International Gas Union Research Conference
IGRC COPENHAGEN 2014
September 17-19
Gas Innovations Inspiring Clean Energy

WO7-2:

Remote Monitoring of Pipeline Cathodic Protection and Coating Integrity

Lars Vendelbo Nielsen
MetriCorr ApS

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WO7-2:

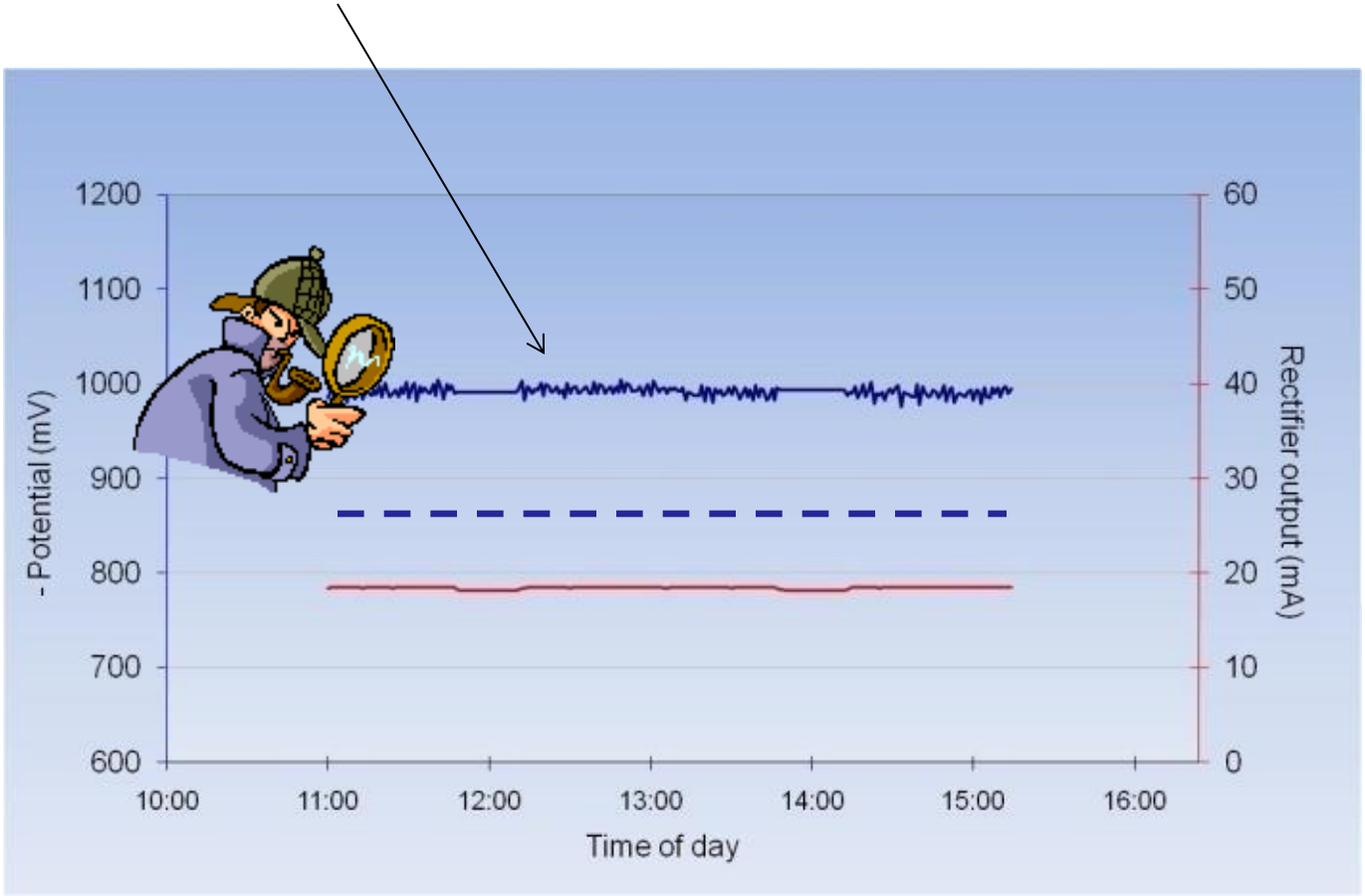
Focus on
Corrosion Rate Monitoring in “Problematic” Test Posts

Lars Vendelbo Nielsen
MetriCorr ApS

MetriCorr

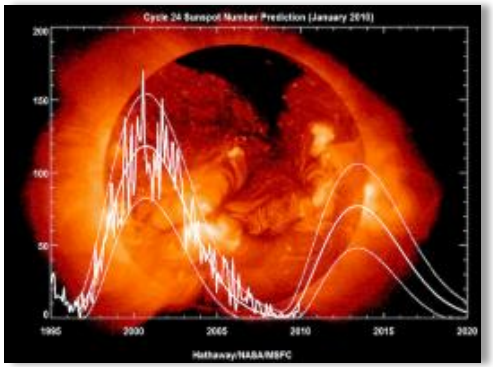
Cathodic Protection Potential

Why keep starring when nothing happens?



DC STRAY CURRENTS

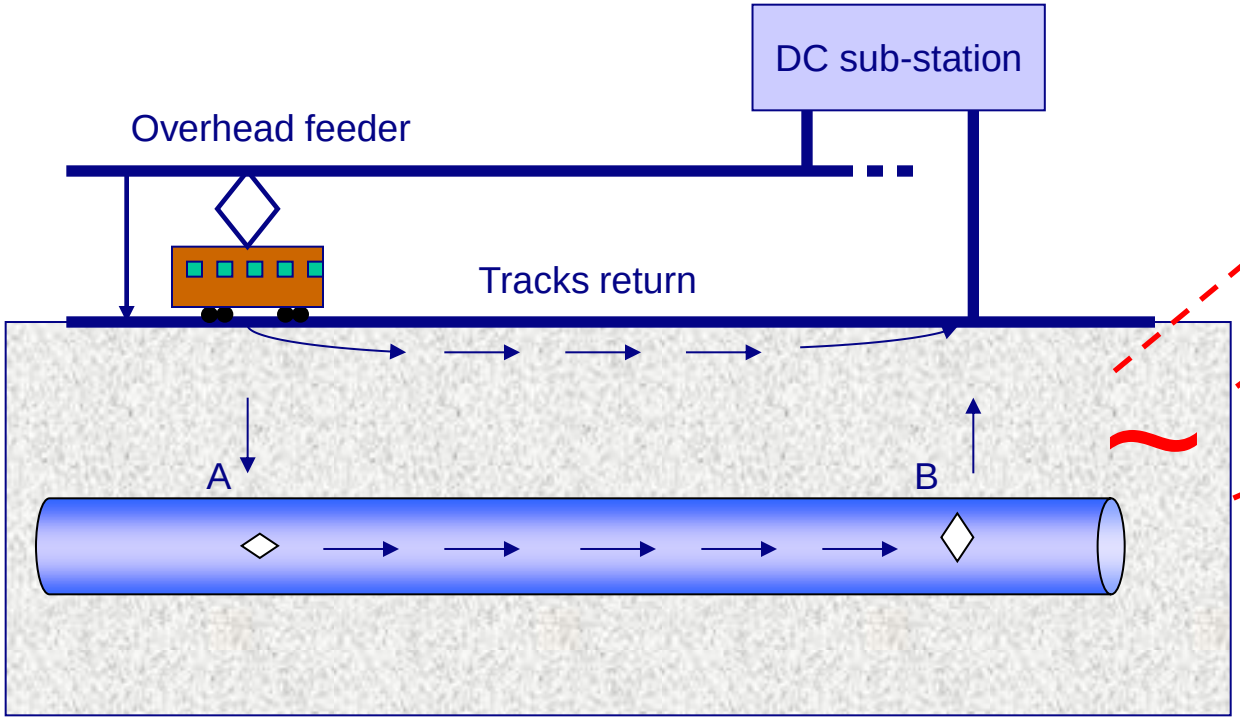
AC INTERFERENCE



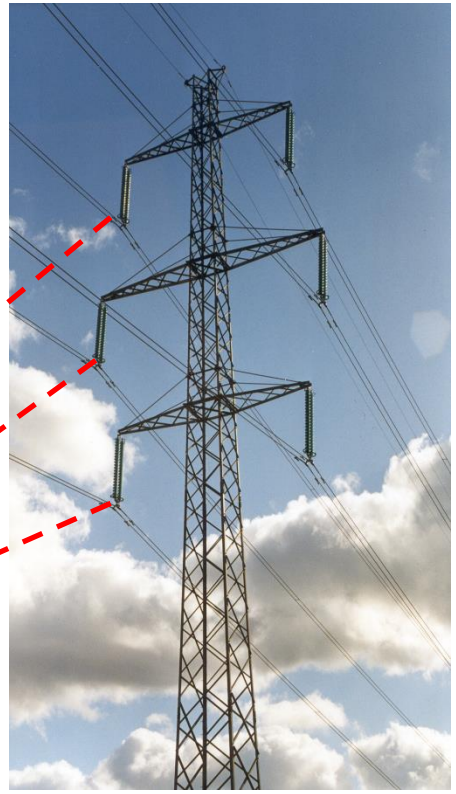
TELLURICS

PROBLEMATIC TEST SITES

AC and DC Interference

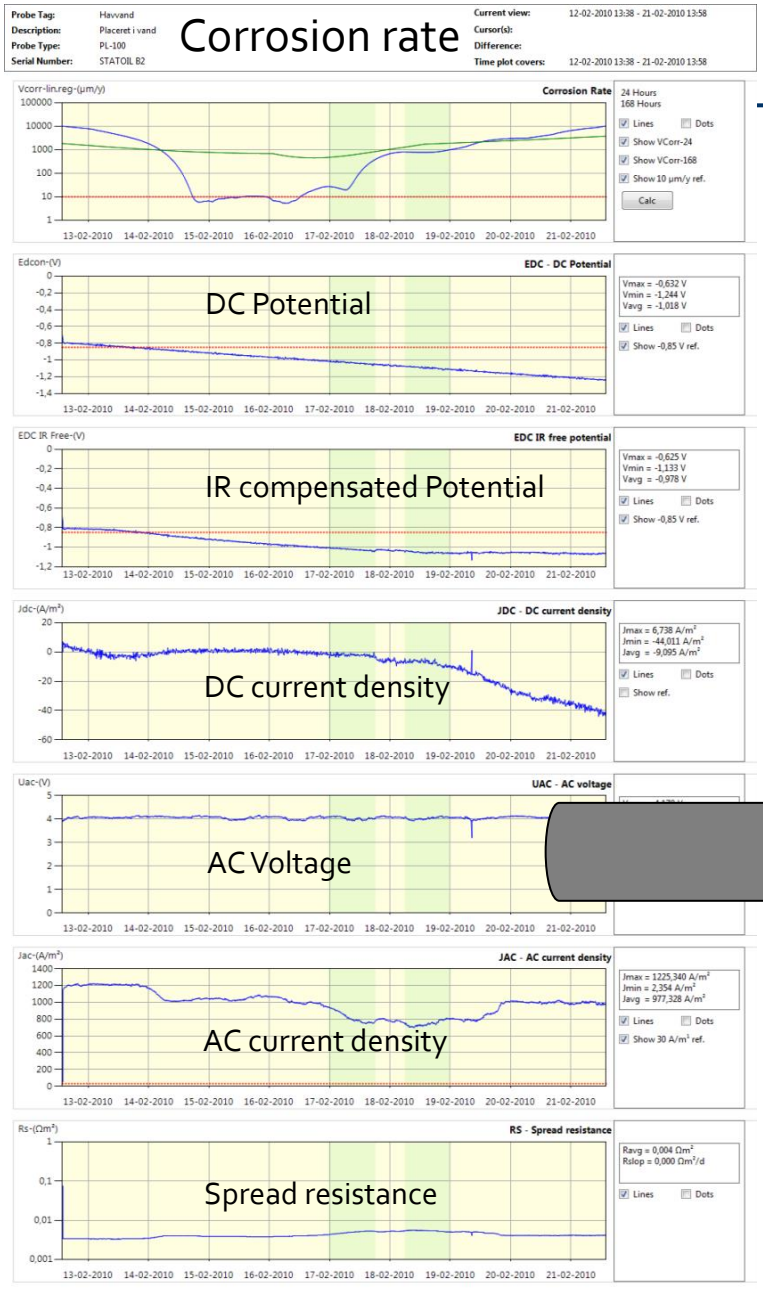


DC interference



AC Interference

Corrosion rate



Data Logger

Ref

Pipeline

Corrosion Probe


Flush type


Rod type


ОХРАННАЯ ЗОНА

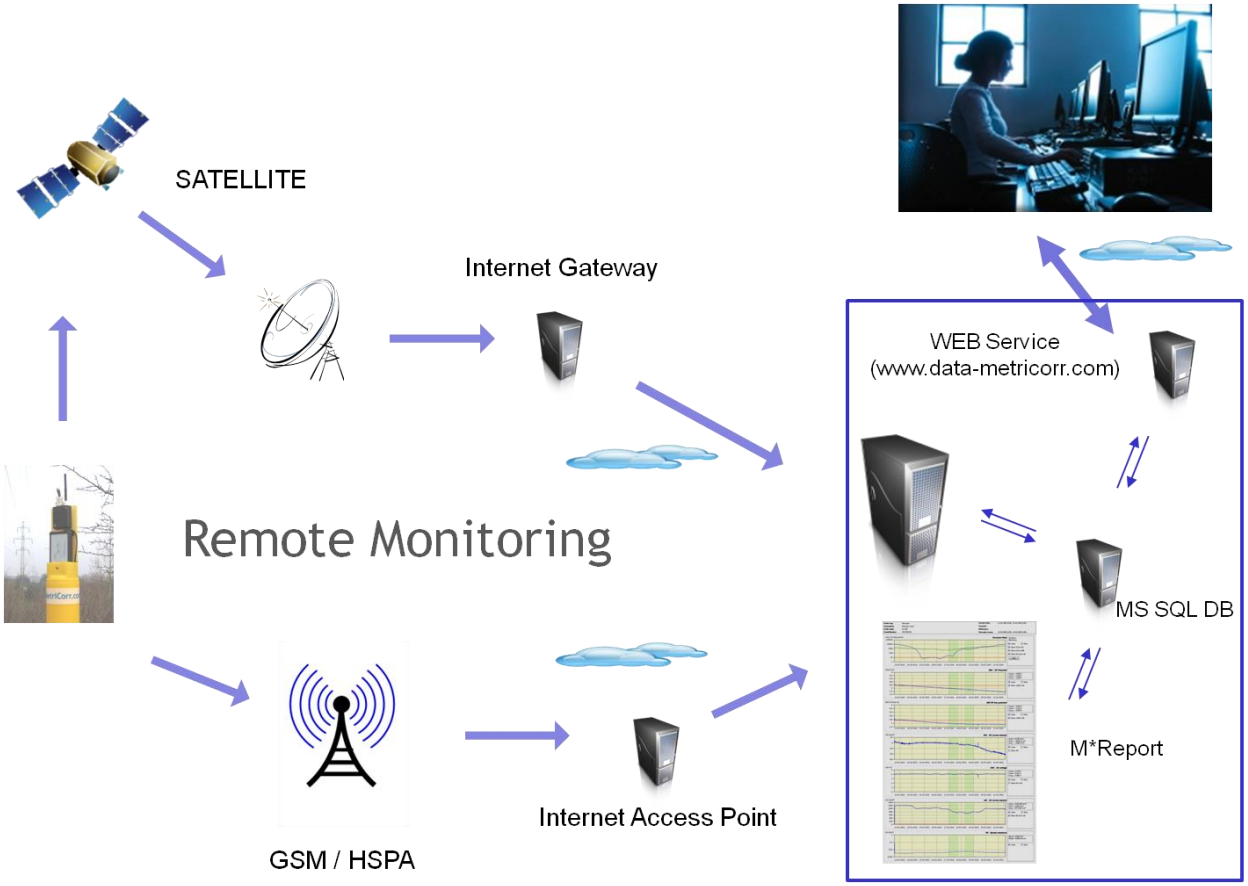

ОСТОРОЖНО - ГАЗ
ВЗРЫВО-ОГНЕОПАСНО!


