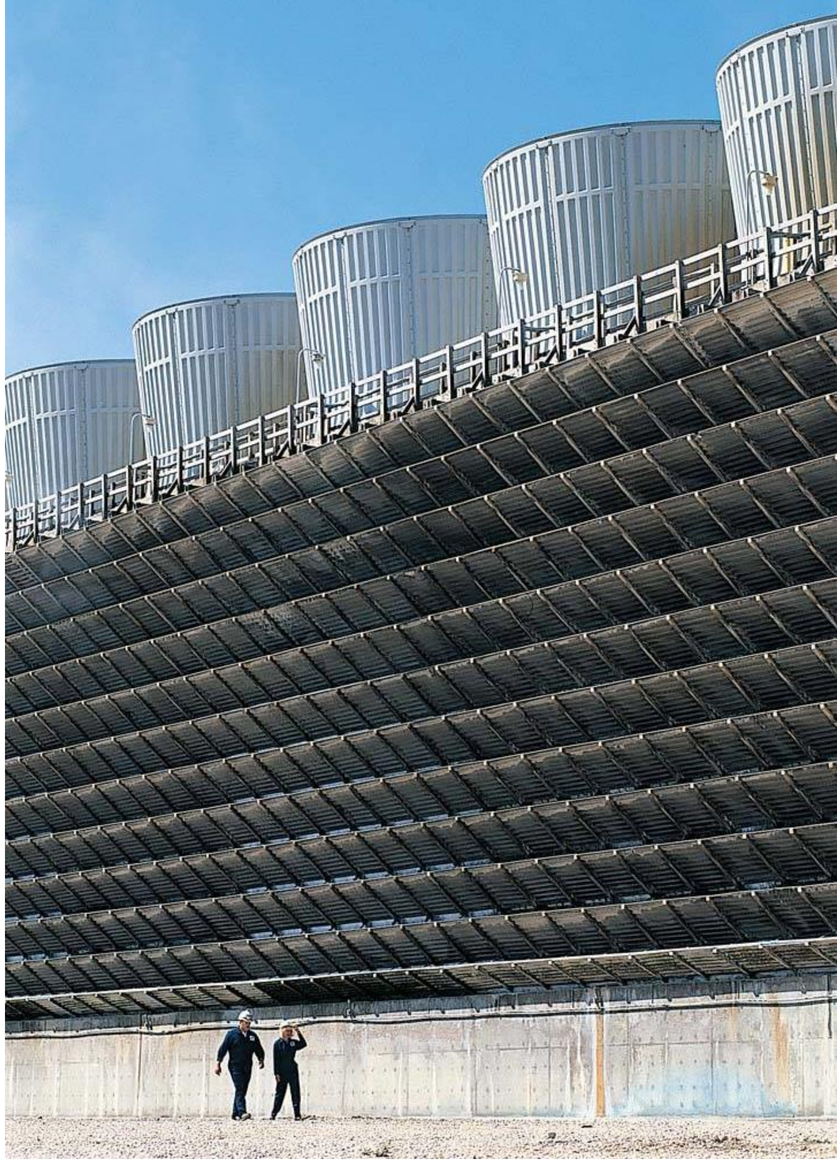
- HVTS cladding technology has been evaluated against controls for use in renewable upgrade / refurb to mitigate damage mechanisms associated with the corrosive feed.
- Rigorous performance qualification is required, with engineering standards, qualifications, and procedures are required.
- Advanced refinery feed-specific corrosion assessments have been conducted, further work to look at impact of FAME + bad actors needs to be conducted.

Appendix 4

How an integrated solution for heat exchangers and water systems can manage critical assets and anticipate performance to optimize productivity

(Valerie Bour-Beucler)

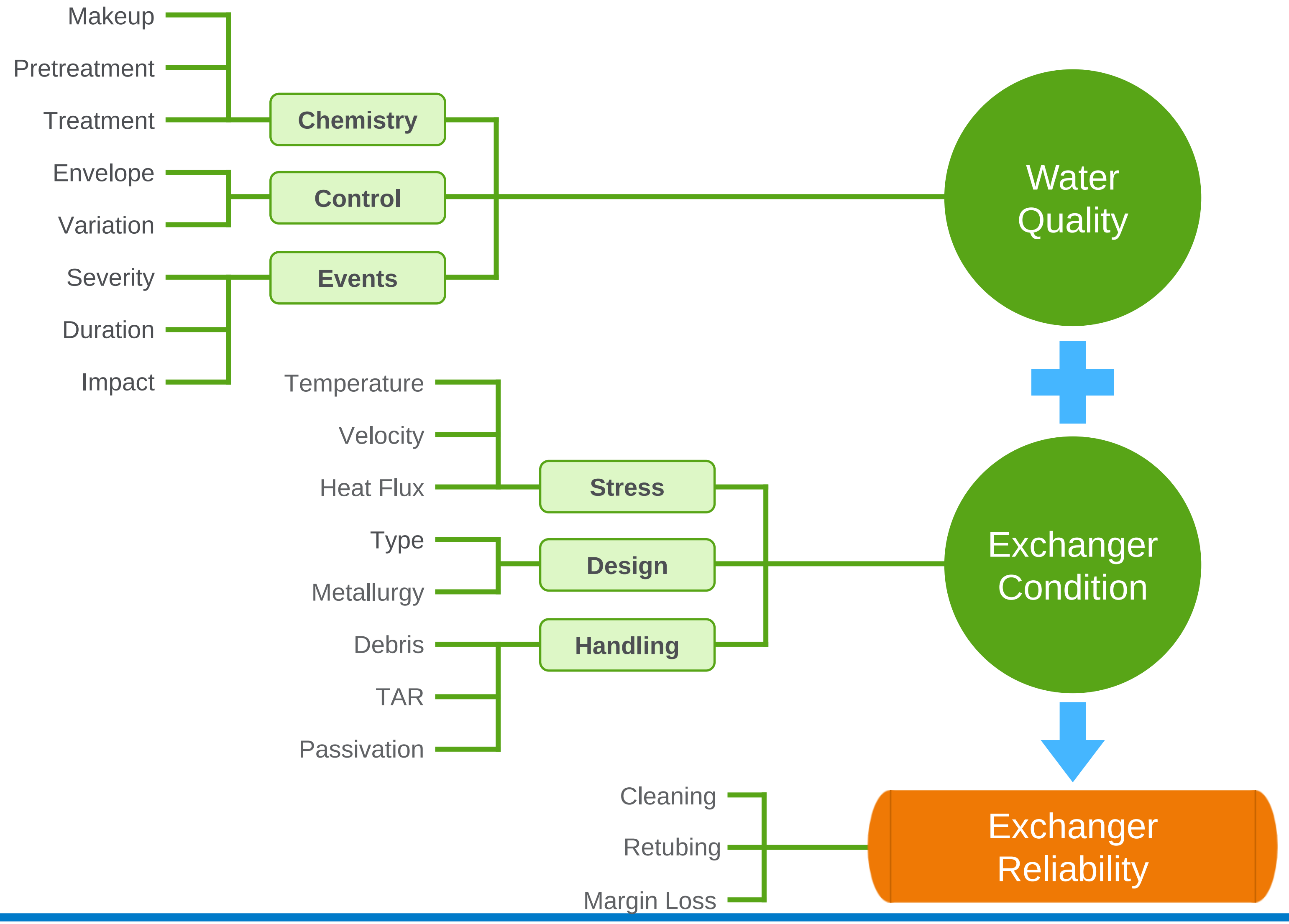
HOW AN INTEGRATED SOLUTION FOR HEAT EXCHANGERS CAN MANAGE CRITICAL ASSETS AND ANTICIPATE PERFORMANCE TO OPTIMIZE PRODUCTIVITY



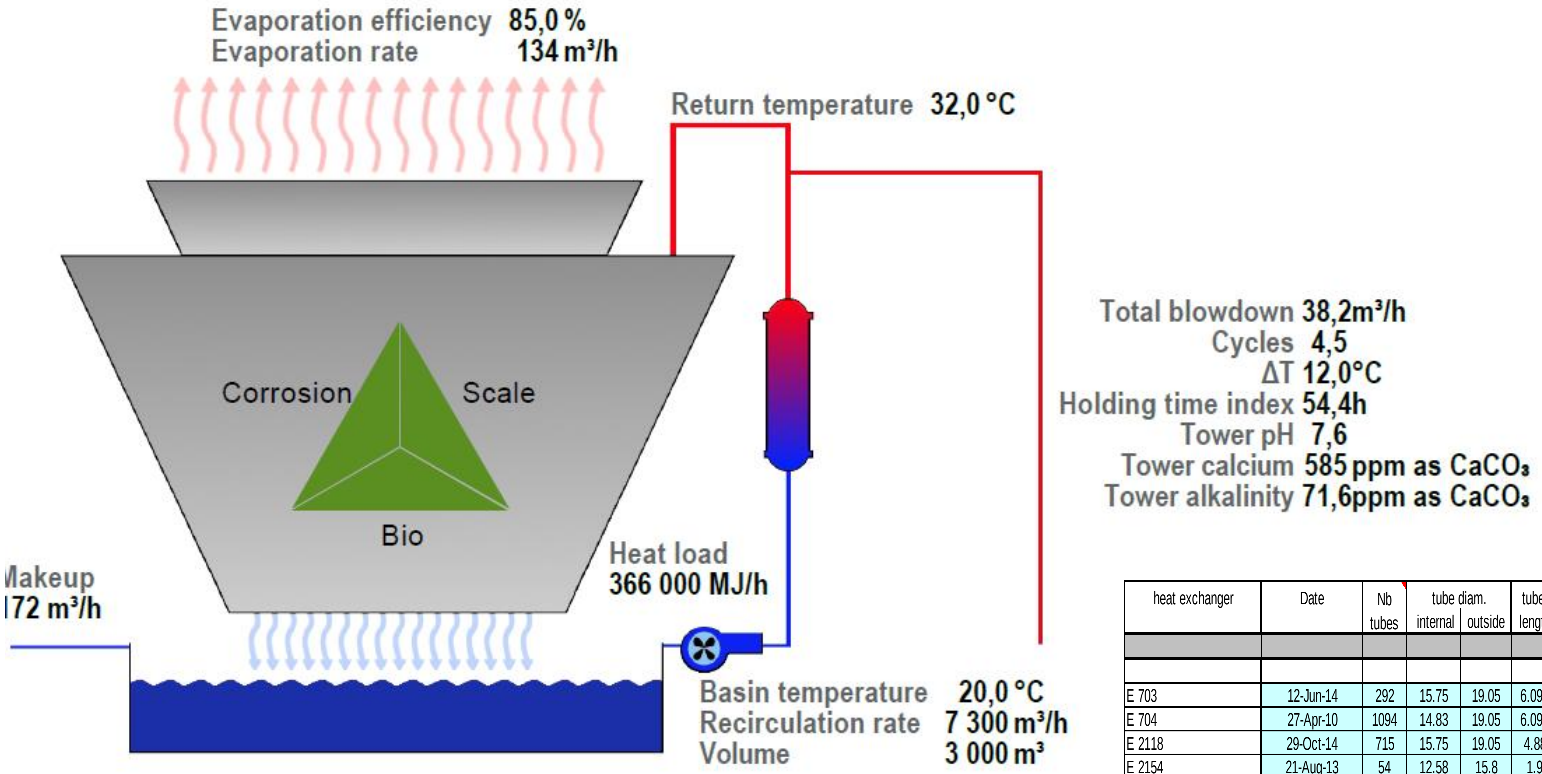
Valerie Bour Beucler

Eurocorr 2022 Berlin 2022 September 1st

MANAGING RELIABILITY



HEAT EXCHANGER STRESS

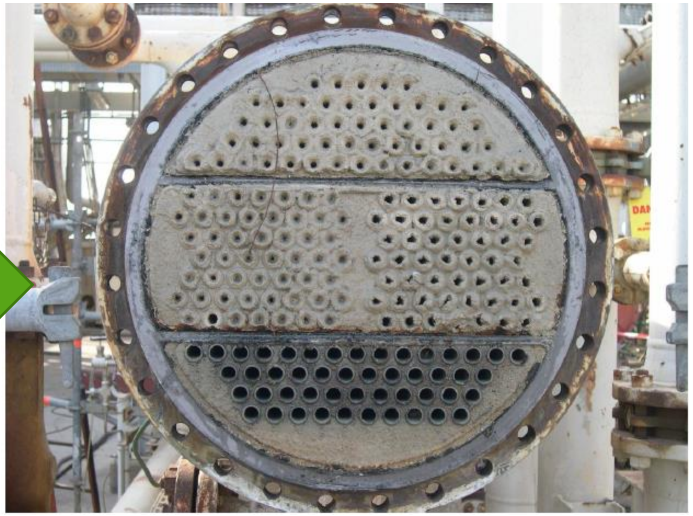


- ✓Velocity
- ✓Skin Temperture
- ✓Heat flux

heat exchanger	Date	Nb tubes	tube diam. internal	tube diam. outside	tube length	Nb passes	water flow	water Temp in	water Temp out	process Temp in	process Temp out	Δ Temp water	LMTD	heat load kW	heat flux kW m2 h	Skin Temp normal	Skin Temp highest	TTD approach	Velocity m/s	Re	U coeff	surface m2
E 703	12-Jun-14	292	15.75	19.05	6.096	2	234	21	25	63	47	4	32	1 088	12	26	46	26.0	2.3	41 537	0.39	107
E 704	27-Apr-10	1094	14.83	19.05	6.096	2	548	17	18	22	19	1	3	637	2	18	20	2.0	1.6	23 808	0.71	399
E 2118	29-Oct-14	715	15.75	19.05	4.88	2	126	21	22	36	29	1	11	146	1	22	30	8.0	0.5	8 604	0.08	209
E 2154	21-Aug-13	54	12.58	15.8	1.9	2	13	24	25	50	42	2	21	29	7	27	39	18.5	1.1	16 106	0.34	5
E 306	15-Oct-14	790	14.83	19.05	6.096	2	284	22	26	131	27	4	33	1 221	5	27	87	5.1	1.2	20 018	0.16	288
E 324	9-Oct-13	96	16.65	19.05	3.8	2	34	19	20	67	21	1	15	36	2	20	48	2.2	0.9	15 578	0.13	22
E 2308	29-Oct-14	110	15.75	19.05	3.58	2	61	22	25	129	27	3	33	213	11	27	86	5.0	1.6	28 743	0.33	24
E 2309	29-Oct-14	68	15.75	19.05	1.4	2	61	25	26	82	28	1	18	43	9	27	60	2.7	2.6	47 302	0.51	6
E 2310	12-Jun-14	164	15.75	19.05	4.88	2	87	21	21	83	21	0	12	20	1	21	58	0.3	1.5	25 313	0.04	48
E 2602	12-Jun-14	526	15.75	19.05	4.5	6	98	21	35	103	25	14	23	1 640	14	38	70	4.2	1.6	34 687	0.61	142
E 612	29-May-14	88	15.75	19.05	6.096	4	23	20	33	36	32	13	6	347	13	35	30	12.0	1.5	31 276	2.02	32
E 613	29-May-14	114	15.75	19.05	6.096	2	68	17	27	55	27	10	17	766	22	31	40	9.7	1.7	32 107	1.29	42
E 1906	13-Aug-14	42	15.75	19.05	1.524	2	10	23	30	118	76	8	69	92	29	42	80	53.5	0.7	13 624	0.42	4

Lab analyses	units	setpoint	mean	min	max	st. dev.	in spec
pH		8,7 - 9,2	8,8	8,7	9,1	0,1	100%
Calcium Hardness	ppm CaCO3	350 - 550	438	396	496	30	100%
M-alkaliteit	ppm CaCO3	285 - 360	338	328	344	4	100%
Ortho PO4	ppm PO4	< 1	0,3	0,2	0,5	0,1	100%
Iron	ppm Fe	< 1	0,084	0,039	0,240	0,050	100%
turbidity	FAU	< 5	2,0	0,0	4,0	1,2	100%
free halogen return	ppm CL2	0,1 - 0,8	0,37	0,10	0,60	0,17	100%
Total ATP	RLU	< 600	91	21	234	55	100%
Microbieel ATP	RLU	< 300	37	4	89	25	100%

Corrosion inhibition	unit	KPI set	KPI result	% on target
mild steel corrosion (coupon)	mpy	< 0,5	0,5	100%
Cu/Nicorrosion (coupon)	mpy	< 0,3	<0,1	100%
iron	ppm Fe	< 0,5	0,05	100%
MS (localized corrosion)		no	yes	
Cu/Ni (localized corrosion)		no		
Deposit inhibition				
visual inspection corrosion coupons		no	no	100%
flow drop since TA	%	< 5%	?	100%
Microbio inhibition				
Microbiology	CFU/ml	<10.000		100%
SRB	CFU/ml	< 1		100%
legionella	CFU/liter	< 1000		100%
Leak detection				
oil/grease	ppb	< 200		
AOX		< 0,8	0,36	100%

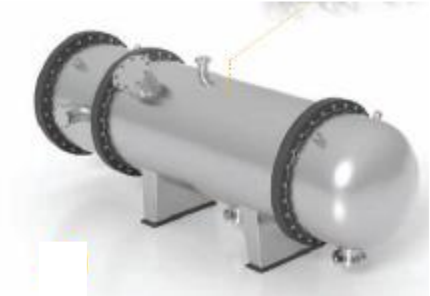


WHAT IS OMNI™?

Digital evolution of treatment programs, focusing on customer's outcomes, maximizing reliability and profitability.

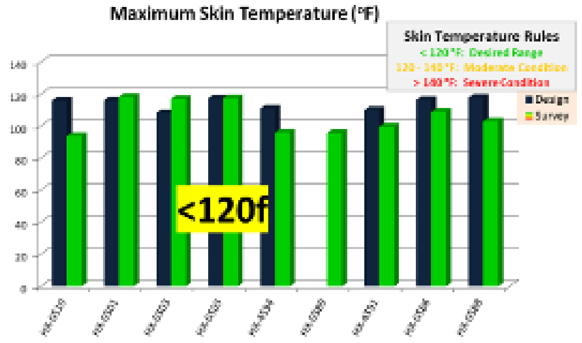
OMNI™ HX brings Cooling Water control program to a new level.

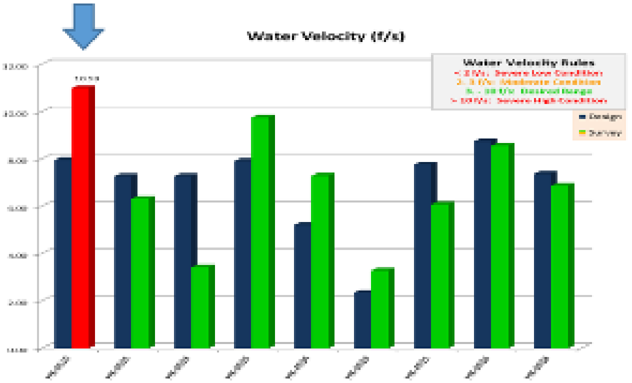
From the controlling water chemistry to controlling based on customer core KPI: Heat Exchanger Performance.

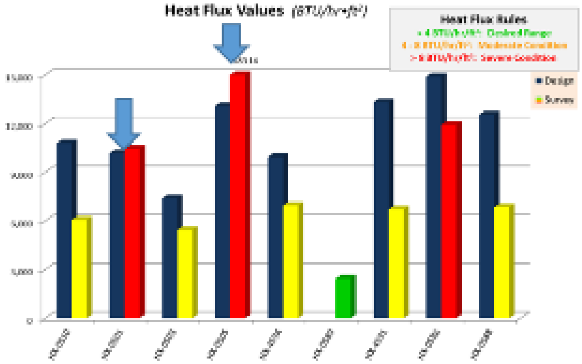


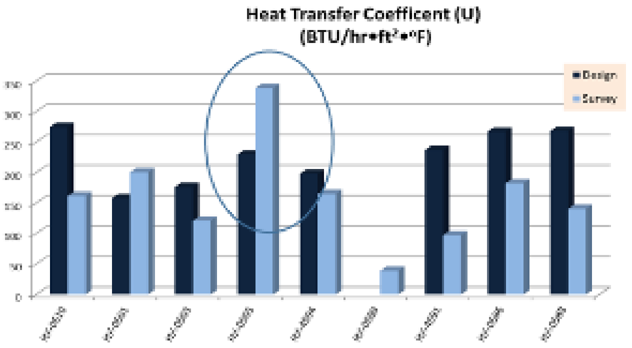
OMNI™ HX AUDITS

- First step for OMNI™ implementation.
- Heat Exchangers selection: based on audit to understand historic problems / criticity, as many as needed.
- Benchmark of stress KPIs used to select the most critical exchangers for OMNI implementation.
- Audits can be routinely repeated every year also to take decisions on cleaning maintenance and optimize general T/A works.





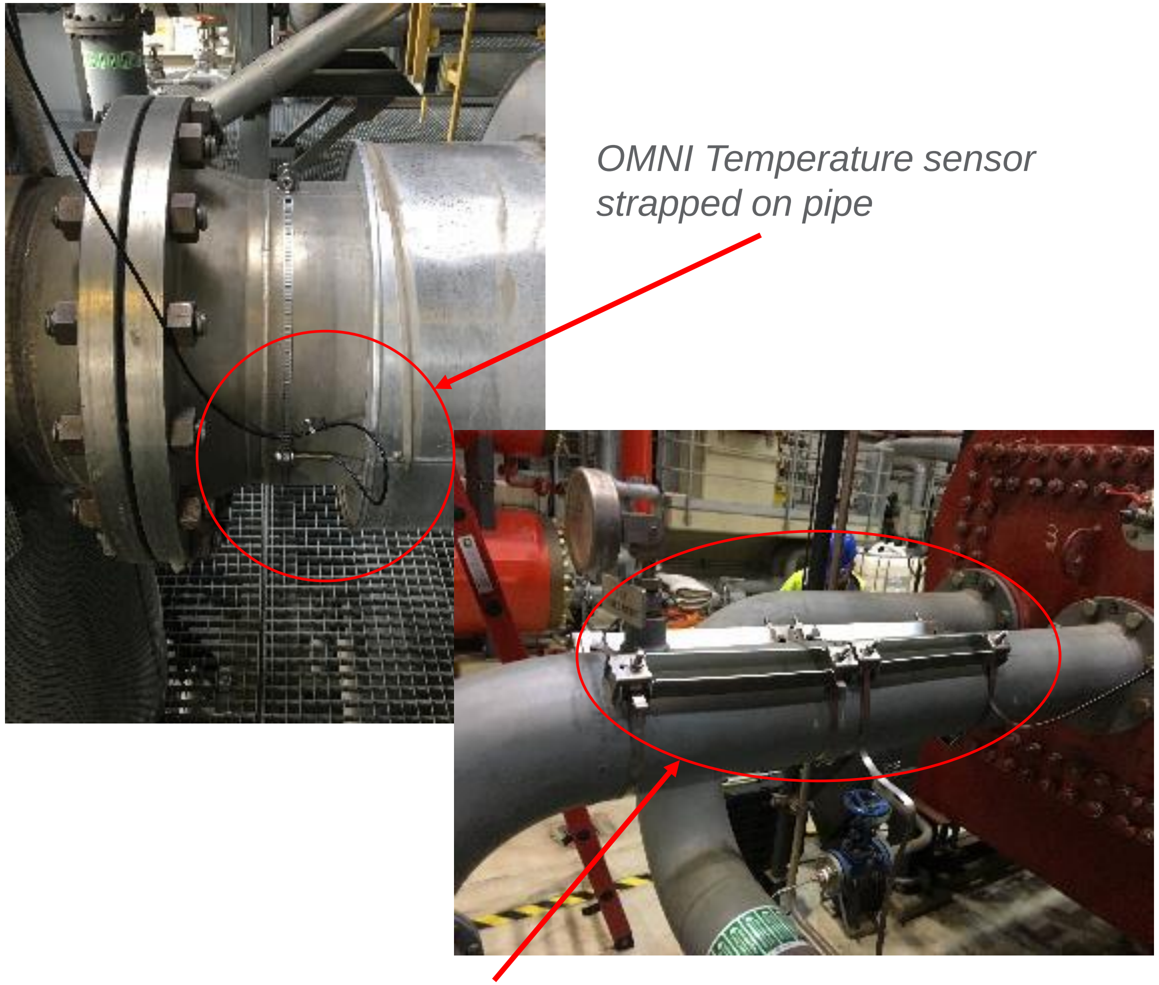




OMNI™ HX SENSORS

Installation:

- Non-invasive, strap-on sensors.
- Installed on-line, no to customer operations.
- Low plant involvement: Power supply and permits.
  - Sometimes insulation removal requested.
- 4 Temperature Sensors:
  - CW and Process in/out
- CW Flow measurement
  - Ultrasonic technolology
- Wireless data transmission into the cloud.



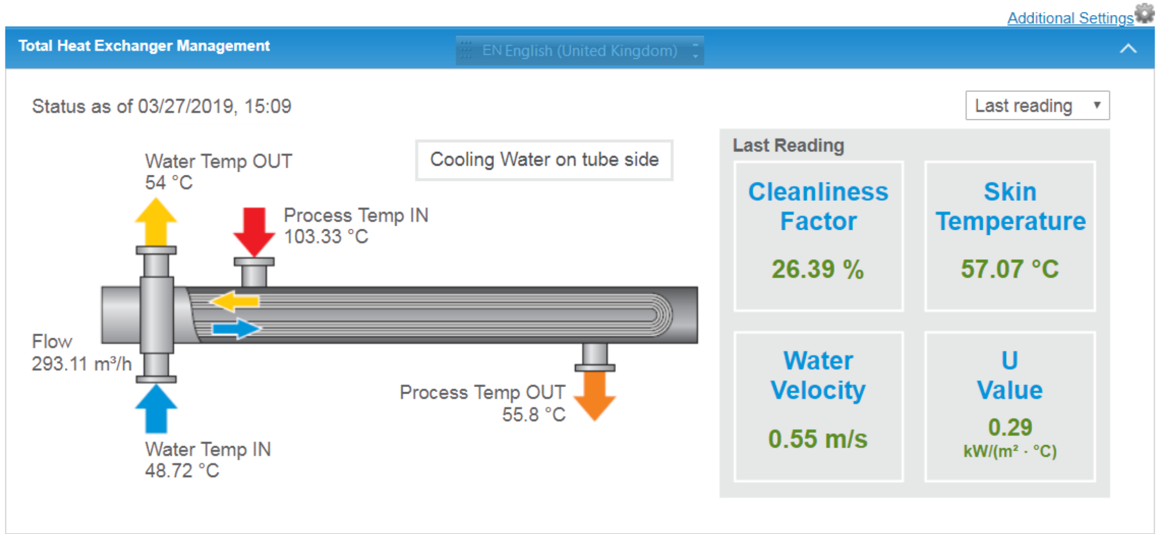
OMNI Temperature sensor strapped on pipe

OMNI Flow meter on CW inlet pipe

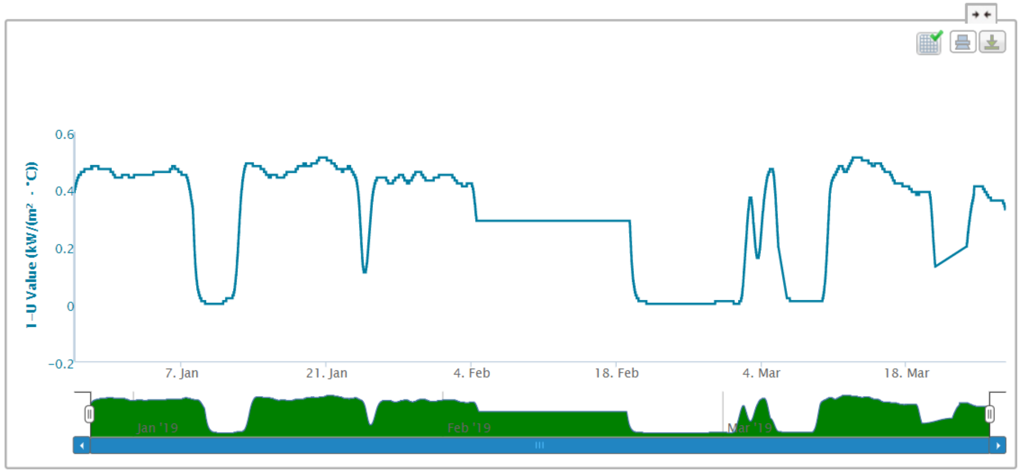
OMNI™ HX SENSORS

Insights & Control:

- Real-time key CW stress parameters:
  - Skin Temperature
  - Water velocity
  - Heat Flux
- Real-time U value (Heat Transfer Coefficient)
  - HX most important KPI
- Data analytics and availability in the cloud and via enVision platform.
- Take Mechanical, Chemical and Operational actions to reduce stress and recover performance.
- Patent-pending technology.

