Appendix 1

List of participants and excused persons

Participants EFC WP15 meeting 26th September 2006 Maastricht

Surname	Name	Company	Country
Delfina	Bersano	Eni R&M	ITALY
Stuart	Bond	TWI	UK
Chris	Claesen	Nalco	BELGIUM
Marit	Dahle	Statoil ASA	NORWAY
Hennie	de Bruyn	Borealis AS	NORWAY
Frank	Dean	Ion Science Ltd	UK
François	Dupoiron	Total Petrochemical	FRANCE
Jean Pierre	Floquet	Honeywell	BELGIUM
Isaak	György	MOL	HUNGARY
Russell	Kane	Honeywell	USA
Maarten	Langbroek	ABB Lummus Global	NETHERLANDS
Maarten	Lorenz	Shell Global Solutions International B.V.	NETHERLANDS
Richard	Mathers	Nalco Energy Service	UK
Martin	Richez	Total	FRANCE
Roberto	Riva	Eni R&M	ITALY
Sabina	Ronneteg	Sandvik	SWEDEN
François	Ropital	Institut Français du Pétrole	FRANCE
Rob	Scanlan	Conoco	UK
Antoine	Surbled	Couronnaise de Raffinage	FRANCE
Stefano	Trasatti	University of Milan	ITALY
Jack	Tulp	Fluor BV	NETHERLANDS
Hildegunn	Urke	Statoil ASA	NORWAY
Lars	Volden	Statoil ASA	NORWAY
Andrew	Walling	Ion Science Ltd	UK
Stefan	Winnik	Exxon Mobil Chemical	UK

Excuses received for the EFC WP15 meeting 26th September 2006 Maastricht

Surname	Name	Company	Country
Curt	Christensen	Force Institutes	DENMARK
André	Claus	GE Betz	BEGIUM
Martin	Holmquist	Sandvik Materials Technology	NETHERLANDS
Joanna	Hucinska	Gdansk Technical University	POLAND
Andrew	Kettle	Exxon Mobil	UK
Istvan	Lukovits	Chemical Research Center	HUNGARY
David	Owen	GE Betz	UK
Jerome	Peultier	Industeel	FRANCE
Alain	Pothuaud	GE Betz	FRANCE
Andrew M	Pritchard	Corrosion & Fouling Consultancy	UK
Iris	Rommerskirchen	Butting Edelstahlwerke GmbH&Co KG	GERMANY
Gerit	Siegmund	ExxonMobil Germany GfKorr	GERMANY
Barrie	Spafford		UK
Betrand	Szymkowiak	IFP Technology Group - AXENS	FRANCE
Jean Luc	Themiot	BP	FRANCE
Anni	Visgaard Nielsen	Statoil Refinery, Kalundborg,	DENMARK

Appendix 2

EFC WP15 Activities

European Federation of Corrosion (EFC)
http://www.efcweb.org

EFC Working Party 15 « Corrosion in Refinery » Activities

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

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

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

Publications

EFC Working Party 15 « Corrosion in Refinery » Activities

WP Meetings

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

Proposal for spring 2007 ???

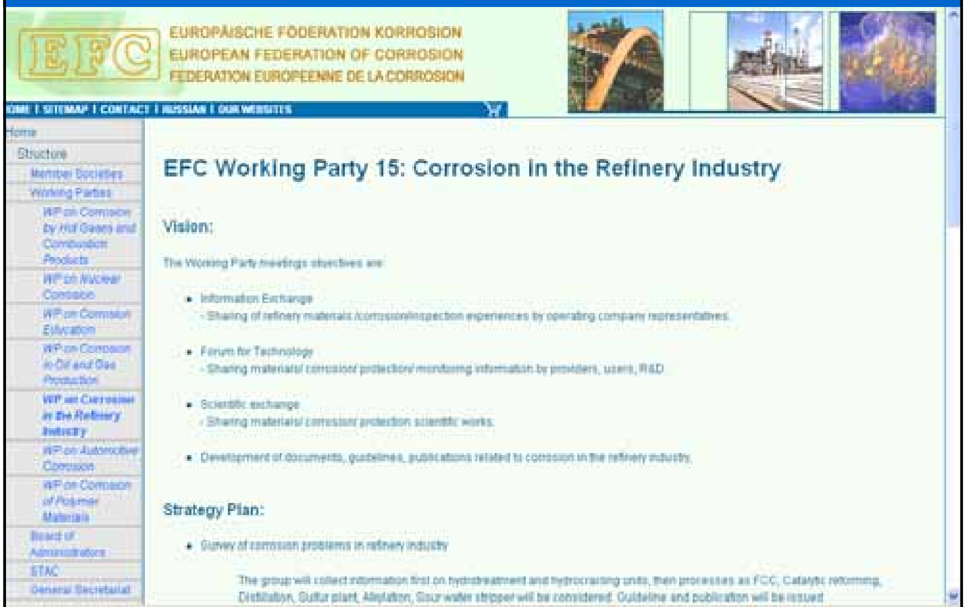
- One meeting at Eurocorr in conjunction with the conference. (this meeting during Eurocorr 2006 26 September in Maastricht)

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

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

EFC Working Party 15 « Corrosion in Refinery » Activities

http://www.efcweb.org/WP_on_Corrosion_in_the_Refinery_Industry.html



EFC Working Party 15 meetings: 2002-2006

- Task force an Corrosion Under Insulation
- Failure cases discussions
- Monitoring presentations
- Exchange of information on standards

Publications

• EFC Guideline n°40 « Prevention of corrosion by cooling waters » available from Maney Editor http://www.maney.co.uk/search?fwaction=show&fwid=623

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

•EFC Guideline n° 42 Collection of selected papers (available July 2007)

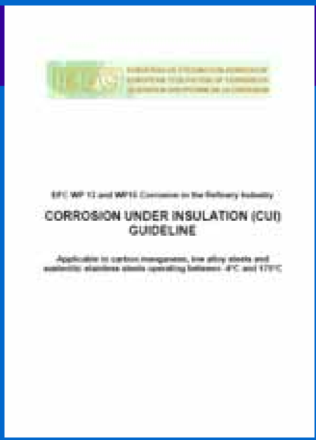
•EFC Guideline n° 46 on corrosion in amine units (available February 2007)

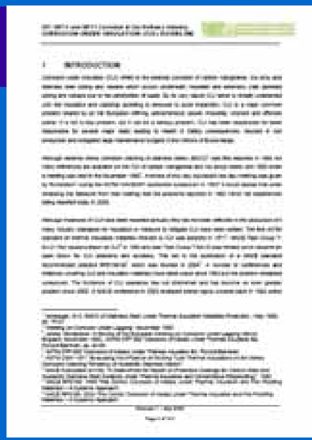
•EFC Guideline on Corrosion Under insulation (we are working on it)

•Future publications

- Typical refinery failure cases atlas ?
  Send your contribition to Francois Ropital
- other suggestions ?

EFC Guideline on Corrosion Under Insulation





Final comments for the 1 December 2006 to be sent to Stefan Winnik (the version will on CUI-EFC website by 1/10)

Submission for publication Dec 2006

CORROSION IN REFINERY INDUSTRY

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

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

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

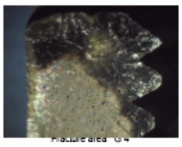
NATURE OF THE INCIDENT : temperature breakaway and breaks of screws

CONSEQUENCES : stop of the unit

MATERIAL: carbon steel

PHOTO AND SCHEME :

Metallographic cross section G 50



Fracture area G 4

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

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

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

CORROSION IN REFINERY INDUSTRY

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

TYPE OF CORROSION : MOLTEN METAL CORROSION

CAUSES :

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

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

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

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

REMEDY :

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

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

BIBLIOGRAPHIC REFERENCES :

EFC Working Party 15 — Eurocorr sessions: 2003-2006

- Opened Corrosion in Refinery Sessions 2003,2004,2005,2006
- Workshop with WP3 (High Temperature) on high temperature corrosion in Refinery Petrochemistry in 2004
- Workshop with WP1 (Corrosion & Scale inhibition) on Naphthenic acid corrosion inhibition in 2005
- Joint Session with WP13 (Oil & Gas) production on sour service in 2003
- Joint Session with WP1 on cooling water inhibition in 2006

EFC Working Party 15 — Spring meeting: 2003-2006

- 10 April 2003 in Pernis (NL)
- 8-9 March 2004 in Milano (I) in cooperation with NACE Italia
- 17-18 March 2005 in Trondheim (N)
- 31 March 2006 in Venezia (I) in cooperation with NACE Italia

EFC Working Party 15: Future objectives of the group

- **Eurocorr Sessions**

✓Implements of Eurocorr sessions or workshops with other WP and NACE (a workshop can be on a topic without formal presentation)

✓Implication of young corrosion students, PhD at Eurocorr session with a dedicated poster session

- **Working Party Meetings**

✓Future topics of task forces

✓Facilitating student trainings outside their countries in our companies

✓Presentation of UE funding projects in our area (if they are)

✓Collaboration on Standard

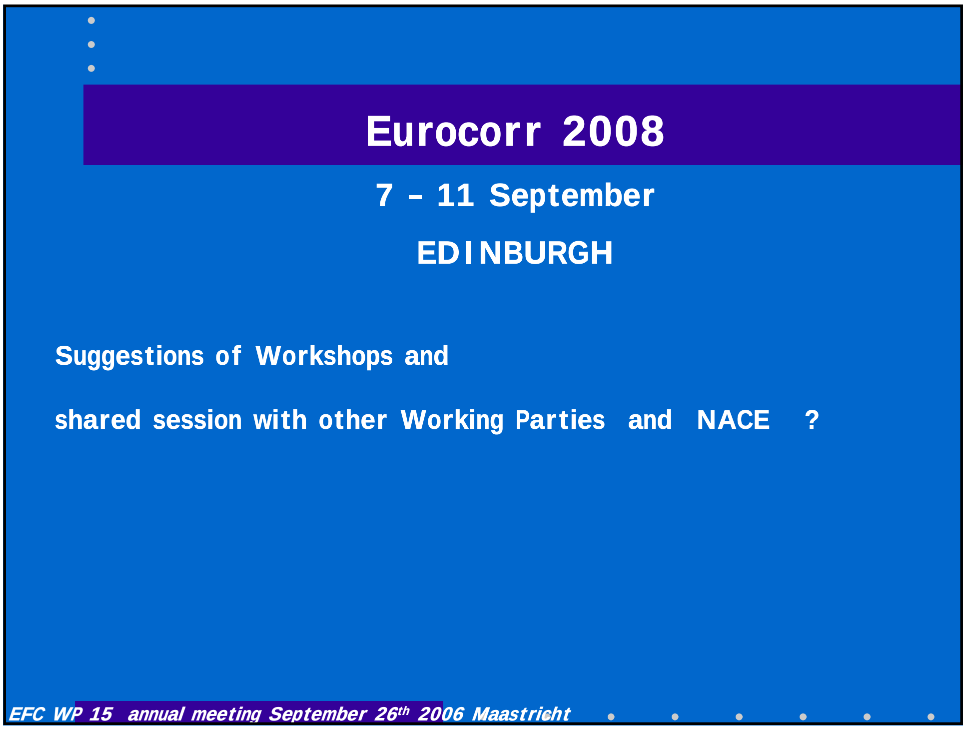
Increase of the collaboration with NACE
a NACE proposal is on cooling water systems in relation with WP1
Who from WP15 will like to join the WP1-15 Task force ?
(discuss in WP1 working meeting at 11h30 on Wednesday 27 Sept)

http://www.eurocorr.org/EUROCORR_2007.html

- Corrosion in refinery session

- Workshop with WP3 (High Temperature) in collaboration with NACE STG 37 group on "High Temperature Corrosion in the Chemical, Refinery and Petrochemical Industries"

15 January 2007 Deadline for submission of abstracts


Eurocorr 2008
7 – 11 September
EDINBURGH
Suggestions of Workshops and
shared session with other Working Parties and NACE ?
EFC WP 15 annual meeting September 26th 2006 Maastricht

Appendix 3

Collaboration between NACE and EFC

WP1+WP15 on cooling water treatments.

Extract of the WP1 annual meeting

On 27 September; a specific meeting has been hold in Maastricht during WP1 (corrosion and scale inhibition) on the "cooling water treatments topics". The participants were:

G. Schmidt WP1 chairman,

G. Hays representative of NACE,

L. Koersvelt

F. Ropital

The creation of a task force between NACE and EFC to develop recommended practices, guidelines and standards for corrosion control in water treatment processes has been decided The task force will be a group of about 8-10 persons, representatives of NACE, EFC WP1 and EFC WP15 groups. The first official meeting of the task force will be hold during the NACE 2007 Conference in Nashville.