steca
SOLSUM 6.6F
MetriCorr.com
Important instruction
KS 1444 020
025269


DONG
DONG

Solar

Data flow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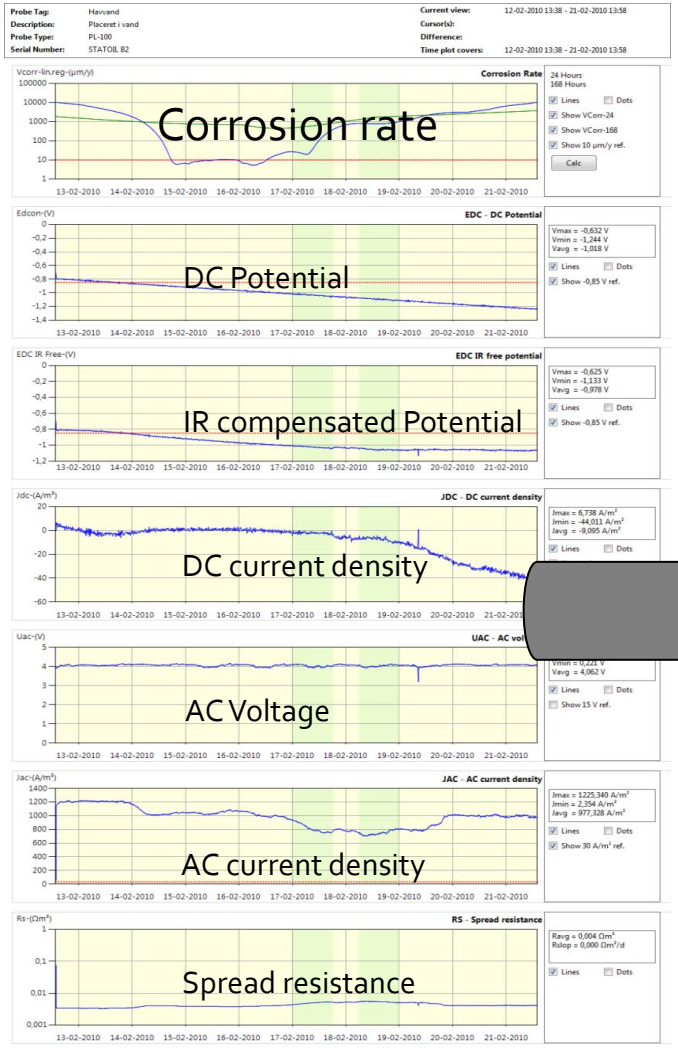
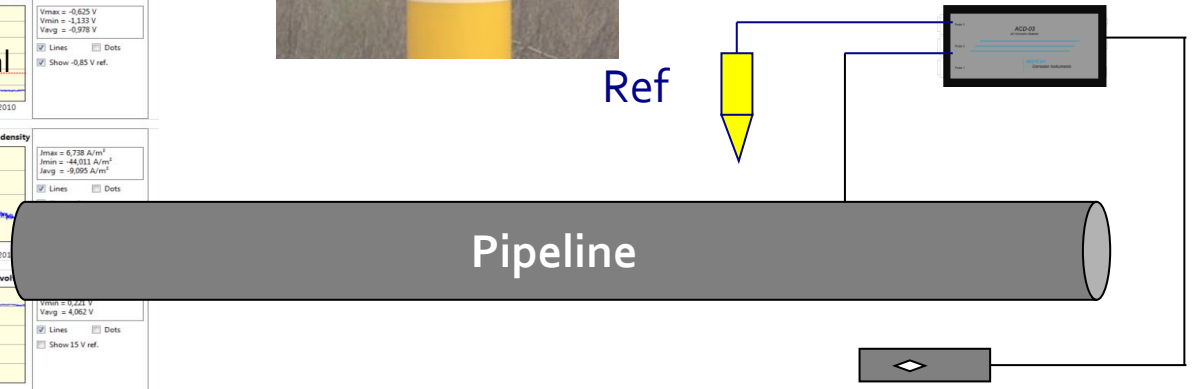
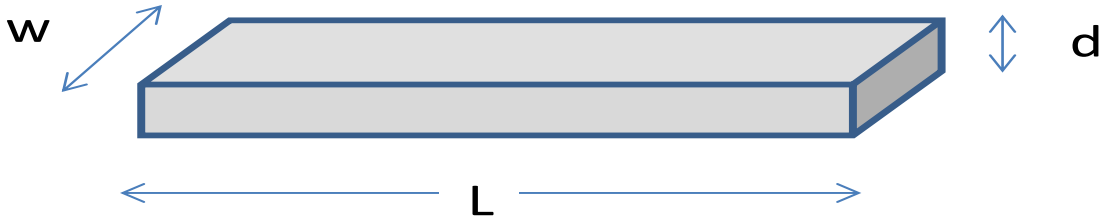
Internet Gateway
Remote Monitoring
WEB Service
(www.data-metricorr.com)
MS SQL DB
M*Report
Internet Access Point
GSM / HSPA





MetriCorr Probe

Specialized Electrical Resistance Technology



$$R = \rho_m(T) \cdot \frac{L}{W \cdot d}$$

$$\rho_m(T) = \rho_m(T_0) \cdot (1+\alpha)^{T-T_0}$$

$$\Updownarrow$$

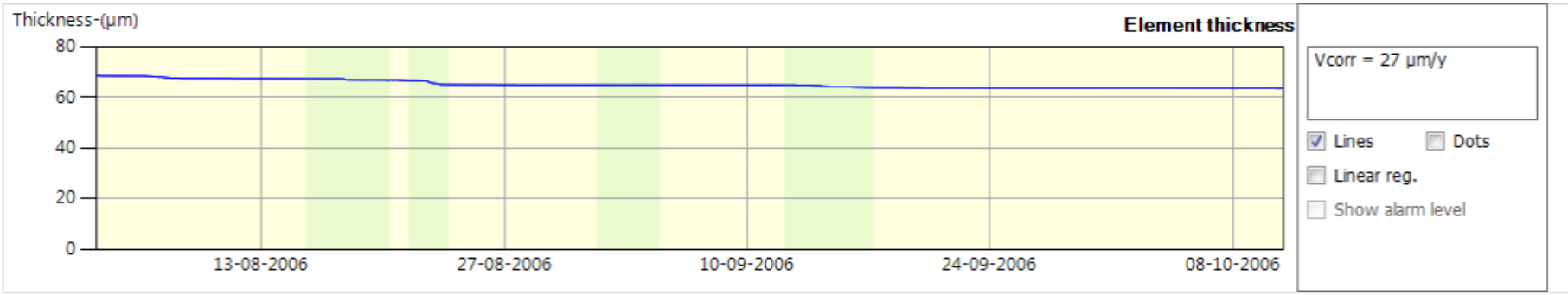
$$d = \rho_m(T) \cdot \frac{L}{W} \cdot \frac{1}{R}$$

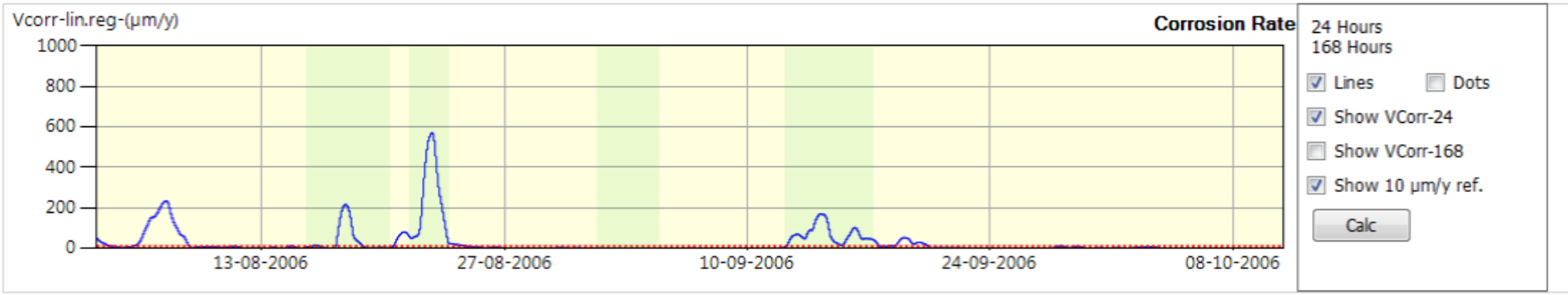
$$\Downarrow$$

$$CR = \frac{dR}{dt} \cdot \frac{W}{L} \cdot \frac{d^2}{\rho_m(T)} \Rightarrow \Delta t = \frac{\Delta R}{CR} \cdot \frac{W}{L} \cdot \frac{d^2}{\rho_m(T)}$$

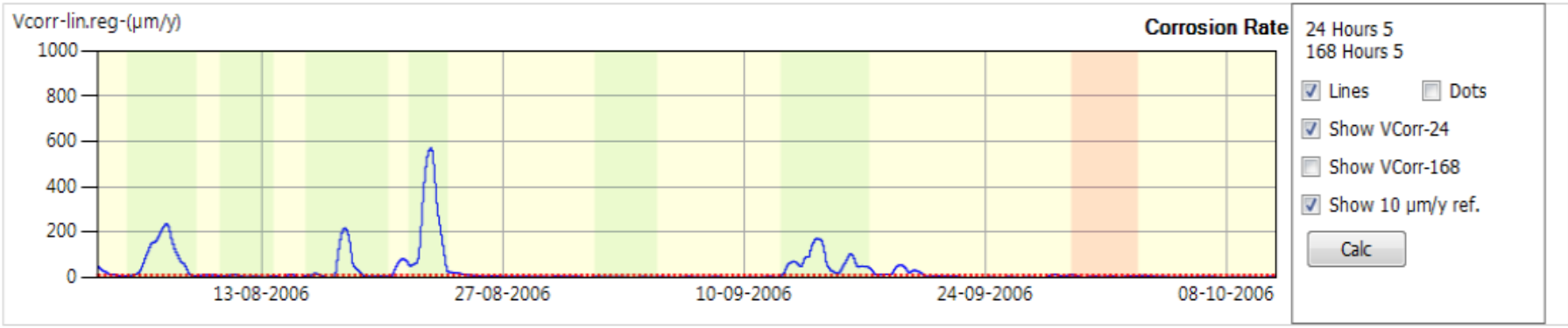
Corrosion rate calculation

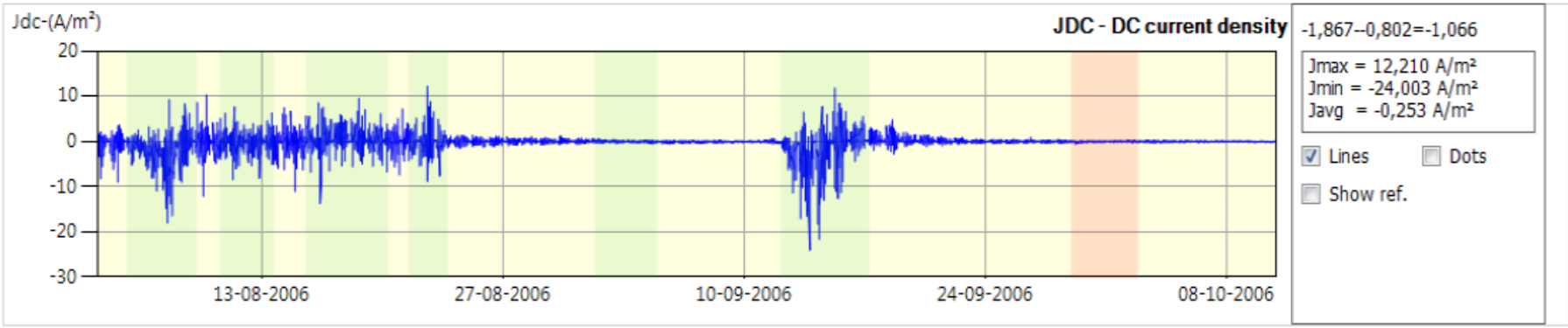
Tag	?	**Current view**	03-08-2006 11:29 - 10-10-2006 21:39
Description	?	**Cursor(s)**	
Probe type	PA-0.4-10-0.1-6	**Difference**	
Serial number	PA04270025	**Time Plot covers**	03-08-2006 11:29 - 10-10-2006 21:39