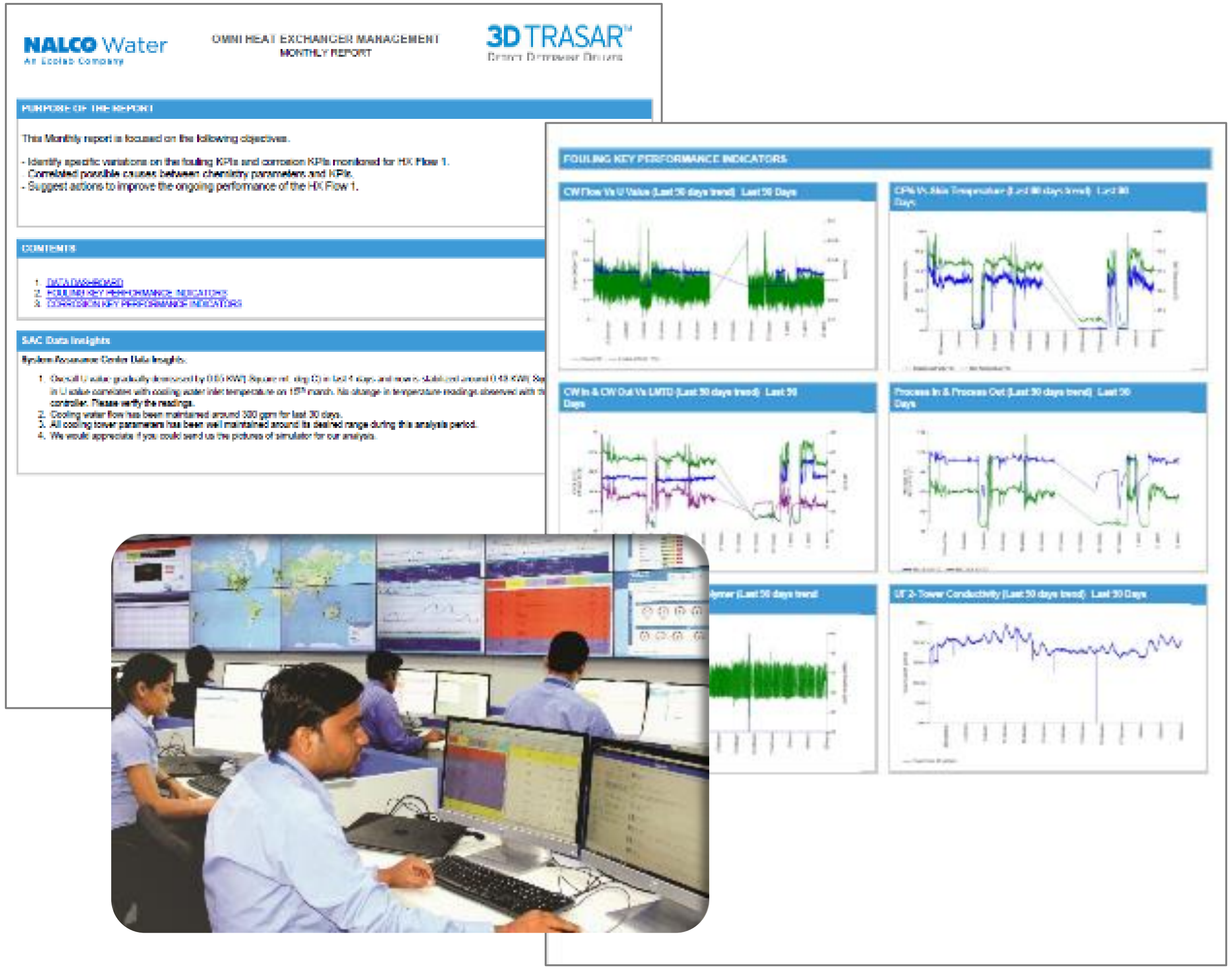


OMNI™ HX interface in enVision.

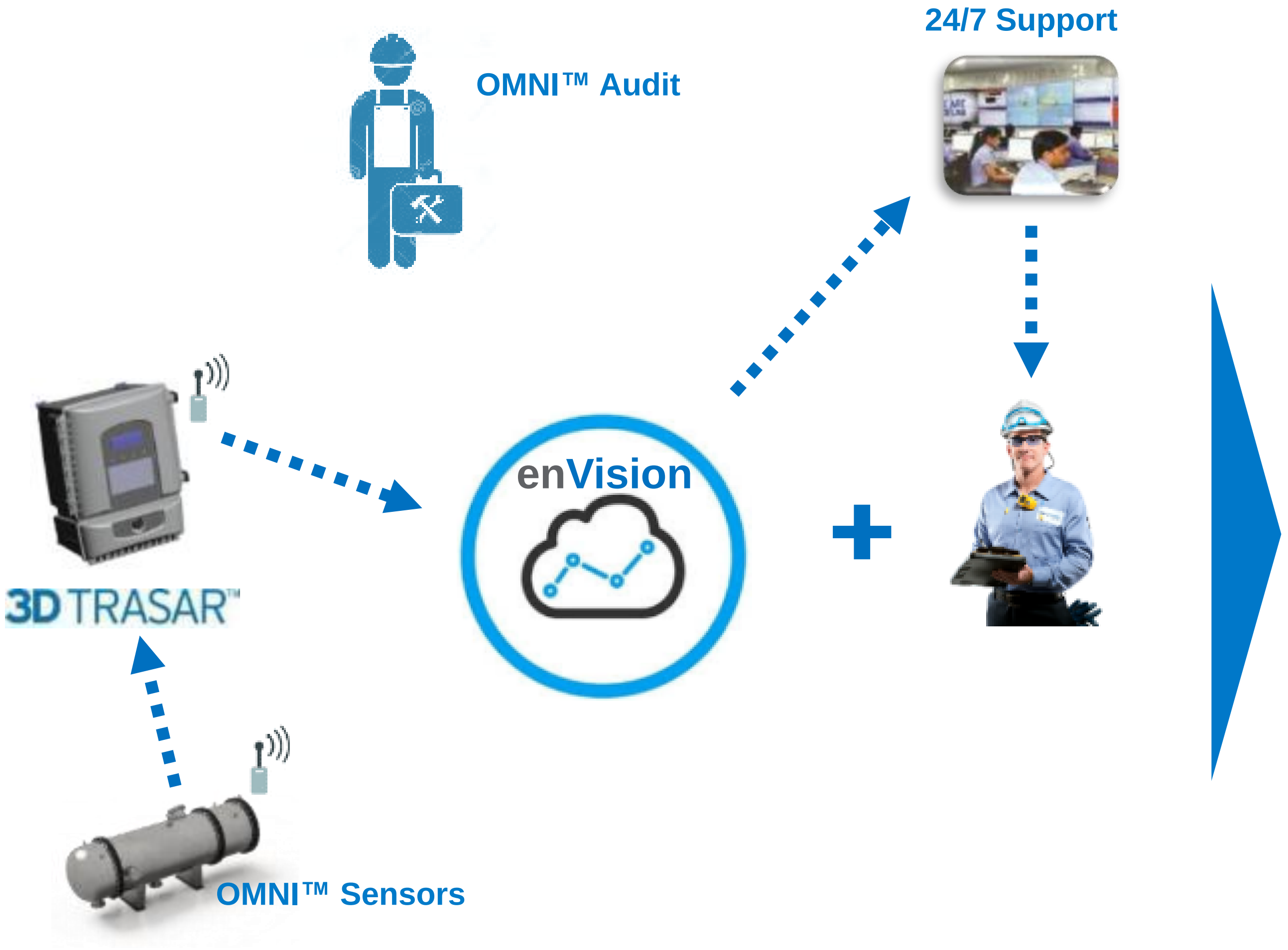


SYSTEM ASSURANCE CENTER (SAC)

- Trained chemical engineers follow all our 3DTRASAR™ and OMNI™ systems globally.
- 24 / 7 / 365 coverage.
- Immediate alarms in case of detection of HX performance deviation.
- Monthly report with trends analysis.
- Faster reaction time.



OMNI™ HX IN A SNAPSHOT



Reliability

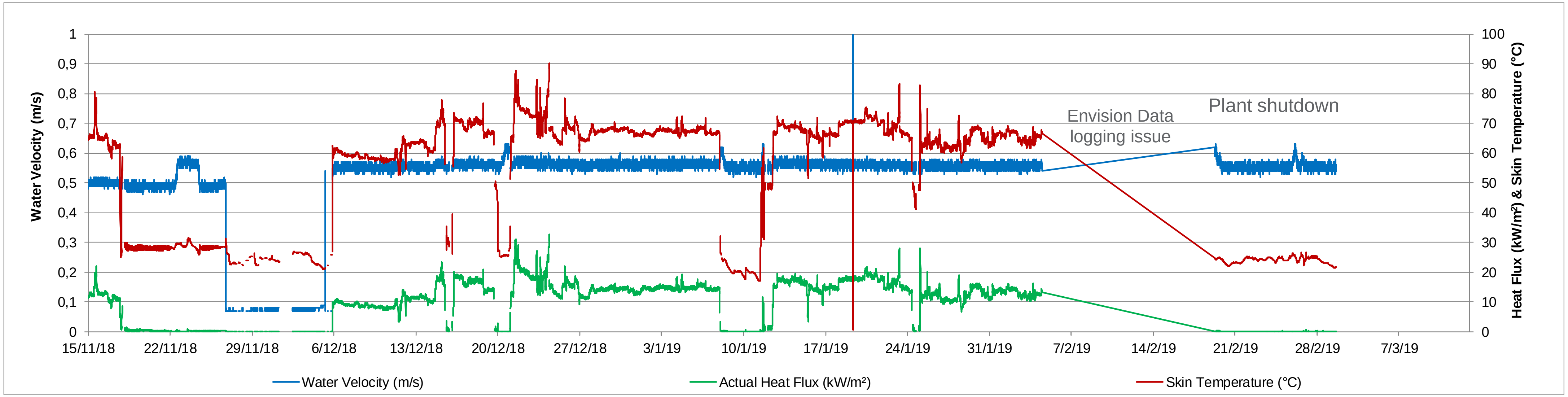
- **Prevent** downtime and lost production
- **Prolong** asset life
- **Predict** maintenance and production enhancements

Profitability

- **Extend** run lengths
- **Increase** output
- **Reduce** energy consumption (MWh)

OMNI™ HX SENSORS – EU CASE STUDY

OMNI™ statistical analysis unveils extreme skin temperature conditions.



SKIN TEMPERATURE STATISTICS

% Time	Skin Temp.	Stress Level
1,7%	< 50 C	Mild Stress
9,7%	50-60 C	Moderate Stress
72,8%	60-70 C	High Stress
15,9%	> 70 C	Severe Stress

Design max: 46 C

WATER VELOCITY STATISTICS

% Time	Velocity	Stress Level
0,0%	> 1 m/s	Mild Stress
0,0%	0.6 - 1 m/s	Moderate Stress
100,0%	0.3 - 0.6 m/s	High Stress
0,0%	< 0.3 m/s	Severe Stress

Design: 1.50 m/s

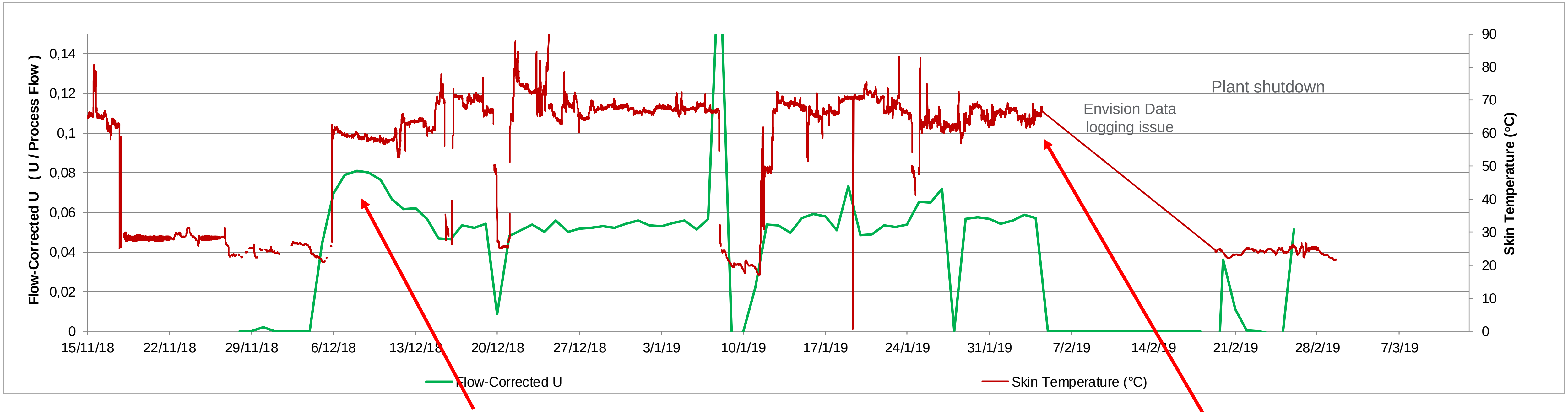
HEAT FLUX STATISTICS

% Time	Velocity	Stress Level
2,7%	< 7.5 kW/m2	Mild Stress
96,7%	7.5 - 25 kW/m2	Moderate Stress
0,6%	25 - 40 kW/m2	High Stress
0,0%	> 40 kW/m2	Severe Stress

Design: 24.8 kW/m2

OMNI™ HX SENSORS – EU CASE STUDY

OMNI™ unveils a scaling incident not detected by plant or CW chemistry..



H6804 in service again on 6/12. Initial Flow-Corrected U is high at 0.08 but it quickly decreases to 0.05 in a week time. Why?

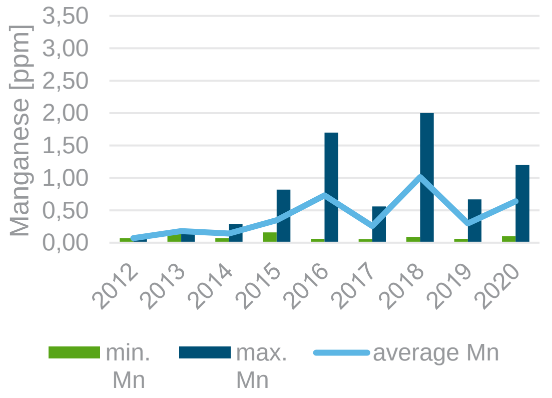
- Same CW flow
- Same CW Inlet T
- But increasing Process Inlet T and Skin T → Scaling?

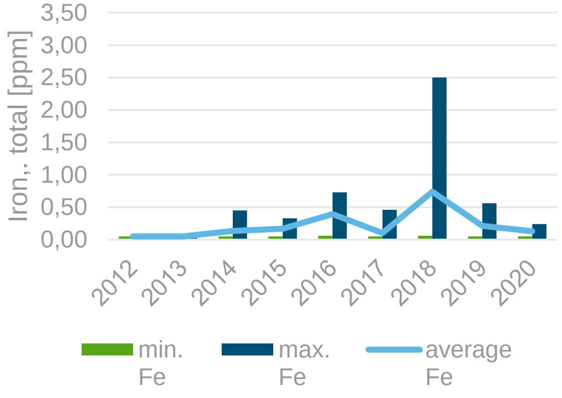
Process Inlet T back to initial values of 6/12 but Skin T higher than initial → Indication of insulation due to scale accumulated?

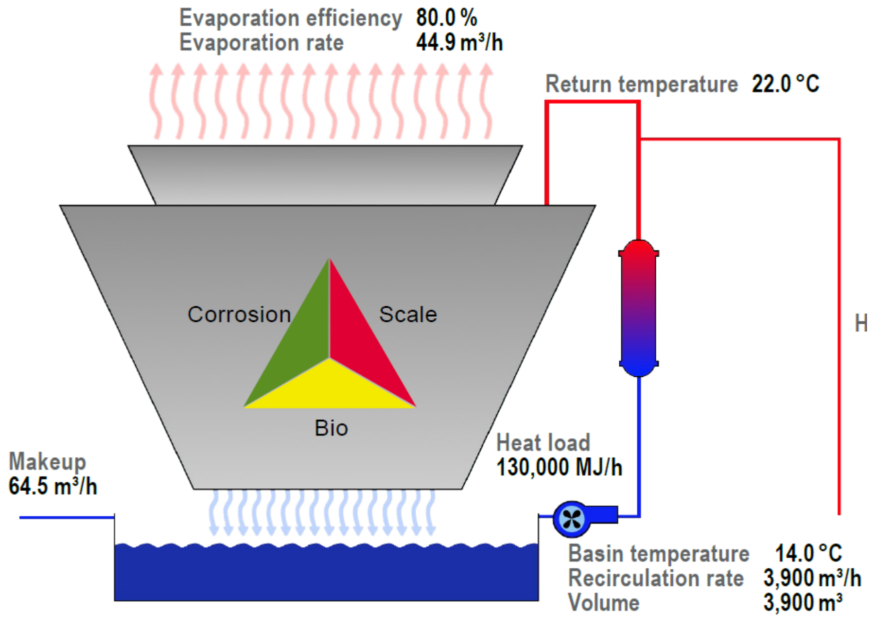
HISTORICAL BACKGROUND

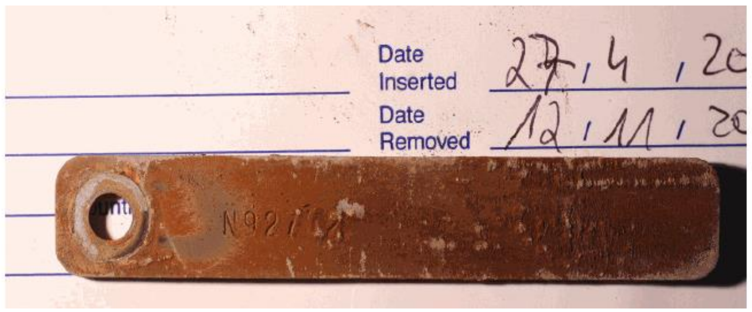
The cooling circuit had its “challenges”

- MU: Reuse of effluent (no filtration in place)
- Fe, Mn and Zn will consume polymer, sufficient active polymer is needed to prevent scale formation
- Biocide: Ozone – degrades tag, but also the polymer





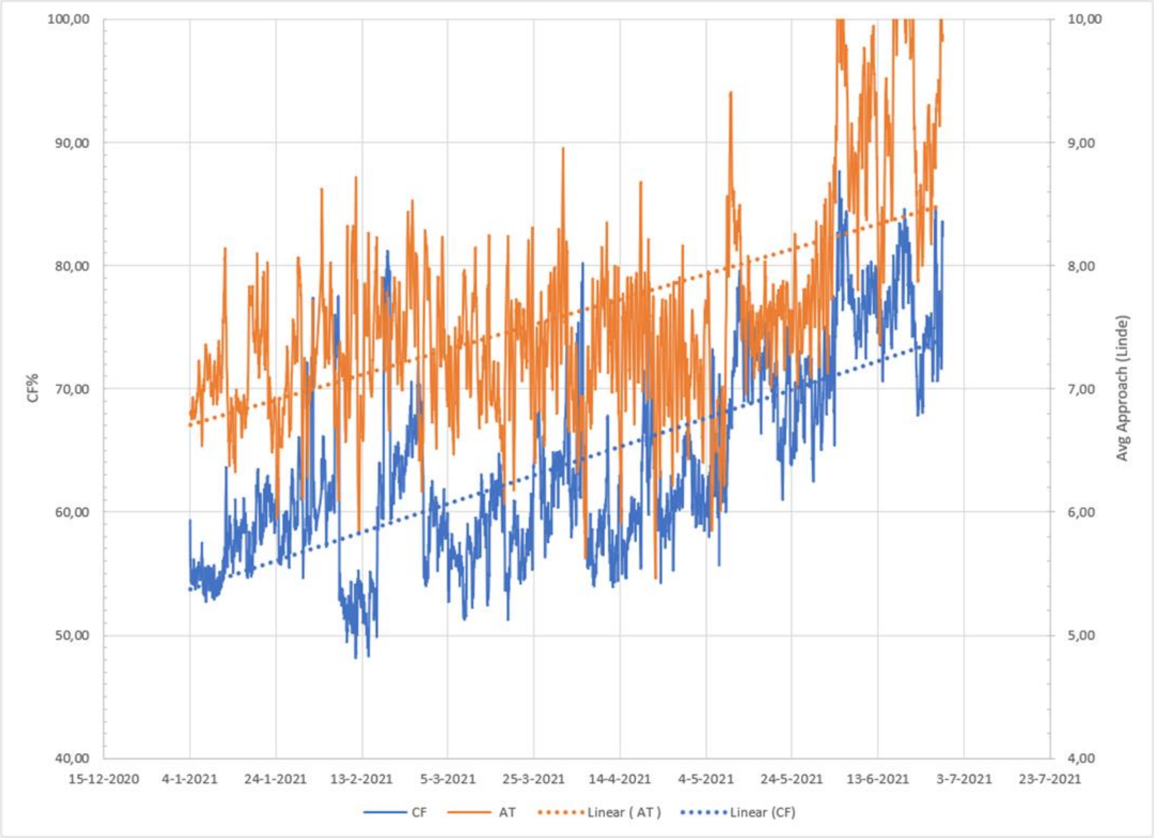


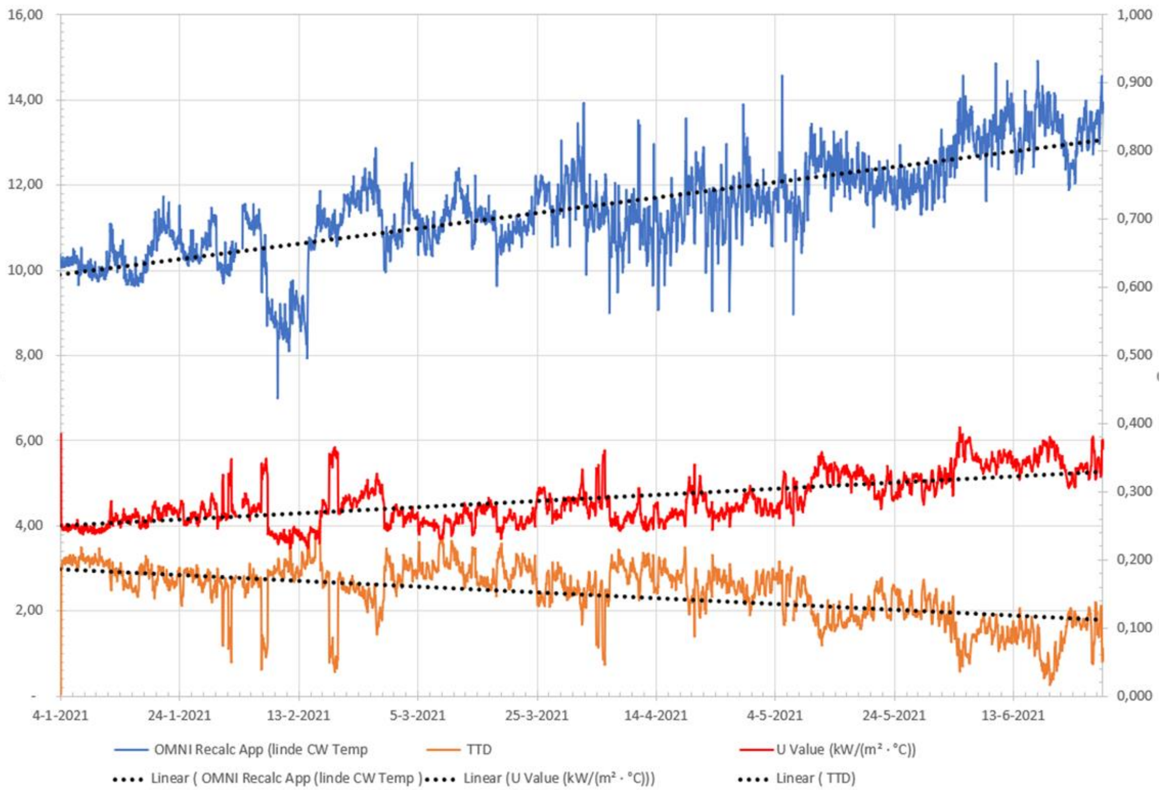


Mild steel Coupon 2020 with fouling

- Implemented OMNI HX for monitoring improvements in critical interstage cooler performance
- Considering Chlorine dioxide (PURATE)

IMPROVED HX CLEANLINESS WITH POLYMER OVERLAY





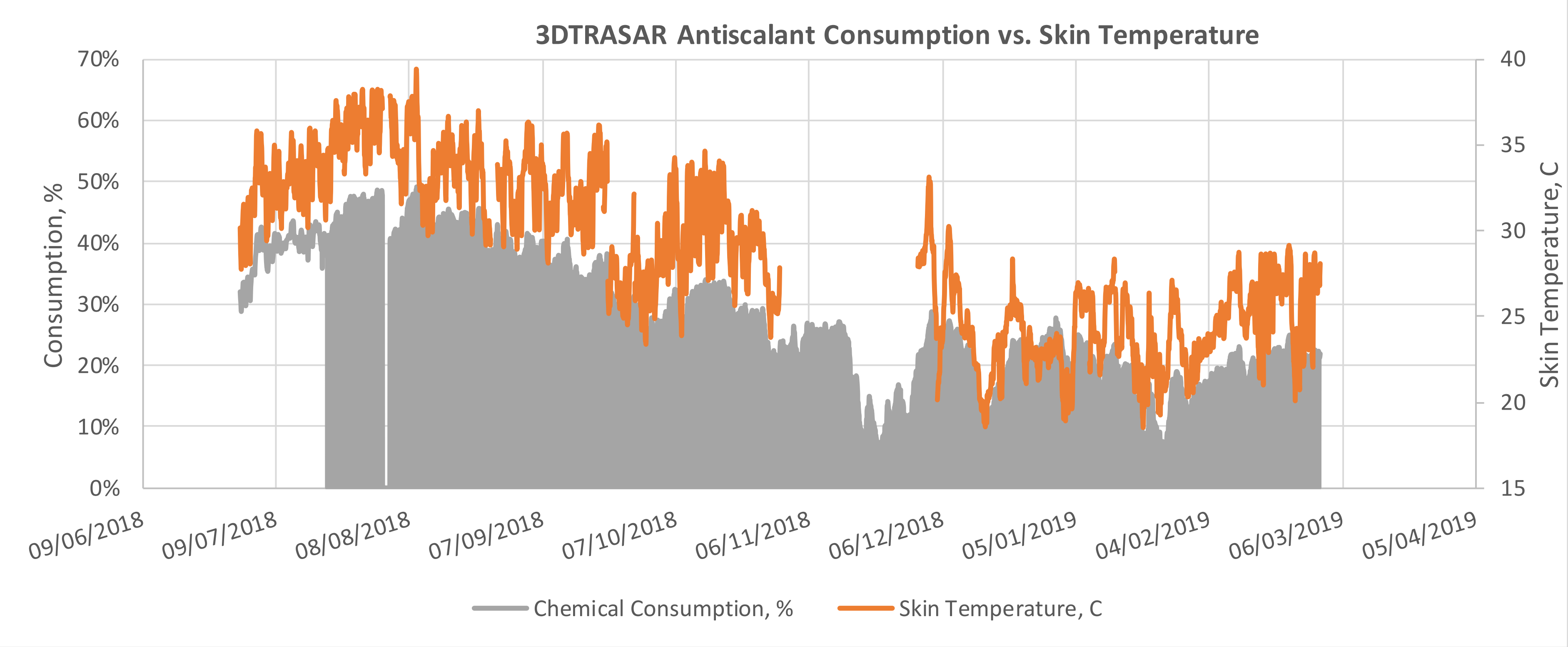
Mild steel Coupon Nov 2020

Mild steel Coupon Mar 2021

Mild steel Coupon Jun 2021

OMNI™ HX SENSORS – EU ASU CASE STUDY

OMNI™ unveils strong correlation of Chemical Consumption and Skint T
Should 3DTRASAR Polymer setpoint be controlled by OMNI Skin T?.