Appendix 4

Artificial Neural Network for corrosion control and data management

S. Trasatti (University of Milan)

Artificial Neural Network for corrosion control and data management

Stefano P. Trasatti, G.Zangari
Dept. of Physical Chemistry and Electrochemistry
University of Milan
Via C.Golgi 19 - 20133 Milan, ITALY

EUROCORR 2006 – Maastricht, 25/29 September 2006

Artificial Neural Network for corrosion control and data management

Laboratory test

- ANN for naphthenic acid corrosion
- ANN for crevice corrosion
- ANN for CO_2 corrosion

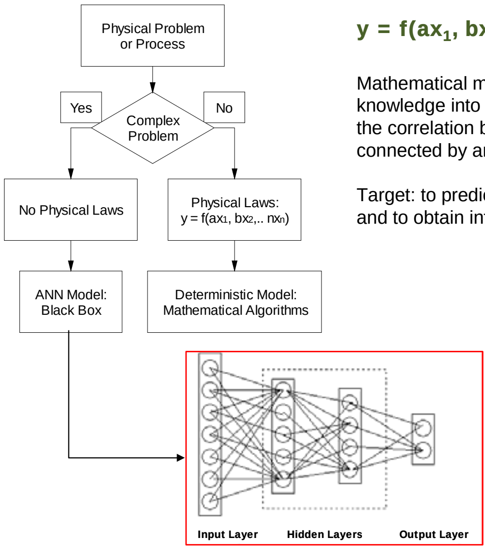
On-line industrial application

- ANN for mechanical properties estimation
- ANN for process quality estimation

In progress application

- ANN for control process (refinery industry)
- ANN for EN spectra analysis

ARTIFICIAL NEURAL NETWORK



$y = f(ax_1, bx_2, .. nx_n)$ (real, discrete and boolean)

Mathematical model enables us to embed structured human knowledge into workable algorithms. NN learns the "weights" of the correlation between input and output data apparently not connected by any model (training step)

Target: to predict output from input not used in the training step and to obtain information on the involved mechanism

- Recognition of characters and images
- Analysis of spectra (Raman, NMR, IR, etc.)
- Petrochemical industry (rock properties, well productivity, seismic images)
- Noise filtering
- Chemical process optimization (recognition of failure cases)
- Loan calculation (banks)
- Medical diagnosis (electroencephalogram analysis)

Neural Network features

- Advantages
  - Adaptability to phenomena which are changing
  - High level og robustness (tolerance limit)
  - Non-linear calculation tool
- Limitations
  - Close box tool (no mechanistic understanding of the process being modelled)
  - High number of data for training step
  - Data filtering and codification

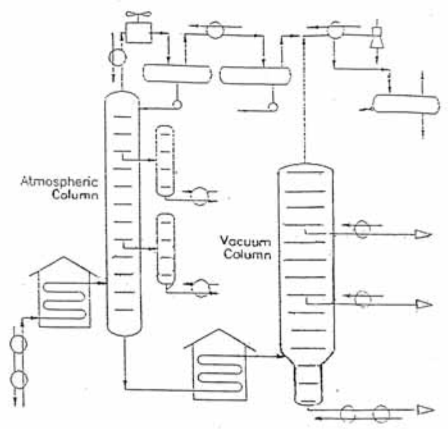
Applications of NNs to corrosion (1)

- H.Smets, W.F.L.Bogaerts – NNs to predict the SCC of 304ss in near-neutral solutions as a function of Cl-, O2 and T
- Urquidi-Macdonald et al. – NN for predicting the number and depth of pits in heat exchangers
- D.C.Silverman, E.M.Rosen – NN combined with an expert system to predict the type of corrosion from polarization curves
- S.P.Trasatti and F.Mazza – NN to study the initiation and propagation step in crevice corrosion of SS and related alloys in near neutral chloride containing media

Applications of NNs to corrosion (2)

- Ramamurthy et al. – NN to analyse impedance data for automobile paint finishes subjected to stone impacts
- S.Nesic, M.Vrhovac – NN to predict corrosion of steel in CO_2-containing solutions
- A.Turnbull et al. – NNs to predict SSCC of Duplex ss
- T.F.Barton et al. – NN to identify pitting and crevice spectra in electrochemical noise

Naphtenic acid corrosion



Fe + 2RCOOH = Fe(RCOO)2 + H2
Fe + H2S = FeS + H2
Fe(RCOO)2 + H2S = FeS + 2 RCOOH

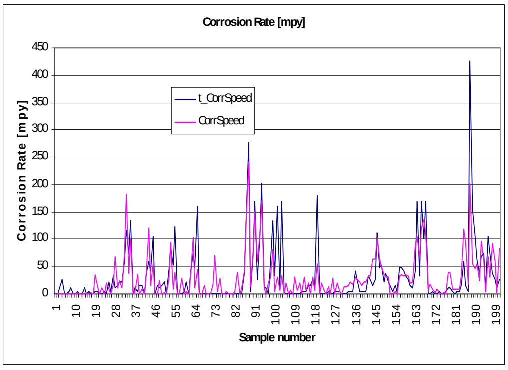
- TAN
- Flow Rate
- Temperature
- %S
- Crude oil type
- Two phase flow
- Metallurgy

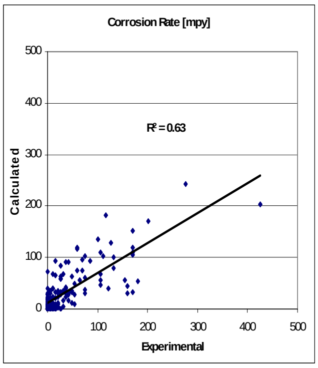
ANN for naphtenic acid corrosion

Parameter	Min	Max.	Variable type	use
Temperature (°F)	70	725	Process	Input
Pressure (atm)	1	69	Process	Input
Flow Rate (m/s)	0	7	Process	Input
Exposure Time (hours)	6	768	Process	Input
TAN	0	46.1	Crude oil	Input
S_%	0	4.17	Crude oil	Input
Cr_%	0.01	20	Plant	Input
Mo_%	0	4.64	Plant	Input
Corrosion Rate (mpy)	0	425	Process	Output

The database used in this work consists of 525 data lines reporting the operating conditions and the results (corrosion rate in miles per year) of laboratory experiments and field inspections: 405 have been used to develop the NNs and 120 for validation

NN for all materials



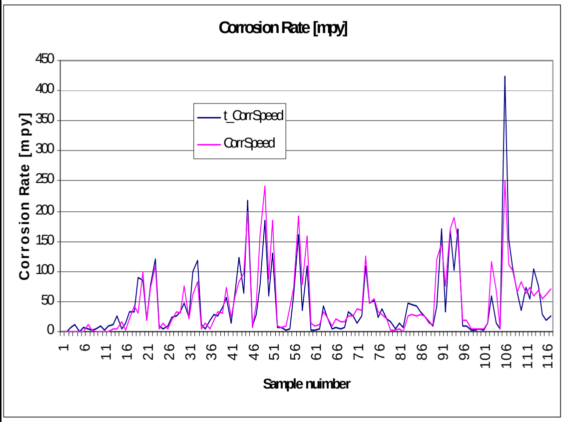


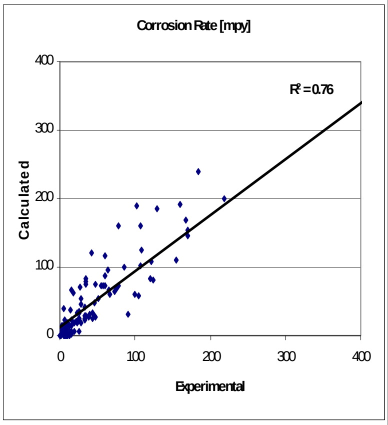
Input layer	8
Hidden layer 1	9
Hidden layer 2	3
Output layer	1

Variable importance ranking list

Variable	**Value**	**%**	**Sum%**
TAN	7.4	22.7	22.7
Press	5.2	15.8	38.4
temp	4.5	13.6	52.1
ExpTime	4.4	13.5	65.5
FloRate	3.4	10.3	75.8
Mo_Perc	3.3	10.1	85.9
Cr_Perc	2.8	8.5	94.5
S_Perc	1.8	5.5	100.0

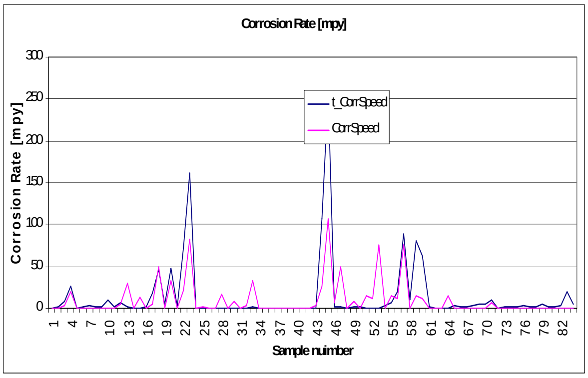
NN for Carbon Steel

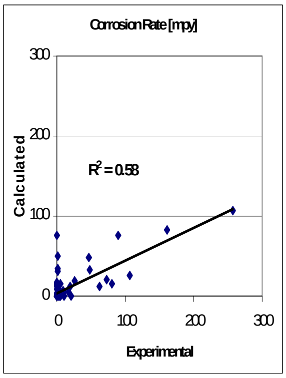




Input layer	8
Hidden layer 1	9
Hidden layer 2	5
Output layer	1

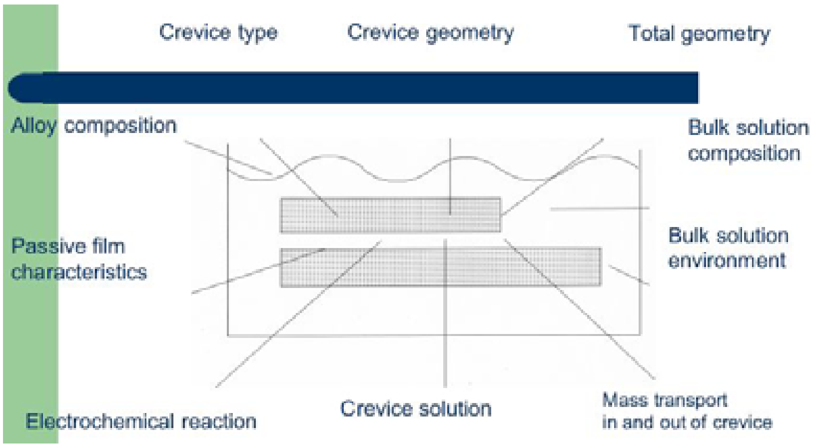
NN for Stainless Steel



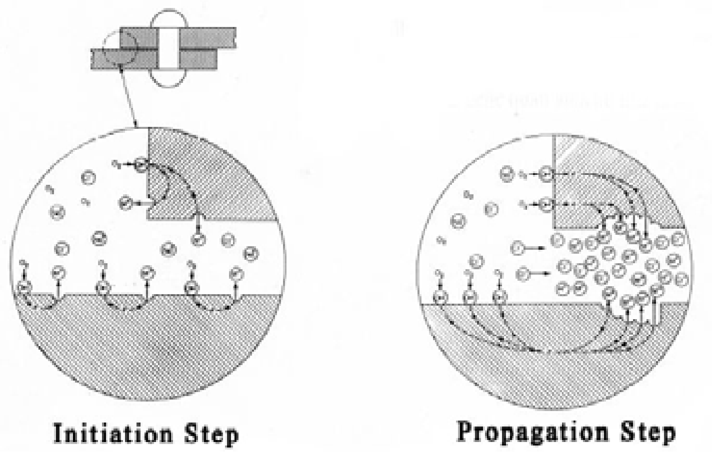


Input layer	8
Hidden layer 1	7
Hidden layer 2	3
Output layer	1

ANN for crevice corrosion



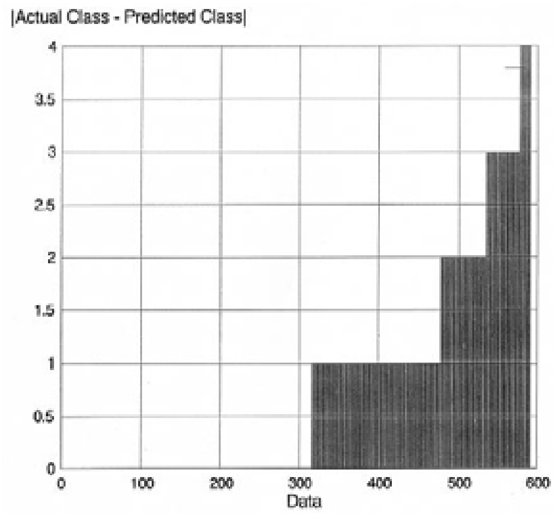
CREVICE CORROSION



Input parameter	Training set	Test set AISI 304	 AISI 904L
Mn content, wt-%	0·02–8	1·64	1·46
Cr content, wt-%	12·4–30·6	18·6	20·5
Mo content, wt-%	0·1–17·6	0·49	4·70
Ni content, wt-%	0·04–70·6	9·4	24·7
Cu content, wt-%	0–3·27	0·5	1·57
N content, wt-%	0·01–0·5	0·03	0·06
Temperature, °C	10–70	30	30
Test duration, days	30–3600	60	60
Torque, Nm	2–10	8·5	8·5
Flowrate, m s^{-1}	0–3	0·02	0·02
Cathodic area/ anodic area ratio	5–150	150	150
Cl^- content, ppm	600–21 700	1, 10, 100, 1000, 5000, 10 000, 20 000	1, 10, 100, 1000, 5000, 10 000, 20 000
pH	2·5–8·2	8·2	8·2
Environment	NaCl, sea water, etc.	Sea water	Sea water
Alloy matrix	Austenite, ferrite, etc.	Austenite	Austenite
Surface finish state	As received, prepassivation, etc.	Mill	Mill
Crevice assembly	SCA, MCA, etc.	MCA	MCA

Initiation			Propagation		
Class	Range of values	No. of data in class	Class	Range of values	No. of data in class
1	0	184	1	0	185
2	>0, $\leqslant 8{\cdot}3$	101	2	>0, $\leqslant 0{\cdot}07$	101
3	$>8{\cdot}3$, $\leqslant 33{\cdot}3$	102	3	$>0{\cdot}07$, $\leqslant 0{\cdot}32$	104
4	$>33{\cdot}3$, $\leqslant 75{\cdot}83$	102	4	$>0{\cdot}32$, $\leqslant 0{\cdot}9$	101
5	$>75{\cdot}83$, $\leqslant 100$	103	5	$>0{\cdot}9$, $\leqslant 5$	101

NN for propagation step



ANN for CO_2 corrosion

DB1: 325 records (lab)

DB2: 97 records (field)

DB1 data set

Parameter	Min value	Max value
T	20.0	90.0
pH	3.5	7.0
Fe** content	0.04	0.08
Flow arte	0.1	13.0
pCO2	0.325	21.45
CR	0.1	69.675

DB2 data set

Parameter	Min value	Max value
Temp	14.0	145.0
PTotal	0.0	326.0
pCO_2	0.1	9.5
FlowR	0.1	20.0
PH	2.5	7.2
pH_2S	0.001	80.0
WaterCut	0.1	100.0
GOR_e3	0.0	1500.0
TimeY	0.25	30.0
CorrRate	0.0	7.0

The neural models have been developed for each data base updating recursively one of the following items:

- The number of the input parameters;
- The training file: two different files or a unique one
- Neural network family: Back Propagation or Radial Basis Function;
- The number of nodes of the hidden layer;
- The number of epochs;
- The learning rate coefficient by means of a multiplier factor

ANN for CO_2 corrosion

Laboratory data set DB1: reference ANN model

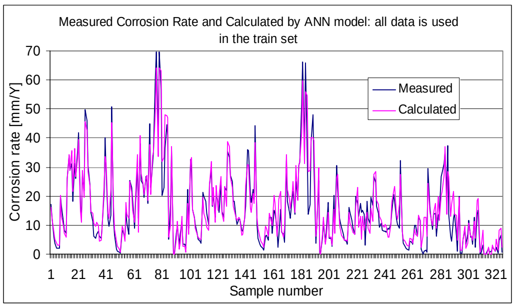
A reference ANN model was defined with 5 input nodes and 6 hidden nodes in a single hidden layer structure. The model is trained using all the parameters and two different files with standard learning rate coefficients

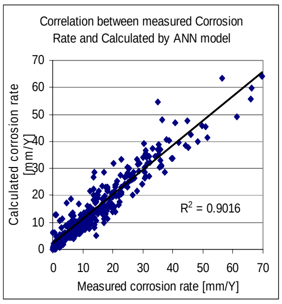
Performance of the reference ANN model for DB1 data set and other mo

Models	Train RMS	Test RMS	R^2	R
Reference ANN	0.083	0.084	0.66	0.81
EC_model (new)	-	-	0.38	0.61
KSC II model	-	-	0.67	0.82
SHELL'95 model	-	-	0.52	0.72
Linear Multiple Re	-	-	0.62	0.8

Importance ranking list

Input	Value	%	Sum%
pCO2	5.6	35.5	35.5
pH	5.5	34.8	70.2
d	2	12.6	82.8
Temp	1.8	11.6	94.4
FlowRate	0.9	5.6	100





ANN for CO_2 corrosion

Field data set DB2: reference ANN model

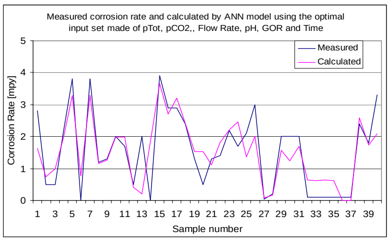
A reference ANN model was defined similar to the one developed for DB1 data set regarding the input parameters. Further ANN models differ for the input pattern

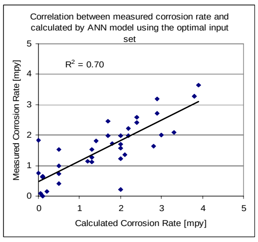
Performance of the tested ANN models

input	Input node	TrainRMS	TestRMS	R^2	R
Classic **input**	6	0.134	0.134	0.31	0.55
All variables	9	0.077	0.077	0.68	0.82
optimal input	6	0.074	0.074	0.70	0.84
Reduced input	4	0.093	0.093	0.54	0.73

Importance ranking list of the input variables

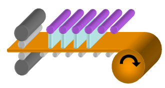
Input	Value	%	Sum%
TimeY	22.6	44.3	44.3
FlowRate	7.5	14.7	59
GOR_e3	5	9.7	68.7
pCO2	4.1	8.1	76.8
PTotal	3.9	7.6	84.4
pH	3.7	7.2	91.6
Temp	1.8	3.5	95.2
WaterC	1.5	3	98.1
H2S	0.9	1.9	100





ANN for Mechanical Properties estimation of hot rolled steel strip

Yield Stress, Ultimate Tensile Stress and Elongation of hot rolled steel strip are a function of the operating procedures.

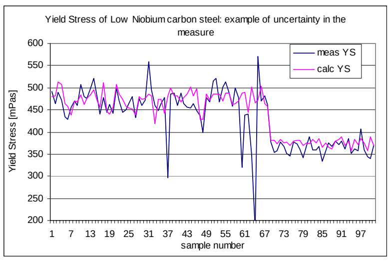


Input variables:

- Steel chemical composition
- Strip thickness
- Strip speed out of the last rolling stand
- Strip thermal evolution during coiling

Output variables:

- Yield Stress
- Ultimate Tensile Stress
- Elongation



LMR

Mechanical property	Correlation R^2	Standard deviation
UTS	0.76	17.1
YS	0.61	23.5
EL	0.28	3.5

ANN

Mechanical property	Correlation R^2	Standard deviation
UTS	0.80	15.2
YS	0.67	20.5
EL	0.31	2.2

ANN for REAL TIME PREDICTION OF PROCESS (PRODUCT) QUALITY

Continuos casting steel (melting and solidification)

The continuous casting process is described by time dependent variables. A reference data set is made of sample of only correct processes. If an unknown sample is similar to one (or more) from the reference data set, the probability that it regards a correct process increases (otherwise the process should be not correct, not steady or not frequent).

A NN Associative Memory was trained to codify correct process sample (transient or unspecified process condition are neglected). The network is trained to reproduce in output the same input pattern.

The RMS error is calculated as difference between the input and output. This identifies a process quality index.

The lower the RMS error, the higher the probability that the process is similar to a correct one.

Input Process Variables

Steel level in the mould:

- Standard deviation of mould steel level oscillation
- mould steel level measure
- time trend of mould steel level

Mould wall temperature

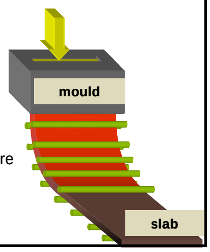
- Measured temperature
- Standard deviation of temperature

Cooling water:

- Standard deviation of flow rate
- Standard deviation of delta temperature

Casting speed:

- Standard deviation



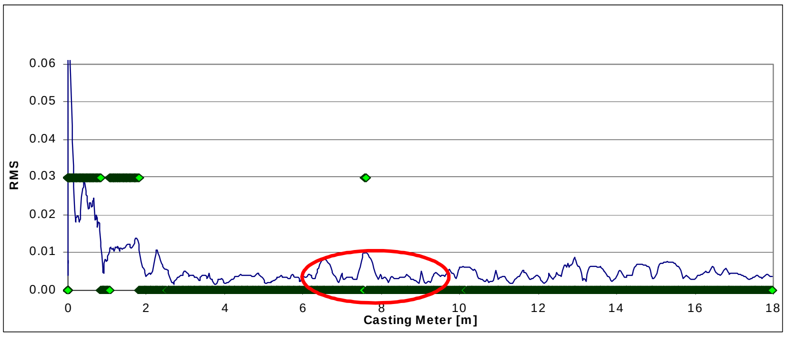
ANN for REAL TIME PREDICTION OF PROCESS (PRODUCT) QUALITY

Casting steel (melting and solidification)

The red circles reasonably identify the time when a product with defect occurred that can be associated to not steady state process condition.

The green squares identifies the ANN model response with an RMS error above a threshold.

The on line version produces the signal below; in most of cases these are related to low quality products

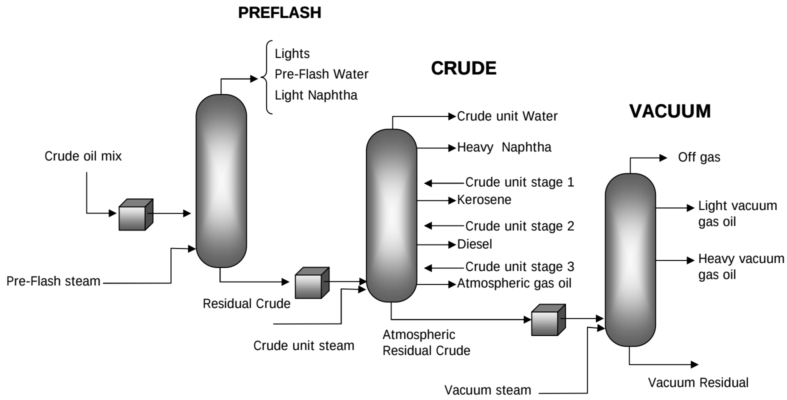


ANN for on-line residual life estimation: refinery plant

Corrosion rate of CS changes accordingly to the aggressiveness of crude and to new required process conditions.

ANN models are under development for:

- on-line prediction of the corrosion rate along the transfer lines.
- process quality
- virtual sensor

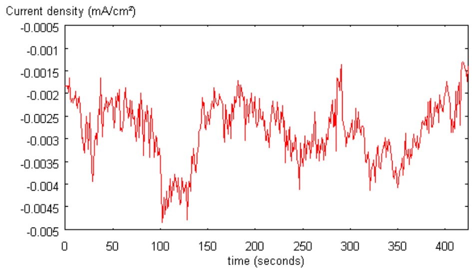


ANN for analysis of electrochemical noise spectra

Corrosion occurrence can be related to the features of EN spectra in time domain.

Records processed by the ANNs consist of the following information:

- **Current signal**
- **Potential signal**
- **Slope of interpolating 1st order curve**
- **Standard deviation**
- **Skewness**
- **Kurtosis**
- **FFT-parameters**



The first ANN is an Associative Memory. It classifies uniform and localized corrosion sample: for this reason the ANN is trained only with uniform corrosion samples. The RMS error made by the ANN, processing an unknown sample, identifies the probability for a localized corrosion sample (applying similarity criteria).

Once a case of not uniform corrosion is identified, a second ANN classifies the type of localized corrosion (pitting, crevice and others).

Appendix 5

Pulsed Eddy Current inspection
Latest developments

M. Lorentz (Shell Global Solutions)

CONFIDENTIAL

Shell Global Solutions

Pulsed Eddy Current inspection

Latest developments from

Shell Global Solutions International B.V.

Maarten Lorenz

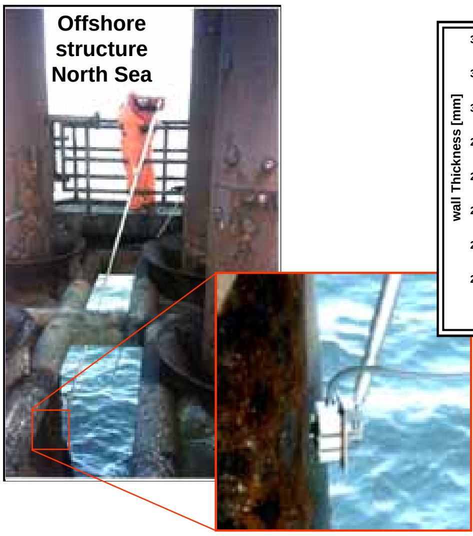
EFC WP15 meeting,
Maastricht, 26 September 2006

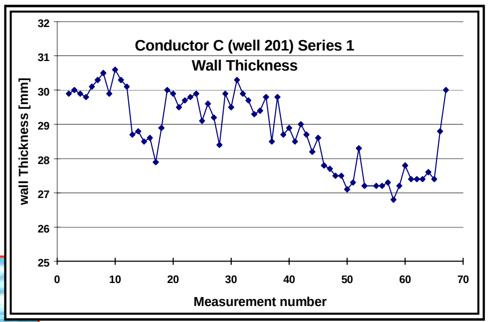
Corrosion Under Insulation: PEC can inspect in-service without removing insulation

17.9	16.9	13.6	14.4	14.2	17.5	16.5	16.9
17.5	17.1	12.4	13.9	13.9	17.1	14.5	16.6
17.5	17.1	11.3	12.9	12.0	17.2	11.8	16.4
17.6	16.9	11.1	11.6	11.4	17.3	11.8	15.0
17.5	17.2	11.1	11.2	10.8	17.3	12.3	15.0
17.5	17.0	10.7	11.3	10.5	17.0	14.0	16.5
17.4	16.8	9.9	10.8	11.1	16.9	16.9	16.8
17.5	16.9	11.3	10.2	9.7	16.7	17.5	17.2
17.5	17.0	10.8	8.5	8.5	17.0	17.5	17.4
18.4	17.4	10.2	8.2	8.2	17.2	14.8	17.4
17.3	17.4	9.9	8.2	8.3	17.1	14.7	17.2
17.0	14.8	8.7	8.5	8.8	17.0	10.6	16.3
16.7	11.7	8.7	8.6	8.7	16.8	14.4	16.7
17.3	11.4	8.9	8.7	8.7	16.9	16.8	17.1
17.7	11.1	9.0	8.6	8.6	17.1	17.6	17.2
17.6	15.7	10.0	9.1	15.6	17.2	17.5	17.5
17.7	16.9	11.0	9.5	16.3	17.4	17.7	17.6
17.8	17.4	12.3	10.1	16.6	17.3	17.5	17.5
17.8	17.5	12.5	10.7	17.1	17.4	17.5	17.5
17.4	17.6	12.8	11.7	17.2	17.2	17.3	17.4
18.0	17.5	12.7	13.0	17.9	17.8	17.7	17.8
18.0	17.6	13.0	14.4	17.9	17.7	17.8	17.8
18.1	17.9	16.5	16.8	17.9	17.8	17.3	17.8
18.1	18.0	17.6	17.8	17.8	17.7	17.6	17.7
17.6	17.7	18.0	17.9	18.0	17.6	17.6	17.4
16.2	16.3	17.8	18.0	17.6	17.4	17.5	17.6
16.6	16.7	17.8	18.0	17.9	17.3	17.4	17.6
17.1	17.2	17.8	18.1	17.8	17.6	17.6	17.8
17.9	18.0	17.9	18.1	17.9	17.7	17.8	18.3

Color-coded wall thickness graph

Riser inspection in splash zone (1)





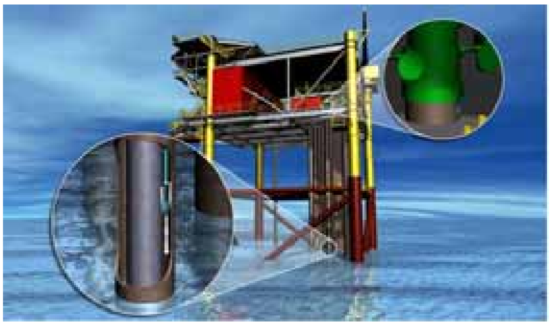
- Measures remaining wall thickness
- Through corrosion
- Above and below water surface