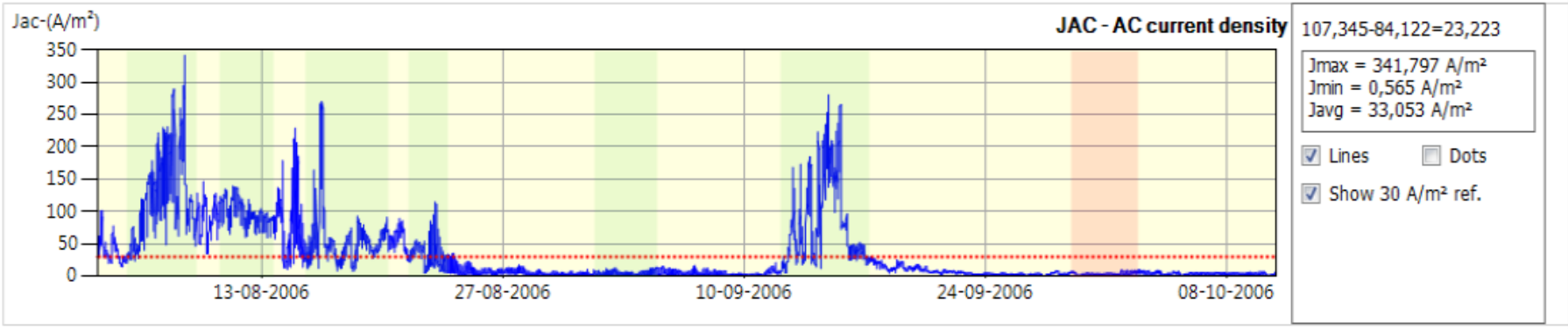


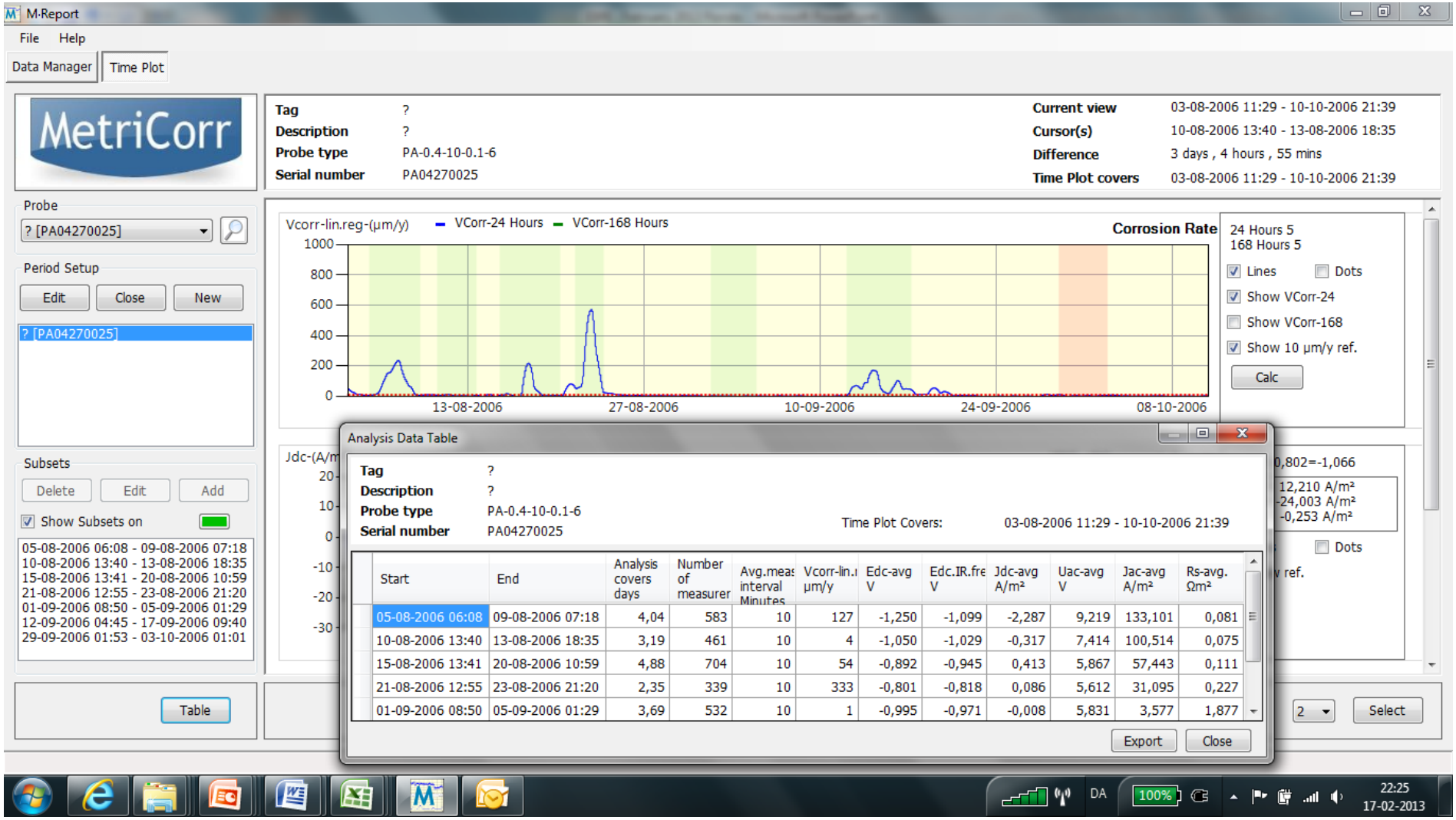


Tag	?	**Current view**	03-08-2006 11:29 - 10-10-2006 21:39
Description	?	**Cursor(s)**	10-08-2006 13:40 - 13-08-2006 18:35
Probe type	PA-0.4-10-0.1-6	**Difference**	3 days , 4 hours , 55 mins
Serial number	PA04270025	**Time Plot covers**	03-08-2006 11:29 - 10-10-2006 21:39





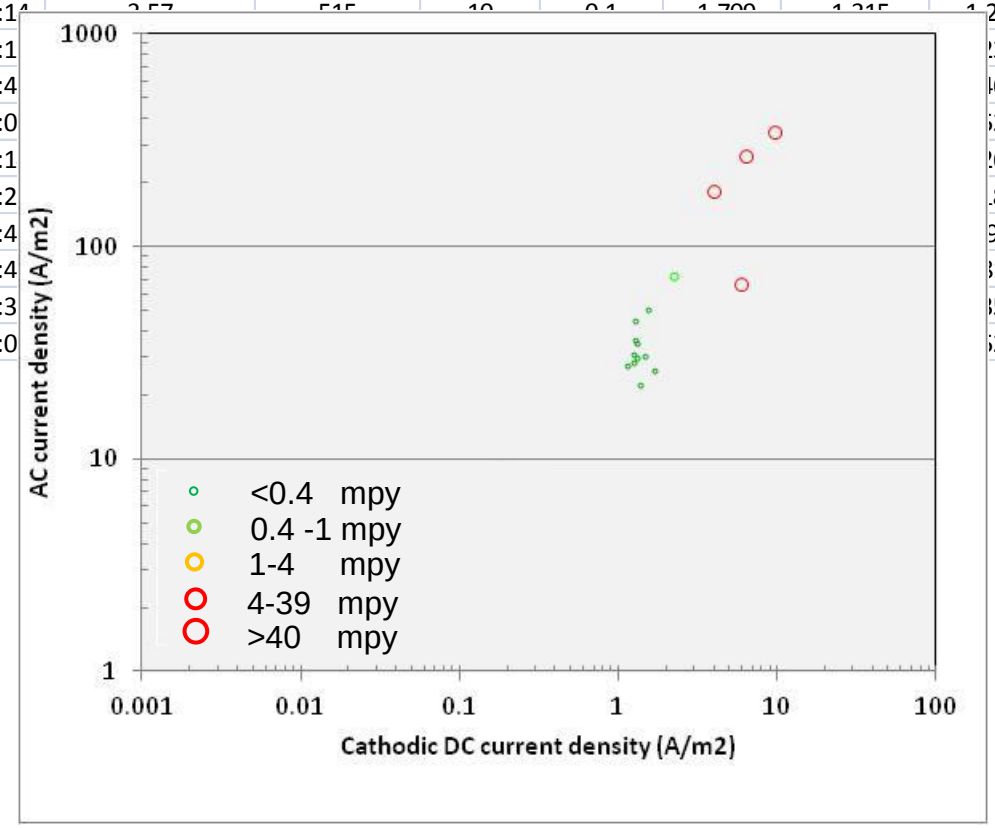




Start	End	Analysis covers days	Number of measurer	Avg.meas interval Minutes	Vcorr-lin.r µm/y	Edc-avg V	Edc.IR.fre V	Jdc-avg A/m²	Uac-avg V	Jac-avg A/m²	Rs-avg. Ωm²
05-08-2006 06:08	09-08-2006 07:18	4,04	583	10	127	-1,250	-1,099	-2,287	9,219	133,101	0,081
10-08-2006 13:40	13-08-2006 18:35	3,19	461	10	4	-1,050	-1,029	-0,317	7,414	100,514	0,075
15-08-2006 13:41	20-08-2006 10:59	4,88	704	10	54	-0,892	-0,945	0,413	5,867	57,443	0,111
21-08-2006 12:55	23-08-2006 21:20	2,35	339	10	333	-0,801	-0,818	0,086	5,612	31,095	0,227
01-09-2006 08:50	05-09-2006 01:29	3,69	532	10	1	-0,995	-0,971	-0,008	5,831	3,577	1,877

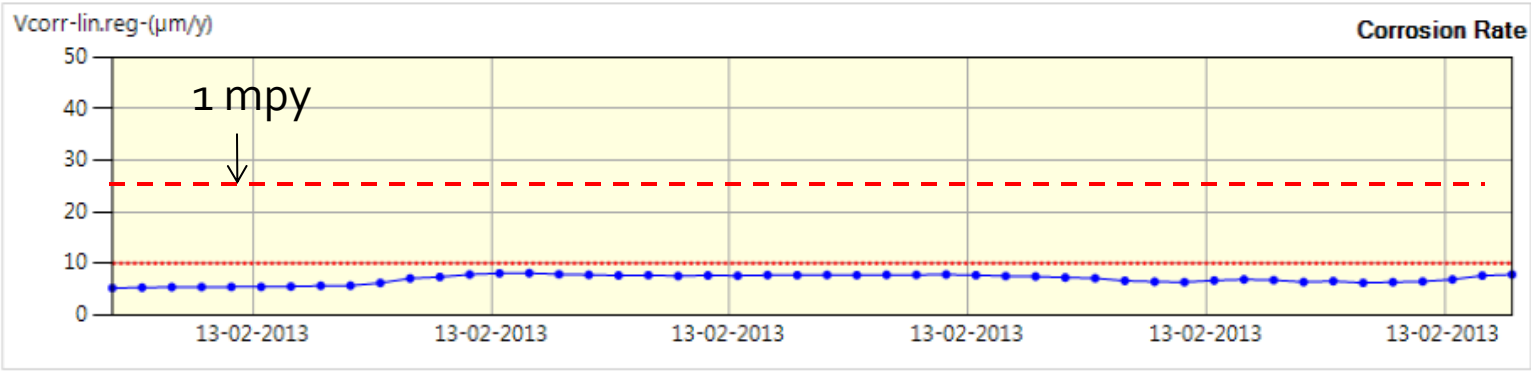
Development of criteria for CEN EN 15280

Start	stop	Analysis covers	Measpoints	AVG int	Vcorr	Edc-avg	IR.free-avg	Jdc-avg	Uac-avg	Jac-avg	Rs-avg.
		days	n	Minutes	mpy	V	V	A/m²	V	A/m²	Ωm²
09/03/2012 20:59	11/03/2012 22:34	2.06	291	10	0.0	-1.71	-1.366	1.349	5.739	22.557	0.255
12/03/2012 05:35	16/03/2012 13:04	4.31	620	10	0.0	-1.68	-1.331	1.278	9.853	36.249	0.273
26/03/2012 10:39	30/03/2012 02:28	3.59	456	11	0.0	-1.65	-1.333	1.25	7.865	31.197	0.253
16/03/2012 17:23	18/03/2012 23:17	2.24	322	10	0.0	-1.686	-1.357	1.117	8.136	27.688	0.294
23/03/2012 04:05	26/03/2012 02:42	2.94	418	10	0.0	-1.68	-1.351	1.302	7.618	30.391	0.252
10/02/2012 23:45	13/02/2012 01:04	2.04	280	10	0.0	-1.709	-1.322	1.679	5.953	26.256	0.231
21/02/2012 17:20	25/02/2012 07:14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.29	10.68	35.256	0.304
25/02/2012 20:36	04/03/2012 23:1							33	7.562	28.672	0.265
18/02/2012 11:05	21/02/2012 09:4							463	8.599	30.7	0.284
05/03/2012 12:39	09/03/2012 12:0							526	11.688	50.76	0.234
19/03/2012 05:03	22/03/2012 23:1							268	12.368	45.078	0.28
15/02/2012 16:17	18/02/2012 03:2							.88	16.278	72.902	0.241
13/02/2012 05:06	15/02/2012 06:4							95	26.585	183.883	0.163
03/02/2012 23:42	06/02/2012 03:4							317	5.238	67.014	0.082
06/02/2012 08:19	10/02/2012 19:3							351	26.754	268.973	0.111
01/02/2012 14:09	03/02/2012 20:0							529	24.114	346.438	0.071



Examples from the field

Tag	Serum	**Current view**	12-02-2013 21:38 - 13-02-2013 21:08
Description	Prøveinstallation ved Serum	**Cursor(s)**	10-08-2006 13:40 - 13-08-2006 18:35
Probe type	PA-1.0-10-0.1-6	**Difference**	3 days , 4 hours , 55 mins
Serial number	PA12011755	**Time Plot covers**	12-02-2013 21:38 - 13-02-2013 21:08



24 Hours 5
168 Hours 5

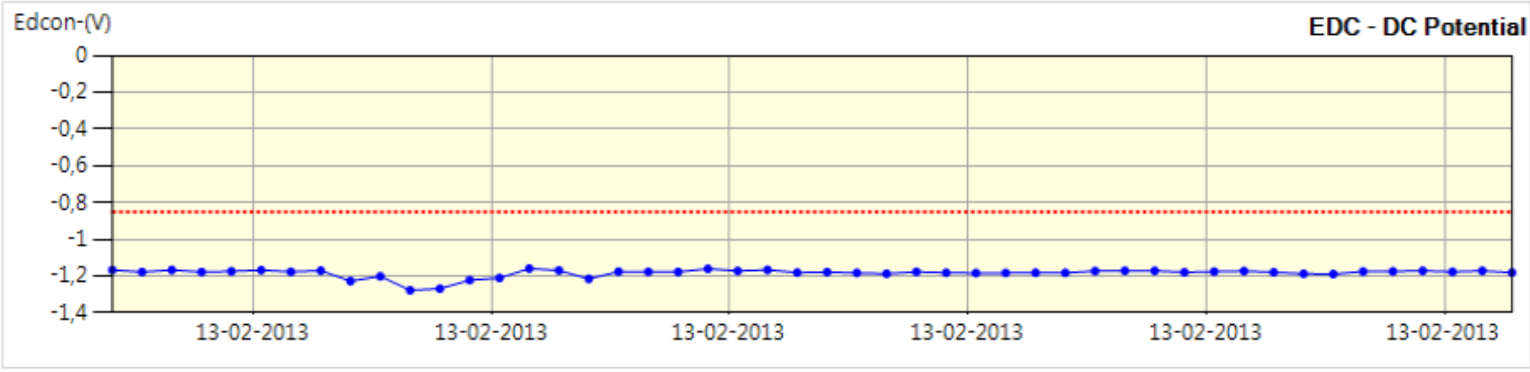
☑ Lines ☑ Dots

☑ Show VCorr-24

☐ Show VCorr-168

☑ Show 10 µm/y ref.