HOW OMNI™ IMPACTS OUTCOMES

Avoid Downtime

- Prolong operation cycle of HXs.
- No maintenance need due to scale or corrosion.
- Mechanical, Operational and Chemical changes thanks to OMNI™ HX Audit.
- Real-time insights and actions with OMNI™ HX Sensors and Simulator.

Profitability Reliability

Maximize Heat Transfer

- Avoid performance loss during cycle, no scale or biofouling.
- Mechanical, Operational and Chemical changes thanks to OMNI™ HX Audit
- Real-time insights and actions with OMNI™ HX Sensors and Simulator.

Profitability

Prolong Assets Life

- Minimize corrosion and maximize your exchangers life.
- Mechanical, Operational and Chemical changes thanks to OMNI™ HX Audit.
- Real-time insights and actions with OMNI™ HX Simulator.

Profitability Reliability

HOW OMNI™ IMPACTS OUTCOMES

Run Harder & Smarter

- Increase throughput by running exchangers in conditions you feared before.
- With OMNI™ HX real-time monitoring, mechanical, operational and chemical changes you can reliably explore new operation limits never considered before.

Profitability Reliability

Avoid Cleaning Costs

- Reduce cleaning maintenance costs in between general turnarounds.
- Mechanical, Operational and Chemical changes thanks to OMNI™ HX Audit
- Real-time insights and actions with OMNI™ HX Sensors and Simulator.

Profitability

Optimize Turnaround Plan

- Reduce the number of exchangers opened and cleaned.
- With OMNI™ HX Audits on your heat exchangers network decide which exchangers you can skip cleaning.

Profitability

Appendix 5

Utilization of High Velocity Thermal Spray (HVTS) to prevent corrosion in amine systems designed for CO_2 removal

(Vitaly Geraskin)

IGS Solutions for

Amine Systems stripping CO2

www.integratedglobal.com

HVTS

HVTS[sm]

an IGS Solution

- High Velocity Thermal Spray
- Robust Corrosion and Erosion Alloy Cladding
- Applied Turnkey in Situ
- Installed since 2003

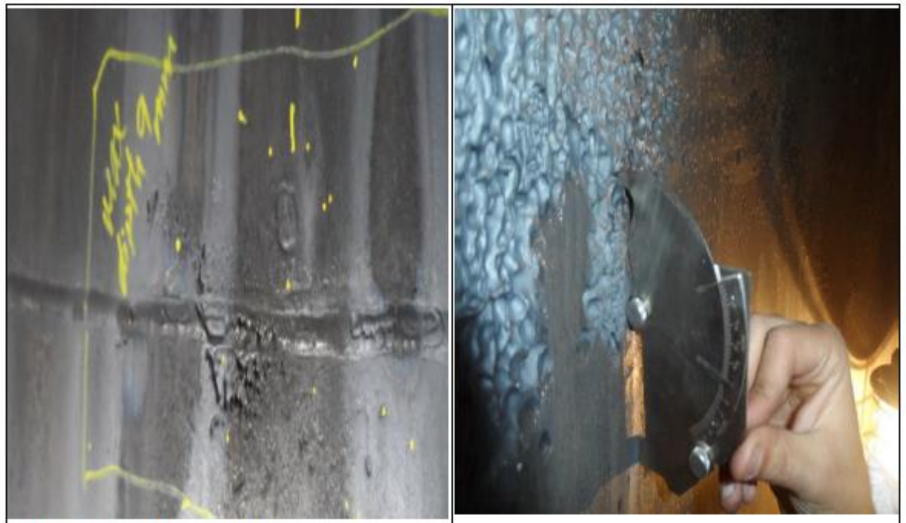
CO_2 Corrosion

- CO2 is an acid gas and hence corrosive to carbon steel, unlike H2S, in an amine treating unit CO2 does not form a protective film (iron sulfide) on the surface of the steel that acts as protection and as such is considered more aggressive.
- Several potential corrosion mechanisms exist in amine process equipment. In the lower section of a regenerator for example, carbon steel surfaces not wetted by the amine solution may be attacked by water vapor condensation and the formation of carbonic acid. Acid gas ratio, choice of amine, contaminants, two phase flow, flashing, high velocities, vessel design and insulation are all factors.
- CO2 causes corrosion in the form of deep pitting with sharp edges as a result of CO2 gas reacting with droplets of condensation and forming carbonic acid.
- CO2 can also lead to the formation of an Iron Carbonate layer, which is not protective but porous and can act as a "sponge" to attract moisture which leads to carbonic acid formation on the shell, and gradual thinning.

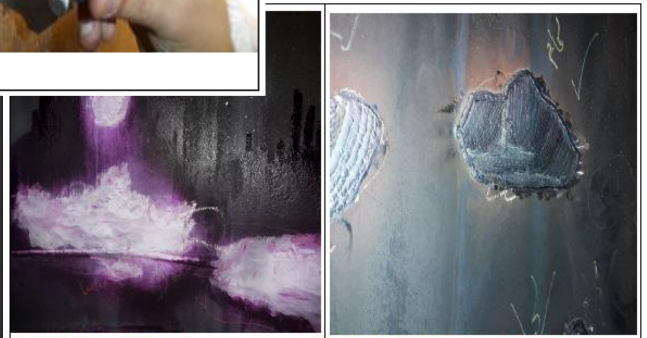
AMINE SYSTEM CO2 CORROSION DAMAGE:

Inspection Report Amine CO2 Stripper Column:

- The process fluid: Process gas/ Rich MDEA/CO2.
- The affected part of shell material: SA 516 Gr.70 thickness: 12 mm. with corrosion allowance 3 mm.
- The Design pressure: 3.6 Bar.
- The Design Temperature: 150°C
- Internal Diameter: 2300 mm.
- Operation temperature about 103°C

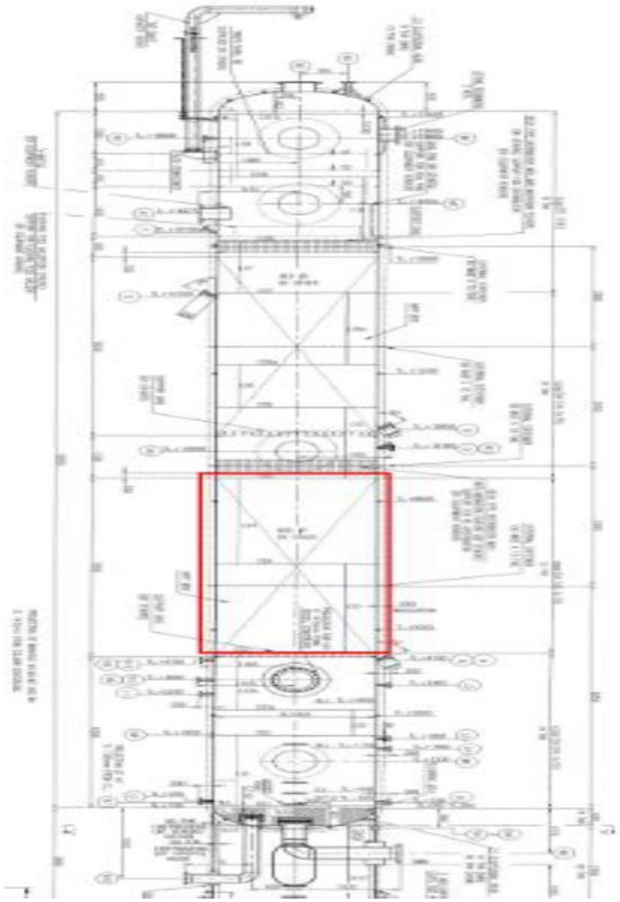


Pitting reached to 9 mm depth



PT test for new weld deposit

Weld-overlay/ deposit over corroded areas



Materials of construction:

- Upper part: SS-316L
- Lower part: SA-516 Gr.70

Lower portion of stripper, carbon steel part, the loss of wall thickness is up to 9 mm

AGR AMINE ABSORBER TOWERS

Applications in 2011 and 2012:

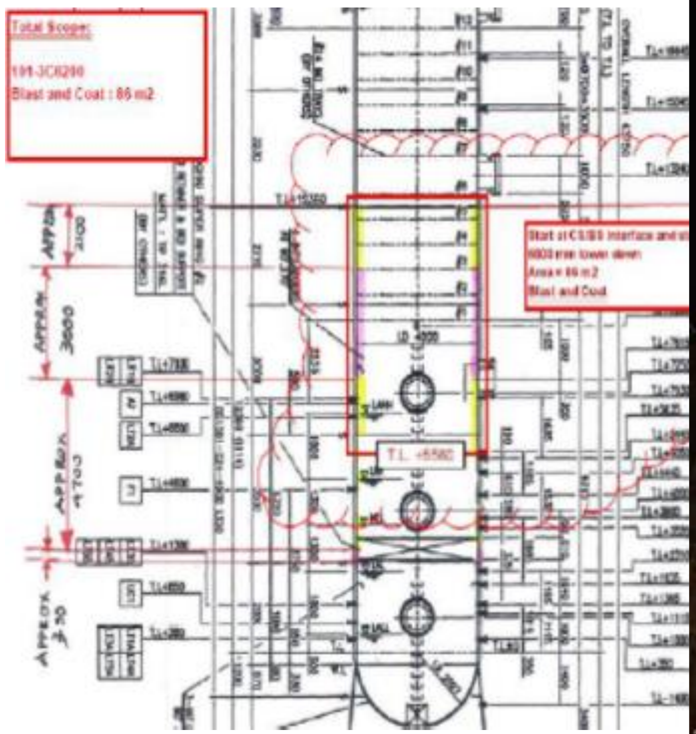
During inspection in 2011 significant pitting corrosion was discovered in various assets e.g. unclad carbon steel sections of AGR Amine Absorbers below the CRA weld overlay and in other discrete locations.

Substrate /Base:

Carbon Steel

Process Used:

IGS HVTS cladding was applied to the vessels below the CRA weld and in other discrete locations where pitting corrosion was identified during the turnaround within the critical path schedule provided by the client.



AGR AMINE ABSORBER TOWERS

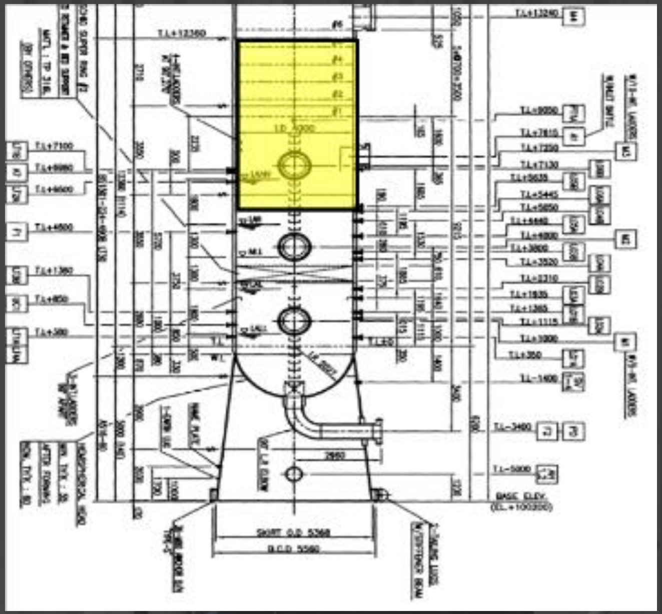
Inspection Results

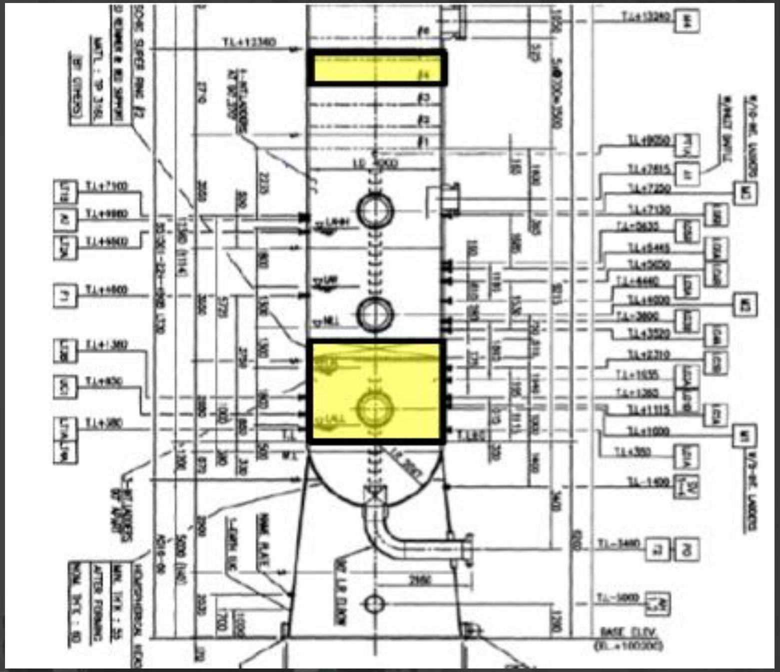
Inspection Feb. 2020:

Inspection Results:

IGS HVTS cladding is in excellent condition.

- **No repairs required.**





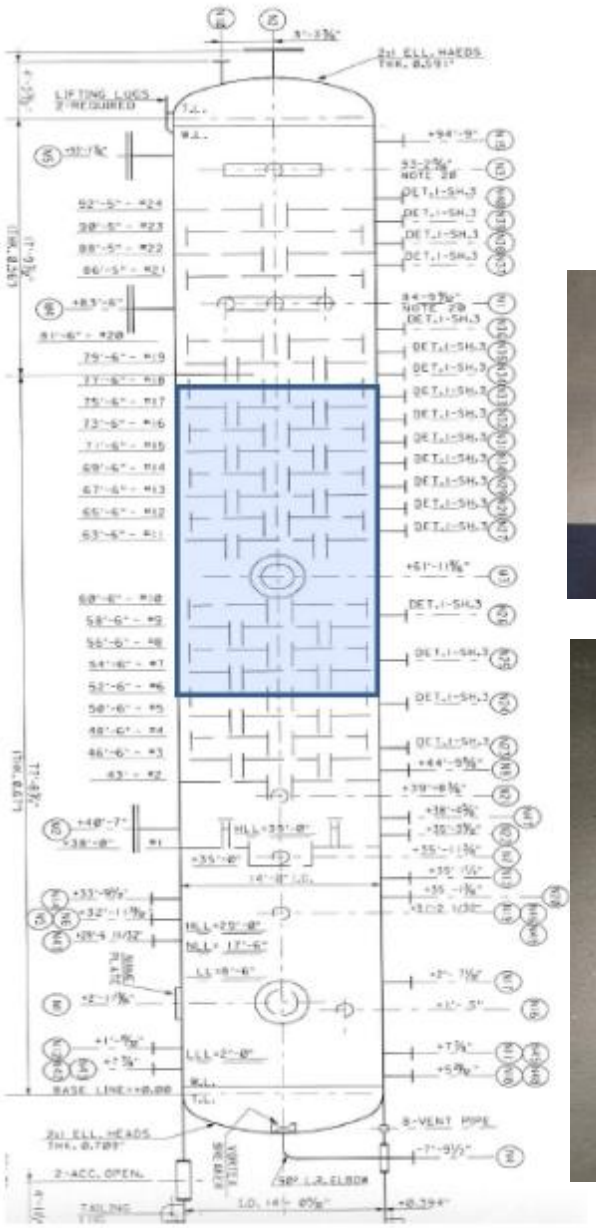
DGA AMINE STRIPPER COLUMN

Stopped critical column replacement or field weld overlay, PWHT and an extended T&I (2 to 3 week extension).
HVTS TA impact – 1 week
External inspection service prevented unplanned shutdown.

Amine column experiencing large scale corrosion, including deep pitting in the central section of the column, trays number 6 to 18, initial application in 2016.
Sister column was HVTS clad in 2015.
Warranty provided through to next planned shutdown.

IGS HVTS applied to freeze the surface condition in the critical areas of the column shell, including manways, horizontal and vertical tray supports

In 2018 the client measured lower vessel wall thickness and questioned the internal cladding integrity. IGS performed an external inspection to prove the integrity of the internal HVTS cladding and prevented the client shutting down the unit. In 2020 IGS returned to extend HVTS to tray 1 and internally inspected the column to prove HVTS performance.



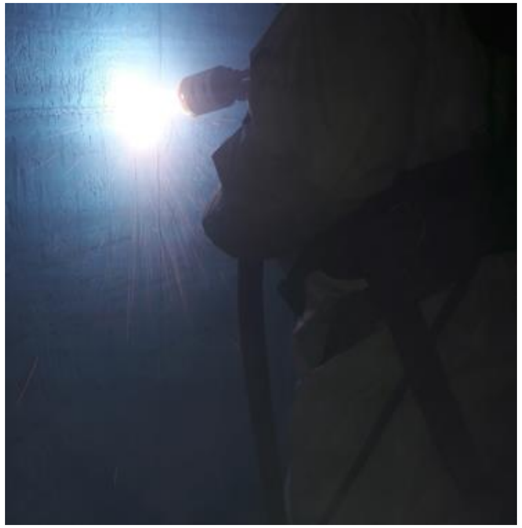
MDEA AMINE REGENERATOR COLUMN

Prevented critical column replacement or weld overlay, PWHT and an extended T&I (3 to 4 week extension).
HVTS TA impact - 120 hours
Estimated Life cycle saving – $50M

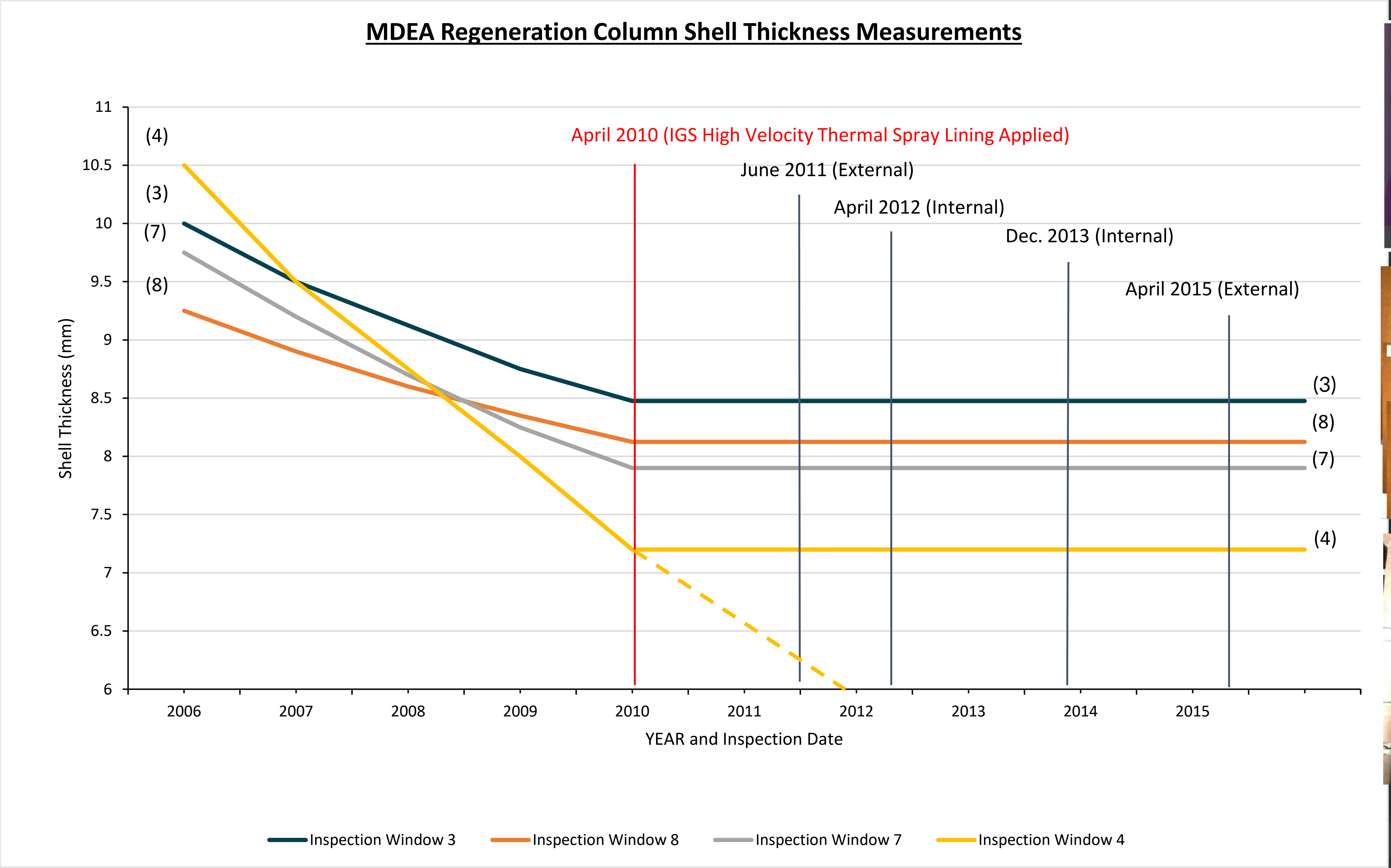
Amine column experiencing large scale deep pitting and washing out due to acid vapour condensation (e.g. Carbonic) in cold bridges from Heat Stable Salts (HSS) regenerating upstream in the reboiler, discovery scope.
Client was seeking a four-year solution

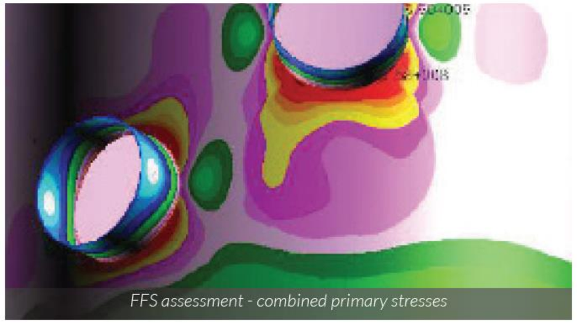
IGS 5420 applied using HVTS to freeze surface condition in the critical areas of the column shell, including manways, horizontal and vertical tray supports

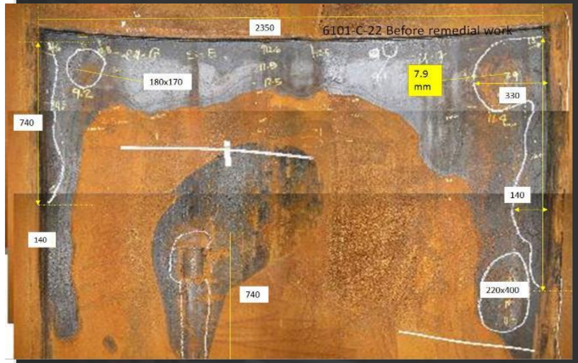
After 6 years, the shell had not experienced any further metal loss (inspected on an annual basis) when the vessel was replaced by 2 new columns in a debottlenecking expansion exercise



MDEA AMINE REGENERATOR COLUMN







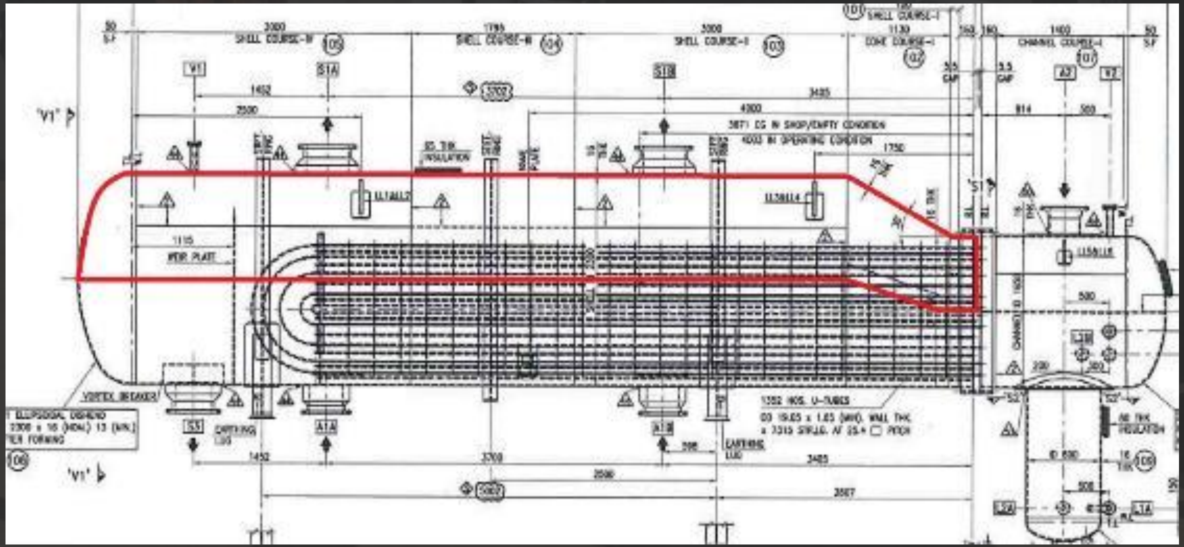
AMINE REBOILERS (e.g. MDEA)

Amine reboiler experiences aggressive corrosion and wash out in the hot, vapour phase in the top 1/3rd of the vessel, worst in the 11 to 1 o'clock position. Additional corrosion on the tube sheet and weld seams of the vessel. When working with MDEA (weakest base) and in the hottest parts of the process (e.g. the reboiler), HSAS will regenerate to acids, e.g. formic/acetic acid vapours that will then re-condense on the vessel walls where the temperature decreases = aggressive corrosion damage.