Riser inspection in splash zone (2)

Vertical Position [mm]	Clock Position [hours]					
	2	4	6	8	10	12
0	16.5	12.5	17.2	16.9	15.1	16.5
-100	16.8	12.4	17.0	16.7	13.8	16.4
-200	16.7	10.4	16.4	16.7	11.3	16.1
-300	16.5	10.5	14.3	16.5	12.2	15.9
-400	17.1	9.6	13.3	16.4	11.1	16.4
-500	16.9	9.7	12.9	16.3	12.5	16.6
-600	16.5	10.2	13.9	16.3	15.3	16.7
-700	16.9	9.1	13.4	16.0	16.5	16.4
-800	16.6	8.6	11.9	16.1	16.4	16.7
-900	16.9	8.4	11.9	16.3	16.5	16.8
-1000	16.5	7.9	12.0	16.4	16.4	16.7
-1100	16.1	8.0	13.5	16.2	14.2	16.6
-1200	14.9	8.1	13.0	16.2	16.5	16.3
-1300	13.9	8.5	13.8	16.3	16.7	16.1
-1400	14.7	8.6	14.0	16.3	16.9	16.6
-1500	15.8	9.1	13.3	16.3	17.0	17.4
-1600	16.5	9.5	12.8	16.3	16.9	16.8
-1700	15.3	11.7	13.2	16.4	16.8	16.8
-1800	16.4	11.6	16.7	16.5	16.7	16.4
-1900	16.4	12.0	16.9	16.4	16.6	16.5
-2000	16.7	12.7	17.0	16.4	16.6	16.5
-2100	16.8	13.7	17.0	16.3	16.6	16.5
-2200	16.8	16.0	16.9	16.3	16.5	16.7
-2300	16.6	16.8	16.9	16.2	16.2	16.3
-2400	15.5	16.5	17.1	16.3	16.5	16.6
-2500	15.2	16.5	16.0	16.3	16.5	16.5
-2600	15.7	16.6	16.9	16.2	16.5	16.5
-2700	16.4	16.5	16.9	16.1	16.6	16.5
-2800	16.8	16.6	16.9	16.2	16.5	16.4
-2900	16.8	16.7	16.7	15.9	16.2	16.3
-3000	17.1	17.2	17.5	16.7	17.1	17.0

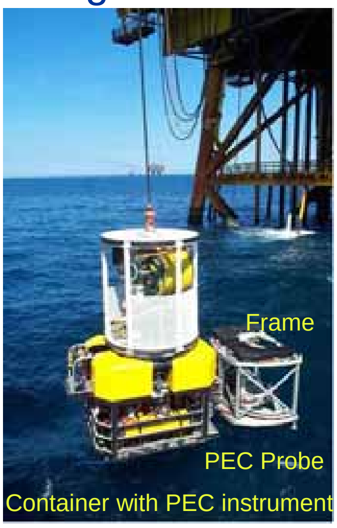
Inspection of outer casings - offshore wells

Problem: Open annulus between conductor and outer casing can contain oxygenated sea water - water level fluctuates with tides, and oxygen is constantly replenished - corrosion can occur on the outside of the casing, potentially affecting mechanical integrity of the well.



- Probe inserted in annulus
- Readings taken in internal "splash zone"
- Measures remaining wall thickness - can detect corrosion on outside of outer casing
- No interruption of production
- No surface preparation

Underwater PEC inspection of platform legs using ROVs



Photograph courtesy of D. Mackay, Subsea7

Vertical Position [mm]	Position along circumference [hours]											
	12	11	10	9	8	7	6	5	4	3	2	1
1550	11.0			11.0			9.7			9.6		
1250	10.2			10.2			10.3			8.9		
1050	9.6	10.5	9.7	10.6	8.9	10.4	10.2	10.0	9.7	9.6	10.2	10.6
800	10.2	10.4	9.9	10.3	8.8	9.4	9.3	10.1	9.0	9.1	9.6	10.2
700	9.3	8.9	9.8	10.2	8.6	8.6	8.6	9.1	8.5	8.9	9.1	9.0
600	8.0	8.0	8.5	8.4	8.1	8.1	7.1	8.7	7.4	7.4	8.5	8.1
500	7.5	6.8	8.5	8.3	8.2	7.7	6.8	8.4	7.7	7.7	8.8	7.9
400	6.1	7.1	7.6	7.7	8.2	7.4	6.7	6.7	6.8	7.5	7.2	7.5
300	5.9	6.0	7.2	7.2	6.9	6.1	5.9	5.9	6.0	6.7	6.4	6.3
200	6.1	5.5	5.8	5.6	5.7	5.5	5.4	5.4	6.3	6.2	5.5	5.8
100	9.5		5.5	5.5	6.5	6.4	5.7		6.5	7.4	6.9	8.9
0	10.7	11.7	8.4	10.2	9.4	11.5	11.7	10.5	8.8	10.8	11.1	11.5
-100	10.8	11.4	10.4	10.3	11.5	10.9	11.5	10.3	10.1	11.0	11.0	10.4
-200	10.6	12.0	11.1	10.5	11.3	11.5	11.8	10.4	10.6	10.8	11.2	10.4
-300	10.6	12.1	12.3	11.9	11.4	12.0	12.2	10.3	10.3	10.8	11.0	11.1
-400	11.7	12.4	12.2	11.7	12.0	12.4	12.0	10.7	10.7	11.9	11.7	11.4
-500	11.1	11.4	11.9	10.8	10.5	12.0	11.7	11.1	11.6	12.2	10.6	10.6
-700	10.3	9.8	9.7	10.6	11.4	10.7	10.2	11.1	10.9	11.7	10.1	10.6
-800	10.1	10.6	9.9	9.9	10.5	11.0	11.0	10.8	10.3	10.1	9.9	10.1
-900	10.6	11.3	9.6	10.2	10.6	11.0	11.7	10.2	10.4	10.2	10.4	10.7
-1000	10.7	11.7	10.8	10.5	10.6	10.6	11.6	10.4	10.1	10.4	11.4	10.7
-1100	10.1			10.4	10.9		11.5			10.3	10.8	
-1300	10.5			11.4			12.0			11.1		
-1500	10.2			11.5			11.7			12.2		

12 mm
10%+
(+/-) 10%
10% - 20%
20% - 30%
30% - 40%
40% - 50%
50% - 60%
60% - 70%
>70%

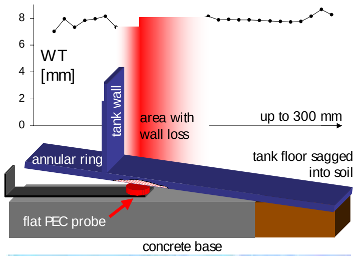
Remaining steel thickness through fireproofing (1)

Sphere legs

Remaining steel thickness through fireproofing (2)

Column skirts

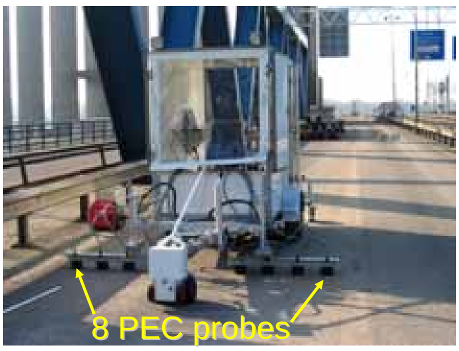
In-service inspection of annular rings of storage tanks

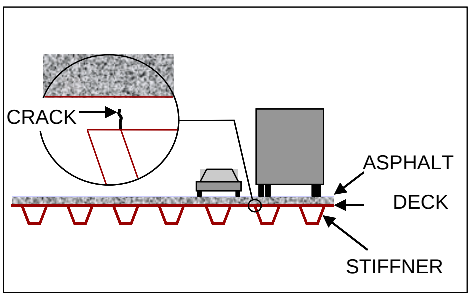


~8 mm access space needed

no need to remove corrosion products

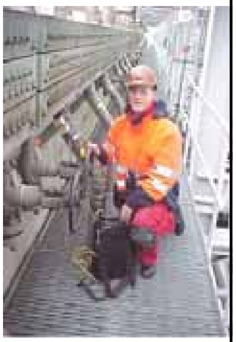
Crack detection in welds of steel bridge decks





PEC corrosion & erosion monitoring

- PEC uniquely suited for wall thickness monitoring
- Measures rate of wall loss of the steel
- Suited for high temperatures (tested to 420°C)
- Can be used to justify extending run time when corrosion rates exceed design
- PEC is cost effective:
  - portability: one sensor with position markers
  - fast data collection by local staff
  - data analysis is automated
- Well suited for both corrosion and erosion monitoring

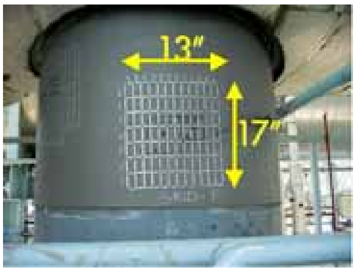


Monitoring of grids: map of corrosion rates

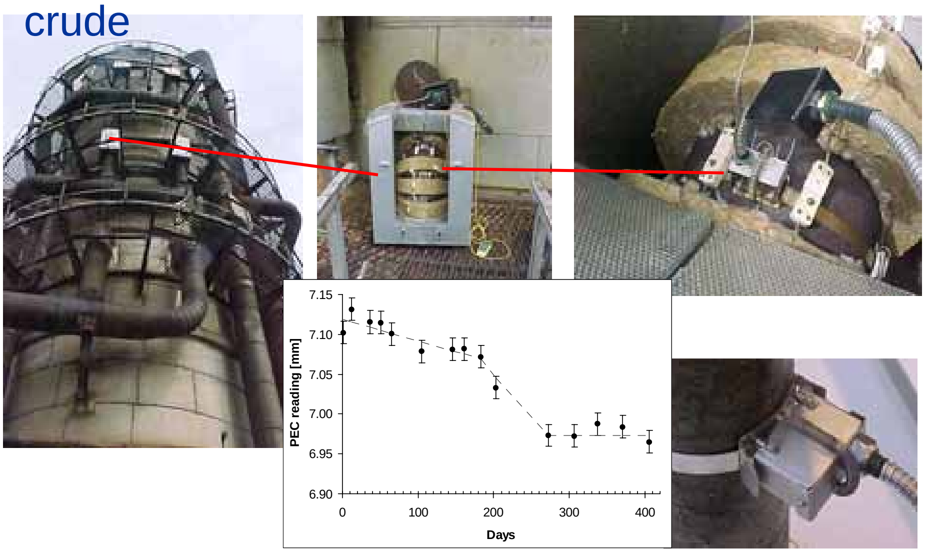
Corrosion rate [mm/y]

Vertical direction [mm] \ Horizontal direction [mm]	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450
0	-0.04	0.01	0.03	0.02	0.04	0.03	0.05	0.05	0.06	0.06	0.06	0.02	0.03	0.03	0.06	0.02
60	-0.02	0.04	0.05	0.09	0.09	0.07	0.03	0.03	0.06	0.07	0.02	0.06	0.04	-0.06	-0.02	0.06
120	0.00	0.01	0.01	-0.02	0.03	0.13	0.08	0.17	0.14	0.09	0.10	0.03	-0.03	0.01	-0.05	-0.05
180	0.05	0.05	0.07	0.02	0.06	0.16	0.14	0.11	0.09	0.09	0.06	0.36	0.15	0.03	0.04	0.04
240	0.20	0.13	0.09	-0.01	0.01	-0.20	0.07	0.06	-0.03	0.04	0.12	0.26	0.19	0.04	0.13	0.14

Area with increased corrosion

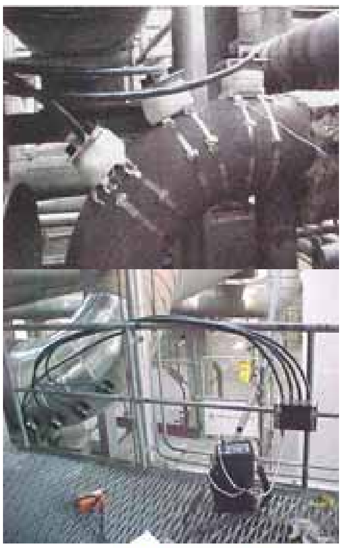


PEC corrosion monitoring for opportunity crude



Shell Global Solutions 13

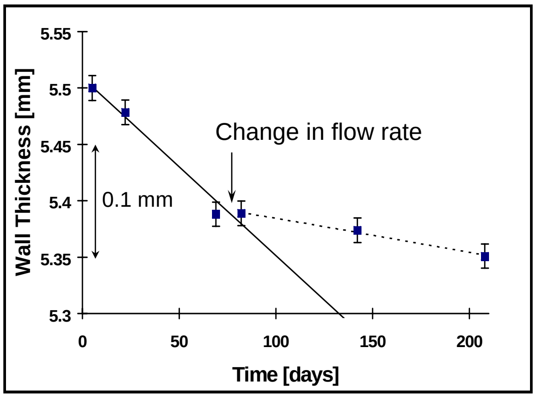
Fixed PEC probes at positions with difficult a



Shell Global Solutions 14

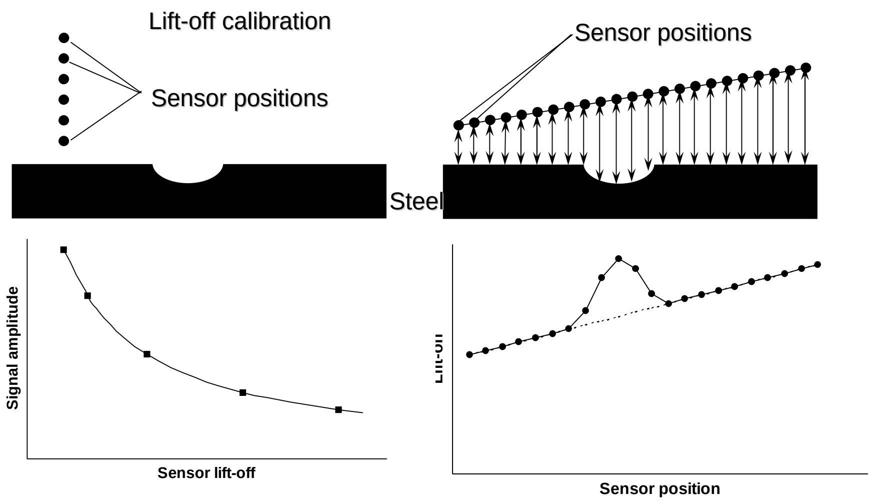
PEC corrosion & erosion monitoring – results