Calc

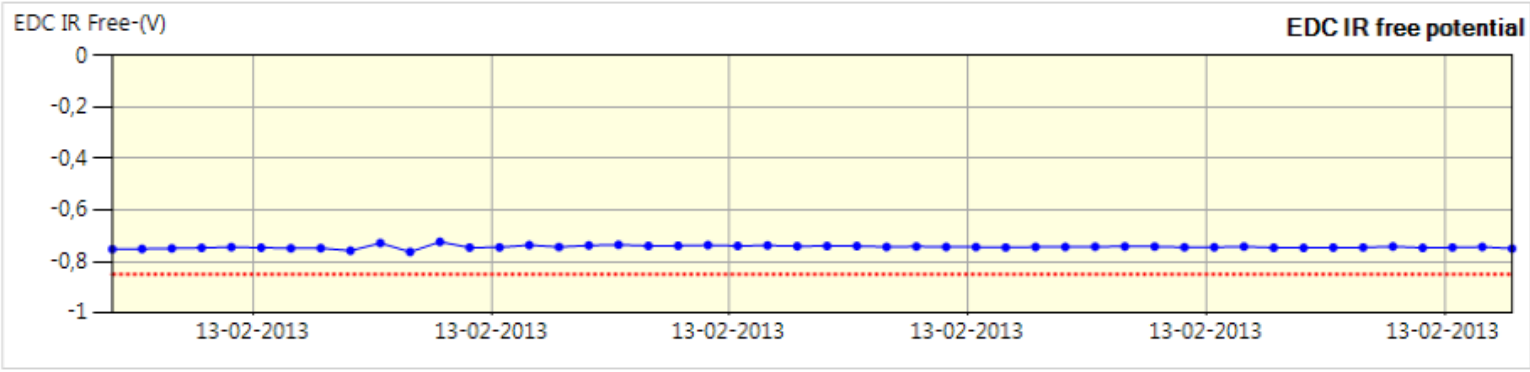


-1,279--1,146=-0,133

Vmax = -1,158 V
Vmin = -1,277 V
Vavg = -1,183 V

☑ Lines ☑ Dots

☑ Show -0,85 V ref.



-1,193--1,085=-0,108

Vmax = -0,724 V
Vmin = -0,763 V
Vavg = -0,743 V

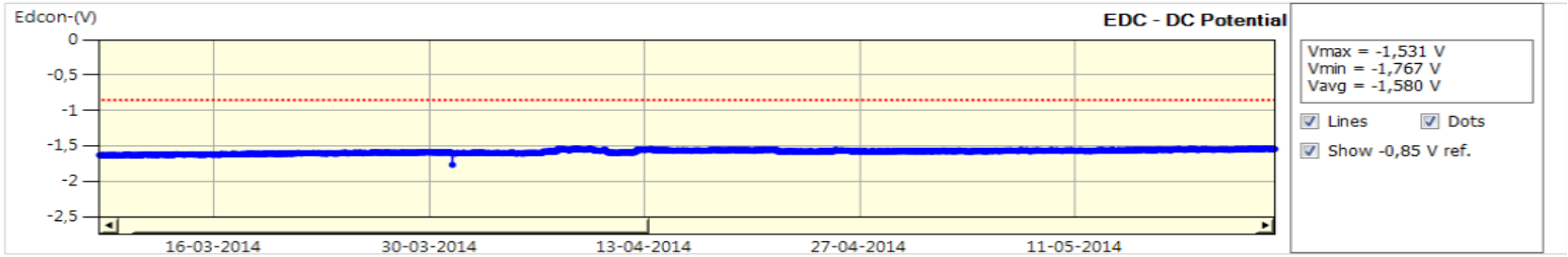
☑ Lines ☑ Dots

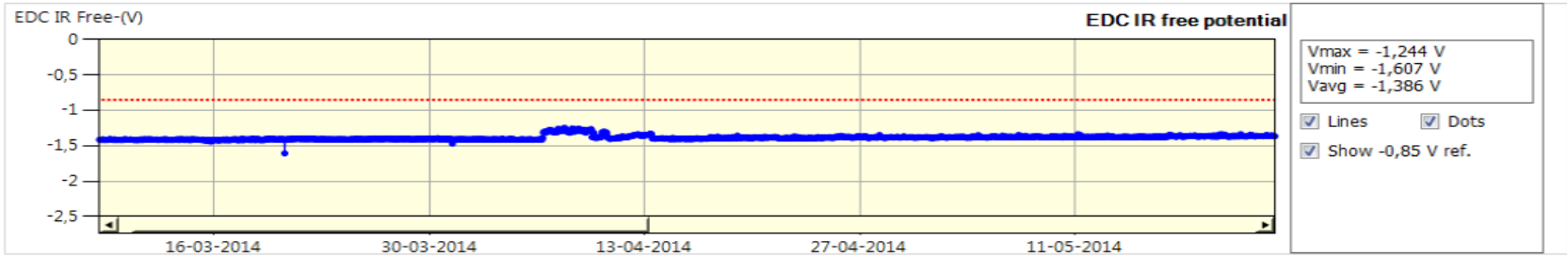
☑ Show -0,85 V ref.

Corrosion rate

Tag		**Current view**	08-03-2014 12:18 - 24-05-2014 01:00
Description		**Cursor(s)**	08-03-2014 12:18 - 24-05-2014 01:00
Probe type		**Difference**	76 days , 12 hours , 42 mins
Serial number		**Time Plot covers**	06-03-2014 10:02 - 22-08-2014 03:02

[redacted]

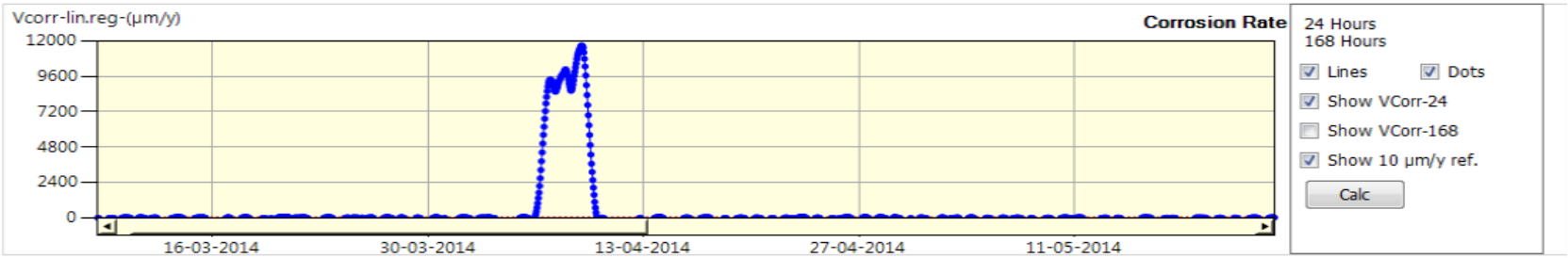


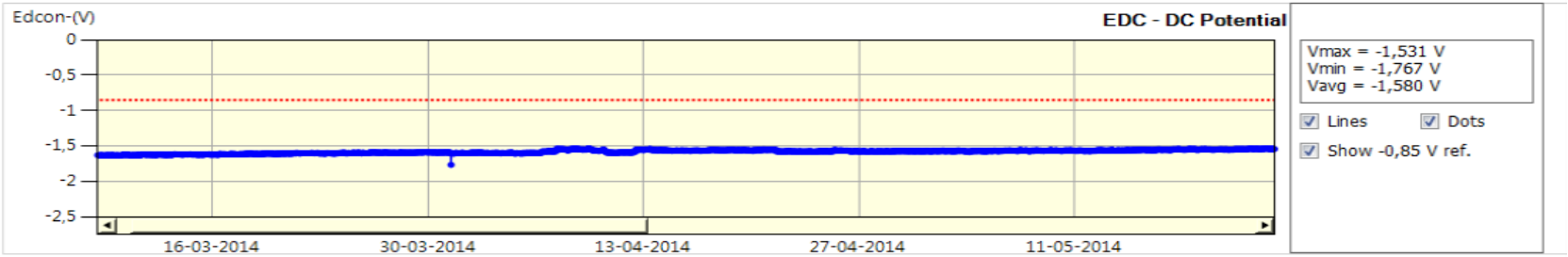


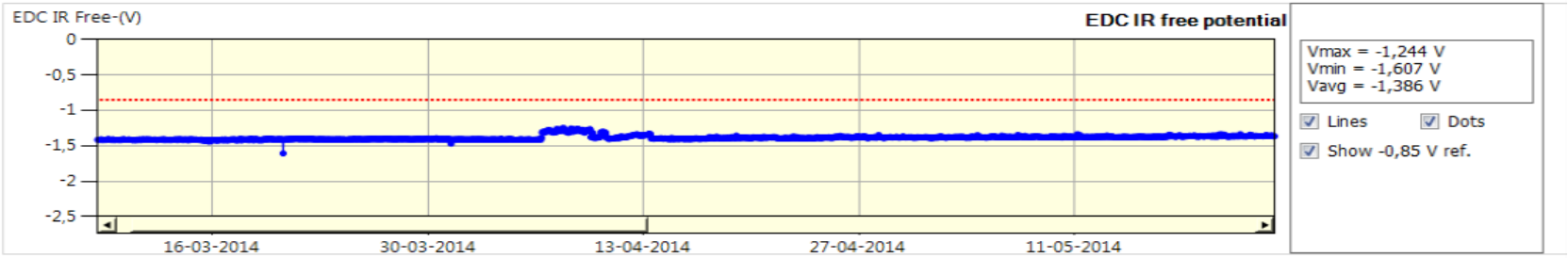
[redacted]

Corrosion rate

Tag		**Current view**	08-03-2014 12:18 - 24-05-2014 01:00
Description		**Cursor(s)**	08-03-2014 12:18 - 24-05-2014 01:00
Probe type		**Difference**	76 days , 12 hours , 42 mins
Serial number		**Time Plot covers**	06-03-2014 10:02 - 22-08-2014 03:02







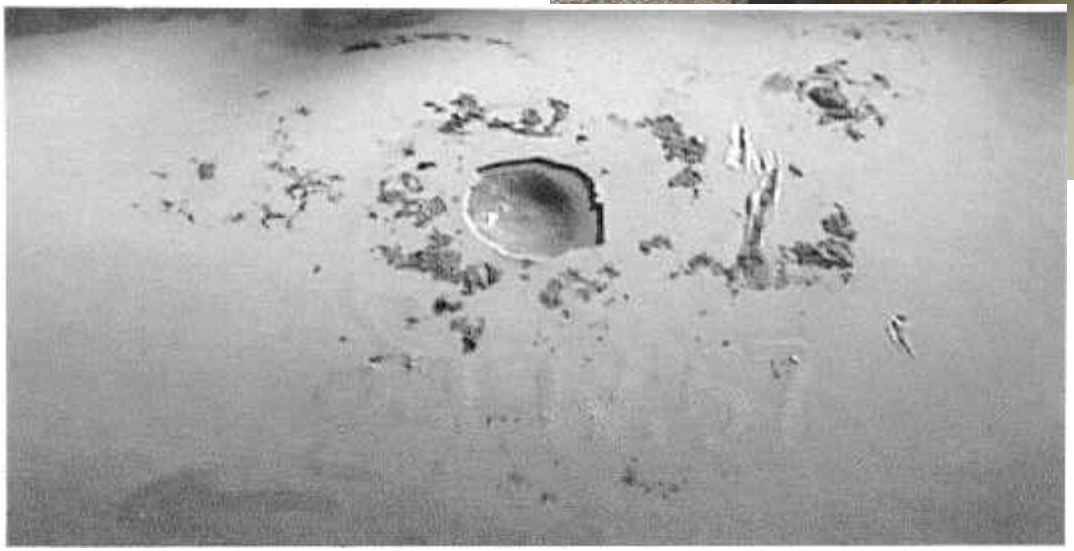
[redacted]

Corrosion rate

Tag		**Current view**	08-03-2014 12:18 - 24-05-2014 01:00
Description		**Cursor(s)**	08-03-2014 12:18 - 24-05-2014 01:00
Probe type		**Difference**	76 days , 12 hours , 42 mins
Serial number		**Time Plot covers**	06-03-2014 10:02 - 22-08-2014 03:02

AC corrosion Morphology

Corrosion rate easily up to10 mm/y (400 mpy) !