HVTS applied CRA cladding installed to freeze the internal surface condition in the critical areas of the vessel shell and on the bundle tube sheet.

Field application avoided field weld overlay (PWHT).

Internal inspection of the reboilers in the following turnaround demonstrated the performance of the CRA cladding as a corrosion barrier in these conditions.



IGS Solutions for

Amine Systems stripping CO2

Any Questions?

Appendix 6

The most probable failure mechanisms in superheater tubes of the steam generation boilers in the gas refineries and the prevention strategy

(Askar Soltani)

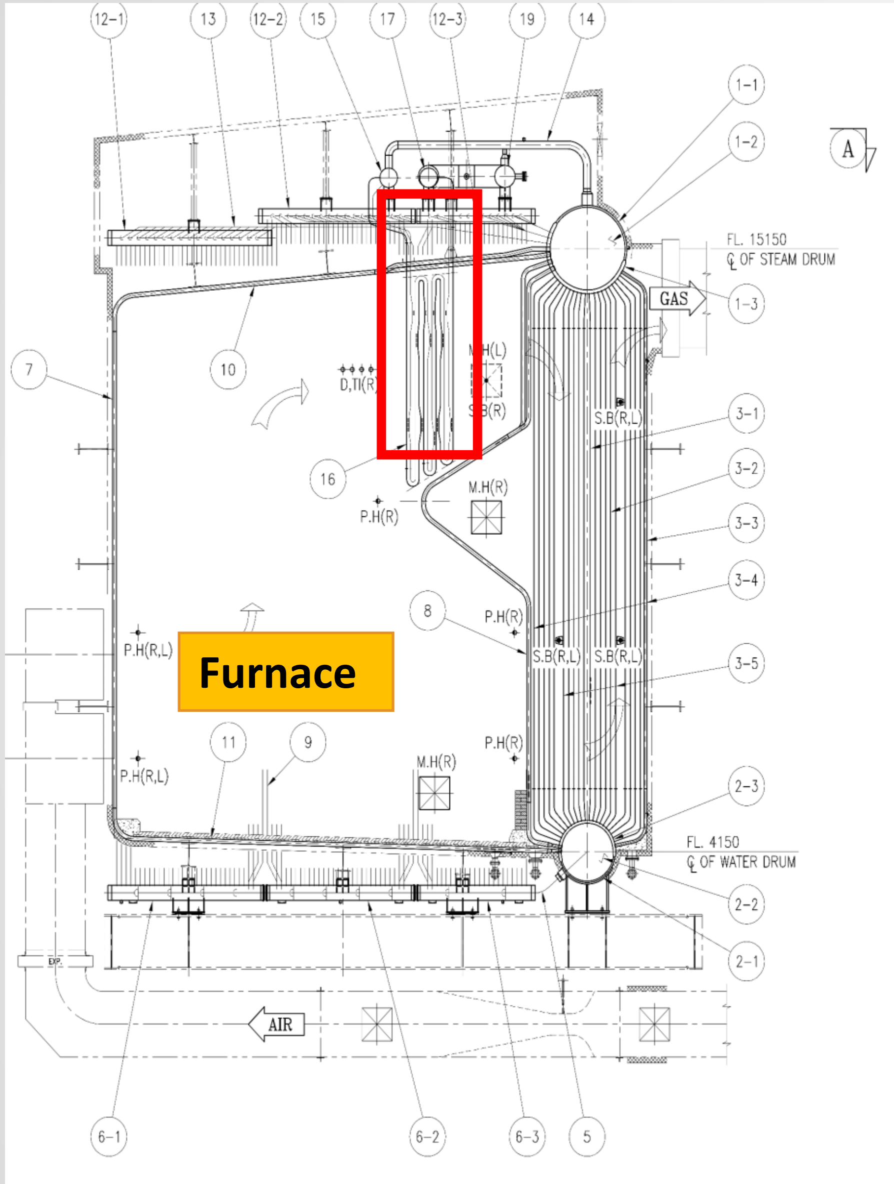
The most probable failure mechanisms in superheater tubes of the steam generation boilers in the gas refineries and the prevention strategy

Presented By: Askar Soltani
Senior Corrosion Engineer, South Pars Gas Complex

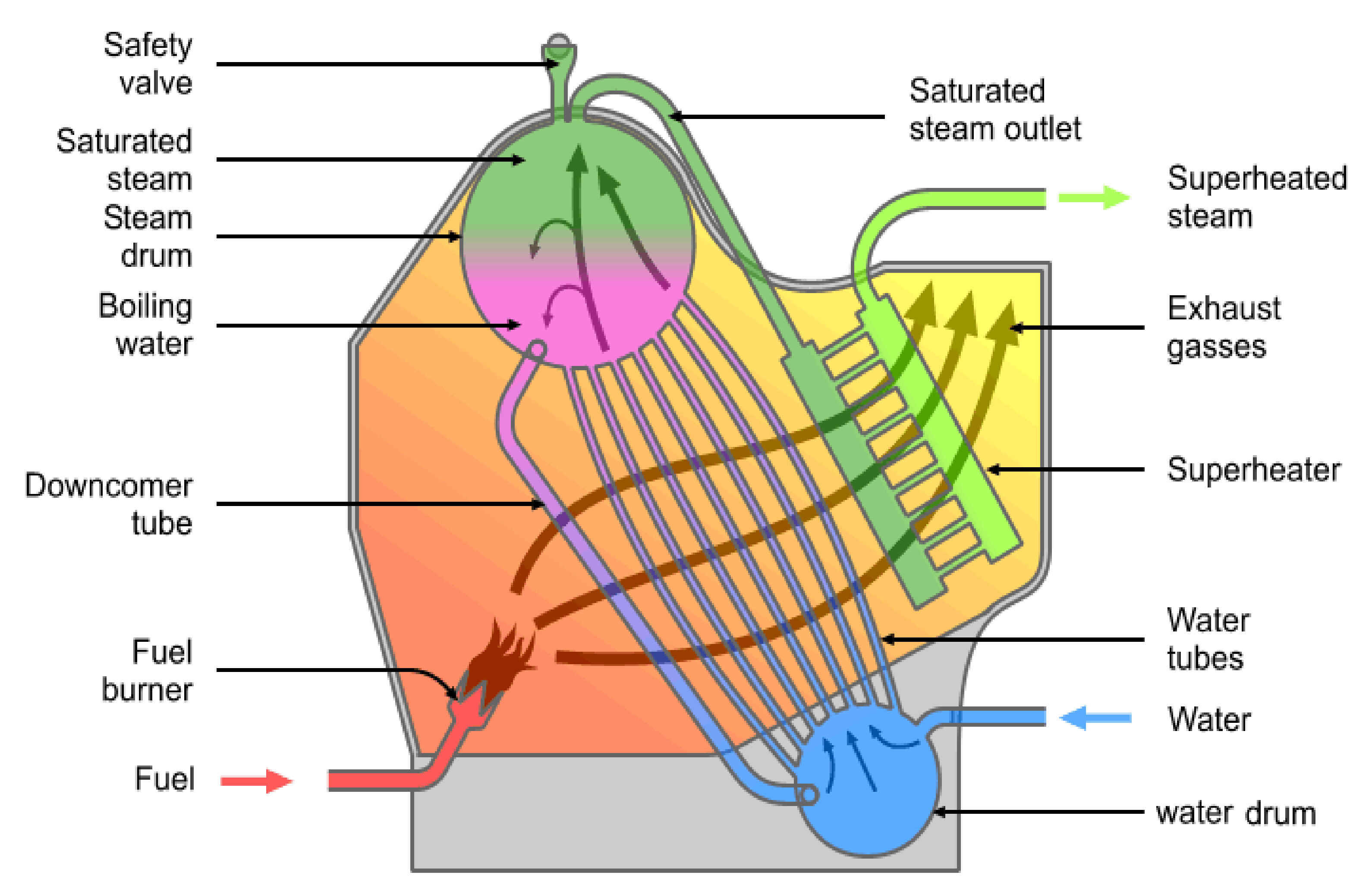
Table of Contents

• Introduction

Schematic Illustration of a Water-Tube Boiler Package



VIEW FROM BOILER RIGHT SIDE VIEW



https://commons.wikimedia.org/wiki/File:Water_tube_boiler_schematic.png

• Common Damage Mechanisms in Boilers

❖ **Common damage mechanisms in the boiler systems can be divided into:**

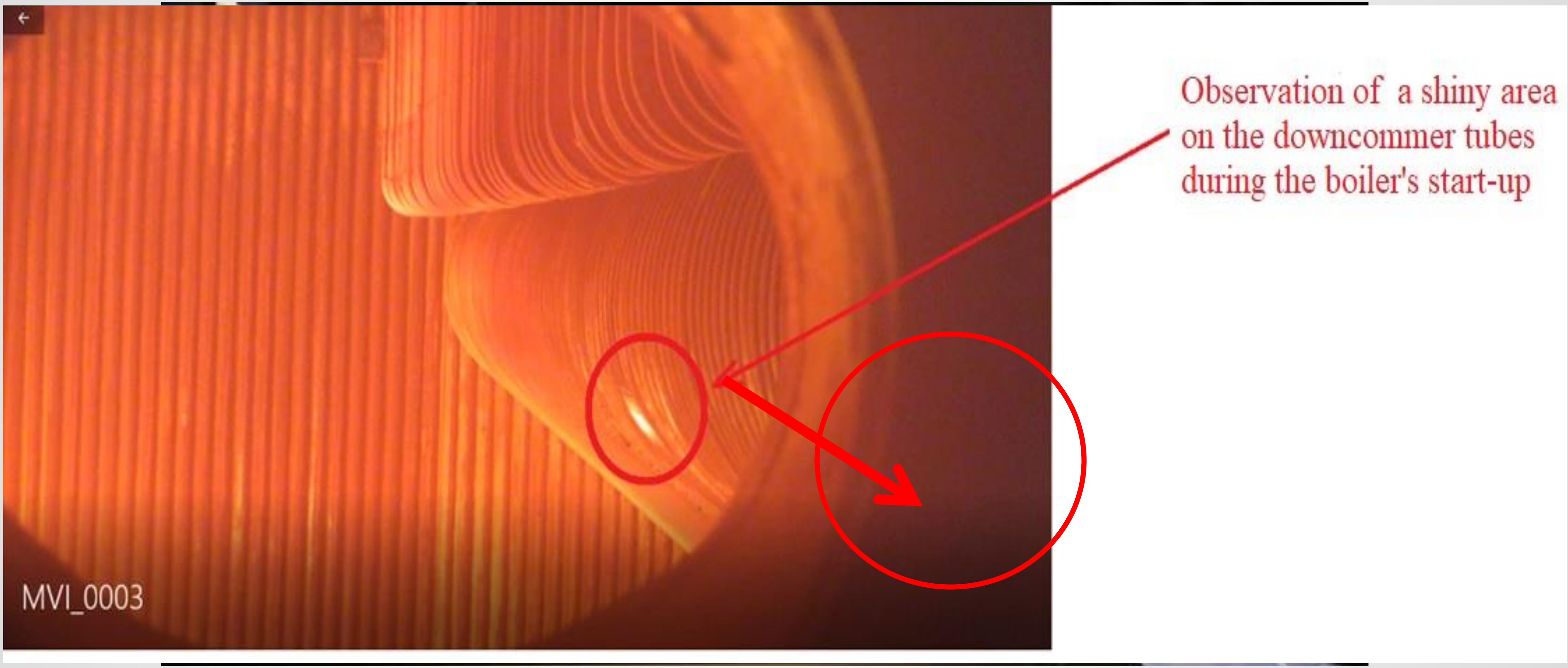
- O_2 Corrosion
- CO_2 Corrosion
- Under deposit Corrosion
- Caustic Gouging
- Acid Phosphate Attack
- Caustic SCC

❖ **Chemicals injection in Boiler systems:**

- Oxygen Scavengers
- Phosphate
- Amine

• Introduction

- **First Observation of Leakage**



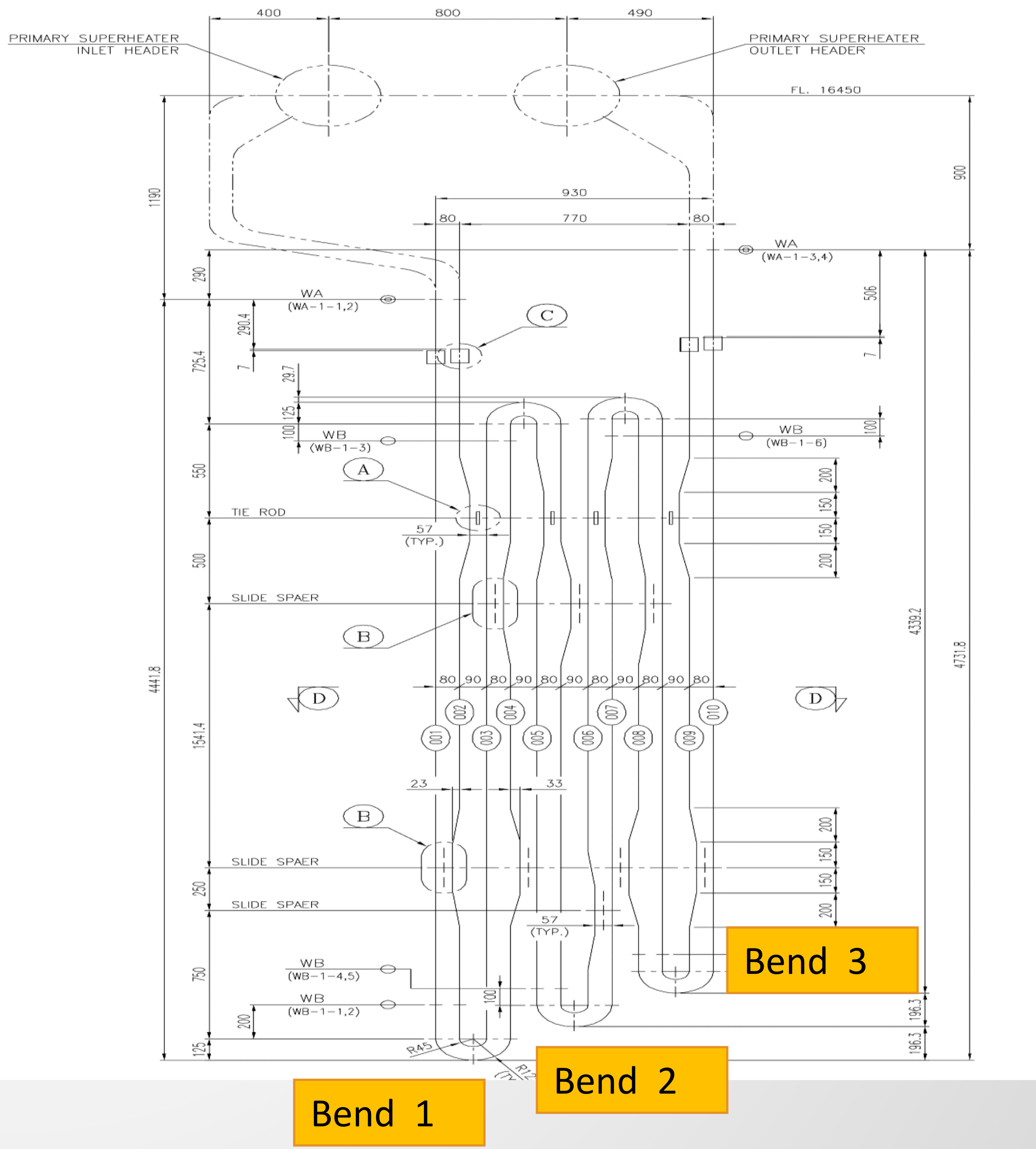
- Thickness Measurement

Superheater Tube's Specification

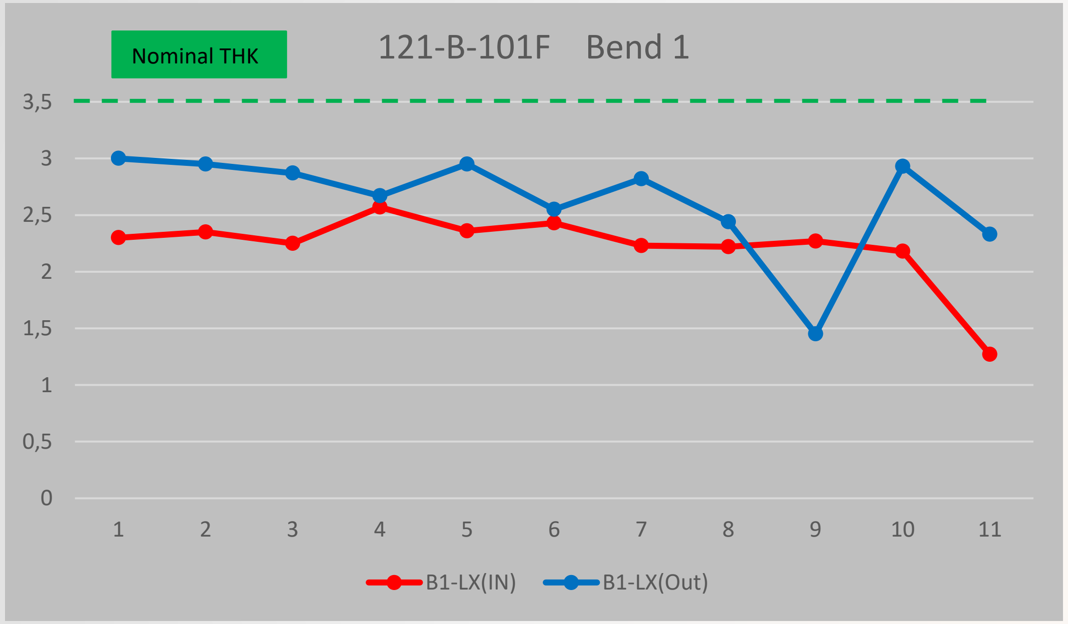
Type	Pendant
Material	ASTM A213-T11
Nominal Thickness	3.5 mm
Corrosion Allowance	1 mm

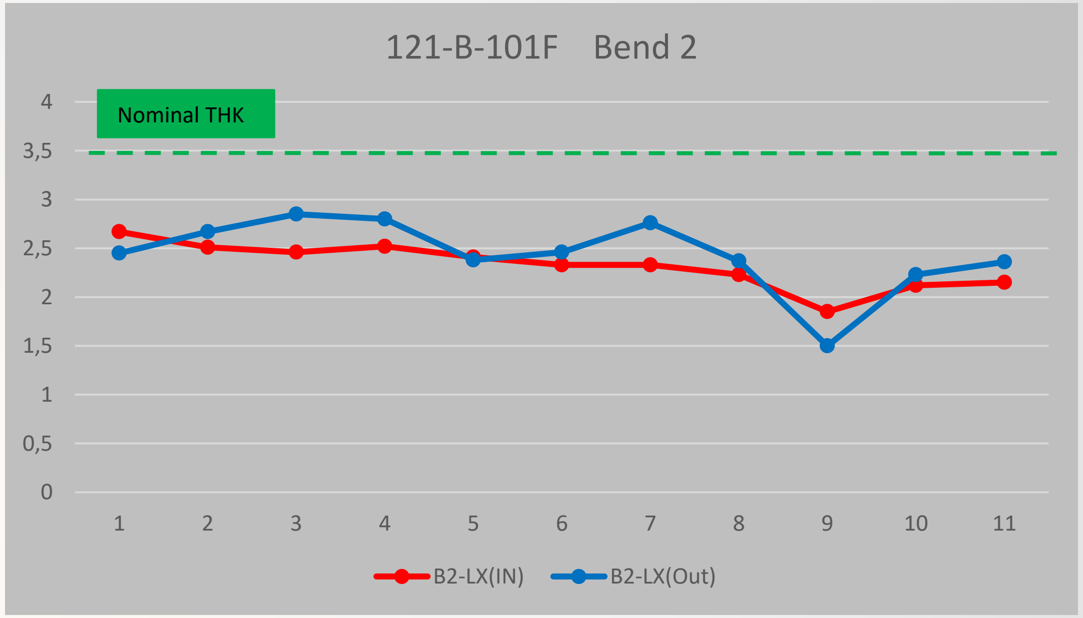
Superheater Tube's Configuration

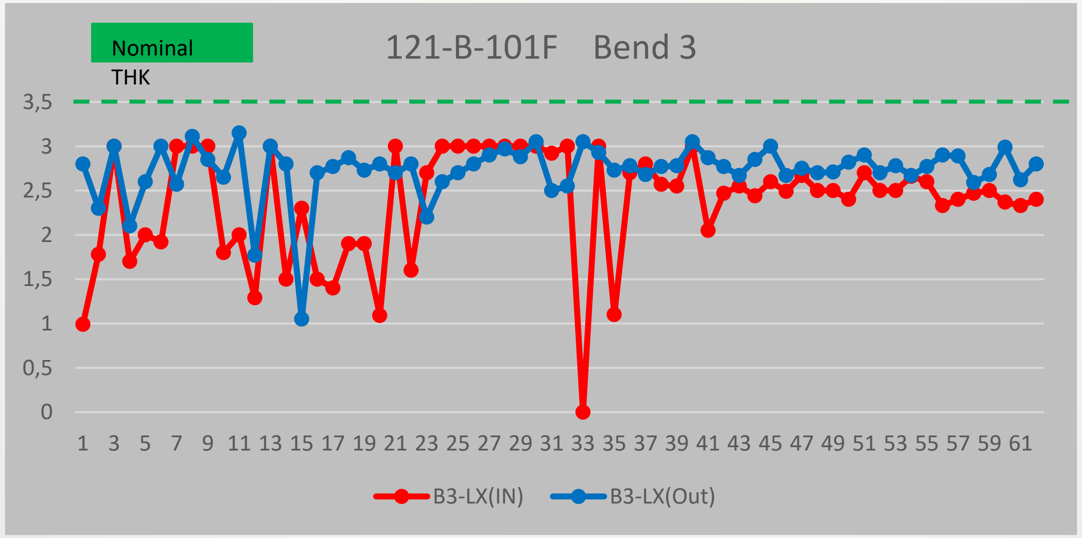
Number of passes	2
Number of rows	62
Number of U-bends in a single tube	5



Thickness Measurement in Superheater Tubes



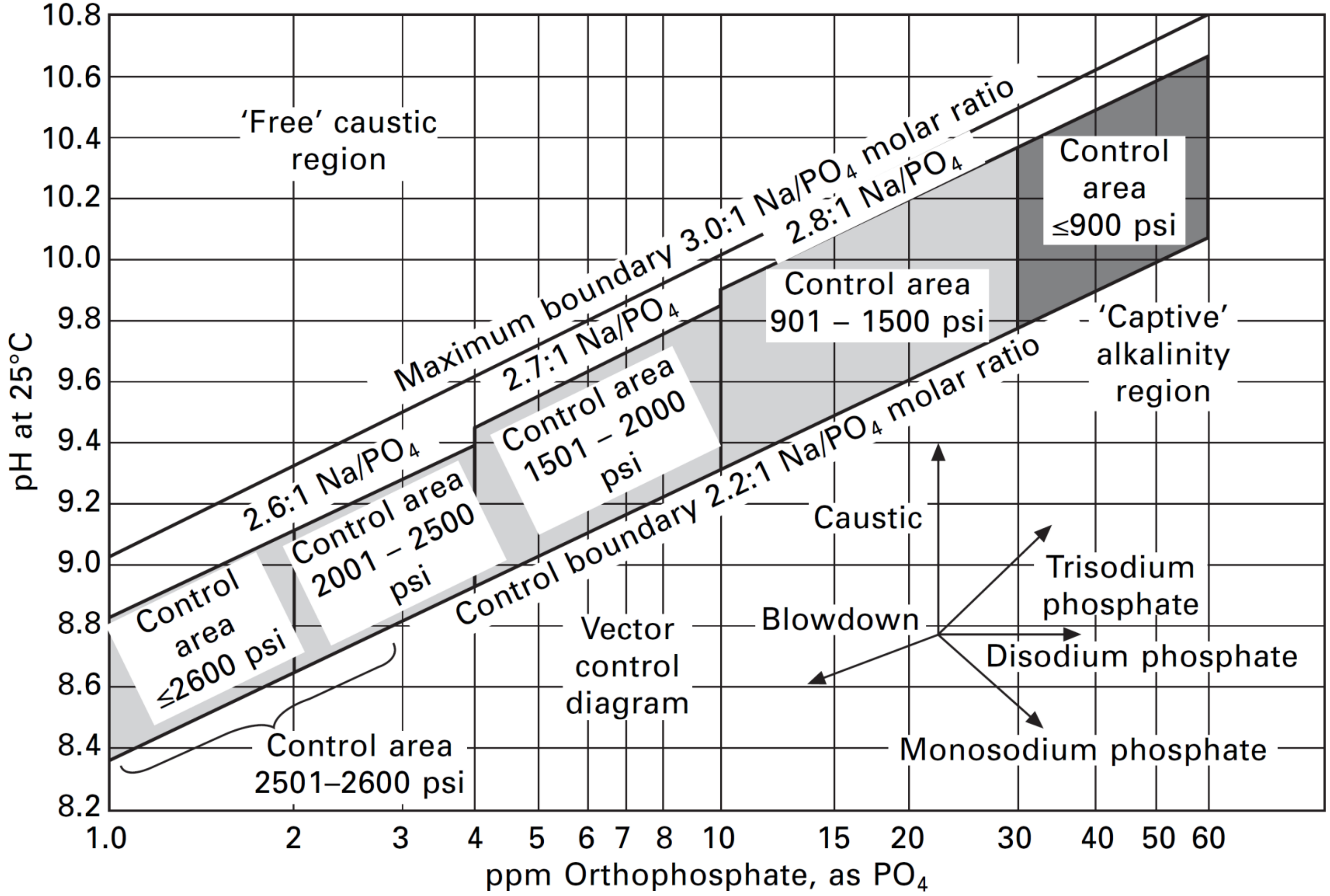




Failure Analysis

- One of the U-bends with high corrosion rate was cut
- A longitudinal Sectional-cut was done
- Two areas were selected to morphological microscopic investigation by SEM and also elemental analysis by EDX

Failure Analysis



14.6 Coordinated phosphate/pH control graph. Source: Betz Laboratories (1991).

IOW for water-tube boilers to prevent CG & PAA damage mechanisms in boiler units

Failure Analysis

Probable corrosion mechanisms in the superheater tubes of the boiler units can be ascribed to under deposit corrosion as:

- Caustic attack (caustic gouging) (if Na/phosphate ratio exceed 3)
- Acid phosphate corrosion (if Na/phosphate ratio goes under 2.2)

Above mentioned mechanisms can be take place under special circumstances in which a concentration process occurs.