PEC monitor points (12 per pipe)

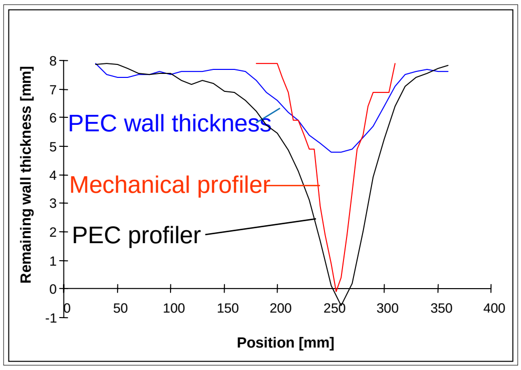


- Establish baseline corrosion /erosion rate
- Change operating conditions
- Determine effect on corrosion /erosion rate

The PEC profiler – measuring lift-off



PEC profiler versus PEC wall thickness



- PEC profiler more defect sensitive than PEC wall thickness
- PEC profiler <u>not</u> dependent on electromagnetic properties of ste
- PEC profiler measures in millimeters; PEC wall thickness in %

PEC: current strengths & limitations

Strengths

- Non-contact, non-invasive
- No removal of: coatings, insulation, marine growth, corrosion products, etc.
- No surface preparation
- No shutdown needed
- Applied on surface temperature up to 420°C
- Monitoring: unique same-spot reproducibility (0.2%)
- Profile measurement through corrosion products

Limitations

- Wall thickness averaged over probe “footprint”
- PEC is a comparator: measures thickness *variations* on same object
- Some geometries can make measurement difficult

CONFIDENTIAL

Shell Global Solutions

Pulsed Eddy Current inspection

Thanks for your attention

Any questions ?

Latest developments from Shell Global Solutions International B.V.

Maarten Lorenz
EFC WP15 meeting,
Maastricht, 26 September 2006

Appendix 6

Developments in High Temperature Hydrogen Flux Measurement Applications

F. Dean (Ion Science Ltd)

Developments in High Temperature Hydrogen Flux Measurement Applications

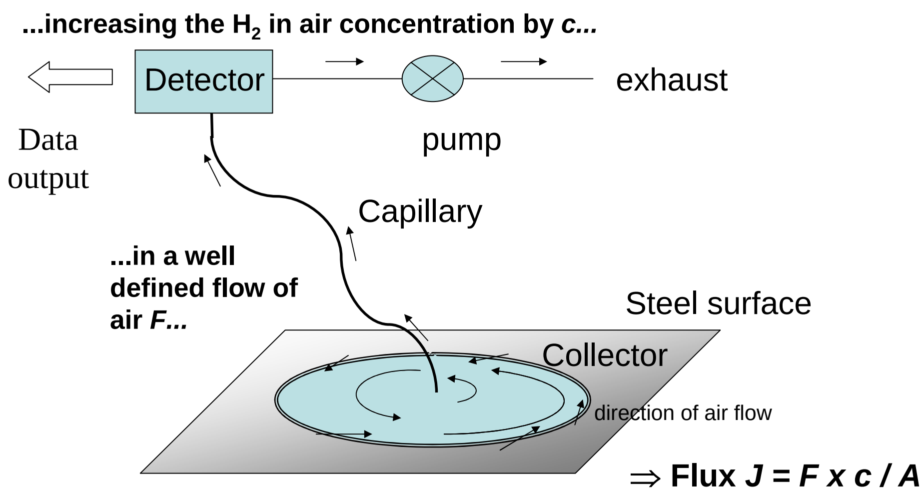
Working Party 15, Refinery Corrosion
Eurocorr 2006, Maastricht,
26 September, 2006

Frank Dean, Ion Science Ltd.

1. ***High flux measurement technology***
2. ***Scope for measurements***
3. ***Applications***

High Temperature Measurement Technology

High temperature flux measurement by the hydrogen collection method



Hydrogen captured from a well defined area, *A*...

Method and devices patented, manufactured and supplied by Ion Science Ltd, UK

High temperature flux measurement technology

Intrinsically safe analyser.

HT-R High temperature (<500 ºC) roaming probe.

AT-S stationary probe for routine spot measurementsband continuous monitoring

Continuous flux monitor Hydrosteel 7000

High Temperature measurement scope

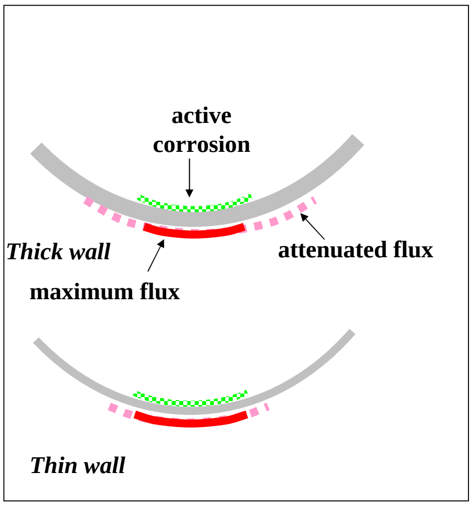
Where is flux measurable?

- (A) Active corrosion causing hydrogen to enter internal wall
- (B) Sufficient steel permeability for appreciable through wall permeation
- (C) Permeability of hydrogen through external surface coatings
- (D) Steel surface geometry appropriate for flux probe attachment
- (E) Adequate measurement tool, operating and being used correctly

Temperature, ºC	(A) Corrosion scenario	(B) Permeable Steels	(C) Permeable coatings
0 to 120	H_2S, amine, NH_4HS / HCN and HF acid *only!*	<2% alloy ('carbon', 'mild')	Most, not zinc.
80 to 200	…plus severe acid corrosion eg acetic.	< 6% alloy	Uncoated. With increasing temperature, chrome oxides present a partial barrier to permeation.
200 to 300	All corrosion liberating hydrogen, including sulfidic and naphthenic acid corrosion	< 10% alloy	
300 to 400		All non-austenitic	
400 to 500		All steels	

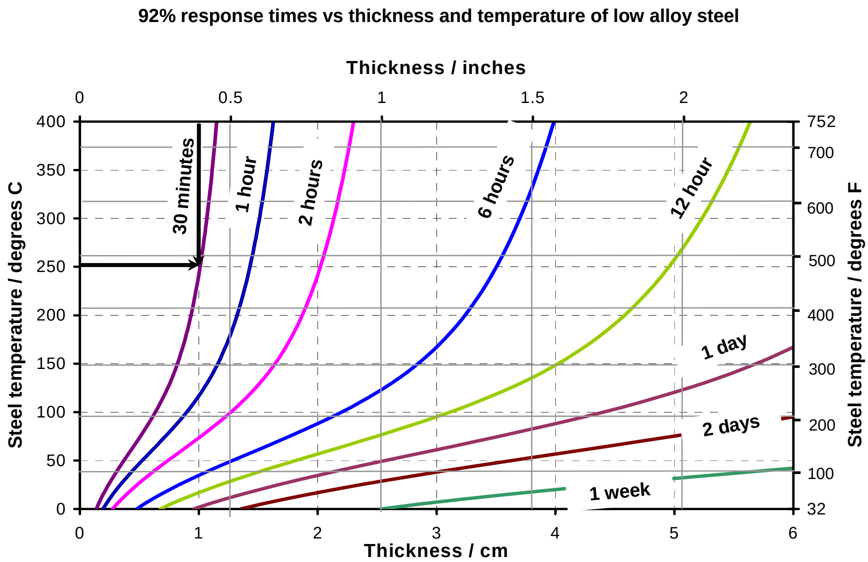
… plus heat treatments, eg PWHT, of steel subject to all the above scenarios

Location specificity of flux measurement



Hydrogen flux is measurable only within a few centimeters of a zone of active corrosion

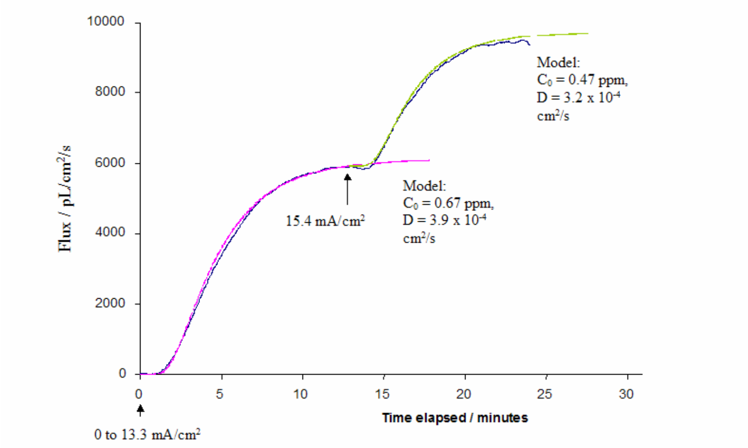
- Time specificity of flux measurement



Contour map defines time required to stabilise flux. Arrows indicate that it will take only about 30 minutes for flux to stabilise through 1 cm thick steel at 250 ºC.

Evidence of meaningful high T flux measurement (1): diffusion profiles

A characteristic flux transient sequence, obtained at 204 ºC, using Na-K hydrogen phosphate eutectic melt and applied current (Pt cathode).

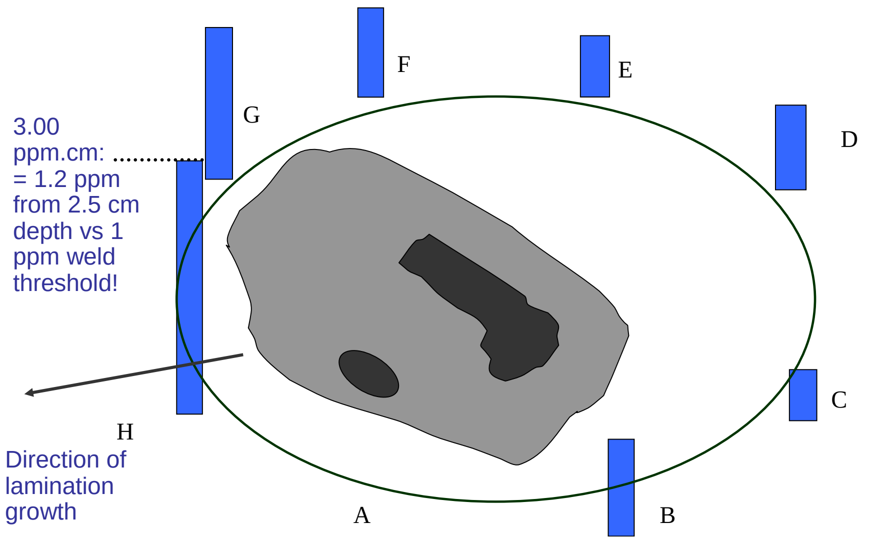


- Flux measurement exactly follows expected (modelled) hydrogen permeation behaviour.

F.W.H.Dean, D.J.Fray, T.M.Smeeton, *J.Materials Sci. and Technology*, 18 (2002), 851 - 855.

Evidence of meaningful high T flux measurement (2): bake out data

Total hydrogen outgassed at 350 ºC, from 8 circumferential sites at top of vessel from which hydrogen blistered (black), and delaminated (grey) steel had been cut away .



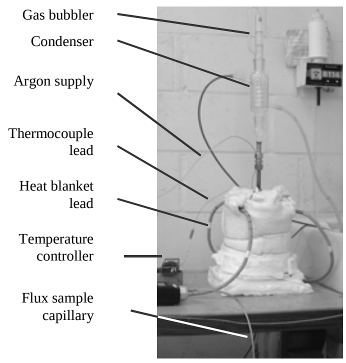
- Total bake-out flux can indicate reasonable hydrogen levels commensurate with hydrogen trapping and damage..

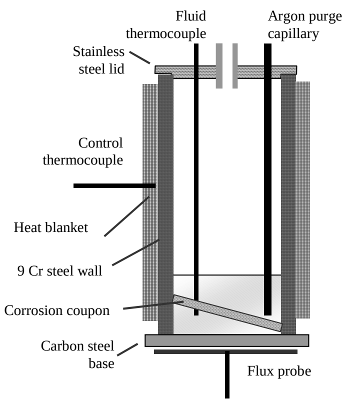
C.N.Brown, M.J.Carroll, F.W.H.Dean, J.H.Harrison, A.Kettle, Corrosion 2004, NACE, Paper 04478.

High Temperature Corrosion Applications

Laboratory evaluation of correlation betweeen hydrogen flux and high temperature corrosion

Use controlled heating of 100 mL sample in an Ar purged enclosure under reflux, and controlled temperature excursion. Measure flux through 6 mm base.



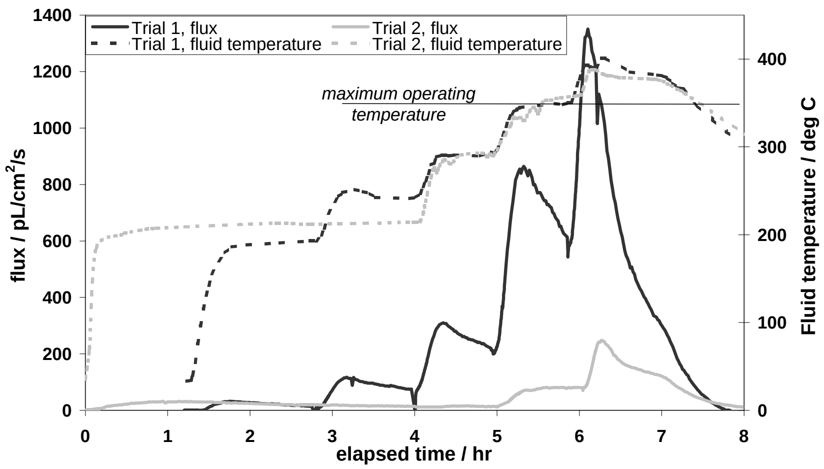


Flux probe

F.W.H.Dean, S.W.Powell, Corrosion 2006, NACE, Paper 6346.