VICIOUS CIRCLE OF AC CORROSION

Induced AC

Small defect

Too much CP

Pre-requisites

Increased AC current

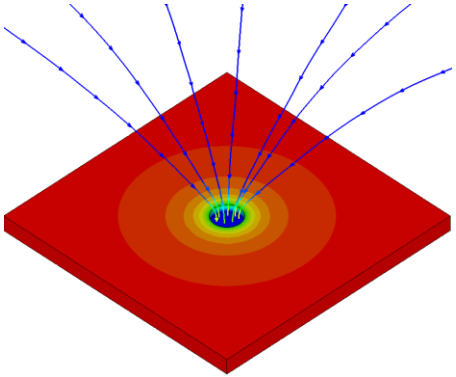
Depolarization

"thorough mitigation"

Excessive CP

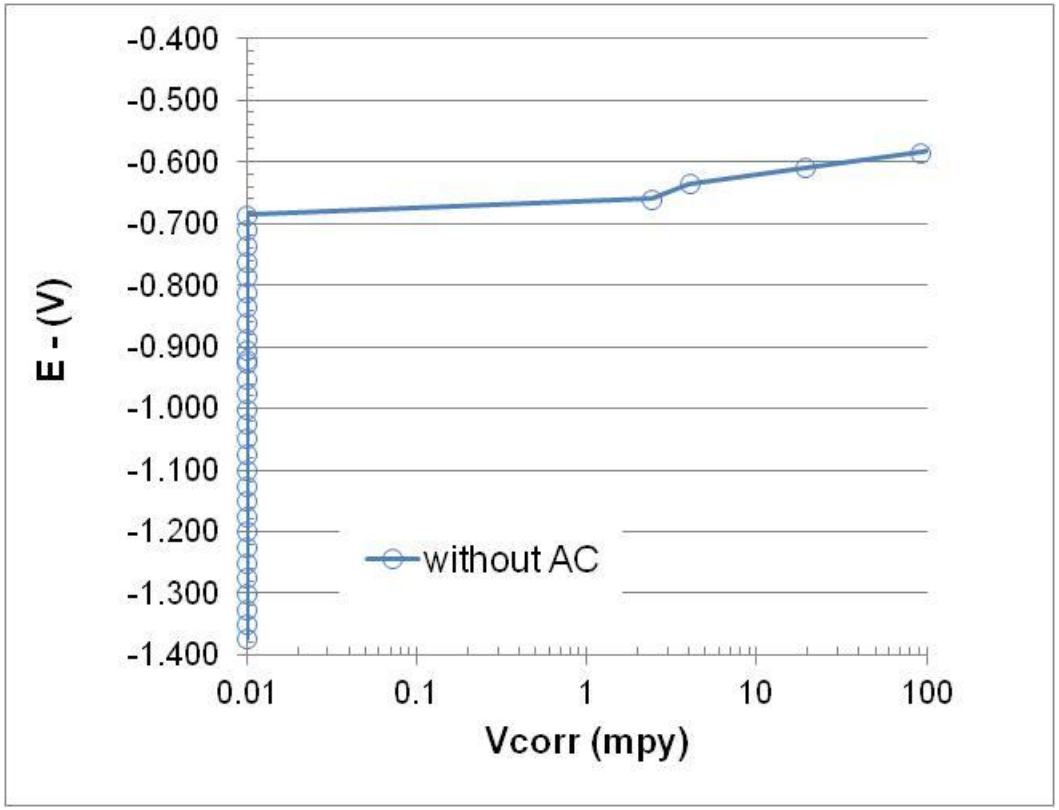
Ohm's law

Alkalinity



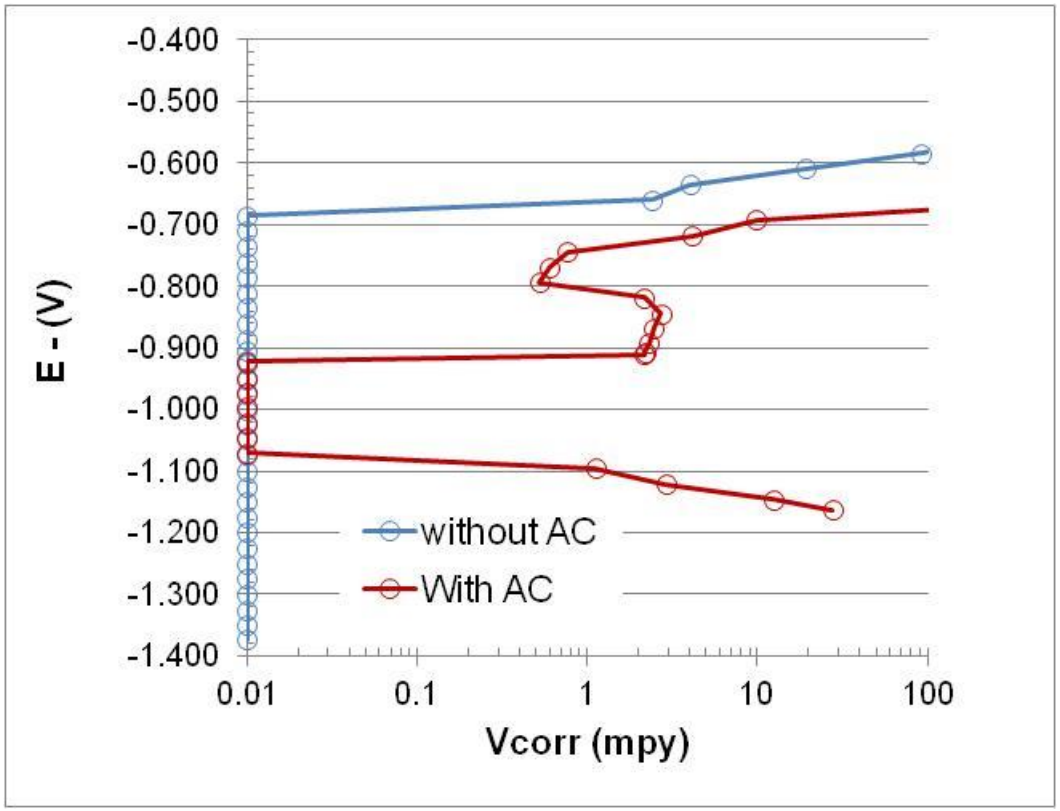
Reduced Spread resistance

AC CORROSION CHARACTERISTICS



CP can mitigate Corrosion

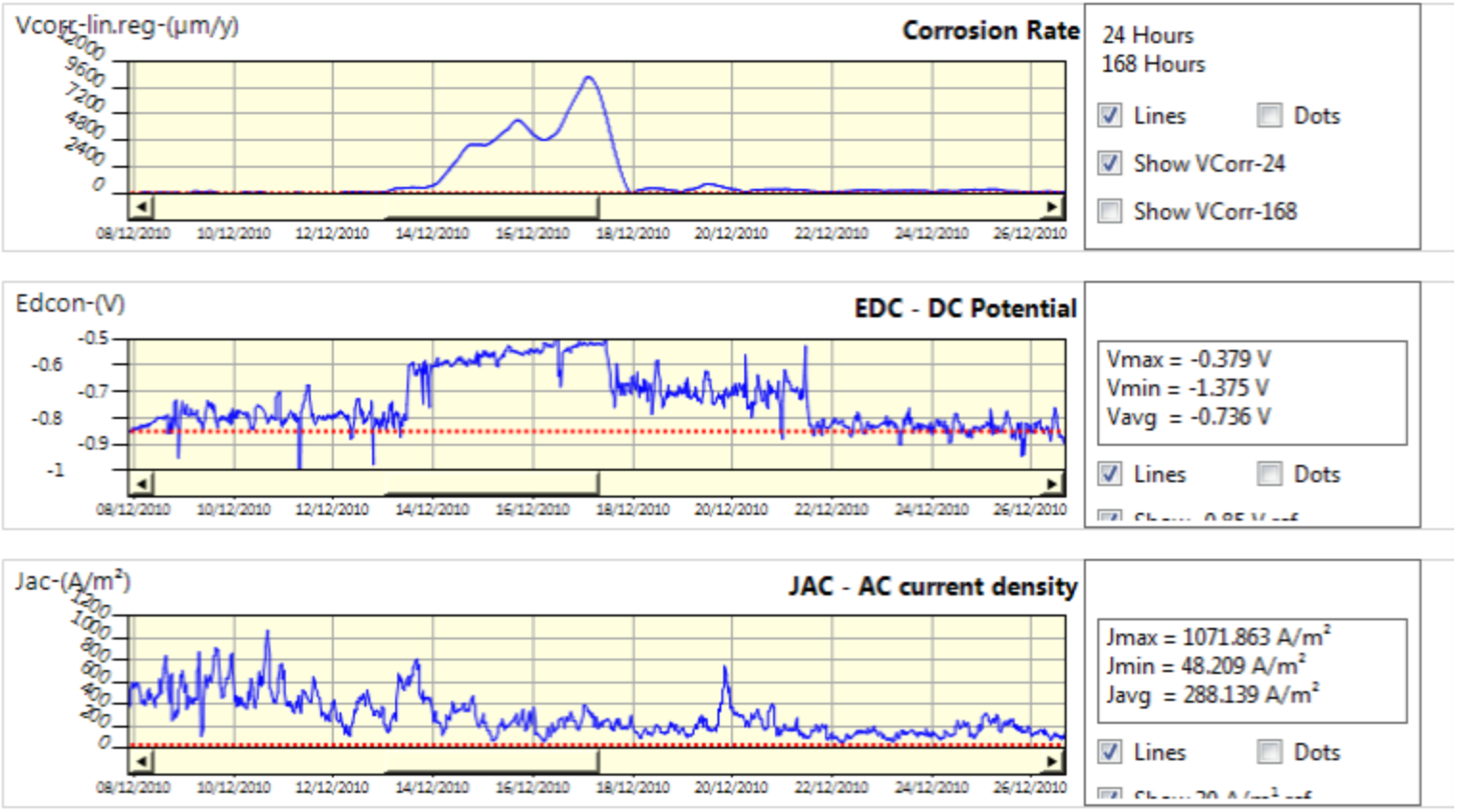
AC CORROSION CHARACTERISTICS