Mechanism of CG and PAA

Proposed Reactions:

At temperatures above 90 C, the concentrated NaOH attacks into the protective magnetite film by the following reactions:

$$Fe_3O_4 + 4NaOH \rightarrow 2NaFeO_2 + Na_2FeO_2 + 2H_2O$$

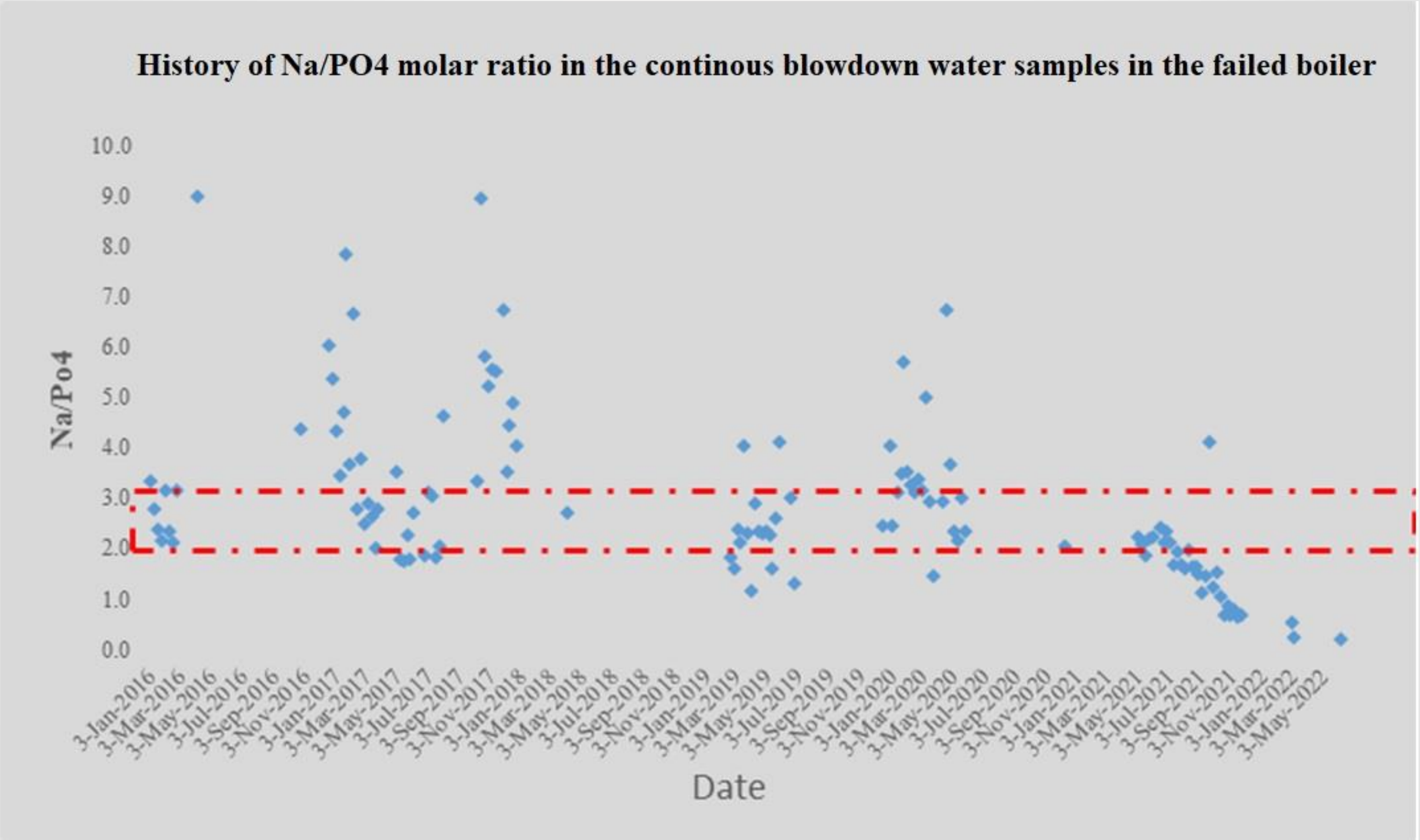
$$3NaOH + Fe_3O_4 \rightarrow 3NaFeO_2 + H^+ + H_2O$$

Gradually, the highly concentrated NaOH dissolves the protective magnetite layer based on above reactions, and the bare iron reacts with NaOH according to the following reactions and corrosion of base metal is taken place by gouging.

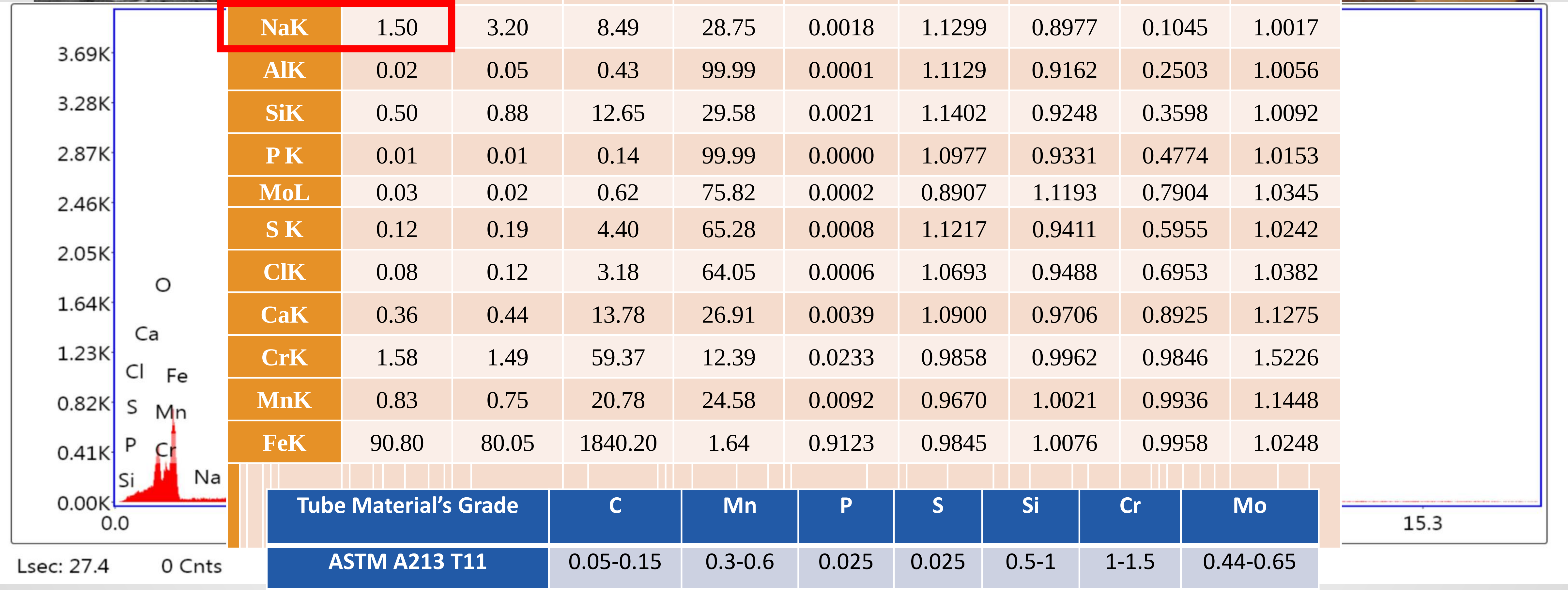
$$NaOH + H_2O + Fe \rightarrow NaFeO_2 + 3H^+$$

$$2NaOH + Fe \rightarrow Na_2FeO_2 + H_2$$

Failure Analysis



Failure Analysis

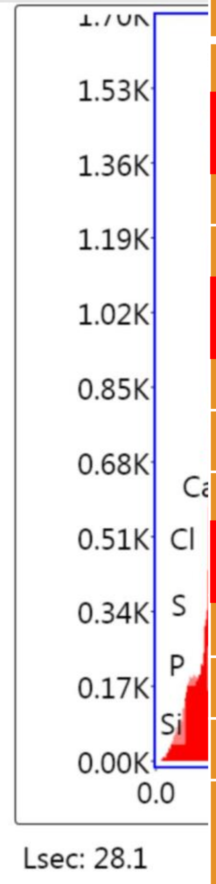


Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
O K	4.17	12.82	81.17	9.73	0.0206	1.2311	0.8669	0.4018	1.0000
NaK	1.50	3.20	8.49	28.75	0.0018	1.1299	0.8977	0.1045	1.0017
AlK	0.02	0.05	0.43	99.99	0.0001	1.1129	0.9162	0.2503	1.0056
SiK	0.50	0.88	12.65	29.58	0.0021	1.1402	0.9248	0.3598	1.0092
P K	0.01	0.01	0.14	99.99	0.0000	1.0977	0.9331	0.4774	1.0153
MoL	0.03	0.02	0.62	75.82	0.0002	0.8907	1.1193	0.7904	1.0345
S K	0.12	0.19	4.40	65.28	0.0008	1.1217	0.9411	0.5955	1.0242
ClK	0.08	0.12	3.18	64.05	0.0006	1.0693	0.9488	0.6953	1.0382
CaK	0.36	0.44	13.78	26.91	0.0039	1.0900	0.9706	0.8925	1.1275
CrK	1.58	1.49	59.37	12.39	0.0233	0.9858	0.9962	0.9846	1.5226
MnK	0.83	0.75	20.78	24.58	0.0092	0.9670	1.0021	0.9936	1.1448
FeK	90.80	80.05	1840.20	1.64	0.9123	0.9845	1.0076	0.9958	1.0248

Tube Material's Grade	C	Mn	P	S	Si	Cr	Mo
ASTM A213 T11	0.05-0.15	0.3-0.6	0.025	0.025	0.5-1	1-1.5	0.44-0.65

EDX results on Spot 1

Failure Analysis

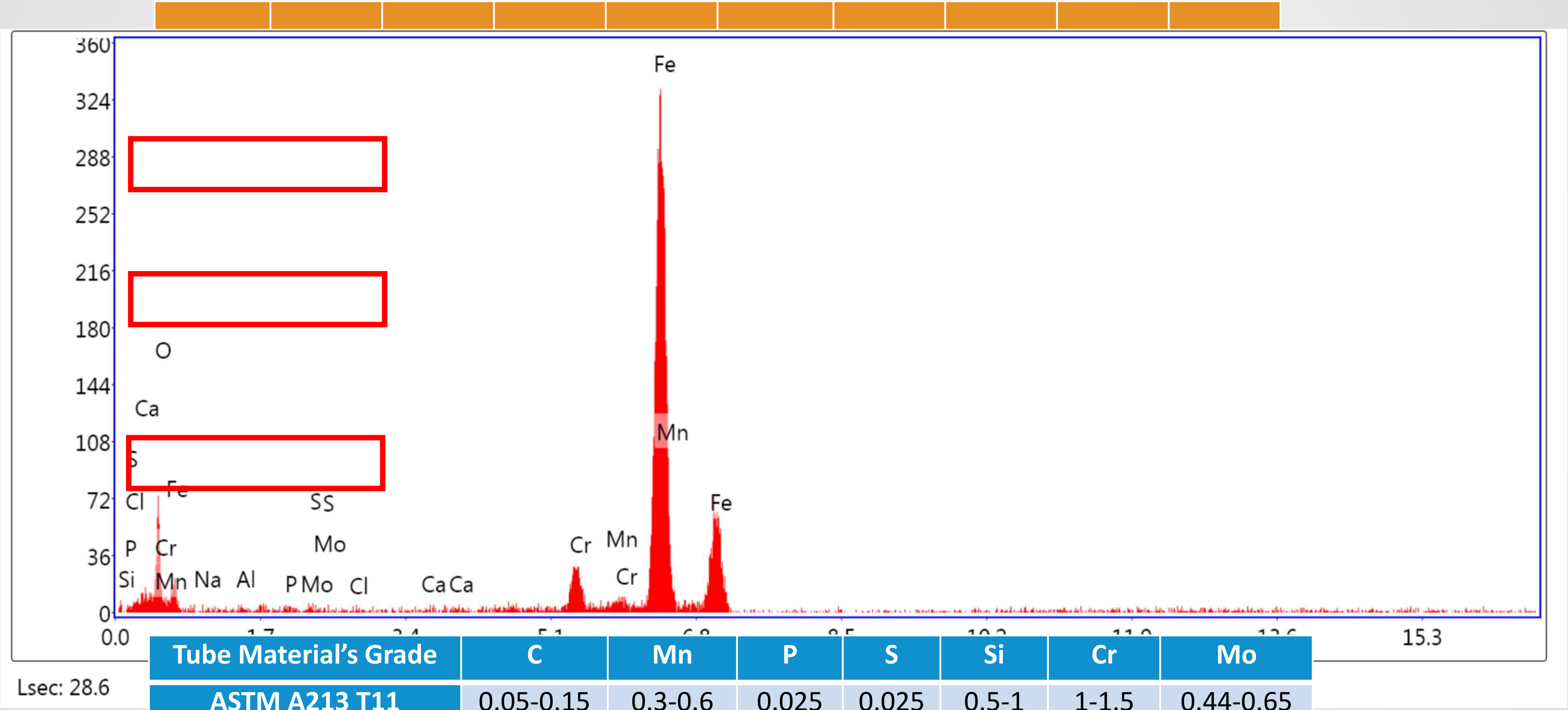


Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
O K	25.83	51.17	338.67	8.22	0.1213	1.1554	0.9073	0.4065	1.0000
NaK	3.69	5.09	17.55	17.31	0.0052	1.0592	0.9374	0.1316	1.0019
AlK	1.16	1.36	15.94	19.77	0.0037	1.0425	0.9551	0.3038	1.0058
SiK	0.96	1.08	18.73	19.97	0.0043	1.0677	0.9633	0.4205	1.0092
P K	5.29	5.41	113.28	8.56	0.0297	1.0276	0.9711	0.5405	1.0123
MoL	0.99	0.33	12.64	30.34	0.0070	0.8335	1.1636	0.8245	1.0280
S K	0.11	0.11	2.81	71.84	0.0008	1.0497	0.9786	0.6200	1.0187
ClK	0.08	0.07	2.14	65.72	0.0006	1.0004	0.9858	0.7120	1.0286
CaK	0.19	0.15	4.76	60.14	0.0019	1.0188	1.0058	0.9011	1.0933
CrK	4.66	2.84	101.52	6.54	0.0562	0.9201	1.0289	0.9896	1.3238
MnK	1.33	0.77	21.28	19.05	0.0132	0.9022	1.0340	0.9967	1.1062
FeK	55.71	31.62	745.26	2.06	0.5213	0.9182	1.0387	0.9902	1.0292

Tube Material's Grade	C	Mn	P	S	Si	Cr	Mo
ASTM A213 T11	0.05-0.15	0.3-0.6	0.025	0.025	0.5-1	1-1.5	0.44-0.65

EDX results on spot 7

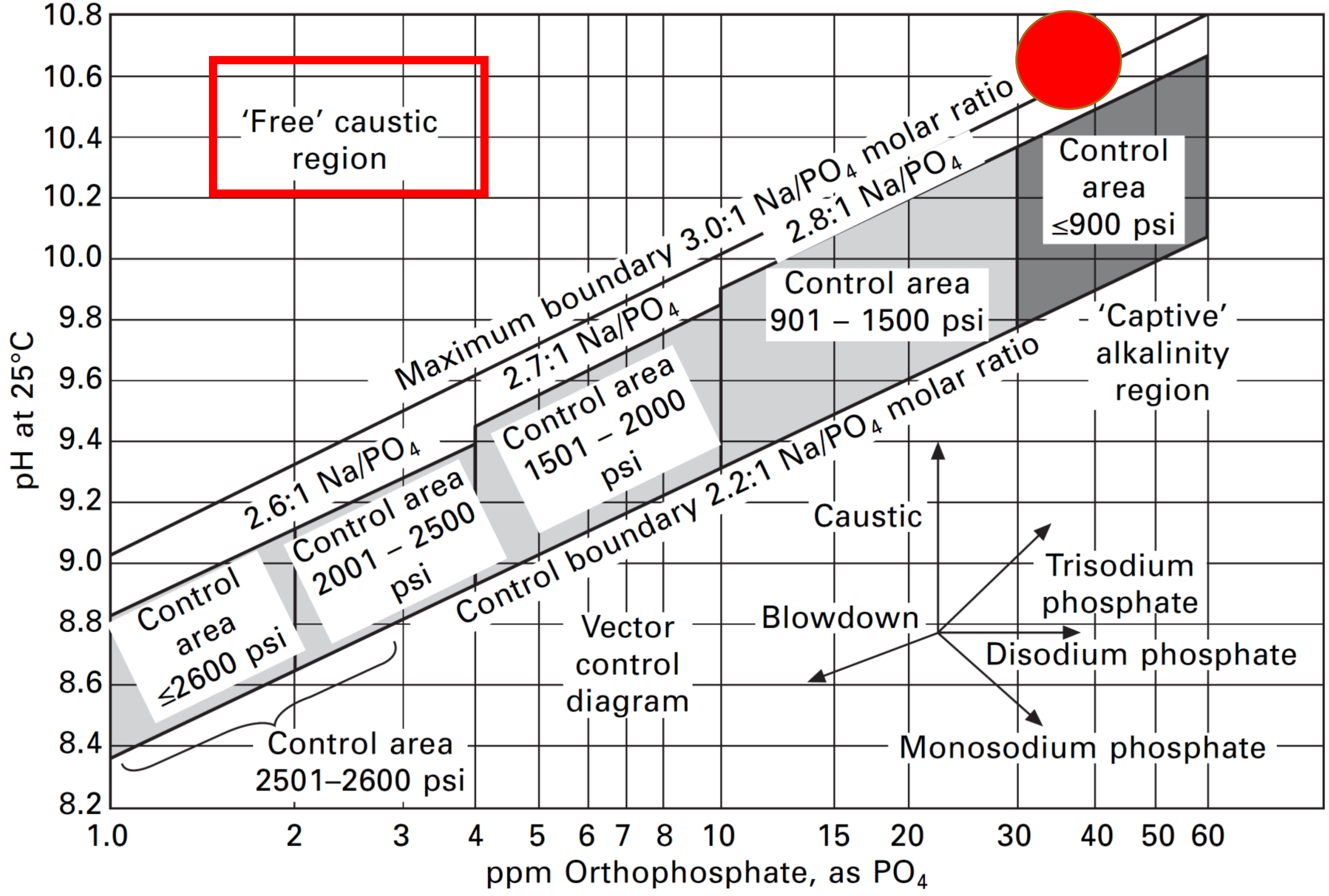
Failure Analysis



Tube Material's Grade	C	Mn	P	S	Si	Cr	Mo
ASTM A213 T11	0.05-0.15	0.3-0.6	0.025	0.025	0.5-1	1-1.5	0.44-0.65

EDX results on spot 8

Failure Analysis



14.6 Coordinated phosphate/pH control graph. Source: Betz Laboratories (1991).

Conclusion and Preventive Strategies

Conclusion:

- Na/PO4 molar ratio was not in the safe zone of IOW and Caustic Gouging was active
- EDX analysis inside the pits revealed the presence of mineral elements like Na and Ca
- Presence of high amounts of Na and P could be the indication of BFW carry-over or condensed steam after boiler stop and cooled-down process
- Damage mechanism was recognized as “Caustic Gouging”

Preventive Strategies:

- Controlling and monitoring the Na/PO4 molar ratio in the safe zone of IOW
- Preventing water carry-over from steam drum into the superheater tubes
- Evacuating the accumulated water in U-bends after boiler cooling up by N2 injection
- Dry preservation of the superheater tubes by Nitrogen gas during the idle period
- Exceuting Hydrotest of superheater tubes with DM water and evacuating U-bends after the hydrotest

Appendix 7

Evolution of CUI technology and CUI standards

(Chris Magel)

Corrosion Under Insulation

Evolution of CUI technology and CUI standards

Chris Magel - PPG

Overview

- Corrosion Under Insulation (CUI)
  - Market Cost
  - Conditions
  - Market needs
  - Coating technologies
- New Construction advantages of PPG HI-TEMP 1027™ HD
  - Key Product Properties
  - Corrosion Prevention Attributes
  - Product Testing Summary
  - Product Benchmarking: Performance Tests and Hardness
- PPG CUI Portfolio Comparison

Corrosion Under Insulation (CUI)

Market Cost

Corrosion

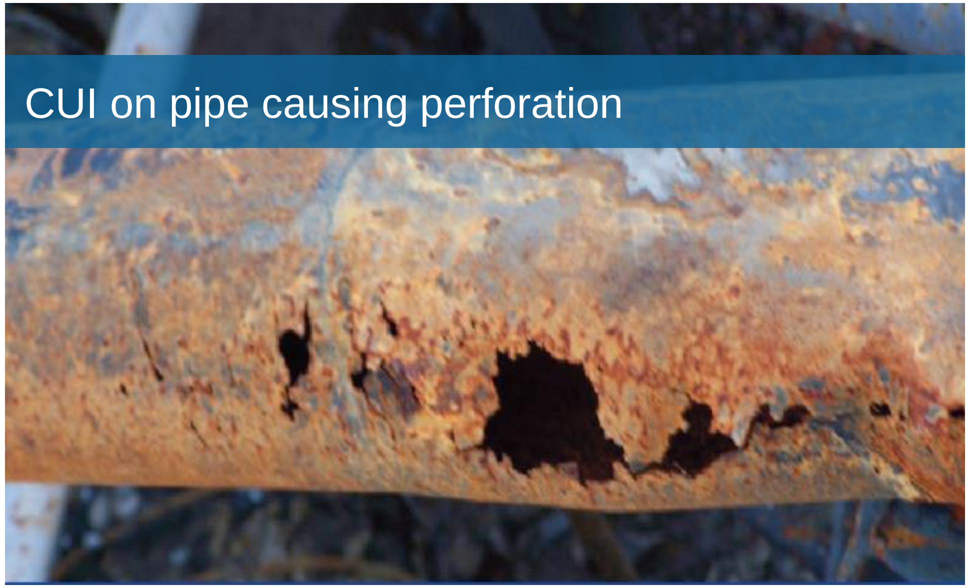
- Costs the global economy an estimated $2.2 trillion (USD); $1 trillion of this occurs in Oil & Gas

Corrosion Under Insulation (CUI):

- 40-60% of pipe maintenance costs are a result of CUI,
- 10% of total annual maintenance cost is dedicated to repairing damage caused by CUI[1]

Oil & Gas Sector:

- 10% of total annual maintenance cost is dedicated to repairing damage caused by CUI[2]


CUI on pipe causing perforation


CUI-induced heat exchanger in olefins plant[3]

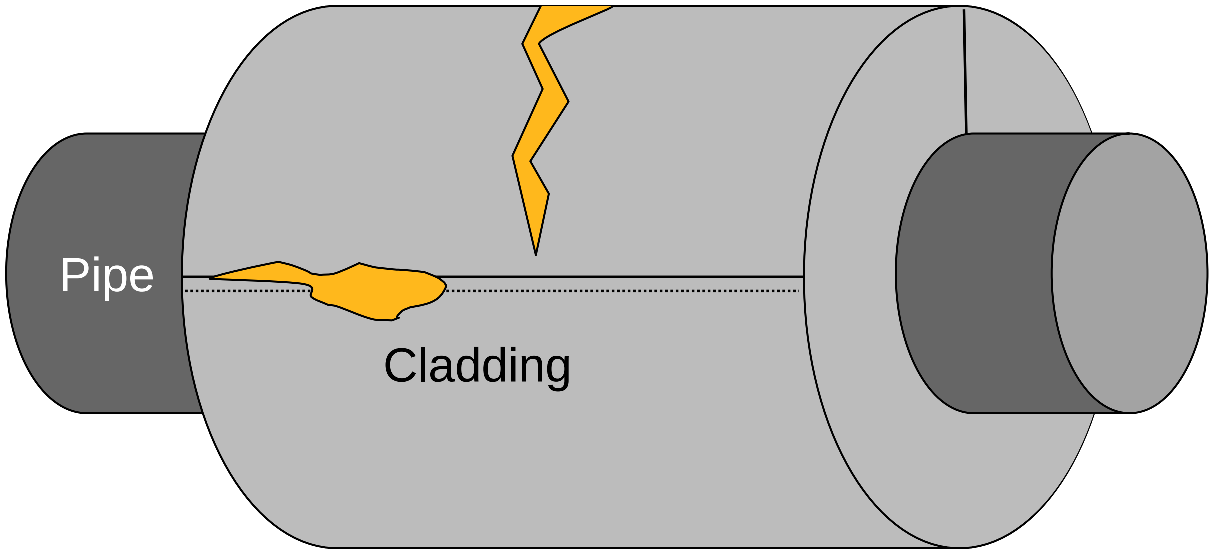
References:
1. World Corrosion Org.
2. National Insulation Association, 2014
3. Engineering Practice, Oct 2016

Corrosion Under Insulation (CUI)

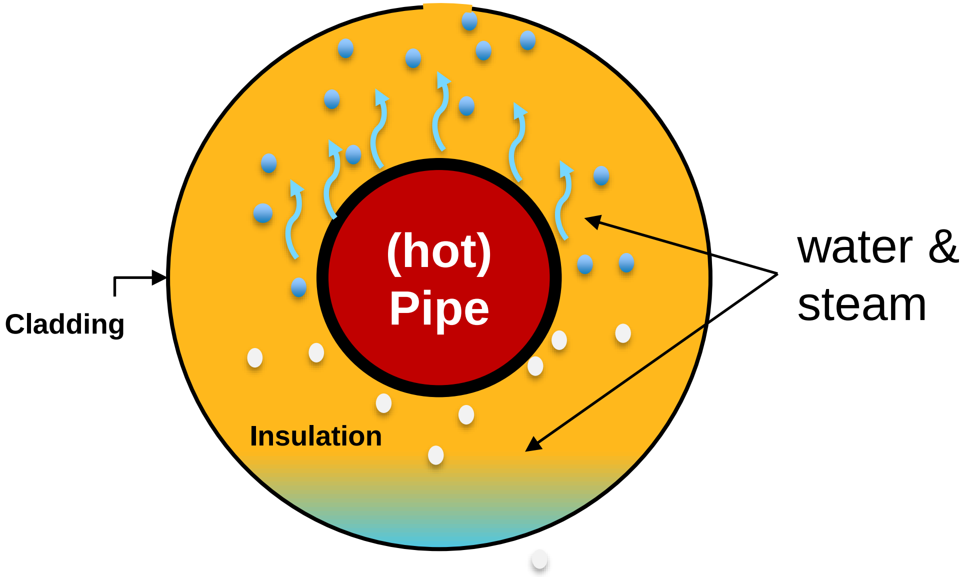
Conditions

- Once water gets under cladding, it never completely evaporates
- Water can continue to enter and damage cladding
- Electrolytes in the water may concentrate
- Insulation may leach chlorides and halides to metal surface

Damages or leaking joints may allow water ingress over time



Creating a permanent wet corrosive environment



Corrosion Under Insulation (CUI)

Market needs

Owner/operator: protection and performance

- High **durability**
- Reduce need for inspection and cost of maintenance

Specifier: wide temperature window and certification

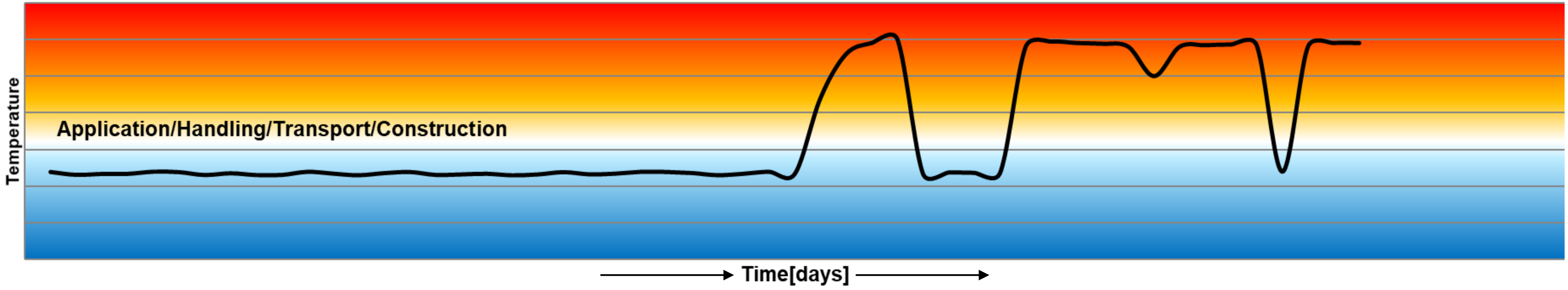
- Covering the widest **temperature window** possible with a small set of systems
- Certified to support durability claims