Indication of flux dependency on temperature and possible inhibitor activation

Red crude sample (300 mL, in steel flask with 6 mm C steel base, under reflux) corrosion induced flux transients from two trials, subject to indicated temperature excursions.

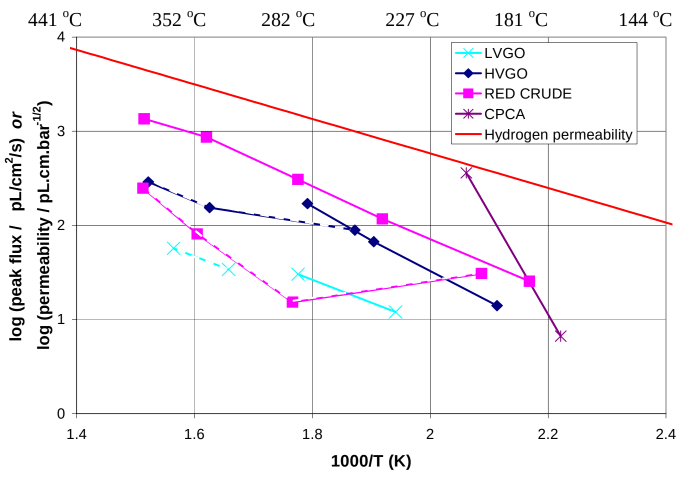


- Increased flux with increased T, and at constant T, flux decays.
- Lower flux after extended dwell at 220 ºC (trial 2 *vs* 1), which is just above inhibitor activation temperature.

F.W.H.Dean, S.W.Powell, Corrosion 2006, NACE, Paper 6346.

Towards correlation of hydrogen flux with corrosion rate

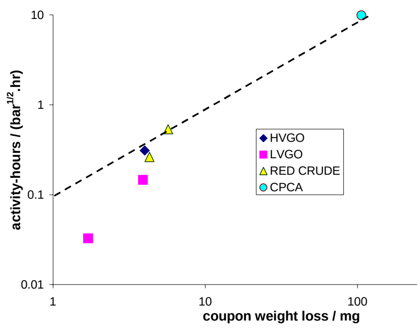
An Arrhenius-type plot of log(peak flux) *vs* 1/T. The plot for carbon steel permeability is also shown for comparison.



- Plots for given corrodant are approximately linear and zoned.
- Gradient of plots is same or greater than that for log(permeability) vs 1/T.

F.W.H.Dean, S.W.Powell, Corrosion 2006, NACE, Paper 6346.

Indication of hydrogen activity-corrosion rate correlation obtained with various distillation unit samples.



Plot of coupon weight loss vs hydrogen-activity hours for various refinery samples studied. Hydrogen activity is calculated from flux, steel thickness and temperature, using steel permeability values. This 'normalises' flux measured at sites of different thickness and temperature

F.W.H.Dean, S.J.Powell, Corrosion 2006, NACE, Paper 6346.

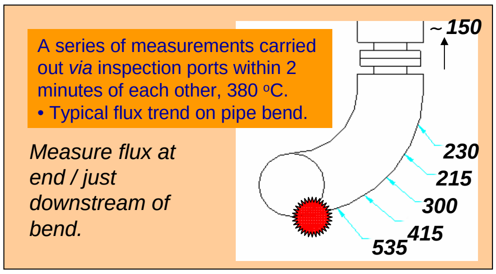
Where flux has been registered from equipment subject to NAC / sulfidic corrosion

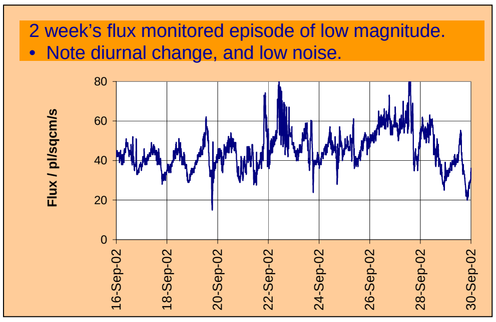
Vacuum and crude distillation unit (CDU and VDU):

- columns
- outlets
- transfer lines
- heaters
- heat exchangers
- discharge
- HVGO cuts
- LVGO cuts
- … and Coker units

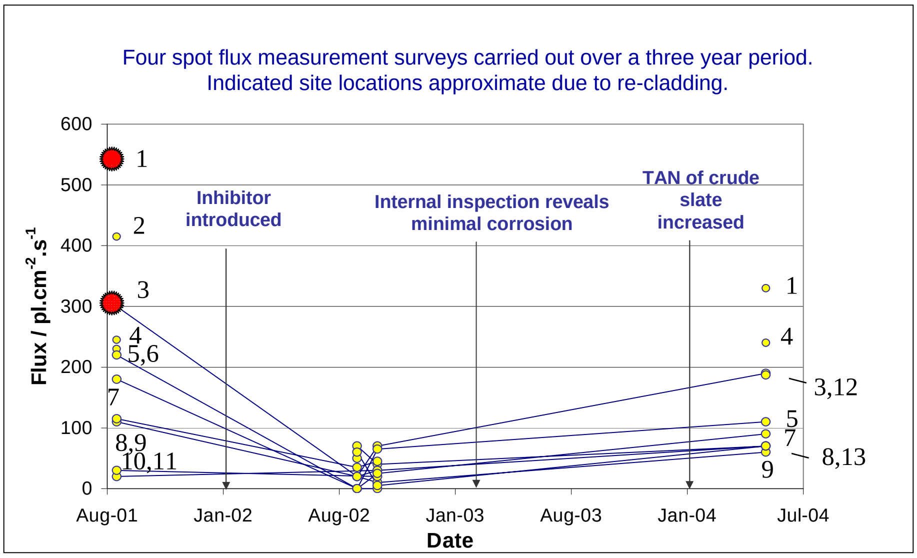
Typical ‘map’ of high temperature flux associated with naphthenic acid corrosion

NAC in particular is very sheer velocity dependent and is liable to be most severe at pipe bends and at areas of high turbulence.





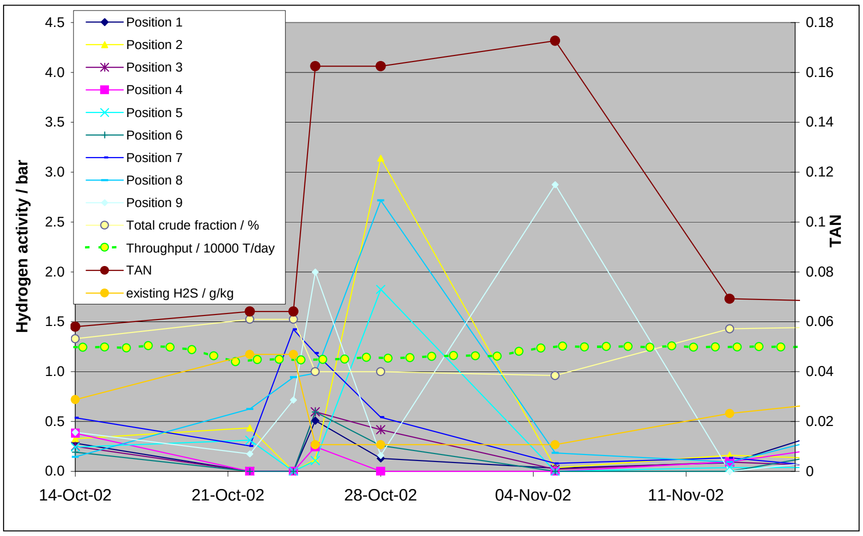
- Monitoring corrosivity changes (1)



- Spot measurements indicate change in corrosivity consistent with use of inhibitor and change in crude blend TAN
- One or two sites provide a good indicator of corrosivity in the heat exchanger outlets.

Monitoring of corrosivity variation changes (2)

Sequential spot flux measurement variability during a corrosion episode due to change in a refinery crude slate TAN at 9 disparate sites.



A.M.Etheridge, E.B.McDonald, D.G.Serate, F.Dean, Corrosion 2004, NACE, Paper 04477

- Conclusions

• Crudes which are corrosive at high temperatures are increasingly processed by refiners. It is important to measure this corrosion so as to optimise feedstock blending, process conditionsl and inhibitor treatment.

• In 2002, a probe was developed by Ion Science which demonstrably measures flux due to active high temperature corrosion.

• There are few methods to monitor high temperature corrosion, let alone actively.

• Lab and field flux measurements on high temperature steel using the hydrogen collection method reflect anticipated corrosive behaviour at the time and position of measurement.

• Naphthenic acid corrosion is complex, whereby quantitative correlation of corrosion and flux will be realised only upon extensive field investigations.

• Future laboratory work should ensure fluid sheer stress typically associated with naphthenic acid corrosion.

• *Thank you for your attention.*

Appendix 7

Refinery Corrosion Prediction:

Ammonium Bisulfide (H_2S/NH_3), Naphthenic Acid, Rich and Lean Amines

R.D. Kane (Honeywell)

Refinery Corrosion Prediction:

Ammonium Bisulfide (H_2S/NH_3), Naphthenic Acid, Rich and Lean Amines

Presentation by:
Dr. Russell D. Kane, Marta Castillo, Peter Ellis
Sridhar Srinivasan, Vishal Lagad, Dick Horvath
Honeywell

JIP Opportunities

- Recent joint industry efforts from Honeywell have focused on leveraging corporate funding to share the development cost of more complete and accurate models for critical processes.
  - Completed programs or completion in 2006:
    - Sour Water (NH_4HS) Corrosion – Phase I (H_2S Dominated Conditions)
    - Sour Water (NH_4HS) Corrosion – Phase II (NH_3 Dominated Conditions)
    - Rich Amine Corrosion
  - Program starting in 2006
    - Sulfuric Acid Alkylation (August 2006)
    - Naphthenic Acid Corrosion (October 2006)
  - Programs planned for 2007
    - Lean Amine Corrosion

H_2S-Dominated NH_4HS Corrosion JIP

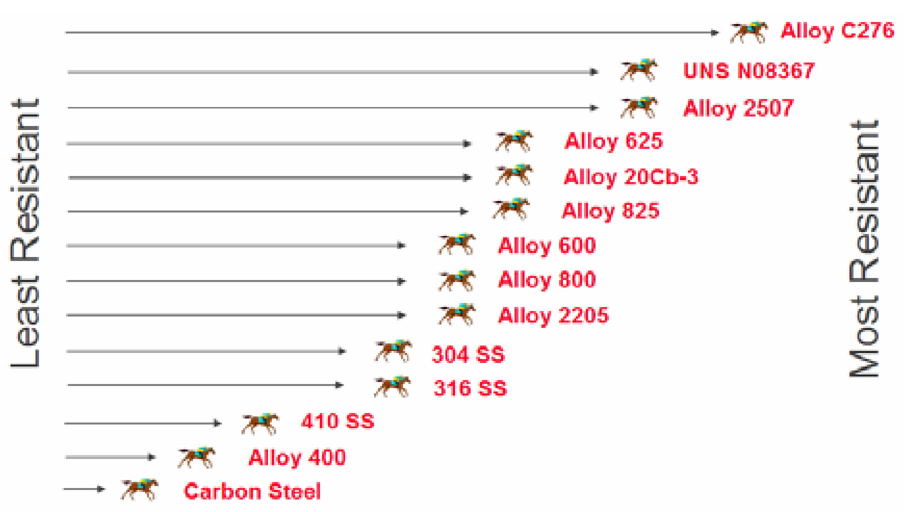
- Old rules of thumb not supported:
  - NH_4HS concentration limit (e.g., 2%, 8%)
    - No single concentration limit exists
  - Velocity limit (e.g., 20 ft/s)
    - No single velocity limit exists
    - Limit can be too conservative or non-conservative depending on concentration and other factors
  - pH cannot be used to predict NH_4HS corrosion
- New rules were developed:
  - H_2S partial pressure has a significant effect on NH_4HS corrosion
  - Three key variables must be considered together to predict NH_4HS corrosion:
    - NH_4HS concentration
    - Velocity (i.e., wall shear stress)
    - H_2S partial pressure
  - Consider other relevant variables
    - Temperature, hydrocarbon, etc.

Recently completed JIP program developed data that serves as the basis for a new predictive model and software tool for evaluation of NH_4HS corrosion.