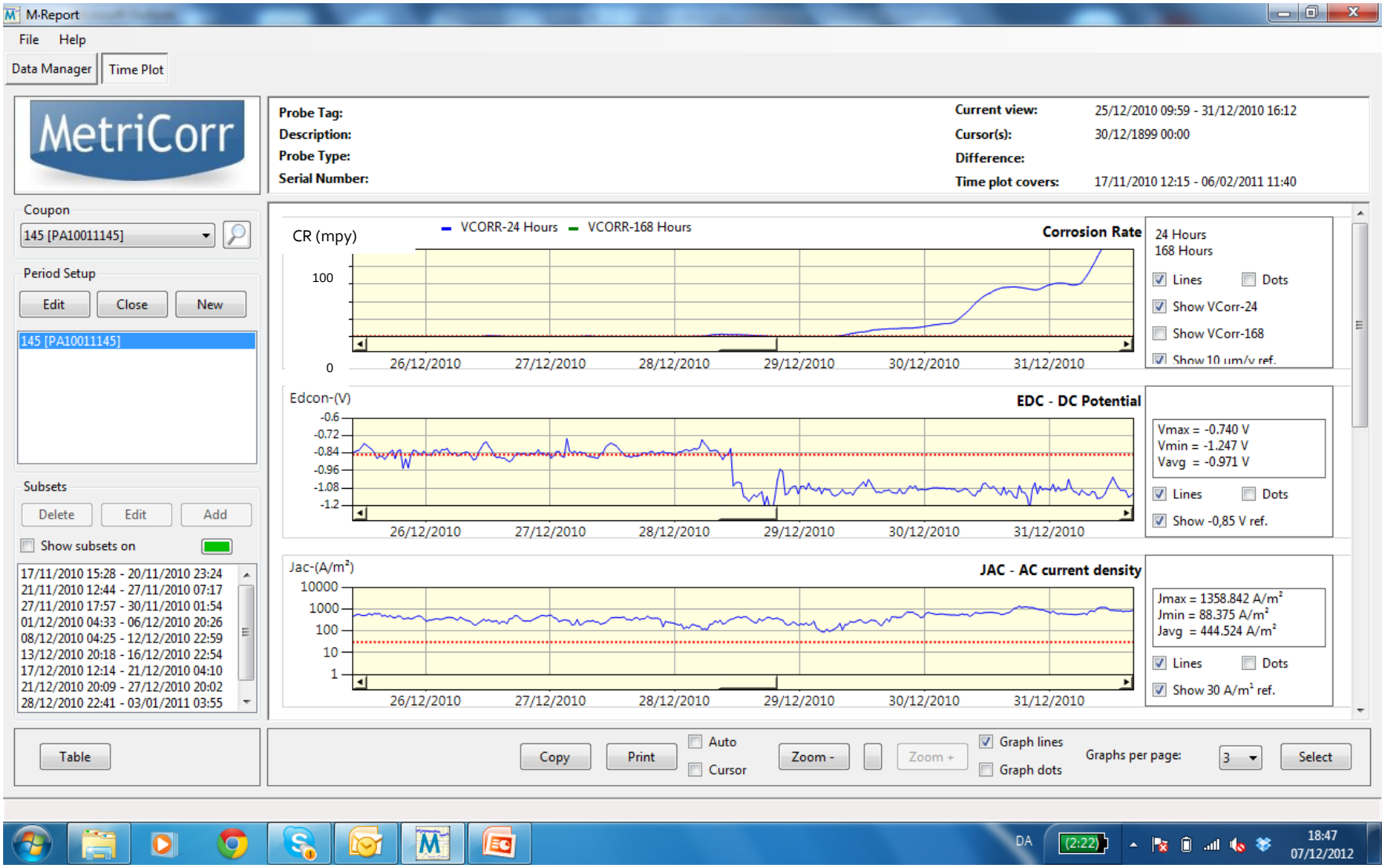
CP can mitigate AC Corrosion but…

AC Corrosion can be found to increase with increasing CP

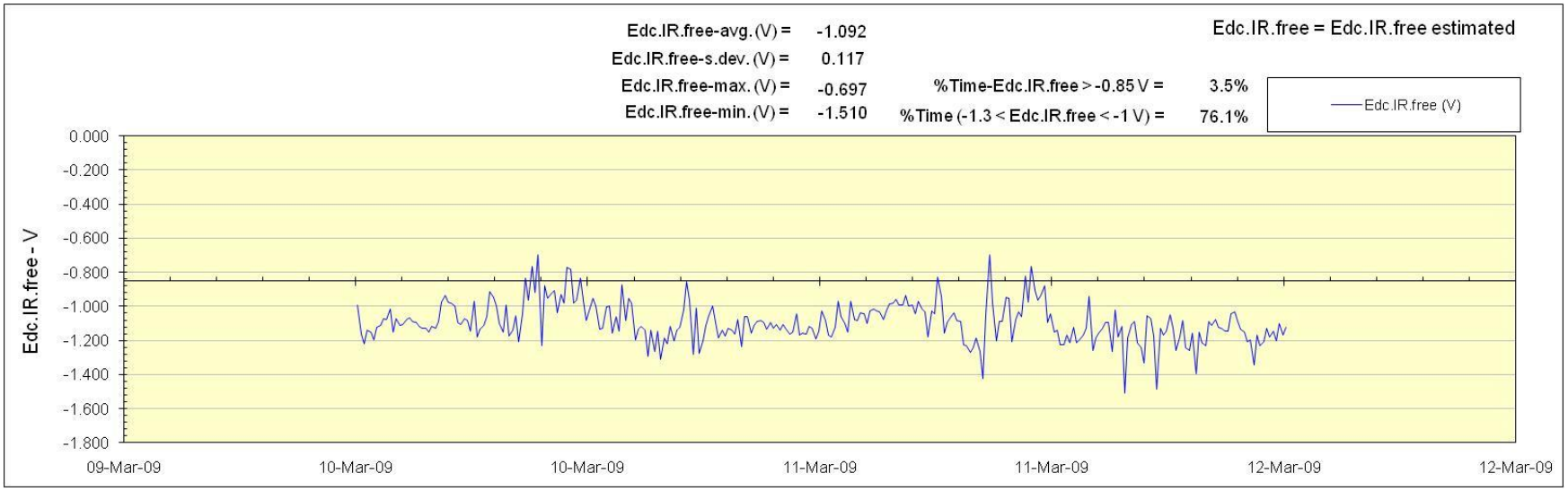
CP does protect

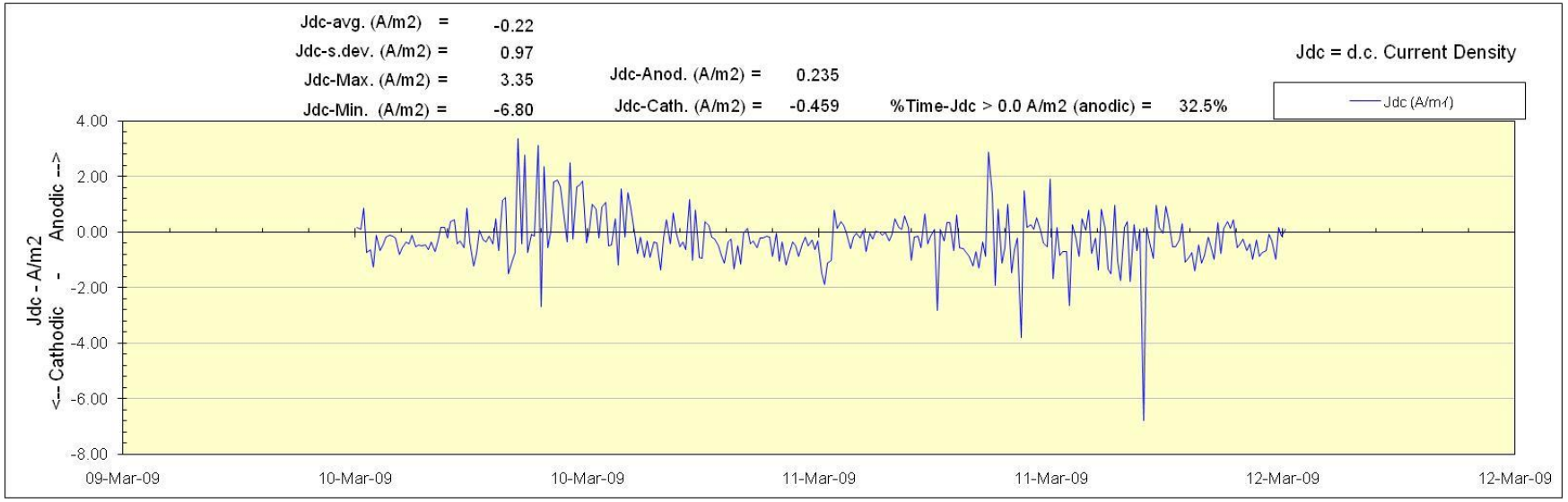


Too much CP gives corrosion

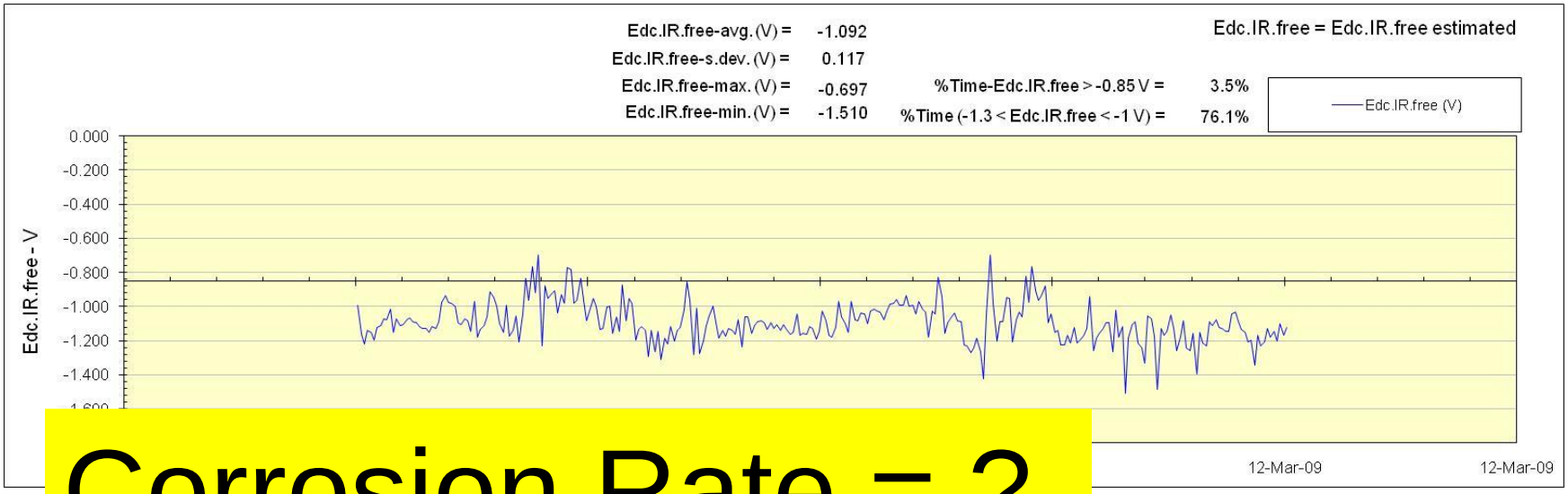


DC INTERFERENCE

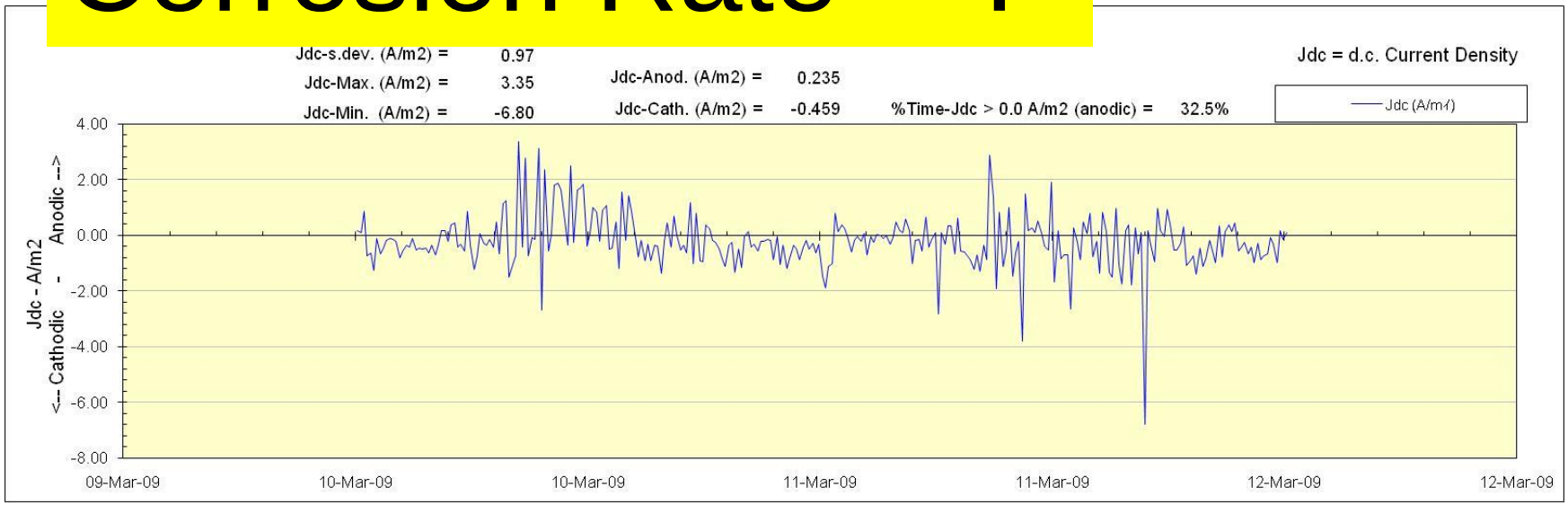




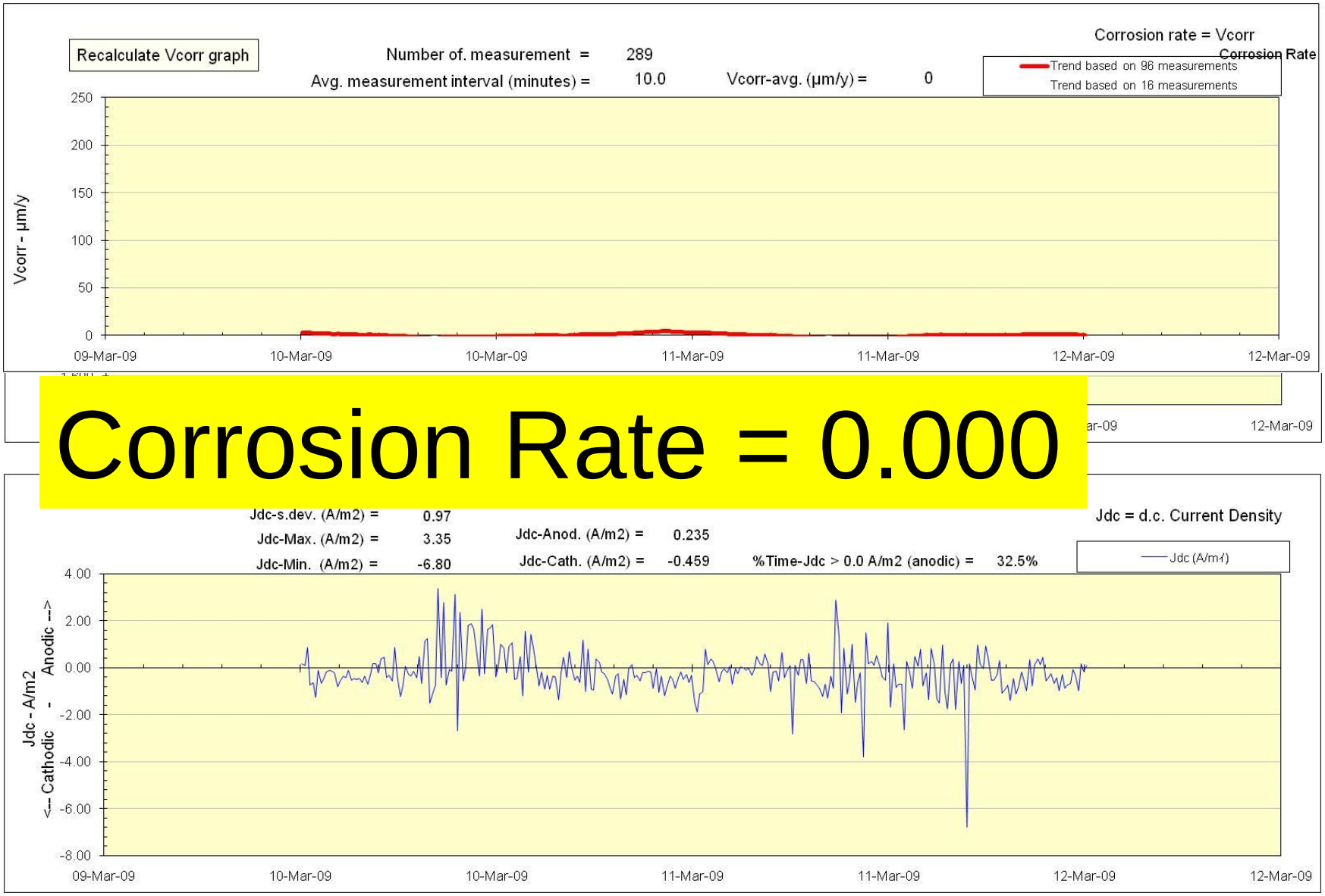
DC INTERFERENCE



Corrosion Rate = ?