Applicator: ease of application and fast ready to handle time

- **Single coat** if possible and allowed by specifier
- Dry to handle/install with limited need for touch-ups
- Availability of repair system

Corrosion Under Insulation (CUI)

Conditions / market needs



Before going into service: ambient

- Application → easy to spray, hold-up,
- Handling → dry to handle time, hardness
- Transport → hardness, corrosion resistance
- Storage → corrosion resistance
- Installation → hardness, easy to repair (welds)

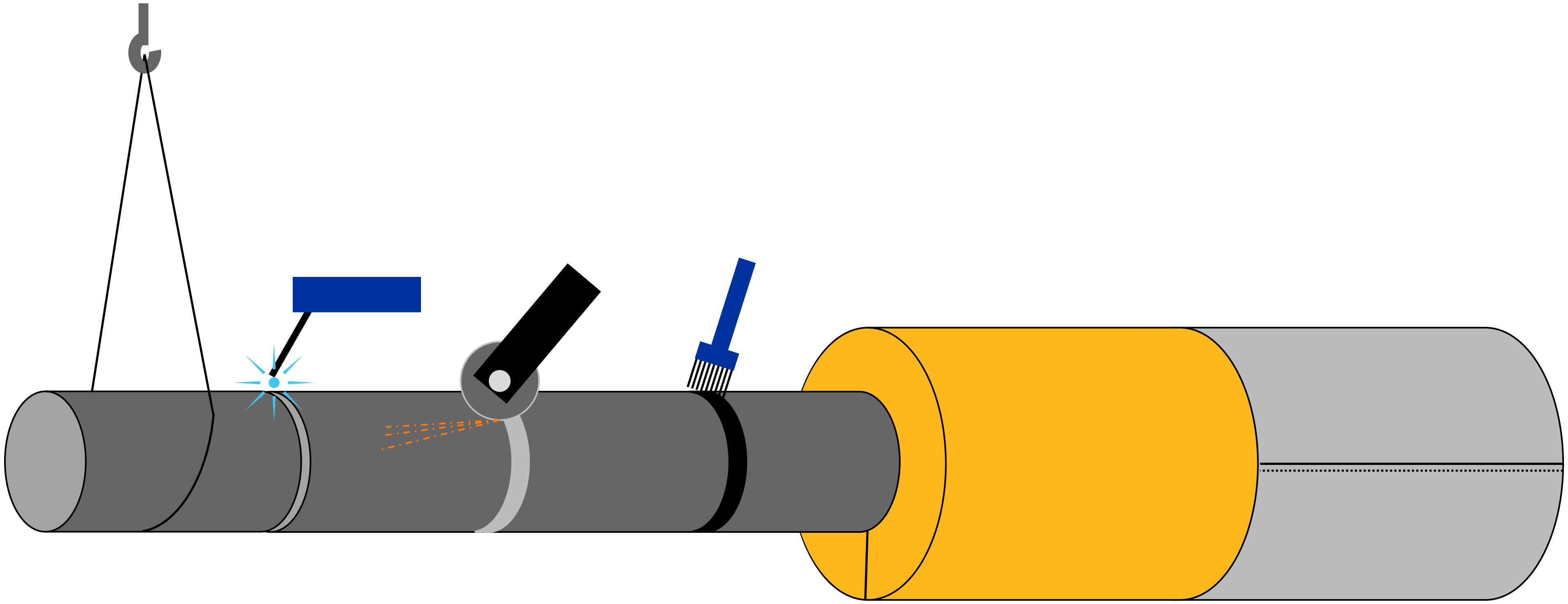
In-service: hot exposure, cycles

- Heat resistance
- Thermal shock resistance
- Corrosion resistance

Corrosion Under Insulation (CUI)

Market needs: durability

- New construction
  - After application: handling and transport and storage
  - Installation: handling and (weld) touch-ups
  - Installation of insulation and cladding
  - Pre-service: ambient exposure (un-insulated and insulated stages)



Heat Resistant Corrosion Protection

Systems Based on Barrier + Galvanic Protection

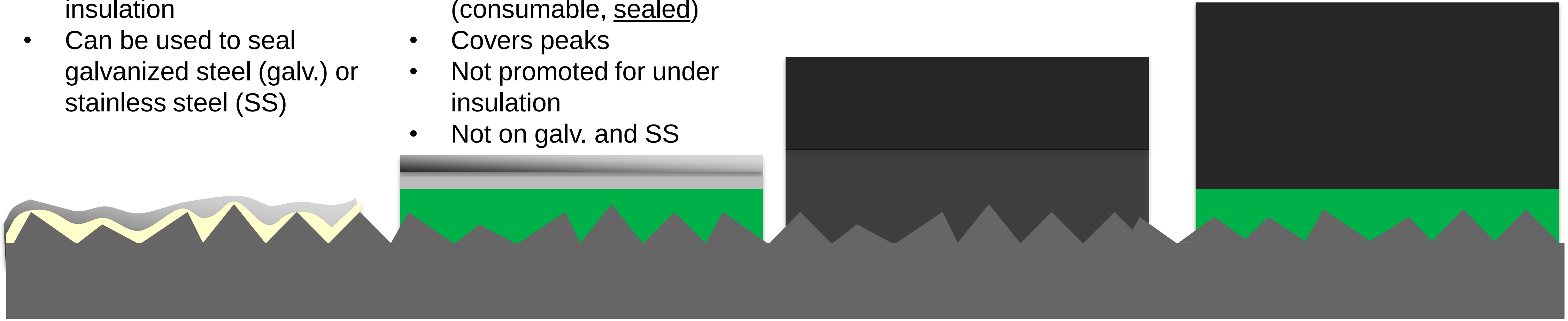
- Blasting profile of 50 µm: peaks covered?
- Barrier against moisture, impact and abrasion?
- Active galvanic protection?

<u>Silicone (acrylic)</u>
- 2 coats of 25 µm
- Total DFT = 50 µm
- Barely covers peaks
- Not suitable under insulation
- Can be used to seal galvanized steel (galv.) or stainless steel (SS)

<u>Zinc and Silicone (acrylic)</u>
- 75 µm zinc primer
- 1-2 coats of 25 µm
- Total DFT = 125 µm
- Galvanic protection (consumable, <u>sealed</u>)
- Covers peaks
- Not promoted for under insulation
- Not on galv. and SS

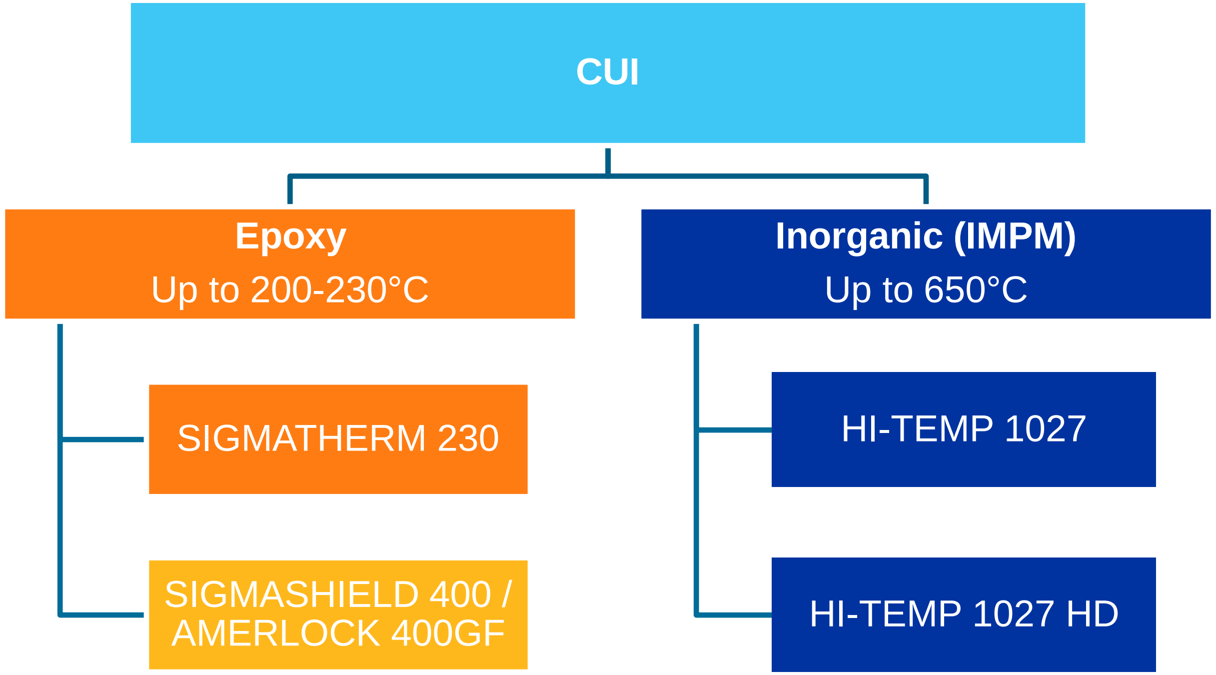
<u>Phenolic or Multipolymeric</u>
- 2 coats of 125 µm = 250 µm
- Option for one-coat system for **PPG HI-TEMP 1027/1027 HD**
- Covers peaks + 200 µm
- Extra barrier with extra coat possible
- OK under insulation
- OK for galv. and SS!

<u>Zinc-silicate + Multipolymeric</u>
- 75 µm + 1 or 2 coats > 300 µm
- Covers peaks + 250 µm
- Heavy barrier over galvanic primer
- Additional protection for transport and installation period
- OK under insulation
- Not needed for galv. and SS



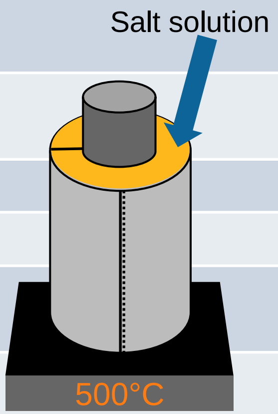
CUI Portfolio

Split by exposure, max. temperature and technology



Laboratory performance testing
ISO 19277

	Artificial ageing, §7.2.2		§7.3	§7.4	Optional	
	Neutral Salt spray	**Water immersion**	**Thermal cycling**	**Multiphase Cyclic CUI (PPG CUI Chamber)**	**§8.1 Cryogenic cycling**	**§8.2 Vertical pipe test**
CUI-1,2,3, Ambient cure	720h	3000h				
CUI-1,2,3, Heat conditioned (5x, 20h heat, 4h ambient)	480h	2000h				
CUI-1			20 cycles 5-60°C / 41-140°F	n/a		
CUI-2			20 cycles 5-150°C / 41-302°F	150°C, 15 cycles (1008h, 42 days)		
CUI-3			20 cycles 5-204°C / 41-400°F	175°C, 15 cycles (1008h, 42 days)		
CUI-1-Cryo					-196°C to 60°C	
CUI-2,3-Cryo					-196°C to 100°C	
CUI-1-Cryo, Heat conditioned (5x, 20h heat, 4h ambient)					-196°C to 60°C	
CUI-2,3-Cryo, Heat conditioned (5x, 20h heat, 4h ambient)					-196°C to 100°C	
CUI-2,3						30 cycles, 6 weeks, 500°C

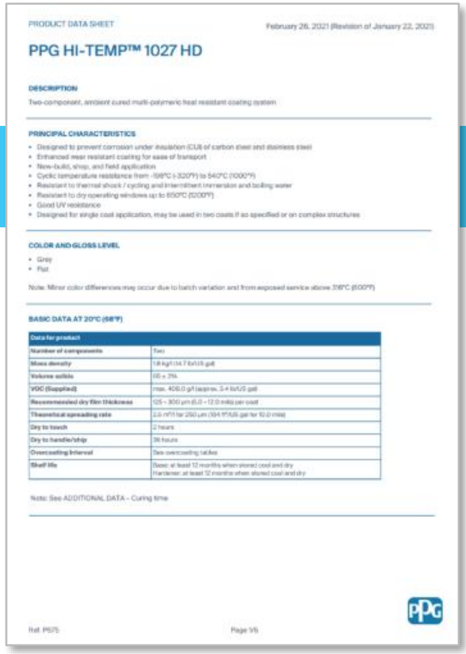


Currently requirement in IOGP-S715 & Norsok rev7

ISO19277 currently under review with ISO TC67

PPG HI-TEMP™ 1027HD

Single coat, two-component, multi-polymeric heat resistant coating system



PRODUCT DATA SHEET

February 26, 2021 (Revision of January 22, 2021)

PPG HI-TEMP™ 1027 HD

DESCRIPTION

Two-component, ambient cured multi-polymeric heat resistant coating system

PRINCIPAL CHARACTERISTICS

- Designed to prevent corrosion under insulation (CUI) of carbon steel and stainless steel
- Enhanced wear resistant coating for ease of transport
- New-build, shop, and field application
- Cyclic temperature resistance from -196°C (-320°F) to 540°C (1000°F)
- Resistant to thermal shock / cycling and intermittent immersion and boiling water
- Resistant to dry operating windows up to 650°C (1200°F)
- Good UV resistance
- Designed for single coat application, may be used in two coats if so specified or on complex structures

COLOR AND GLOSS LEVEL

- Grey
- Flat

Note: Minor color differences may occur due to batch variation and from exposed service above 316°C (600°F)

BASIC DATA AT 20°C (68°F)

Data for product	
Number of components	Two
Mass density	1.8 kg/l (14.7 lb/US gal)
Volume solids	65 ± 3%
VOC (Supplied)	max. 406.0 g/l (approx. 3.4 lb/US gal)
Recommended dry film thickness	125 - 300 µm (5.0 - 12.0 mils) per coat
Theoretical spreading rate	2.6 m²/l for 250 µm (104 ft²/US gal for 10.0 mils)
Dry to touch	2 hours
Dry to handle/ship	36 hours
Overcoating interval	See overcoating tables
Shelf life	Base: at least 12 months when stored cool and dry Hardener: at least 12 months when stored cool and dry

Note: See ADDITIONAL DATA – Curing time

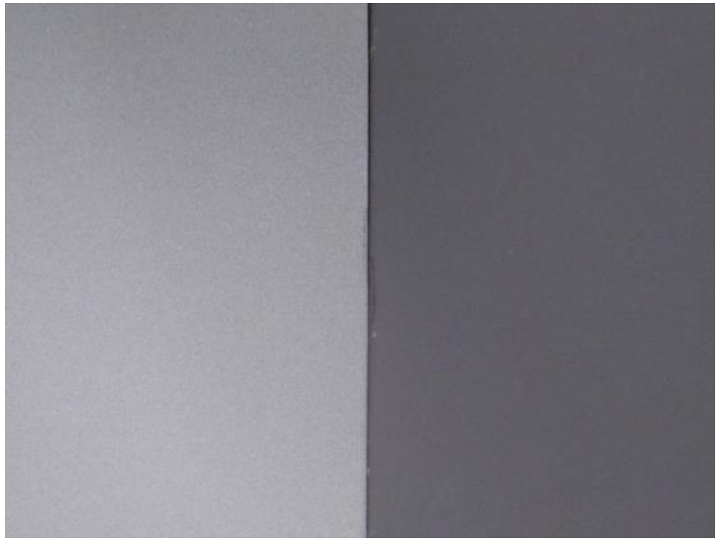
Ref. P575 Page 1/6

PPG HI-TEMP™ 1027 HD

Key Product Properties: application

- Two component, solvent based
  - 2:1 mixing ratio
  - 65% solids
- Single coat
  - Two coat system possible if client specified
  - 5-12mils/125-350µm in a single coat
  - Two shades available for contrast
  - Light shade is darker during wet stage and contrasts well to blasted steel
- Higher hardness before heat exposure
  - 5 steps higher pencil hardness before heat exposure compared to most single pack IMPM products

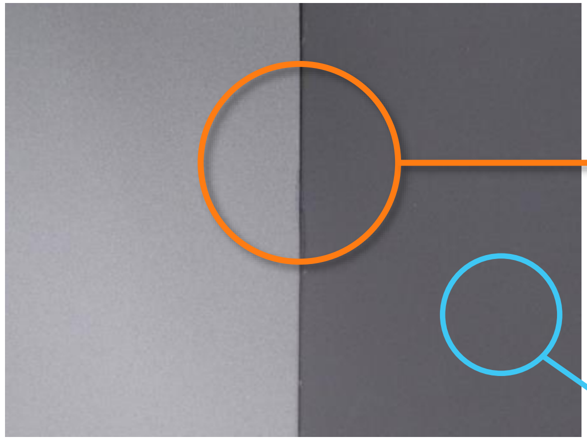
PPG HI-TEMP 1027 HD application



Gray Dark gray

PPG HI-TEMP 1027 HD

Shades



PPG HI-TEMP 1027 HD
gray & dark gray

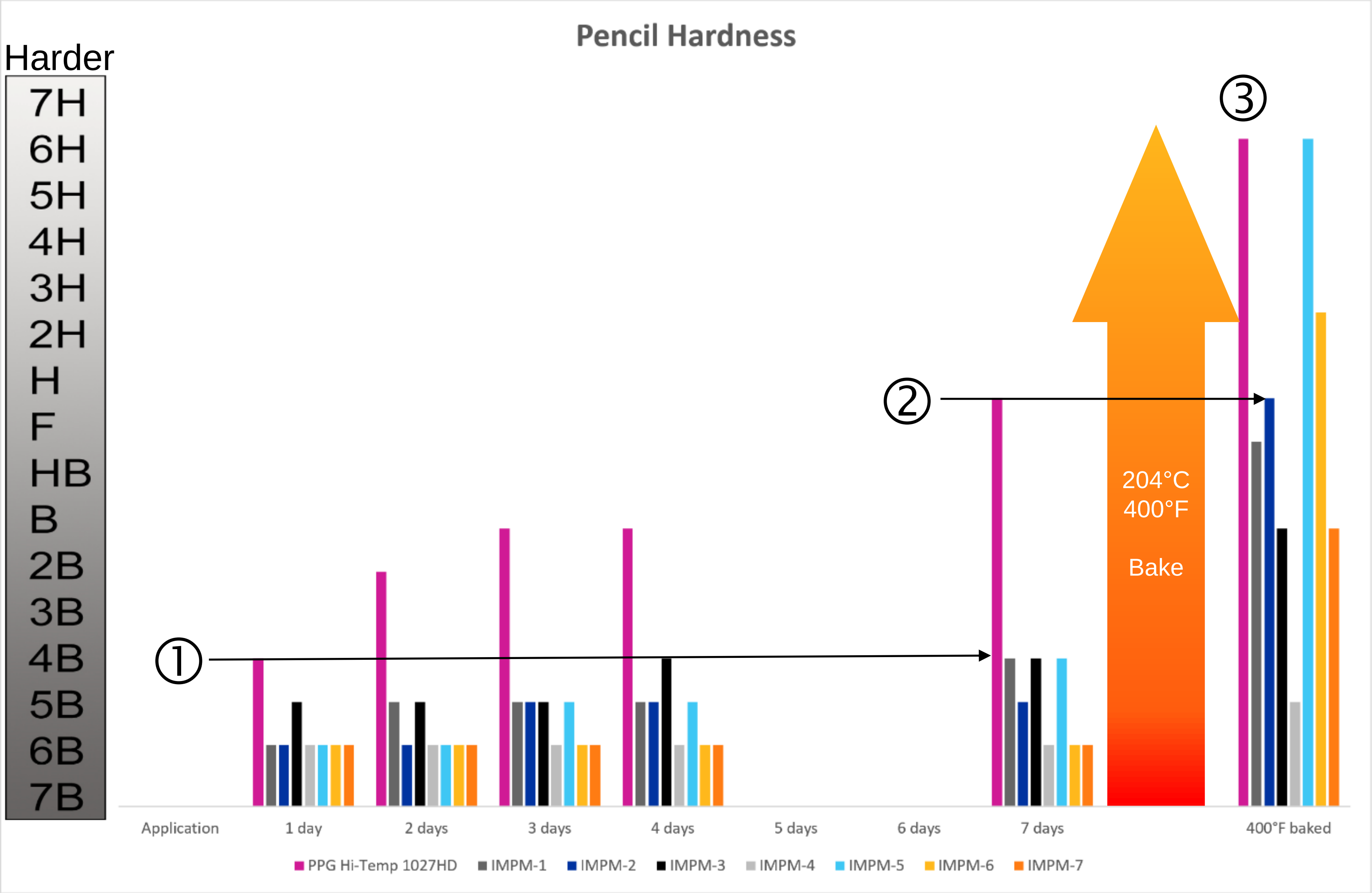
PPG HI-TEMP 1027
gray & black

Improved contrast between shades.

Touch-ups with 1027 Black on 1027HD dark gray are better match than gray.

PPG HI-TEMP 1027™ HD

Ambient Cure and Post-cured Hardness



PPH HI-TEMP 1027 HD

1. 24-hr cure hardness equal to alternatives after 4-7 days
2. Reaches a hardness that require alternatives to be baked
3. Highest hardness of all products tested

No heat cure required!

(bake shows effect of in-service exposure)

PPG HI-TEMP™ 1027 HD

Product Overview

Description	Data
Recommended DFT	250 - 350 µm (10 - 14mils) in a single coat
Dry to touch	2 hours @ 20°C/68°F
Dry to handle/ship*	36 hours @ 20°C/68°F
Temperature Resistance	-196°C to 650°C / -321°F to 1202°F

* Dry to handle/ship can range from 12–36 hours and are dependent on air and steel temperature. Refer to the PDS for additional information.

Freshly applied PPG HI-TEMP 1027 HD gray

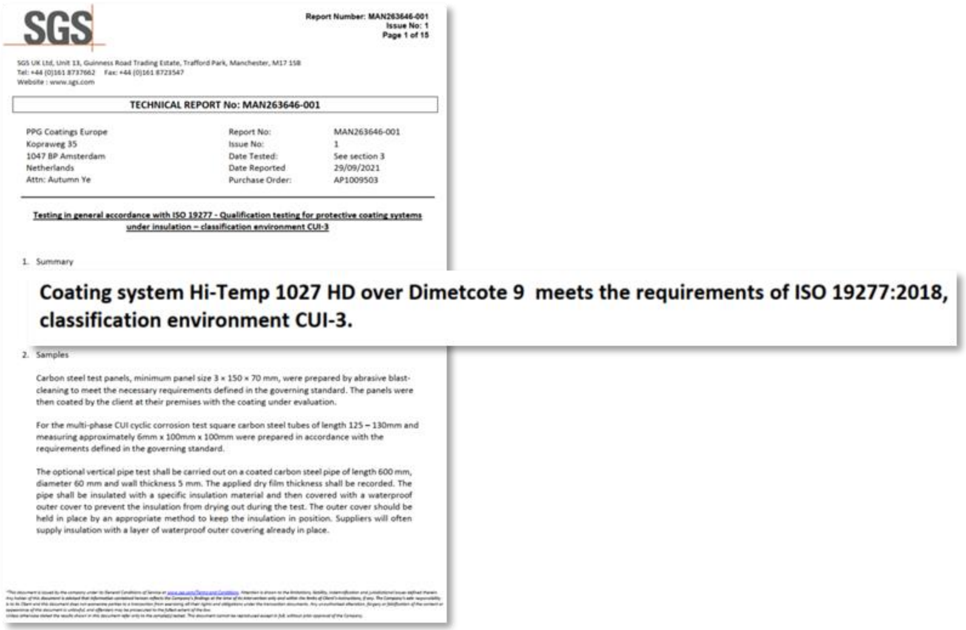
No damage to coating after being moved 24 hours after application

PPG HI-TEMP 1027 HD gray,
24 hours after application

PPG HI-TEMP™ 1027 HD

Key Product Properties: in-service

- Wide temperature exposure window
  - Similar to traditional single pack Hi-Temp 1027
  - Resistant to dry operating up to 650°C (1200°F
  - Cyclic temperature: -196°C (-320°F) to 540°C (1000°F)
- Can be applied on zinc-silicate
  - Passes ISO 19277 CUI3
  - Passes ISO 12944 C5H
- More testing ongoing
- Available worldwide in 2022



SGS

Report Number: MAN263646-001
Issue No: 1
Page 1 of 15

SGS UK Ltd, Unit 13, Guinness Road Trading Estate, Trafford Park, Manchester, M17 1SB
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Website : www.sgs.com

TECHNICAL REPORT No: MAN263646-001

PPG Coatings Europe	Report No:	MAN263646-001
Kopraweg 35	Issue No:	1
1047 BP Amsterdam	Date Tested:	See section 3
Netherlands	Date Reported	29/09/2021
Attn: Autumn Ye	Purchase Order:	AP1009503

Testing in general accordance with ISO 19277 - Qualification testing for protective coating systems under insulation – classification environment CUI-3

1. Summary

Coating system Hi-Temp 1027 HD over Dimetcote 9 meets the requirements of ISO 19277:2018, classification environment CUI-3.

2. Samples

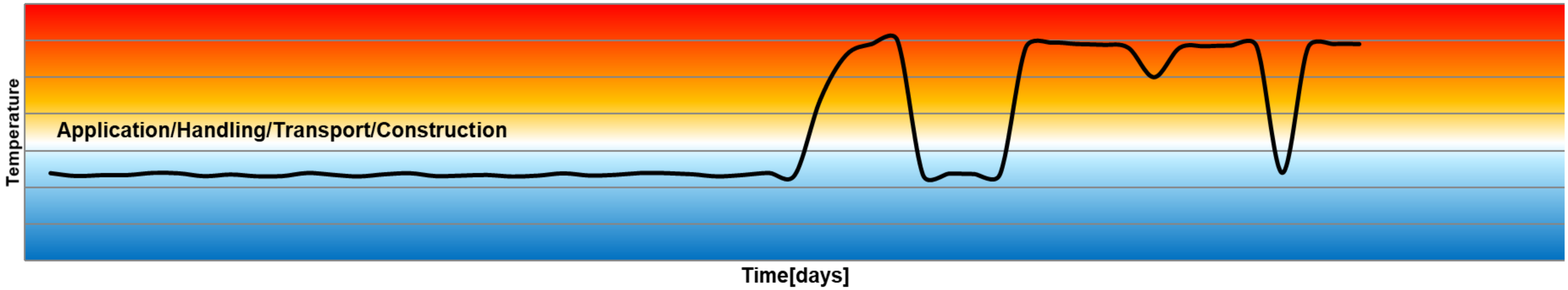
Carbon steel test panels, minimum panel size 3 × 150 × 70 mm, were prepared by abrasive blast-cleaning to meet the necessary requirements defined in the governing standard. The panels were then coated by the client at their premises with the coating under evaluation.

For the multi-phase CUI cyclic corrosion test square carbon steel tubes of length 125 – 130mm and measuring approximately 6mm x 100mm x 100mm were prepared in accordance with the requirements defined in the governing standard.

The optional vertical pipe test shall be carried out on a coated carbon steel pipe of length 600 mm, diameter 60 mm and wall thickness 5 mm. The applied dry film thickness shall be recorded. The pipe shall be insulated with a specific insulation material and then covered with a waterproof outer cover to prevent the insulation from drying out during the test. The outer cover should be held in place by an appropriate method to keep the insulation in position. Suppliers will often supply insulation with a layer of waterproof outer covering already in place.