Now available to Non-sponsors Details: Corrosion/2006 Papers: #06576 and #06577

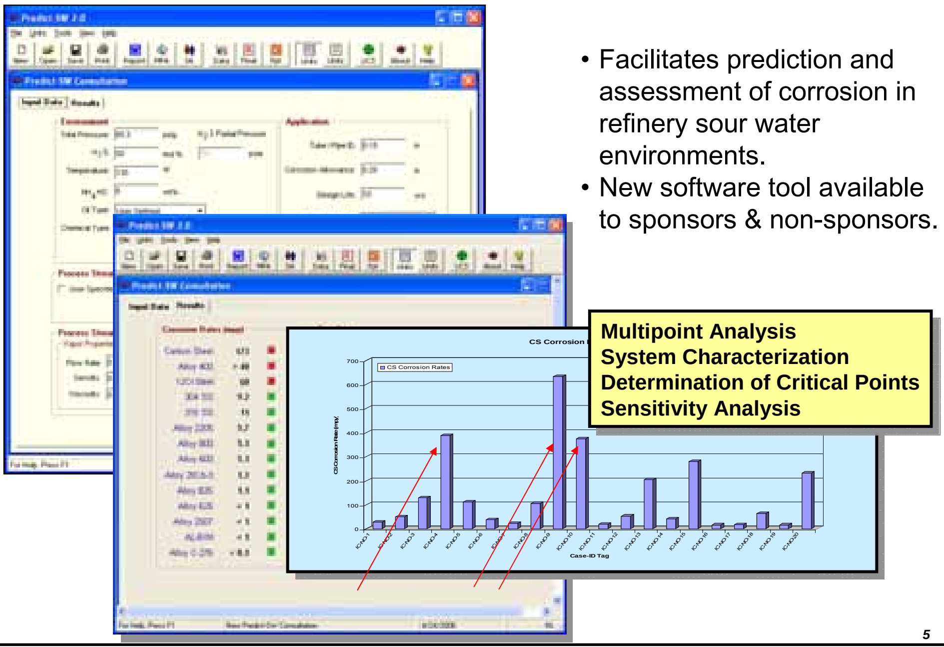
3

Important Find - H_2S-Dominated NH_4HS Conditions



4

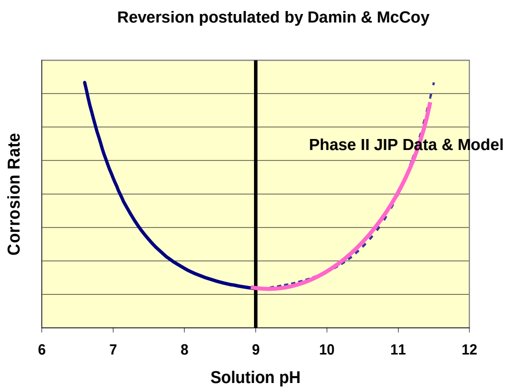
NH_4HS Corrosion – Predictive Software Tool



- Facilitates prediction and assessment of corrosion in refinery sour water environments.
- New software tool available to sponsors & non-sponsors.

NH_3-Dominated NH_4HS Corrosion

- Phase I Sour Water JIP effort was completed.
  - Phase I focused on conditions where substantial P_{H2S} dominated corrosion.
  - However, it has been postulated by Damon & McCoy that there was a possible corrosion ”reversion” at higher pH.
- Phase II was initiated in 2004.
  - Focused on the parametric effects of higher P_{NH3}, temperature and cyanide.
  - **Reversion was confirmed and a model developed to predict corrosion.**
  - ***A critical and unexpected issue especially for stainless steels and some nickel-base alloys***



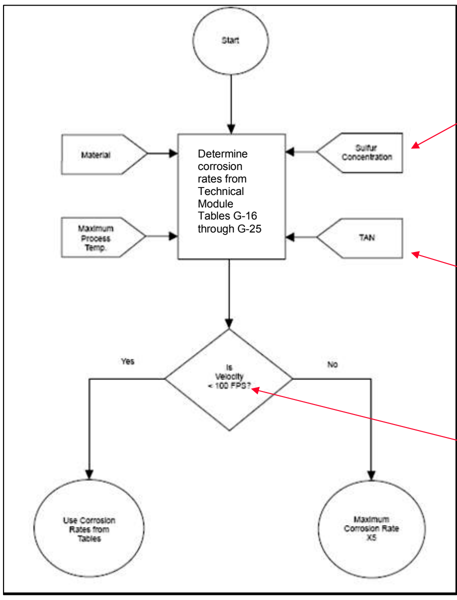
- Program is scheduled to complete by end of 2006.
- Still open for sponsor participation during 2 yr. confidentiality period

Naphthenic Acid Corrosion – New JIP

- Most severe & high velocity areas VDU are alloyed with 316 or 317 SS to prevent corrosion.
- However, the remainder of the circuit is comprised of mainly liquid filled lines with lower wall shear stress conditions (5 to 200 Pa) that are typically made from carbon steels through 12 Cr.
- The main problems are:
  - Only limited data available and limitations in API RP581 risk matrix
  - Many key variables are not included in assessment.
  - Significant risk for deterioration still persists.
  - Impact blending/treatment strategies, assessment of operational risk, inspections intervals, and unit upgrades.

7

Key Concerns with API RP 581 Approach



How to quantify Sulfur?
- Wt. percent
- H_2S partial pressure
- Other

How to quantify nap acid effects?
- Nap acid type
- NAN vs. TAN
- Other

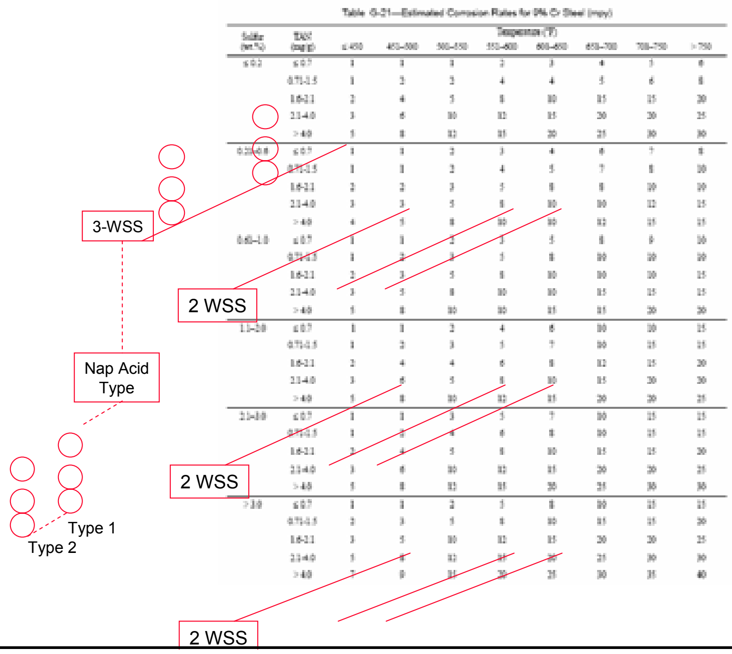
How to quantify velocity effect?
- WSS vs. velocity

8

Naphthenic Acid JIP

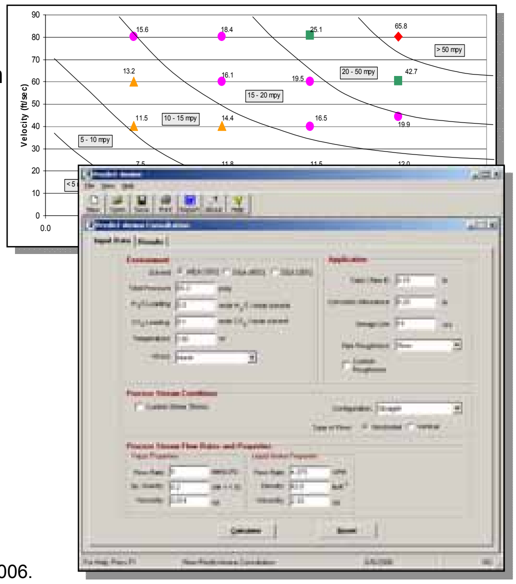
- A new joint industry program (JIP) has been organized and is designed to:
  - An accelerated test for assessing hot oil corrosivity
  - Parametric TAN, WSS and temperature effects
  - Influence of sulfidic species
  - Influence of naphthenic acid “type” – “corrosion” & “non-corrosive”
  - Results integrated into a new software tool to defining corrosivity and operational risk.
- Program is beginning in October 2006.
- Program is open for sponsor participation.

Example Revised Risk Matrix using JIP Data



Rich Amine Corrosion JIP

- Phase I – Rich Amine Corrosion
  - A program was initiated to better define and assess corrosion in rich amine systems:
  - Includes MEA, DEA, DGA and MDEA
  - Similar methodology as used in Sour Water JIP
  - Definition of iso-corrosion curves
  - Parametric relationships of
    - Temperature
    - H_2S loading
    - CO_2/H_2S ratio
    - Impurities
  - Data base and software tool provide rapid corrosion prediction and assessment of plant conditions and materials of construction.



- Program is scheduled for complete by end of 2006.
- Still open for sponsor participation during 2 yr. confidentiality period

11

Lean Amine Corrosion – Proposed New JIP

- Phase II – New Program on Lean Amine Corrosion
  - A program being formulated for 2007 to better define and assess corrosion in lean amine systems:
  - Includes MEA, DEA, DGA and MDEA
- Plant experience shows that lean amine corrosion is most severe where:
  - Gases de-absorbed from rich amine solutions; i.e. heat transfer (ΔT) and high local wall shear stress (WSS)
  - Over-stripping of H_2S can result in more corrosive condition
- Data base and software tool provide rapid corrosion prediction and assessment of plant conditions and materials of construction. Will include:
  - Effects of H_2S loading (0 to 1000 ppm)
  - Bulk temperature (<350 F)
  - Heat transfer conditions (three ΔTs – 0 to 50 F)
  - HSAS levels (TBD)
  - Software tool to link database to actual plant conditions

- Program is scheduled for initiation by mid-2007.
- Comments or suggestions on scope are welcome thru year end.

12

Action

- For additional information or participation, contact:

Dr. Russell D. Kane
Honeywell Process Solutions
14503 Bammel North Houston Road, Suite 300
Houston, Texas 77014 USA
Tele: +1-281-444-2282 Ext 32.
Email: russ.kane@honeywell.com

Appendix 8

Control of Process Instability & Corrosion in a Hot Lean Amine System

R.D. Kane (Honeywell)

Control of Process Instability & Corrosion in a Hot Lean Amine System

Jeff Bulger, Magdy Girgis & Tammy Polvi
Shell Canada Limited

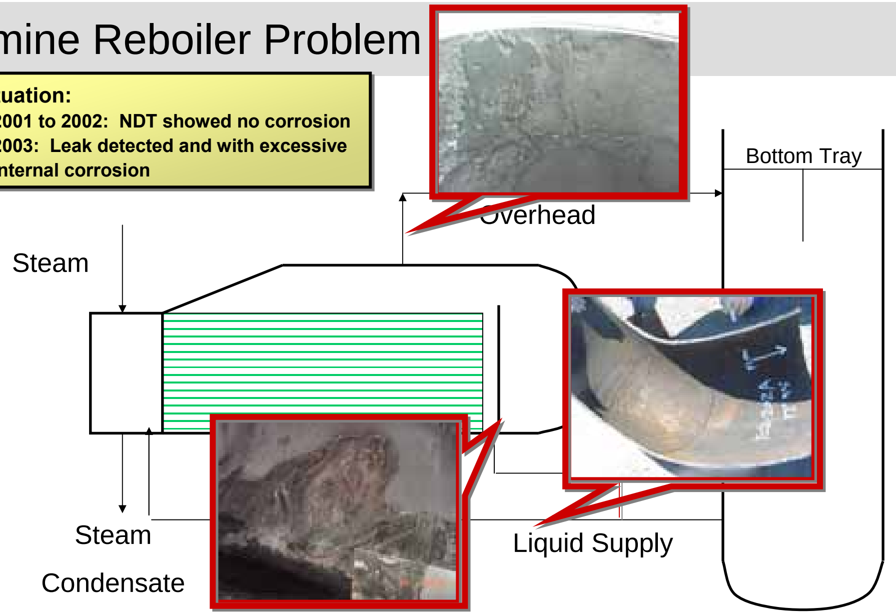
Presented by Dr. Russell D. Kane
at Honeywell Users Group Meeting
Phoenix, AZ – June 2006

Honeywell

Honeywell

Amine Reboiler Problem

Situation:
- **2001 to 2002: NDT showed no corrosion**
- **2003: Leak detected and with excessive internal corrosion**



Honeywell

The system utilized for the monitoring was SmartCET

- **On-line, real-time detection of both general and localized corrosion**

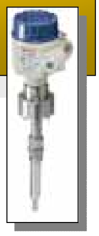
Electrochemical Monitoring Technology

Multiple techniques applied simultaneously

Harmonic Distortion Analysis (HDA) → **Accurate general corrosion rate**

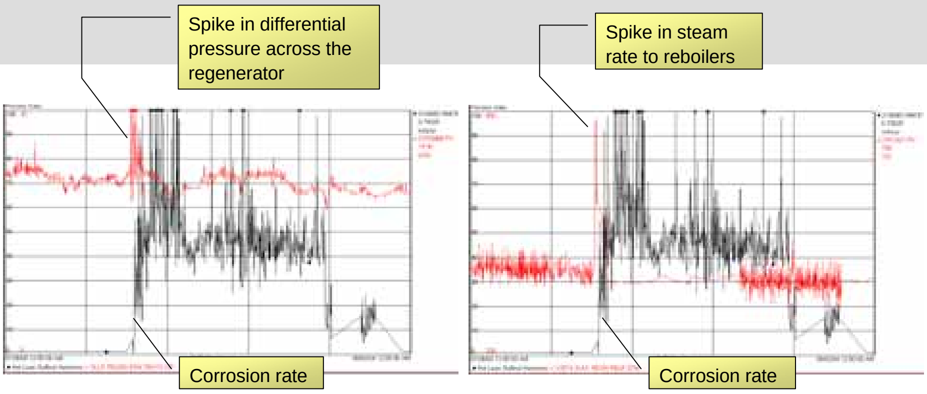
Linear Polarization Resistance (LPR) → **Accurate general corrosion rate**; **Identification of localized corrosion**

Electrochemical Noise (ECN) → **Identification of localized corrosion**



- ❑ **Automated data acquisition and analysis cycle (every 7 minutes) consistent with process control/automation applications**
- ❑ **Applied in hazardous areas (now IS rated)**
- ❑ **Simple interface to process control systems (via HART & 4-20 mA)**
- ❑ **1 to 4 variable output (Corrosion Rate, Pitting Factor, B value, CMI)**
- ❑ **Can be monitored with existing plant personnel**