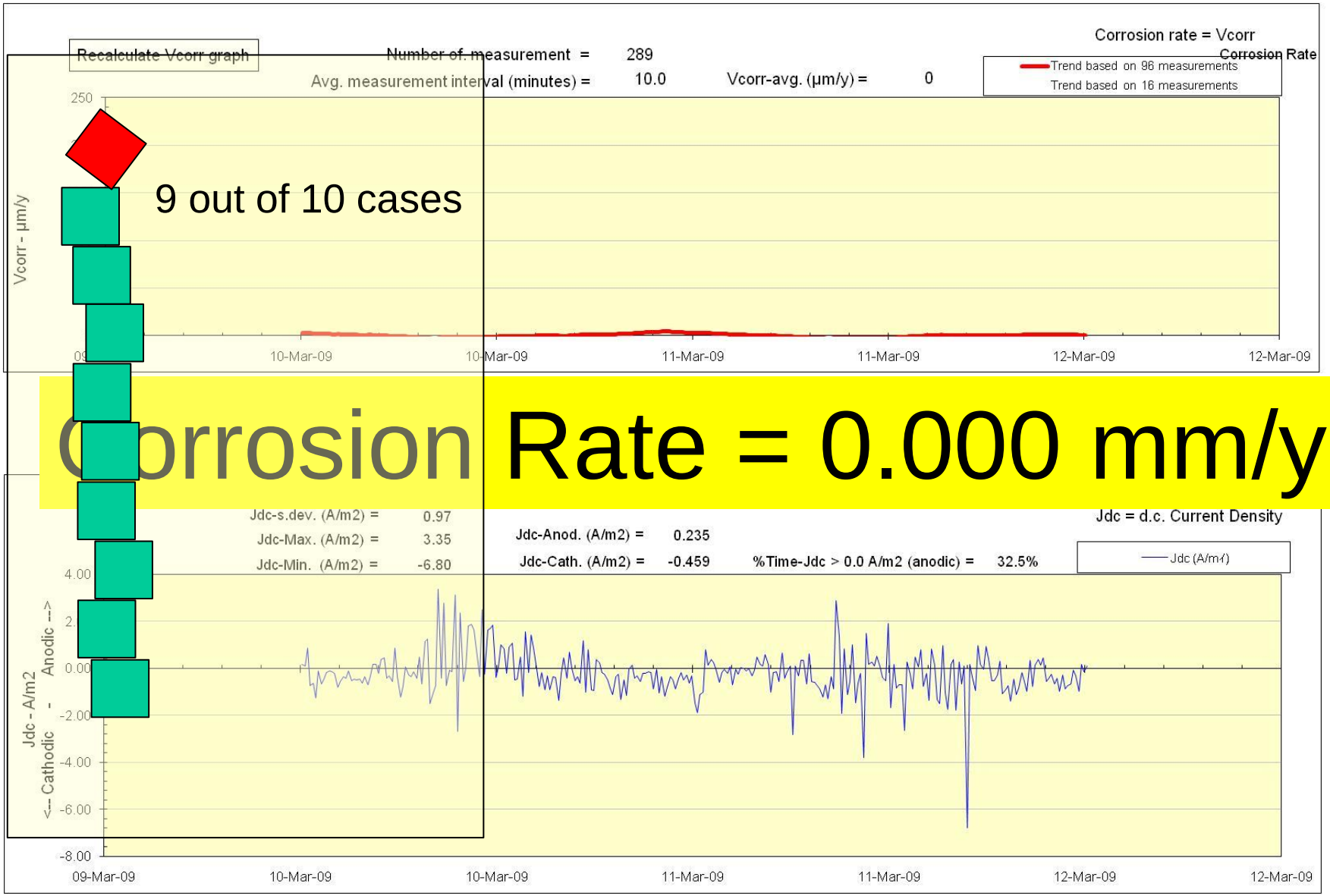


DC INTERFERENCE



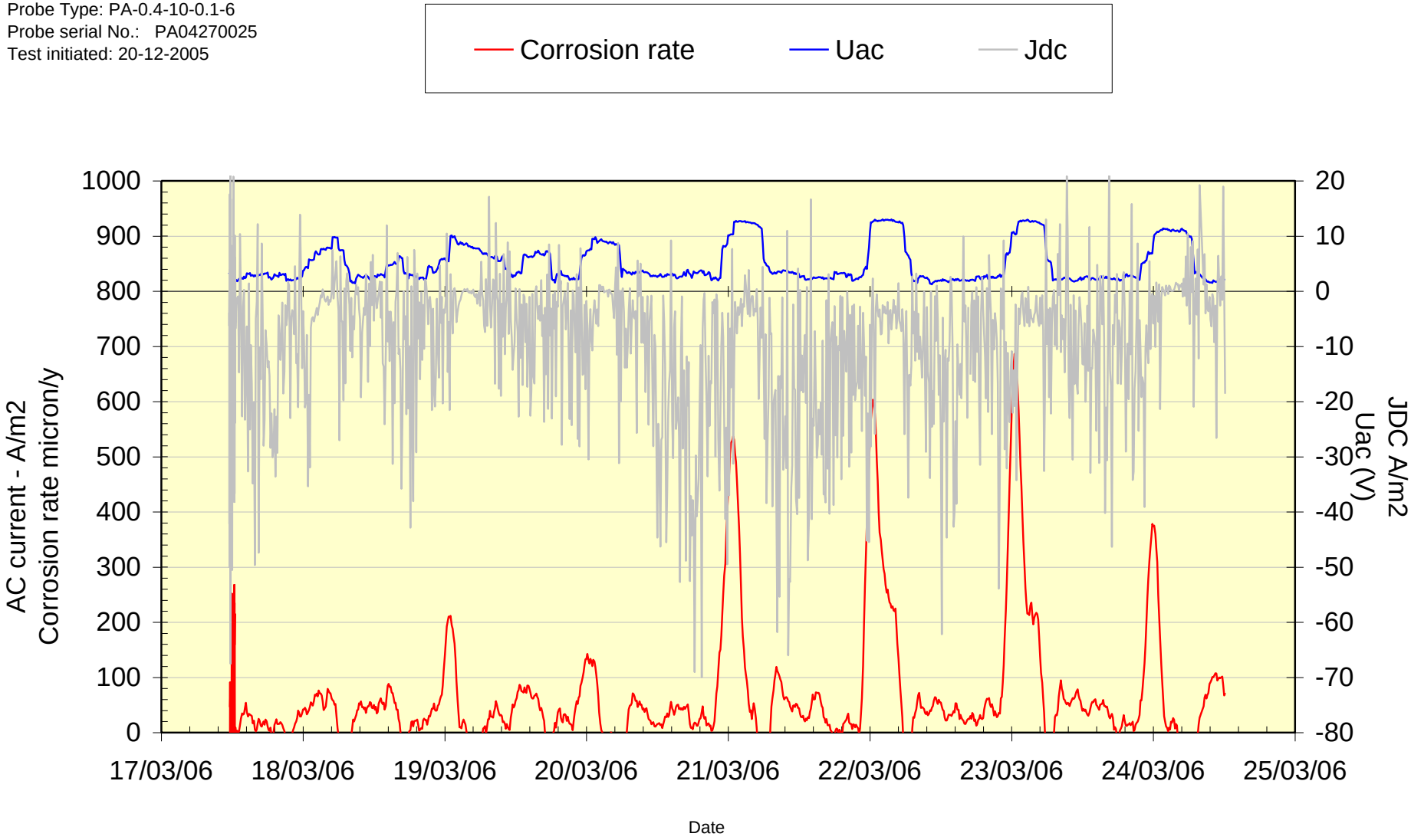
Corrosion Rate = 0.000

DC INTERFERENCE

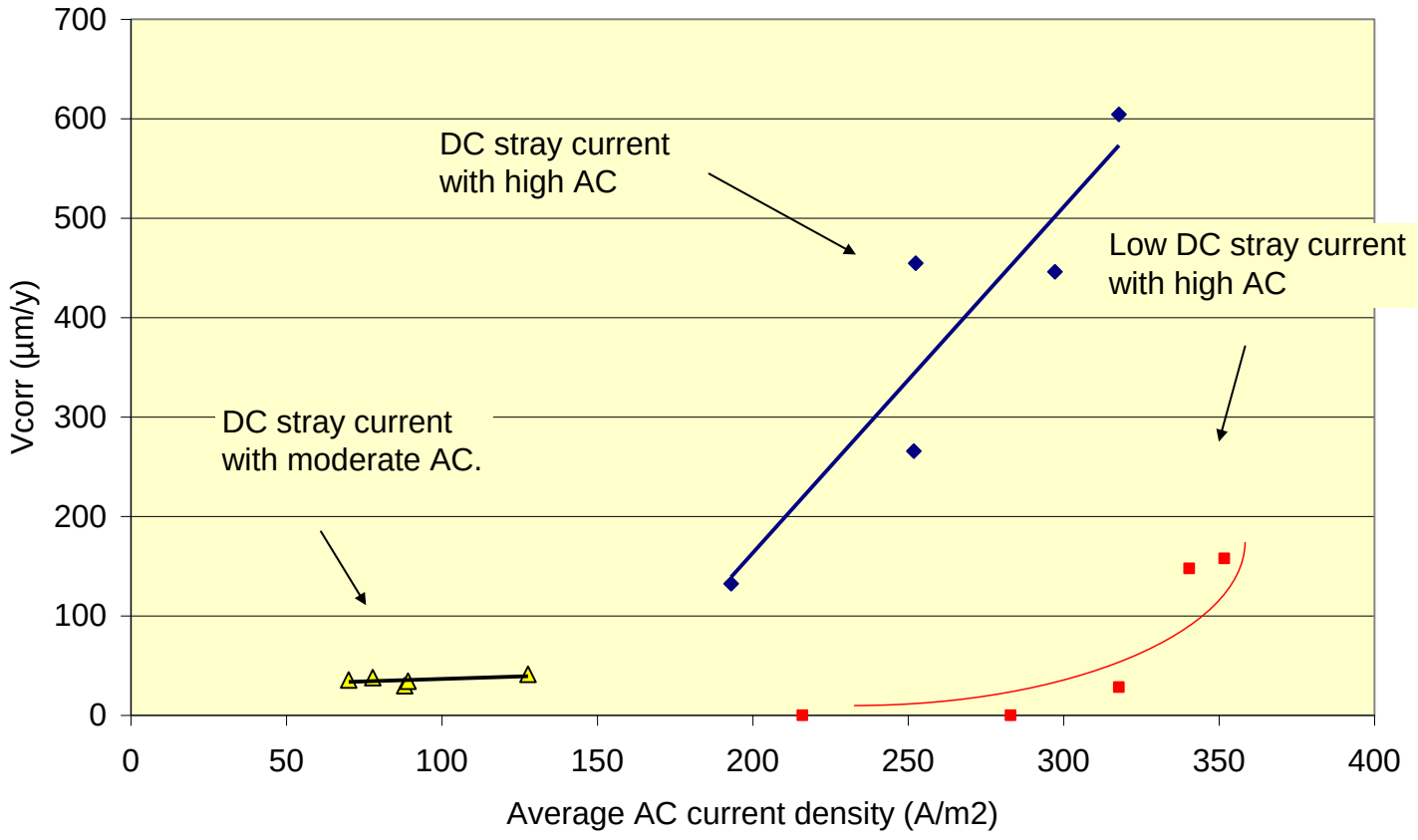


Mixed AC/DC Interference - MEASUREMENTS

Probe-Tag: 5500 K11A-1
Probe Type: PA-0.4-10-0.1-6
Probe serial No.: PA04270025
Test initiated: 20-12-2005