PPG HI-TEMP 1027™ HD

CUI Prevention Attributes



Before going into service, **PPG HI-TEMP 1027 HD** provides a number of attributes

- Ease of application
- Quick hardness development to allow for handling/transportation
- Ambient corrosion resistance
- ISO12944 C5-Medium, C5-High with D9 as primer

In-service, PPG HI-TEMP 1027 HD can withstand extreme CUI conditions

- High heat: up 650°C/1200°F
- Cyclic temperature changes
- Thermal shock
- Wet conditions, Steam-out
- Out-of-service ambient conditions
- ISO 19277, CUI-3 on D9 as primer

PPG HI-TEMP 1027™ HD

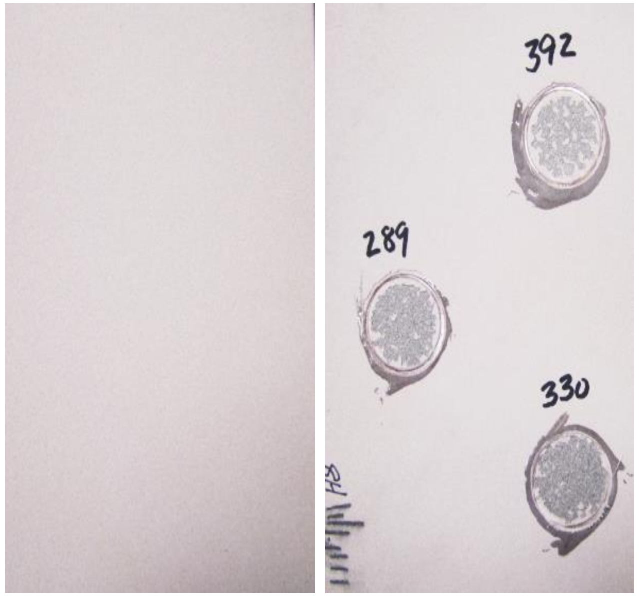
Thermal Shock Heat Resistance at 650°C (ASTM 2485)

Test Protocol

Single-coat Product Application

20 hours (overnight) at temperatures 540°C, 600°C, 650°C. 1000/1100/1200F

Water quenching after each temperature until 650°C



PPG HI-TEMP 1027 HD: 375µm

IMPM* (Competitor 1): 211µm

IMPM* (Competitor 2): 279µm

IMPM* (Competitor 3): 140µm

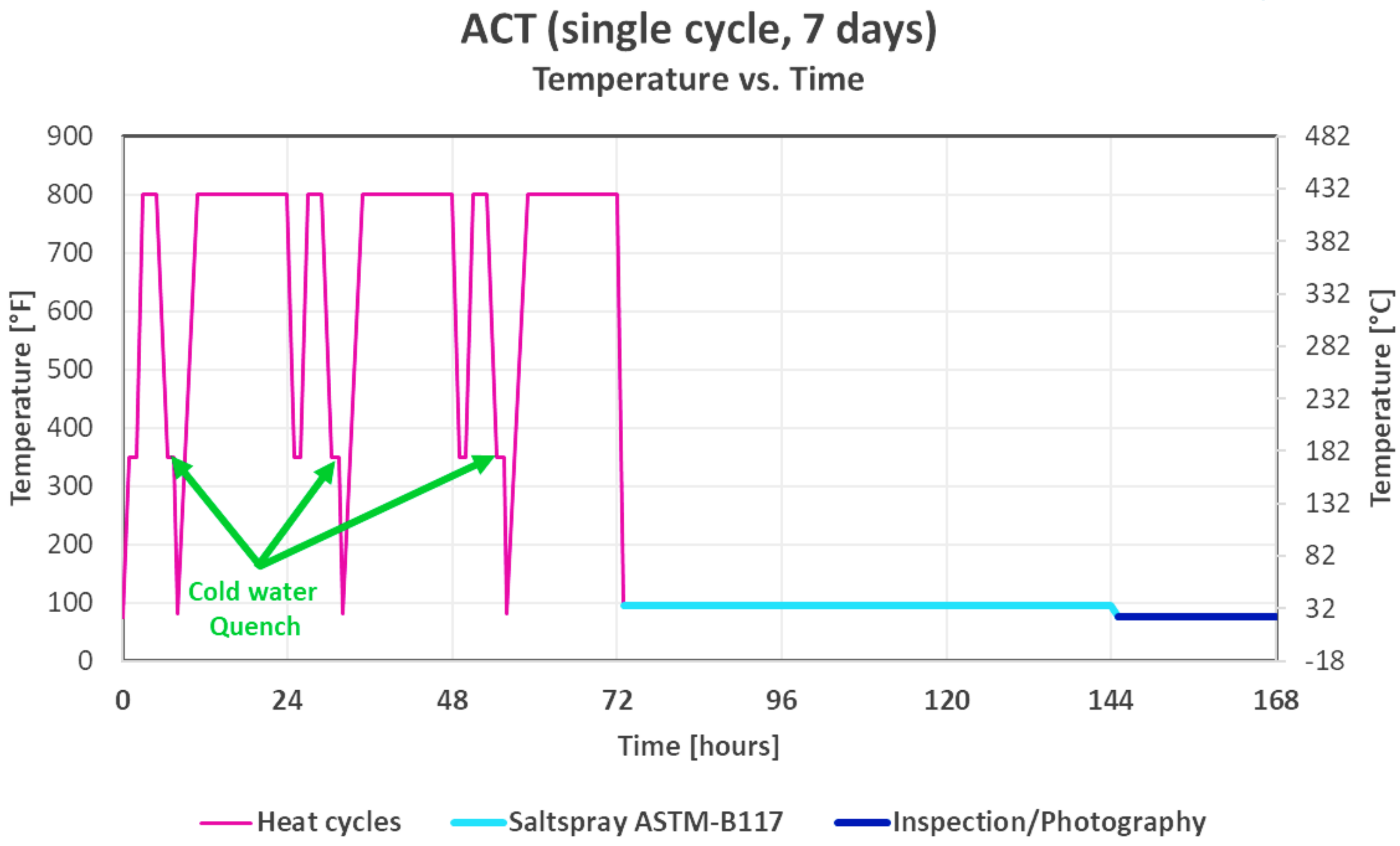
No cracking or delamination of PPG HI-TEMP 1027 HD

*IMPM: Inert Multi-Polymeric Matrix

PPG HI-TEMP 1027™ HD

Product Testing – Benchmarking

Accelerated Thermal Cyclic and Corrosion Testing



Test Protocol:
- (Dry) Thermal Cyclic and
- (Wet) Corrosion test (with salt fog)

Test Duration:
- 7-day cycle
- 3-day thermal cycles,
- 3-day salt fog, 1-day ambient
- repeated until failure

*IMPM: Inert Multi-Polymeric Matrix

PPG HI-TEMP 1027™ HD

Product Testing – Benchmarking

Accelerated Thermal Cyclic and Corrosion Testing (ACT) at 427°C

PPG
HI-TEMP 1027 HD
Cycle 10

IMPM*
(Competitor 1)
Cycle 2

IMPM
(Competitor 2)
Cycle 2

IMPM
(Competitor 3)
Cycle 2

IMPM
(Competitor4)
Cycle1

PPG HI-TEMP 1027 HD passes 10 cycles without damage, most other products fail after two cycles

*IMPM: Inert Multi-Polymeric Matrix

PPG HI-TEMP 1027™ HD

Product Testing – Benchmarking

ISO 12944

- Paints and varnishes – Corrosion protection of steel structures by protective paint systems
- Third-party test reports available
  - C4 high corrosivity meeting high durability (>15 years)
  - C5 very high corrosivity meeting medium durability (7-15 years)
- 720 hours salt fog
- 480 hours condensation

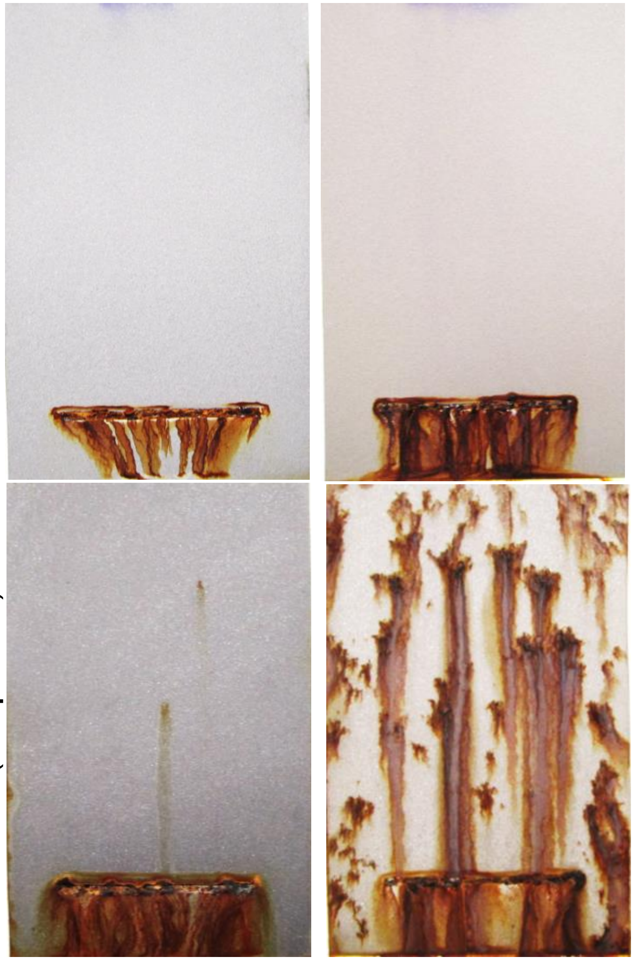
Durability with and without heat exposure

Salt Fog (720 hrs)

ISO 12944, C4 high/C5 medium

PPG HI-TEMP 1027HD

IMPM (**Competitor 1**)



No thermal exposure before salt-spray test	Thermal exposure before salt spray (371°C for 100hr)
Compare to **shipping/installation phase**	Compare to **shut-down cycles in service**

Note: This standard does not include tests related to high temperature or CUI but mentions high temperatures as 150-400°C (302-652°F) that "only occur under special conditions during construction or operation"

Summary

In short: PPG HI-TEMP 1027 HD

Fulfills market needs

HI-TEMP 1027 HD based on PPG's reliable inert multi-polymeric matrix* technology

- Proven Cui performance
- A wide temperature window up to 650°C/1200°F
- Improved hardness before heat exposure giving improved dry to handle properties
- Can be applied in a single coat for systems up to 10-14 mils
  - Two shades available
- Single pack HI-TEMP 1027 can be used for touch-up

Owner/operator: protection and performance

Specifier: wide temperature window and certification

Applicator: ease of application and fast ready to handle time

* IMPM, technology used in HI-TEMP 1027 and mentioned for CUI use in NACE/AMPP SP0198:
Standard Practice - Control of Corrosion Under Thermal Insulation and Fireproofing Materials - A Systems Approach (Formerly RP0198)

Appendix 8

A coating-integrated, impressed current cathodic protection (ICCP) and real time digital asset integrity monitoring system for preventing corrosion under insulation

(Michael Maguire)

Copsys Intelligent Digital Skin

Corrosion Under Insulation (CUI)
Disruptive Solution

Presentation virtually to:
EFC WP15 meeting "Corrosion in refinery and petrochemistry”
Berlin, 1 September 2022

Corrosion Under Insulation (CUI)

Serious process safety incidents	**20%**
Process systems maintenance cost	**40% - 60%**

US $10 Billion

Offshore oil and gas production

Our Solution

- "Feeling" Skin senses and locates pain (coating damage)
- Combination of advanced polymer, electronic and digital technologies
- Visualization via digital twin – First Time!
- Dynamic paint prevents biofouling and corrosion, with no detectable signature

Copsys Intelligent Digital Skin (CIDS)

CUI Digital Transformation

High Cost; High Risk; Sparse and Lagging Data

Live feed; Omnipresent and Real time

CIDS ICCP and Mechanical Performance Lab Tests

Coating Comparative Testing to ISO 19277

CIDS ICCP and Mechanical Performance Lab Tests

Laboratory Results

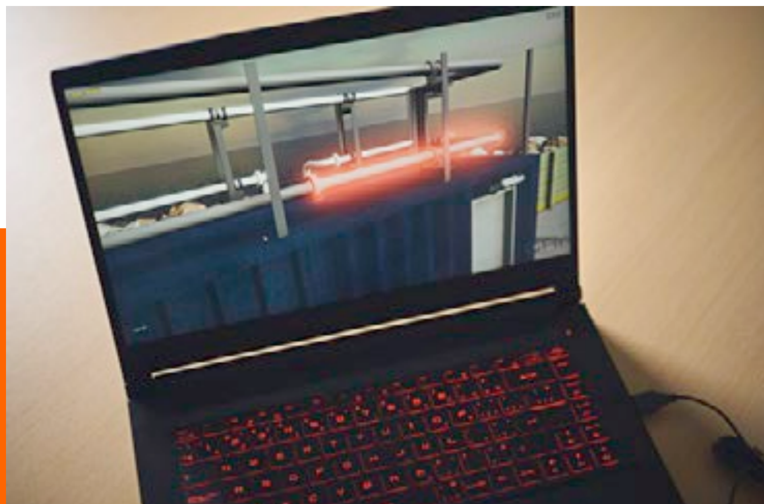
Initial exposure to electrolyte under insulation

Control
Commercial CUI Coating

CIDS Coated

High Temp cyclic loading

CUI Digital Twin

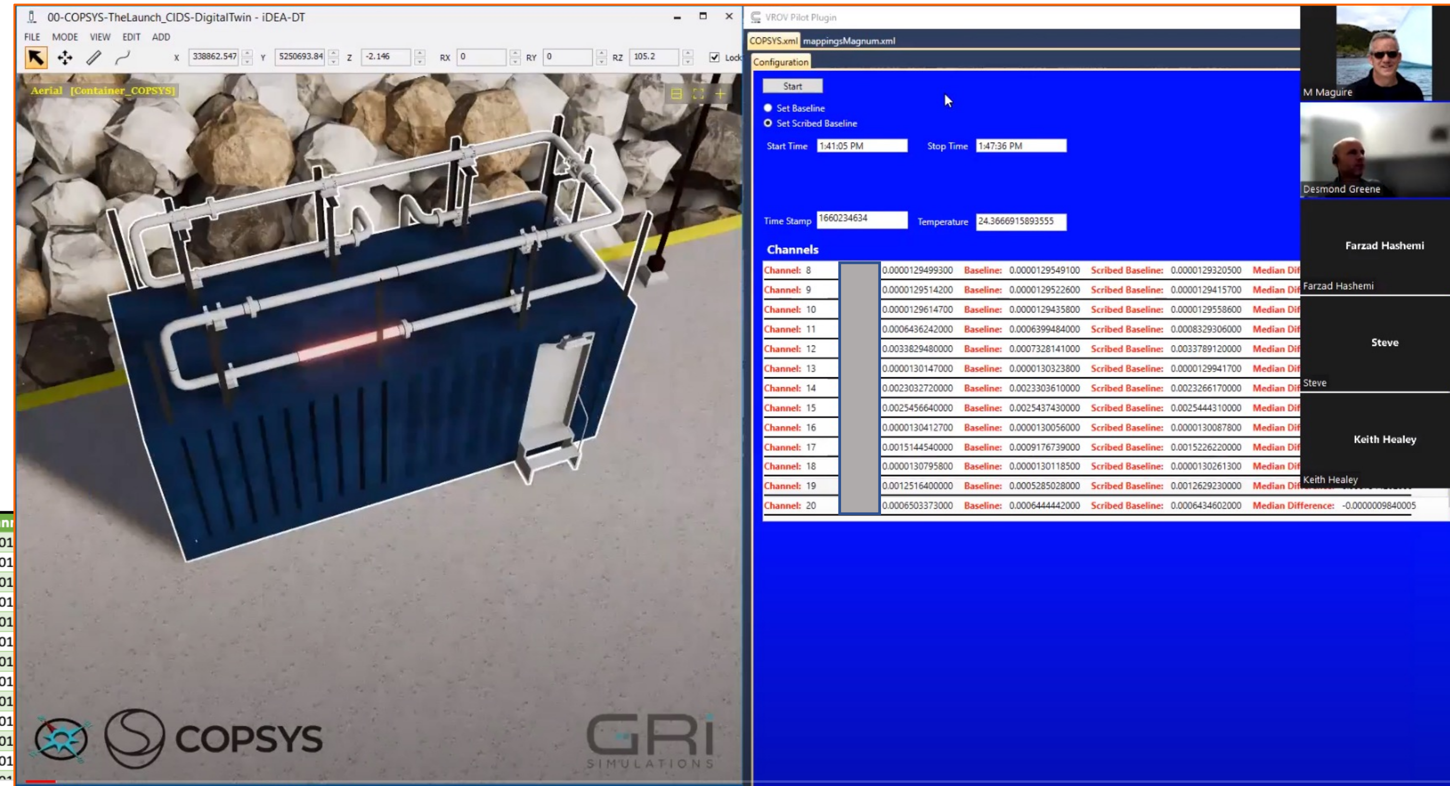


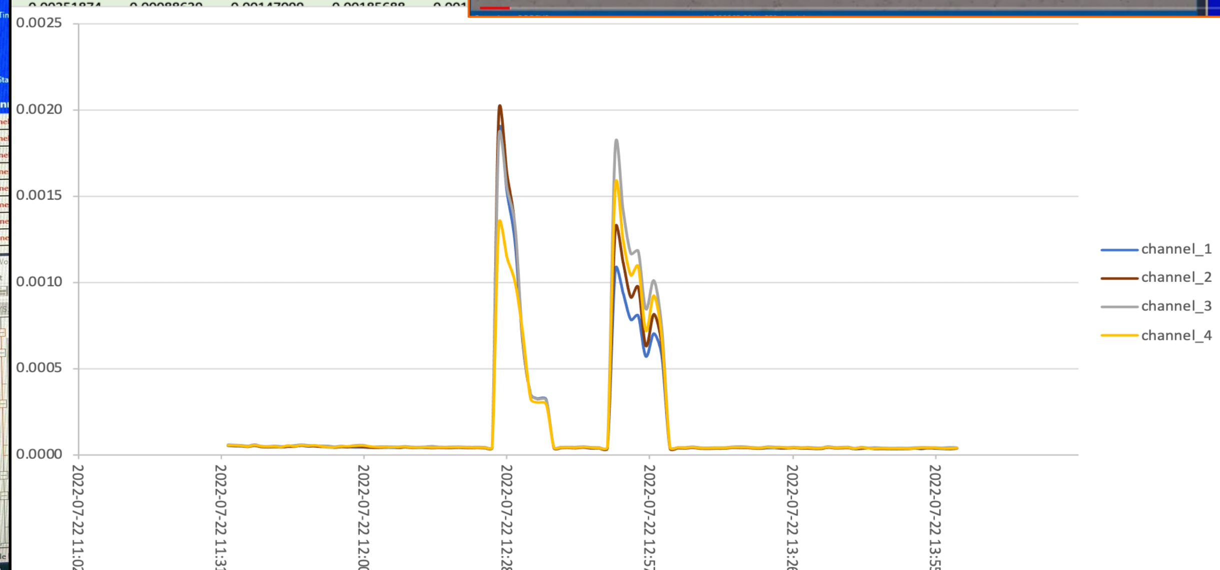
Field Trials
Live Demonstration

11 August 2022

Successful Trial witnessed by Lloyd's Register

ts	channel_1	channel_2	channel_3	channel_4	channel_14	channel_15	channel_16	channel_17	channel_18	chan
2022-07-22 0:00	0.00004341	0.00004319	0.00004281	0.00004335	0.00209257	0.00250944	0.00091767	0.00146836	0.00180718	0.001
2022-07-22 0:02	0.00004277	0.00004308	0.00004322	0.00004302	0.00208519	0.00251746	0.00085935	0.00147487	0.00185717	0.001
2022-07-22 0:03	0.00004255	0.00004390	0.00004330	0.00004377	0.00208724	0.00251811	0.00088543	0.00147453	0.00185692	0.001
2022-07-22 0:05	0.00004298	0.00004296	0.00004292	0.00004276	0.00208625	0.00252123	0.00090986	0.00146945	0.00185667	0.001
2022-07-22 0:06	0.00004380	0.00004459	0.00004460	0.00004342	0.00208365	0.00252390	0.00088599	0.00146915	0.00185598	0.001
2022-07-22 0:07	0.00004264	0.00004262	0.00004329	0.00004265	0.00206581	0.00251821	0.00089177	0.00147009	0.00181420	0.001
202						0.00251922	0.00088593	0.00147127	0.00185719	0.001
202						0.00252201	0.00088610	0.00147553	0.00185389	0.001
202						0.00251388	0.00088590	0.00147056	0.00185412	0.001
202						0.00251705	0.00088622	0.00147689	0.00185613	0.001
202						0.00251856	0.00089904	0.00147055	0.00185027	0.001
202						0.00252279	0.00090110	0.00146016	0.00184941	0.001
202										



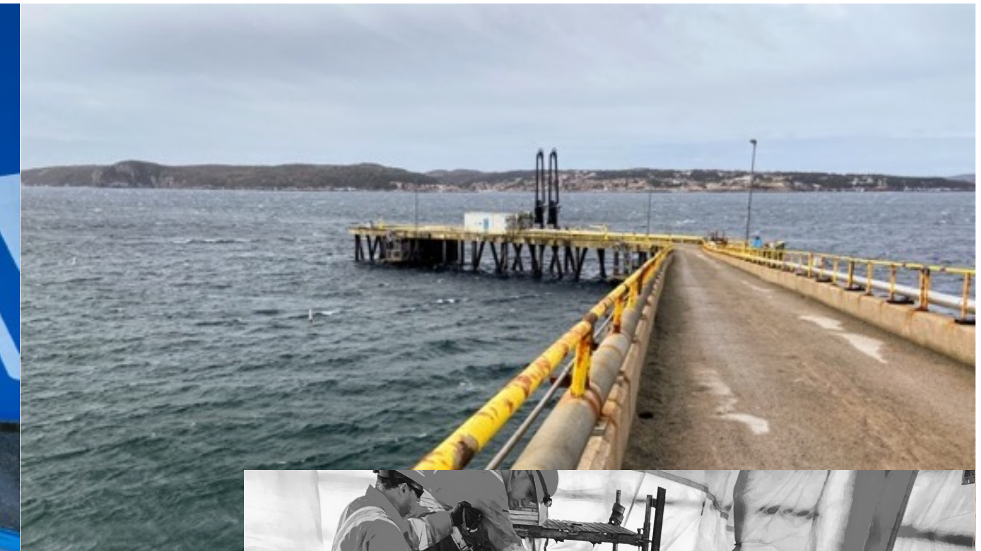


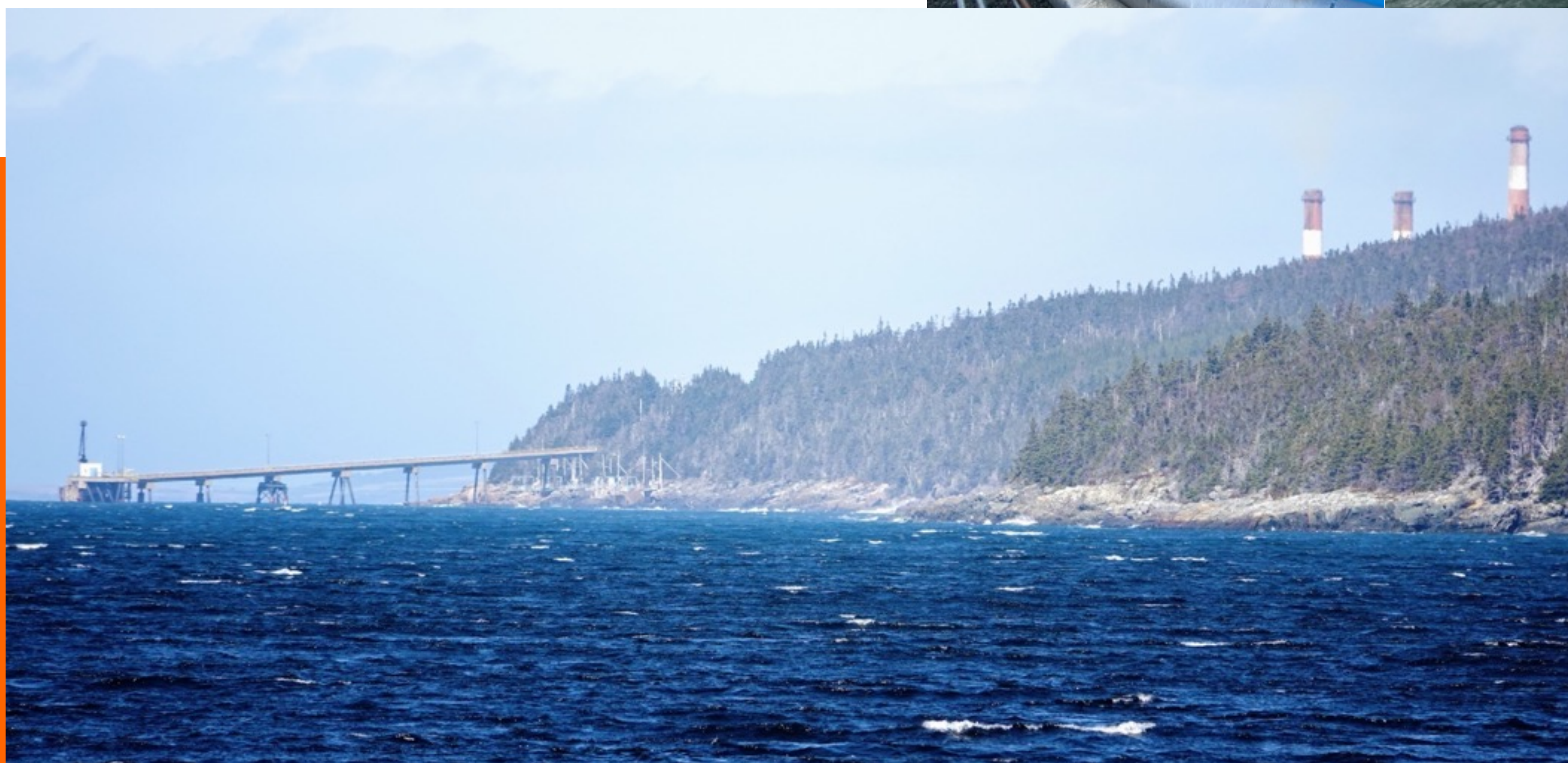
Digital Twin Detection and Location

CIDS Data Outputs and Analytic and Numeric Locating Advancements

Long Term Harsh Environment Exposure

NL Hydro Holyrood Thermal Generation Plant





Net Zero Technology Centre
Technology Driving Transition

Asset Integrity (CUI) Challenge 2022

"Our vision is to eliminate failures due to CUI by 2026 and we need new technology to make this a reality. We are looking for innovative ideas and technology for the detection, inspection and mitigation of CUI. Eliminating CUI will enhance safety, improve production efficiency and reduce fugitive emissions.