Honeywell

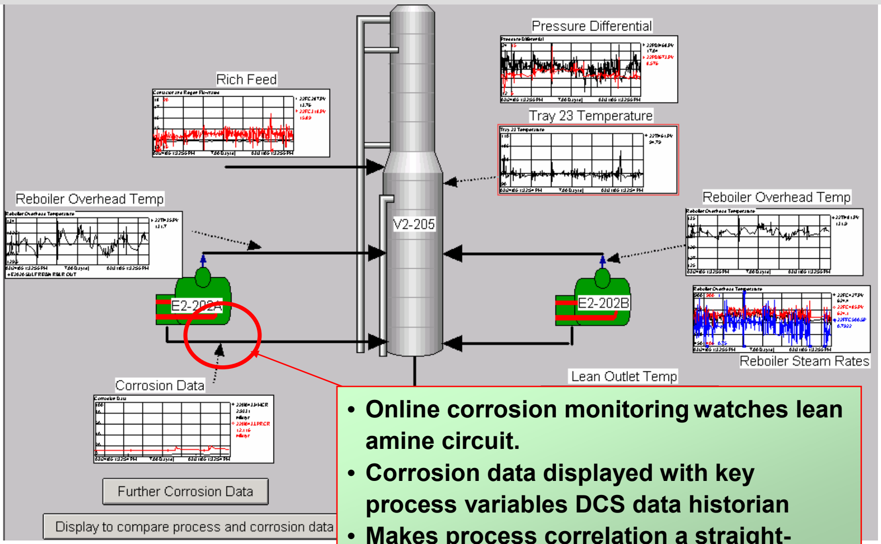


- **Real-time corrosion rate during an upset event.**
- **Specific upset events: ΔP and rapid change in stream rates to reboiler.**
- **Corrosion rate changed from <0.15 mm / yr to 1.25 mm / yr**
- **Corrosion rate remained high even after regenerator regains some stability.**
- **The corrosion rate did not recover until the steam rate to the reboilers and temperature at the top of the regenerator stopped fluctuating.**

Process Instability & Correlation with Corrosion

Honeywell

Real-Time Corrosion Monitoring



- Online corrosion monitoring watches lean amine circuit.
- Corrosion data displayed with key process variables DCS data historian
- Makes process correlation a straight-forward process for operations

Honeywell

Significant Findings

- **Corrosion is not an "always on" process….It was controlled by the process.**
- **High corrosivity events correlated to specific periods of process instability – the instability was related to amine polymer residue.**
- **In order to see these correlations, real-time corrosion data was necessary.**
  - Conventional offline corrosion measurement technologies did not capture real-time events.
- **Once the correlation was made, the problem was resolved by amine reclamation.**
- **Reduction in corrosion rate was also latter confirmed by NDE.**
- **Since resolution of this situation, the unit remains remotely monitored using the same system.**

Appendix 9

Stress Corrosion Cracking in Fuel Ethanol

A Joint Program

American Petroleum Institute

Renewable Fuels Association

R.D. Kane (Honeywell)

Stress Corrosion Cracking in Fuel Ethanol

A Joint Program
American Petroleum Institute
Renewable Fuels Association

Dr. Russell D. Kane
Program Consultant
Honeywell Process Solutions
Houston, Texas USA

What is Fuel Ethanol? Why is it Important?

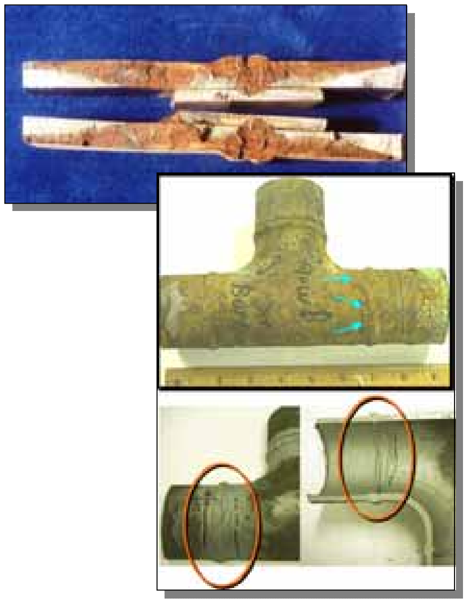
Quality Specification for Fuel Ethanol per ASTM D4806
(In USA most ethanol is derived from corn; other sources Include sugar cane, grapes and biomass)

Property	Units	Specification	ASTM Designation
Ethanol	%v min	92.1	D5501
Methanol	%v max	0.5	--
Solvent-Washed Gum	mg/100 ml max	5.0	D381
Water Content	%v max	1.0	E203
Denaturant Content	%v min %v max	1.96 4.76	D4806
Inorganic Chloride Content	ppm (mg/L) max	40 (32)	E512
Copper Content	mg/kg max	0.1	D1688
Acidity as acetic acid	%m (mg/L)	0.007 (56)	D1613
pHe	--	6.5-9.0	D6423
Appearance	Visibly free of suspended or precipitated contaminants (e.g. clear & bright)		

Global production of fuel ethanol is projected to double in the next 5 years.
Need to minimize risk of SCC failures.

Fuel Ethanol Survey at a Glance

- In the API program, approx. 24 cases of SCC were documented (Yrs 1990-2005).
- Failures were in steel – tank bottoms, wall and roofs; piping, fittings and components. No particular to steel grade.
  - SCC at either a liquids distribution terminals or gasoline blending facilities.
  - No SCC in ethanol manufacturers facilities
  - No SCC after ethanol is blended with conventional gasoline (E10).



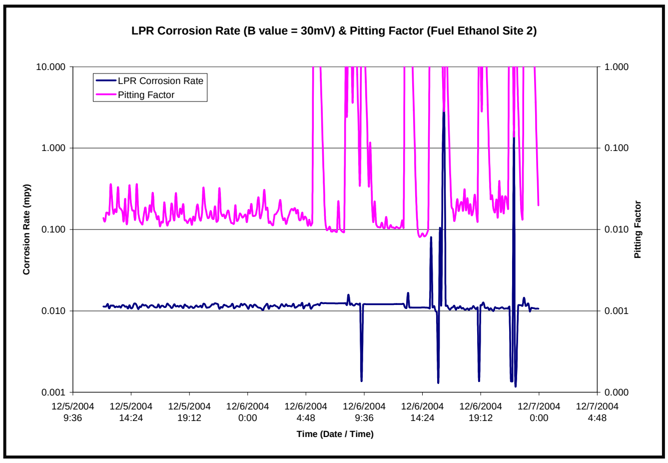
Honeywell

What We Know from Experience Survey

- SCC is related to conditions of:
  - High local tensile stresses, concentration of bending.
  - In weld area (butt welds, lap-seam welds in plates, low heat input tack welds in supports)
  - Residual stresses or cold work – fabrication, forming, fit-up & subsidence
  - Flexing components (tank bottoms, roof plates & spring components)
- Prevention and remediation involves:
  - PWHT of piping welds
  - Coating of tank bottoms and some roof components.

Honeywell

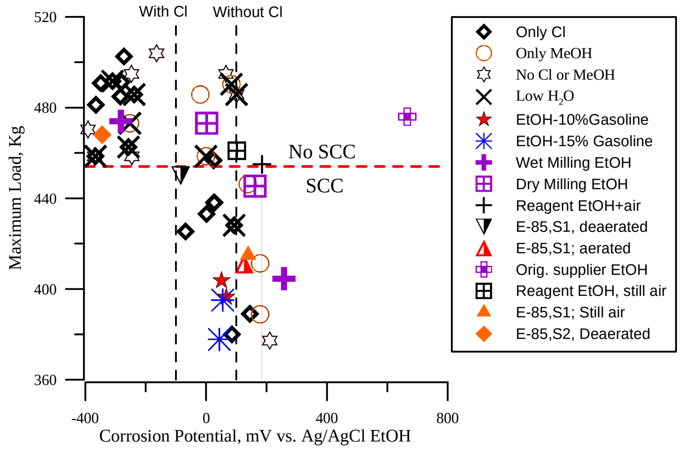
What We Know from Online Corrosion Monitoring



- Highest corrosion and pitting activity during periods of loading and unloading
- Likely that aeration and turbulence support corrosion, localized corrosion & SCC activity

Honeywell

What we Know from Laboratory Research



- **Lab tests were conducted using slow strain rate tests.**
- **Both reagent ethanol blends and field samples show susceptibility to SCC.**
- **Aeration and chlorides tend to be major factors in SCC behavior.**
- **SCC has been observed in both fuel ethanol and E85 blends.**

Honeywell

Current API Activities

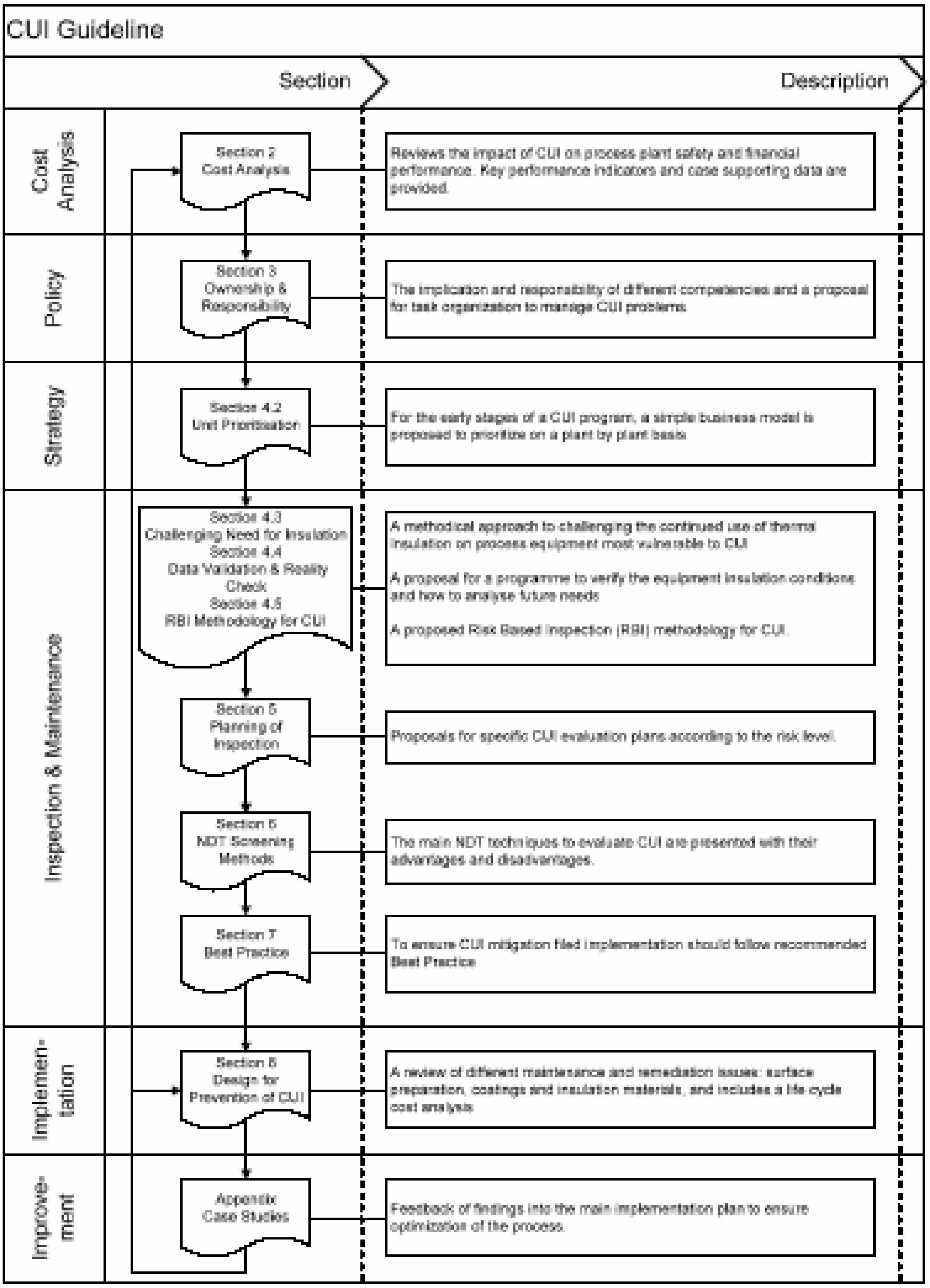
- API lab research continues to examine the influence of other variables on SCC and control mechanisms and examine fracture risks.
- Looking for samples of fuel ethanol for other regions:
  - Brazil (Sugar Cane) and Europe (Wine)
- API has published White Paper API Tech Pub 939D
- API is developing a guidelines document (API 939E) to present current experience and details on prevention, inspection and remediation methods for ethanol SCC.
- For additional information, assistance, ethanol samples or documentation of SCC failures:

Dr. Russell D. Kane
Honeywell Process Solutions
14503 Bammel North Houston Road, Suite 300
Houston, Texas 77014 USA
Tele: +1-281-444-2282 Ext 32.
Email: russ.kane@honeywell.com

Honeywell

Appendix 10

Presentation of the EFC CUI Guideline


CUI Guideline
Section
Description
Cost Analysis
Policy
Strategy
Inspection & Maintenance
Implementation
Improvement
Section 2 Cost Analysis
Reviews the impact of CUI on process plant safety and financial performance. Key performance indicators and case supporting data are provided.
Section 3 Ownership & Responsibility
The implication and responsibility of different competencies and a proposal for task organization to manage CUI problems
Section 4.2 Unit Prioritisation
For the early stages of a CUI program, a simple business model is proposed to prioritize on a plant by plant basis
Section 4.3 Challenging Need for Insulation
Section 4.4 Data Validation & Reality Check
Section 4.5 RBI Methodology for CUI
A methodical approach to challenging the continued use of thermal insulation on process equipment most vulnerable to CUI
A proposal for a programme to verify the equipment insulation conditions and how to analyse future needs
A proposed Risk Based Inspection (RBI) methodology for CUI.
Section 5 Planning of Inspection
Proposals for specific CUI evaluation plans according to the risk level.
Section 6 NDT Screening Methods
The main NDT techniques to evaluate CUI are presented with their advantages and disadvantages.
Section 7 Best Practice
To ensure CUI mitigation filed implementation should follow recommended Best Practice
Section 8 Design for Prevention of CUI
A review of different maintenance and remediation issues: surface preparation, coatings and insulation materials, and includes a life cycle cost analysis
Appendix Case Studies
Feedback of findings into the main implementation plan to ensure optimization of the process.