CIDS Delivers on all aspects of NZTC CUI Problem Statement

- √ **Detection** Detects CUI Hotspots before corrosion damage can occur
- √ **Inspection** Replaces manual inspection processes with persistent digital presence
- √ **Mitigation** Coating-integrated ICCP prevents corrosion even after barrier system failure

Net Zero Technology Centre
Technology Driving Transition

Asset Integrity (CUI) Challenge 2022

Proposed Pilot Project

- CIDS performance independent validation in offshore industrial environment
  - 2023/2024 turnaround
- Fully commercialized CUI solution
- NZTC 50% funding up to £ 1million

Expected Outcomes & Benefits

- Emissions Reduction 4%~7% per facility - Scalable
- CUI Elimination - Uncertainty, Risk, Cost
- Low risk, high return, R&D Eligible investment
- Other value-added applications

Seeking Operator Partner(s)

Partner Ask

- Pilot application of CIDS System to existing or planned facilities
  - Apply to already planned maintenance and repair activities
  - Multiple locations and conditions? Alternative applications?
- In-kind and/or cash support
  - 50% of total project value
- SME and supply chain engagement
- Access to CUI maintenance technical and commercial data and intelligence
- Consideration to work with multiple industry partners

Partner Risk

- Mitigated by CIDS validated superior mechanical and protective barrier performance

Copsys Team

Farzad Hashemi

Co-Founder

Metallurgic Engineer

30+ years Industrial Integrity Management

7 x Serial Entrepreneur

- Industrial Corrosion Management
- Powder metallurgy, die & mould manufacturing
- Domestic appliance manufacturing & distribution
- Medical equipment manufacturing
- Consumer paint manufacturing

Mike Maguire

Co-Founder

Naval Architect - Ocean Engineer

30+ years Energy & Technology Leadership

- Safety, Risk and Compliance
- Innovation & Project Management
- Board and Technical Committee experience
- Global network technical experts and decision makers

Bernardo Faragalli

Project Manager

Mechanical Engineer

18+ years Offshore Oil and Gas Leadership

- Facilties Engineering and Reliability
- Hibernia Team Lead for equipment integrity, fabric maintenance and corrosion remediation; regional lead for pressure equipment integrity
- Project manager for Atlantic Canada GHG Emissions Reduction R&D initiatives

Appendix 9

Gas Dryer: Reducing CUI risk and extending inspection intervals

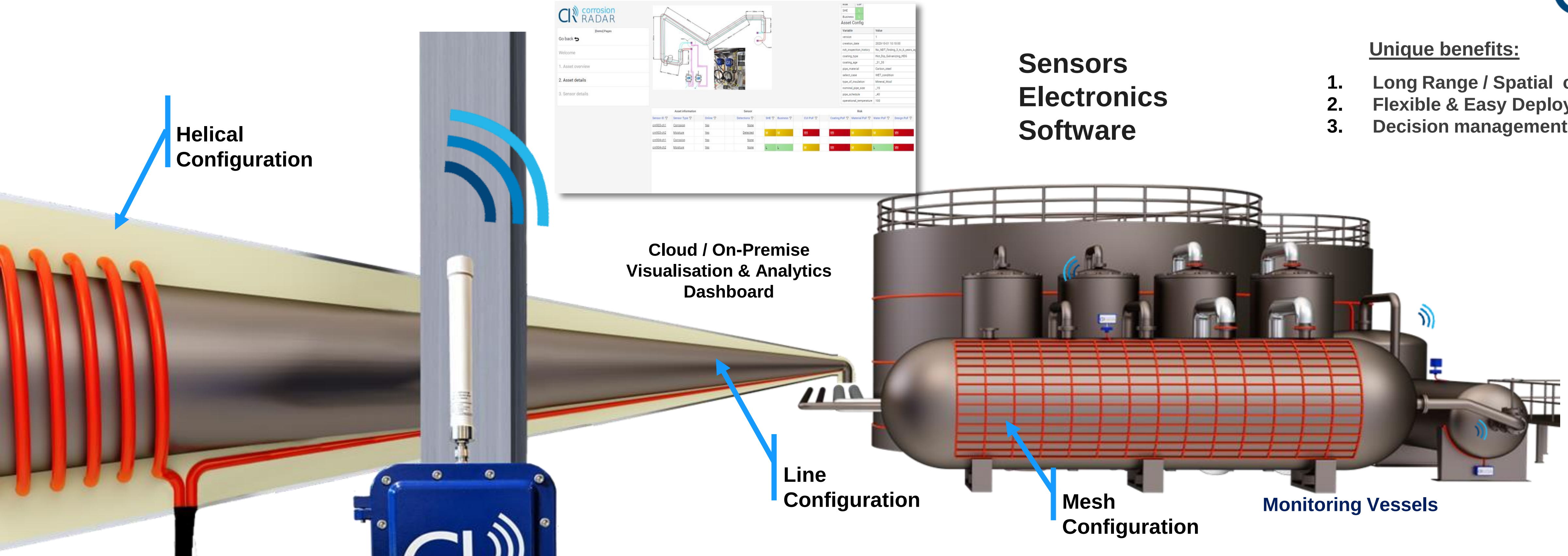
(William Noordink)

corrosion RADAR

Monitoring Risk of Corrosion Under Insulation on Critical assets

William Noordink CorrosionRADAR Ltd (UK) www.corrosionradar.com

CUI Risk Monitoring system with Moisture and Corrosion Sensing



Sensors
Electronics
Software

Unique benefits:

1. Long Range / Spatial coverage
2. Flexible & Easy Deployment
3. Decision management

CR Node (electronics)

ATEX/IECEx /UL Certification	Ex - Zone 1 and Zone 2 USA - Class 1 Div 2 (C1D2)
Ingress Protection	IP66
Power Source	Battery (optional 24V DC or 110V AC)
Communications	Wireless: Cellular/WirelessHART/LoRa Manual data transfer: BLE Tablet / USB

Sensors

Sensor Types	Moisture Corrosion
Sensor Length	Up to 100 m (per node)
Temperature Range (°C)	- 190 to +300 °C

Heading

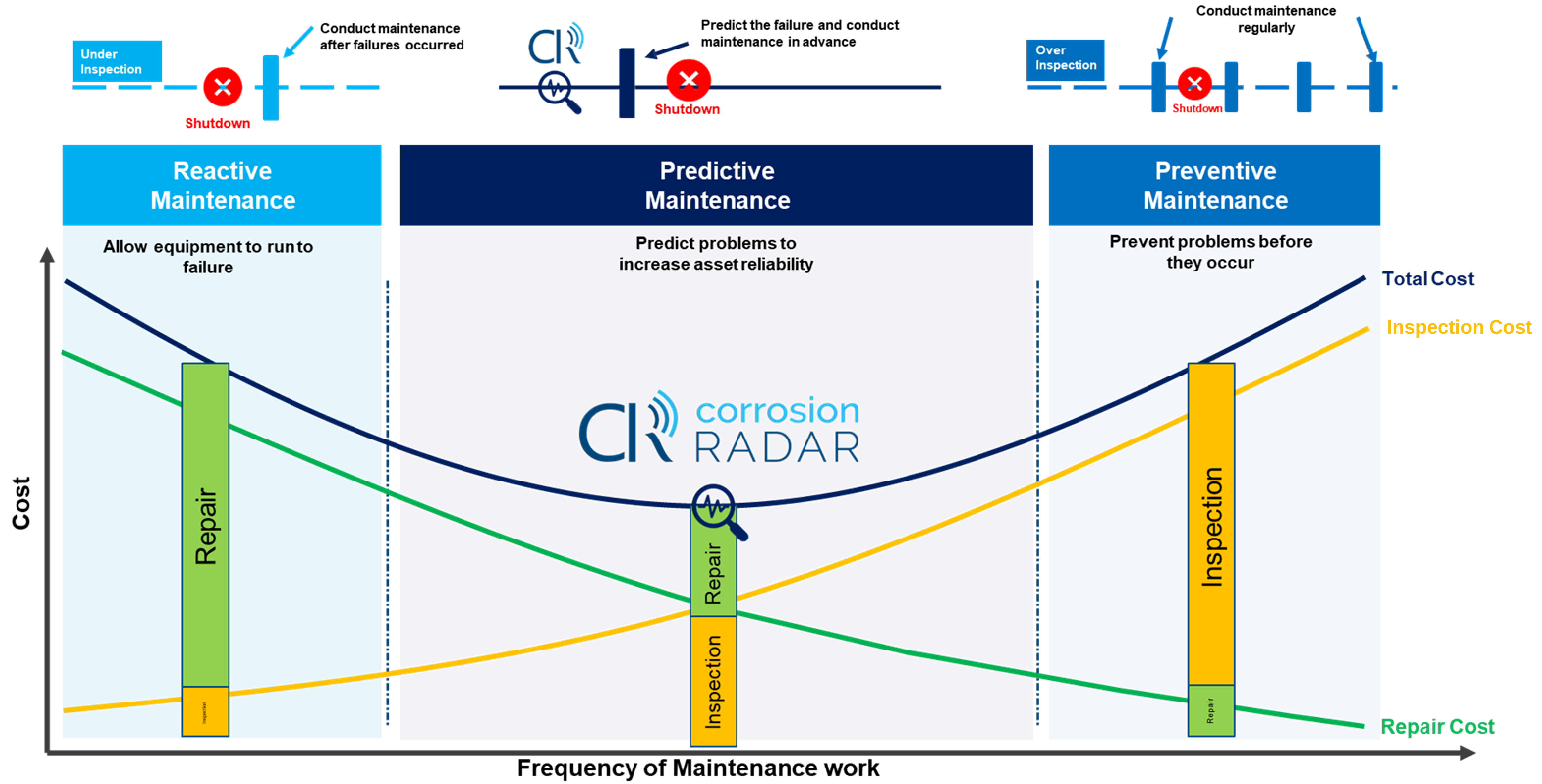
Sub heading

2022 Product Maturity Plan

	2018-2022 H2	2022 Q2	2022 Q4
Customer / Business Driver	**Electrically powered (Customer discovery)**	**Battery power, Bluetooth (Ease of Deployment)**	**Atex Zone 1**
Monitoring System Maturity	**GEN 1 EXd** **Power: Electrical** **Wireless: 4G, LoRA, WH*** **Software: Cloud** 4G	**GEN 3 EXnr** **Power: Battery** **Wireless: LoRA, BLE** **Data: Cloud, Edge** LoRa	**GEN 3 EXi** **Power: Battery** **Wireless: LoRA, BLE, WH*** **Data: Cloud, Edge, On-Prem*** WirelessHART
Sensors / Analytics	**Prove functionality** Corrosion/Moisture CUI Risk DNV	**Long Life** Corrosion (20+ years) Moisture (20+ years) CUI Risk API 581	**Long Life** Corrosion (20+ years) Moisture (20+ years) CUI Risk API 581

Optimise CUI inspection program (reduce cost and risk)

Optimisation of Inspection and Maintenance



Critical assets for CUI

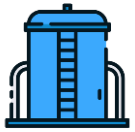
Assets with high probability of failure — H

+

Assets with high consequence of failure — H

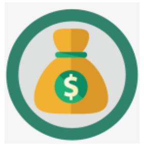
- Assets with intermittent temperature

- Assets with challenges to inspect



- Hazardous fluids or gases

- Large financial implications



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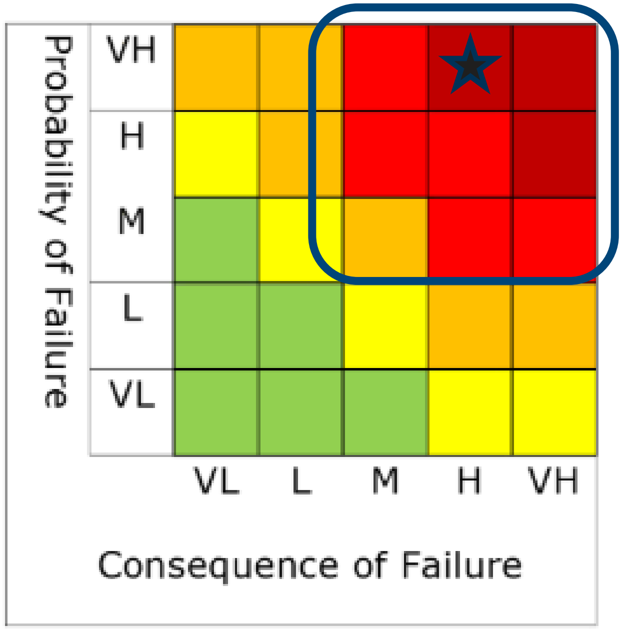
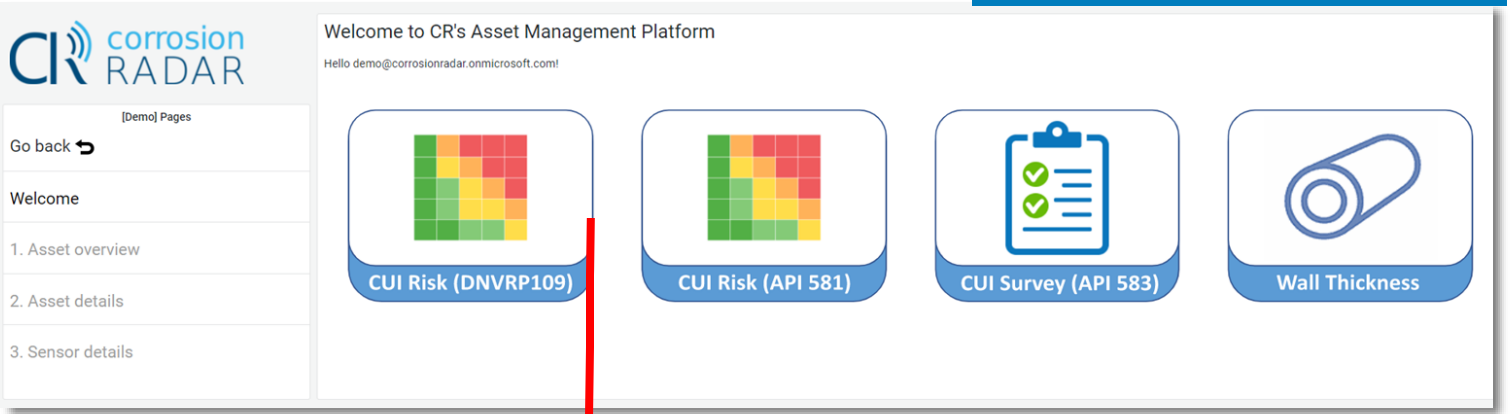
- Dryers/dehydrator units
- Refrigeration units
- Jetty and export Pipelines
- Shipper pump units

Critical applications

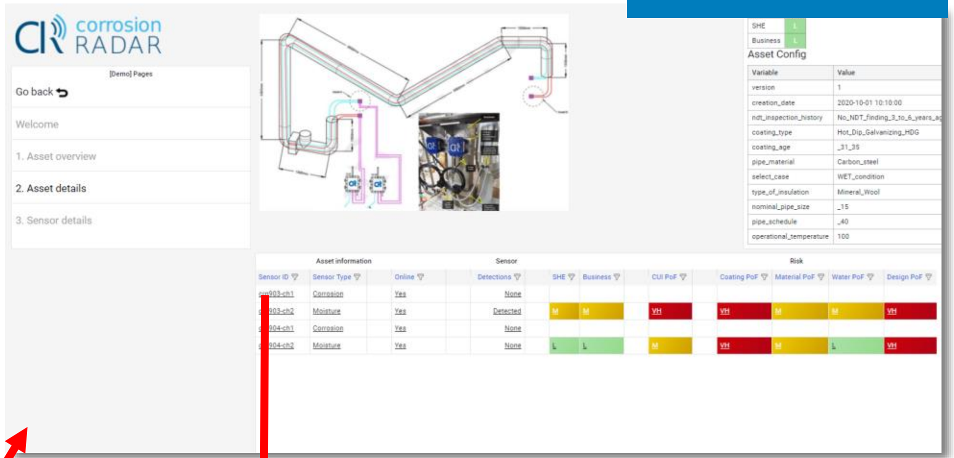


CUI risk software for inspection optimisation - API 581 and DNVRP109

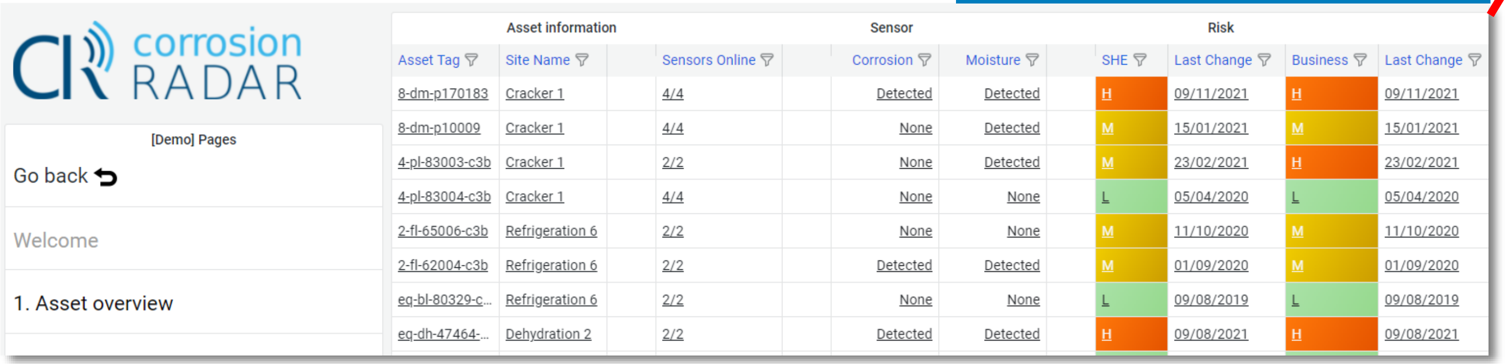
CR Applications



Asset risk (live)

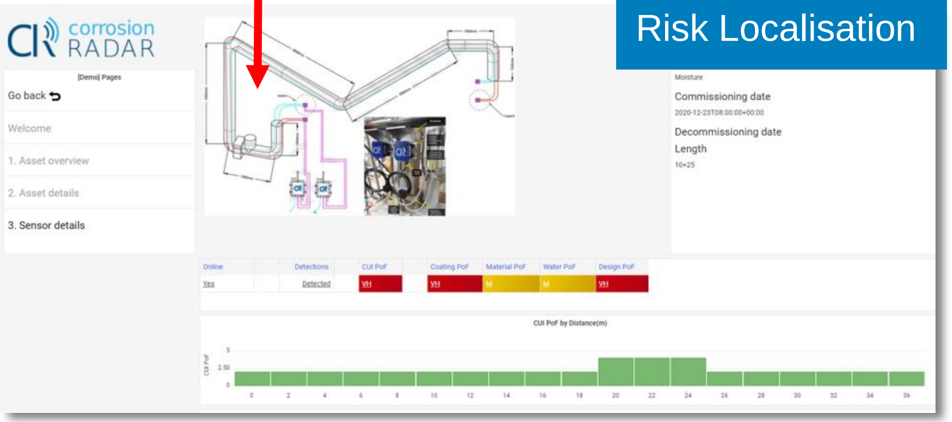


Site wide risk snapshot (live)



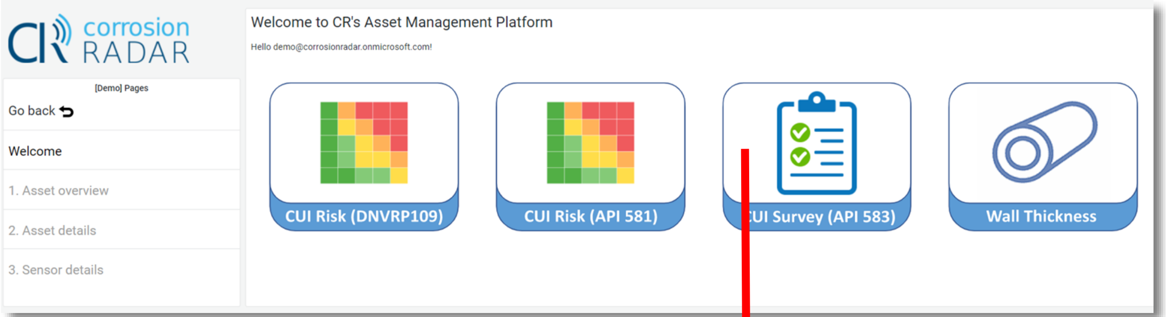
Asset information			Sensor		Risk			
Asset Tag	Site Name	Sensors Online	Corrosion	Moisture	SHE	Last Change	Business	Last Change
8-dm-p170183	Cracker 1	4/4	Detected	Detected	H	09/11/2021	H	09/11/2021
8-dm-p10009	Cracker 1	4/4	None	Detected	M	15/01/2021	M	15/01/2021
4-pl-83003-c3b	Cracker 1	2/2	None	Detected	M	23/02/2021	H	23/02/2021
4-pl-83004-c3b	Cracker 1	4/4	None	None	L	05/04/2020	L	05/04/2020
2-fl-65006-c3b	Refrigeration 6	2/2	None	None	M	11/10/2020	M	11/10/2020
2-fl-62004-c3b	Refrigeration 6	2/2	Detected	Detected	M	01/09/2020	M	01/09/2020
eq-bl-80329-c...	Refrigeration 6	2/2	None	None	L	09/08/2019	L	09/08/2019
eq-dh-47464-...	Dehydration 2	2/2	Detected	Detected	H	09/08/2021	H	09/08/2021

Risk Localisation



How to start?- CUI Survey (API583)

- Identify critical assets
- Deployment plan
- Prioritisation



CUI Assesment

First select Row Number: 2

Tag No.: YY-XX-T-1261

Category / Process unit: Isomerization

Feature / Component: Feed driers

Material Type: Carbon steel

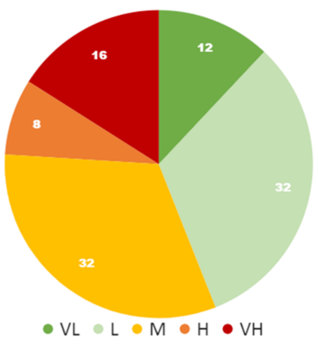
Parameter	Condition	Rating
Operating temperature	77 °C to 110 °C or cyclic service from >177 °C to <110 °C	5
Coating Age	General coating 8 to 15 years	3
Jacketing/ Insulation Condition	Average condition with good maintenance (such as sealed, no gaps, CML ports with plugs)	1
Heat Tracing	Steam system with visible leaks	5
External Environment	Coastal/marine, cooling tower overspray, or local external water source exposure (deluge systems, dripping steam condensate)	5
Insulation Type	Fiberglass, perlite, mineral fiber.Insulation has <10 ppm Cl	3
Line Size or Nozzle Size	≤2 in.	5
Parameter Rating Total		27
Likelihood Rating	High	

Overall CUI susceptibility

Assesment | CUI susceptible areas

Number	Tag No.	Process Unit	Component	Likelihood Rating /Status
1	YY-XX-T-1261	Isomerization	Feed driers	High
2	YY-XX-T-1261	Isomerization	Feed driers	High
3	YY-XX-T-1263	Delayed Coker	Coke drums	Medium
4	YY-XX-T-1264	Delayed Coker	Coke drums	Low
5	YY-XX-T-1265	Hydrotreating	H2S Absorber	Medium
6	YY-XX-T-1266	Hydrotreating	H2S Absorber	Very Low
7	YY-XX-T-1267	Isomerization	Feed driers	Low
8	YY-XX-T-1268	Isomerization	Feed driers	Low
9	YY-XX-T-1269	Isomerization	Feed driers	Very Low
10	YY-XX-T-12610	Isomerization	Feed driers	Very High
11	YY-XX-T-12611	Isomerization	Feed driers	High
12	YY-XX-T-12612	Sulfuric Acid Alkylation	Feed exchangers	Low
13	YY-XX-T-12613	Sulfuric Acid Alkylation	Contactor/Reactor	Low
14	YY-XX-T-12614	Sulfuric Acid Alkylation	Settler	Low
15	YY-XX-T-12615	Sulfuric Acid Alkylation	Deisobutanizer	Low
16	YY-XX-T-12616	Sulfuric Acid Alkylation	Debutanizer	Low
17	YY-XX-T-12617	Sulfuric Acid Alkylation	Depropanizer	Very Low
18	YY-XX-T-126218	Sulfuric Acid Alkylation	Piping	Medium
19	YY-XX-T-126219	Sulfuric Acid Alkylation	Piping	Medium
20	YY-XX-T-126220	Sulfuric Acid Alkylation	Piping	Medium
21	YY-XX-T-126221	Sulfuric Acid Alkylation	Piping	Medium
22	YY-XX-T-126222	Sulfuric Acid Alkylation	Piping	Medium
23	YY-XX-T-126223	Sulfuric Acid Alkylation	Piping	Very High
24	YY-XX-T-126224	Sulfuric Acid Alkylation	Piping	Very High
25	YY-XX-T-12621	Isomerization	Feed driers	Medium
26				

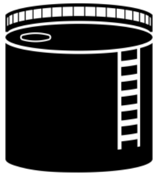
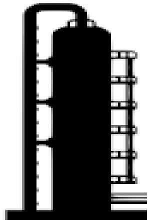
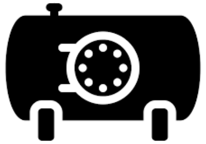
Likelihood Rating %

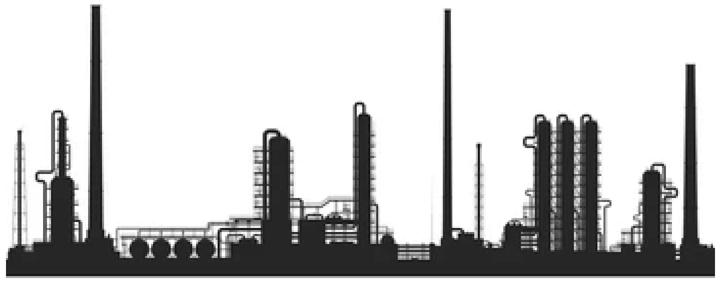


Example ROI - A PLANT WITH ~$3.5M ANNUAL CUI COST

Net 61% Savings

$2.1M Savings pa

$200K Savings	$215K Savings	$235K Savings	$490K Savings	$1.25M Savings
77% Savings	79% Savings	76% Savings	71% Savings	63% Savings
Storage Tanks	**Columns**	**Pressure Vessels**	**Critical Pipelines (100m unit)**	**General Pipelines (100m unit)**
				
2 nos	2 nos	8 nos	20 nos	200 nos



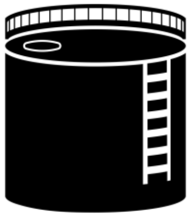
Inspection Tasks	No Monitoring	With CUI Monitoring
Scaffolding Per year	$1.5M	$0.48M
Insulation Per year	$1.3M	$0.42M
Other Costs Per year	$0.7M	$0.23M
CR cost	Nil	$0.27M
TOTAL CUI COST	$3.5M	**$1.4M**
Net Saving	Nil	**$2.1M**
Net Saving %		**61%**

Return On Investment using CR CUI Monitoring on small tank

NET SAVINGS PER YEAR

$18,953

52%



Please see next slide for Return On Investment calculations

Direct Savings:

Through deploying CR's CUI Monitoring System, **Client will save 52% per year** by optimising their current CUI inspection method through the use of continuous monitoring.

This **52% saving excludes indirect savings** such as:

- Risk reduction via automated monitoring to **reduce health and safety incidents**
- Reduce risk of **pollution** (by reducing risk of leaks into atmosphere)
- Reducing risk of loss of **production** due to **reducing downtime** associated to CUI
- **Extending life** of tank

Enabling Smarter Assets

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