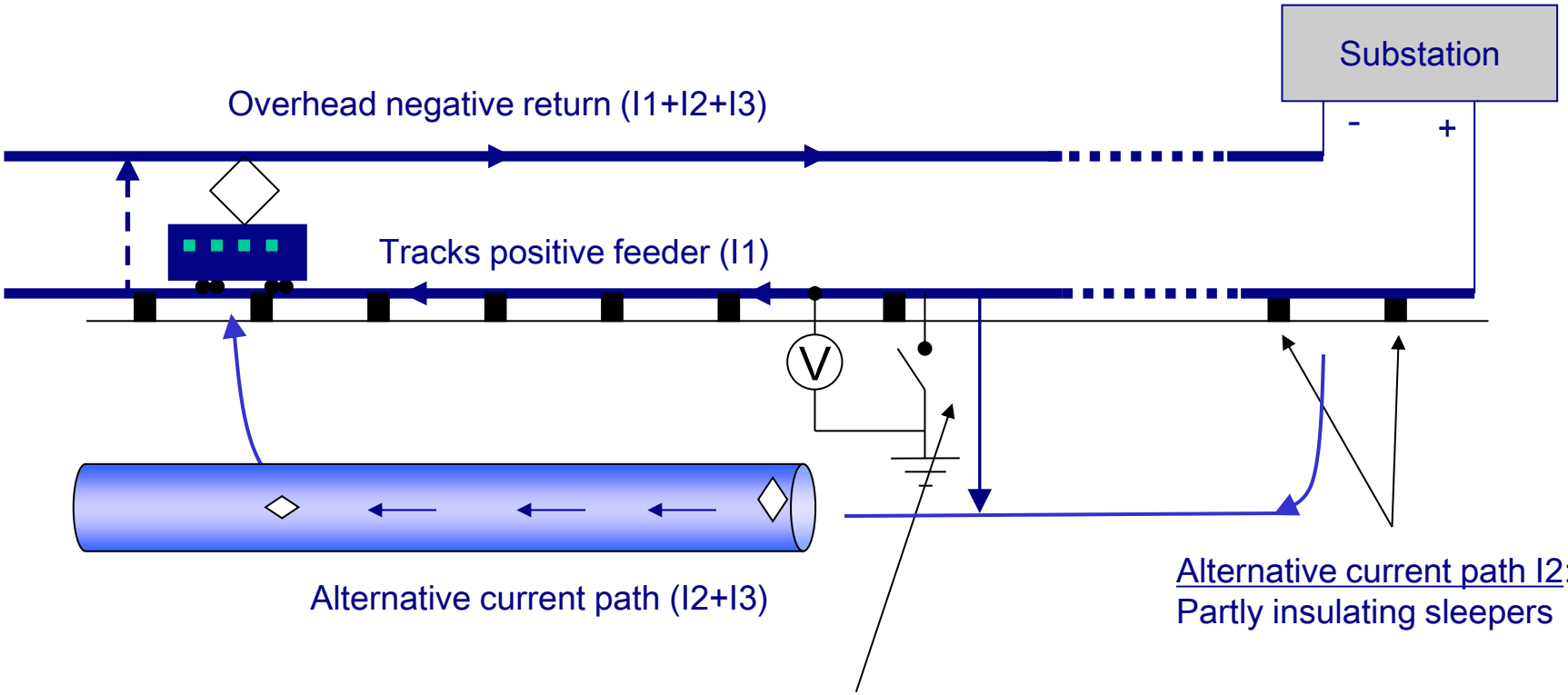


Mixed AC/DC Interference - ANALYSIS

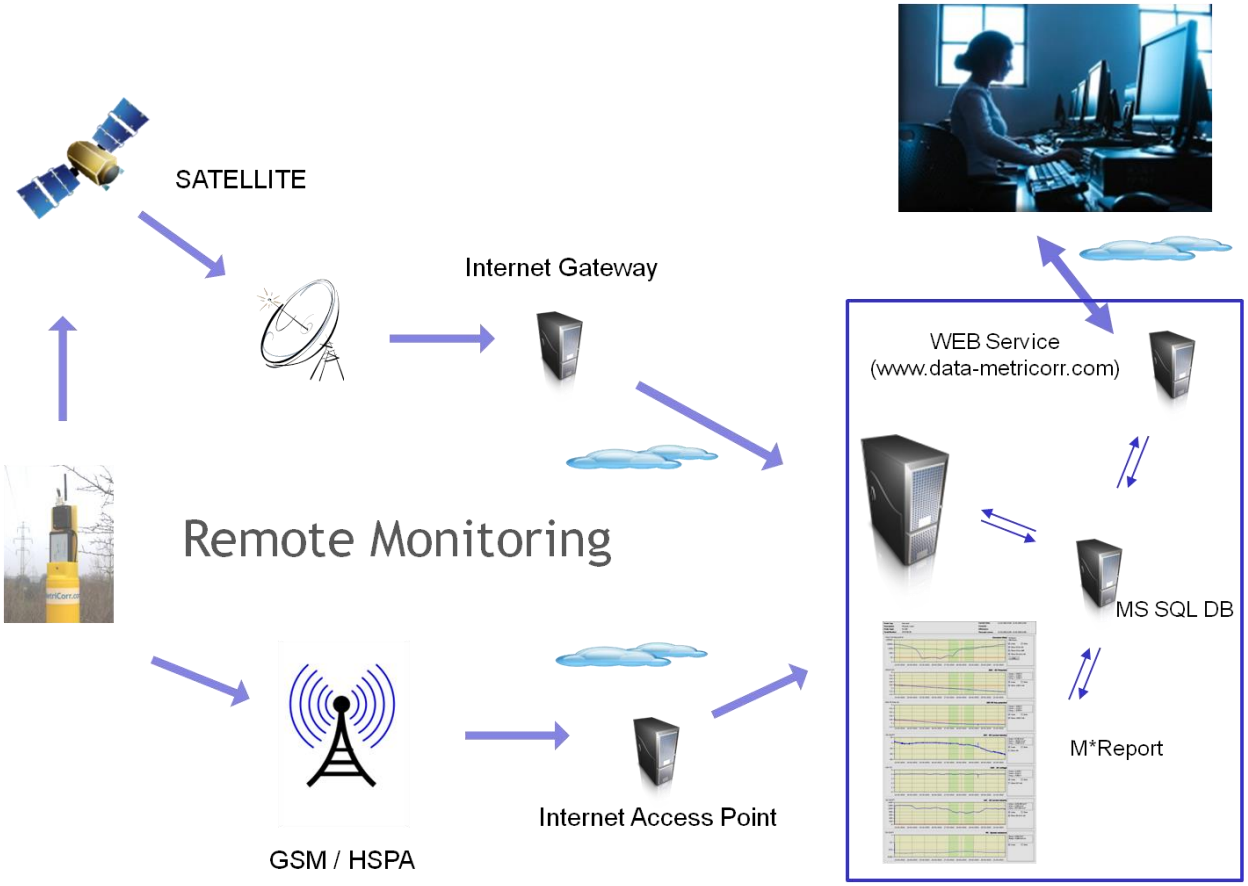


Mixed AC/DC Interference –

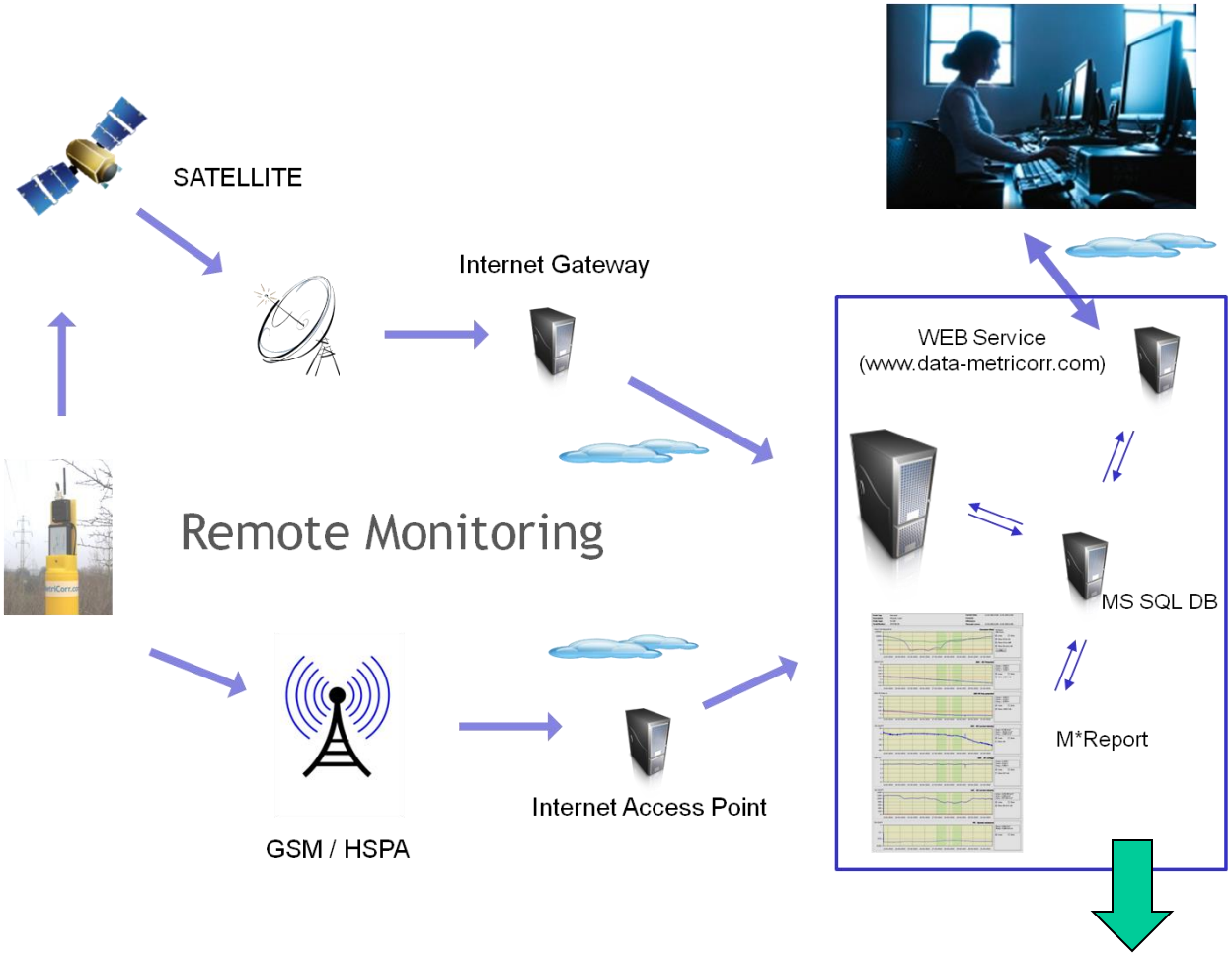
SIMPLE SOLUTION MAKING OPERATOR HAPPY



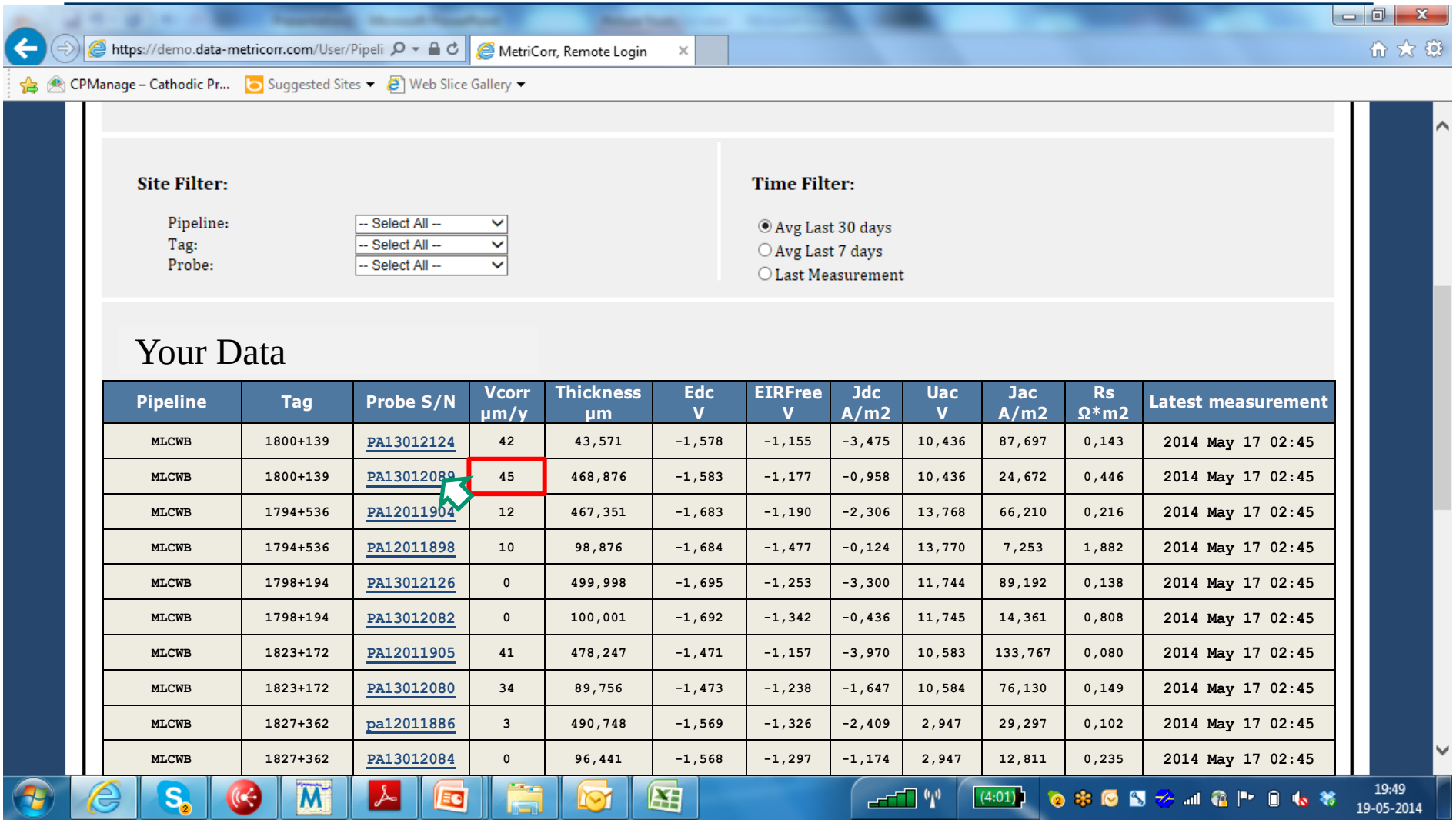
Remote Monitoring - Data flow and Presentation



Remote Monitoring - Data flow and Presentation



Automated processing and feedback to T/R
(Dynamic Cathodic Protection)


https://demo.data-metricorr.com/User/Pipeli
MetriCorr, Remote Login
CPManage – Cathodic Pr...
Suggested Sites
Web Slice Gallery
Site Filter:
Pipeline:
Tag:
Probe:
-- Select All --
-- Select All --
-- Select All --
Time Filter:
Avg Last 30 days
Avg Last 7 days
Last Measurement
Your Data
Pipeline
Tag
Probe S/N
Vcorr µm/y
Thickness µm
Edc V
EIRFree V
Jdc A/m2
Uac V
Jac A/m2
Rs Ω*m2
Latest measurement
MLCWB 1800+139 PA13012124 42 43,571 -1,578 -1,155 -3,475 10,436 87,697 0,143 2014 May 17 02:45
MLCWB 1800+139 PA13012089 45 468,876 -1,583 -1,177 -0,958 10,436 24,672 0,446 2014 May 17 02:45
MLCWB 1794+536 PA12011904 12 467,351 -1,683 -1,190 -2,306 13,768 66,210 0,216 2014 May 17 02:45
MLCWB 1794+536 PA12011898 10 98,876 -1,684 -1,477 -0,124 13,770 7,253 1,882 2014 May 17 02:45
MLCWB 1798+194 PA13012126 0 499,998 -1,695 -1,253 -3,300 11,744 89,192 0,138 2014 May 17 02:45
MLCWB 1798+194 PA13012082 0 100,001 -1,692 -1,342 -0,436 11,745 14,361 0,808 2014 May 17 02:45
MLCWB 1823+172 PA12011905 41 478,247 -1,471 -1,157 -3,970 10,583 133,767 0,080 2014 May 17 02:45
MLCWB 1823+172 PA13012080 34 89,756 -1,473 -1,238 -1,647 10,584 76,130 0,149 2014 May 17 02:45
MLCWB 1827+362 pa12011886 3 490,748 -1,569 -1,326 -2,409 2,947 29,297 0,102 2014 May 17 02:45
MLCWB 1827+362 PA13012084 0 96,441 -1,568 -1,297 -1,174 2,947 12,811 0,235 2014 May 17 02:45
(4:01)
19:49
19-05-2014

https://demo.data-metricorr.com/user_Graph

MetriCorr, Remote Login

CPManage – Cathodic Pr... Suggested Sites Web Slice Gallery

Data presentation:

Start date and time for Graphs:

Start: 06-03-2014 10 : 02

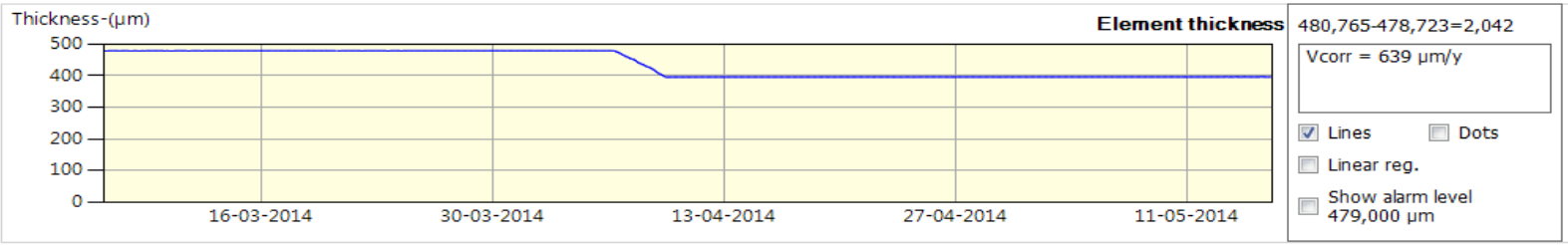
Stop date and time for Graphs:

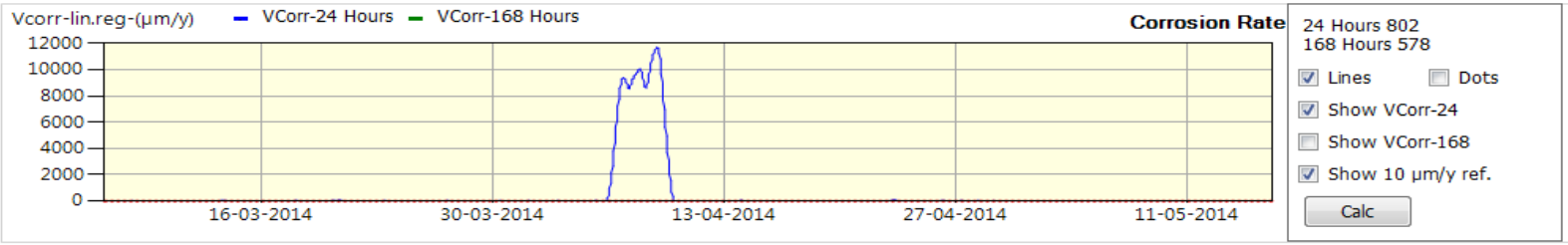
End: 16-05-2014 03 : 02

Update the below Graphs according to settings above

Graphs

Alarms

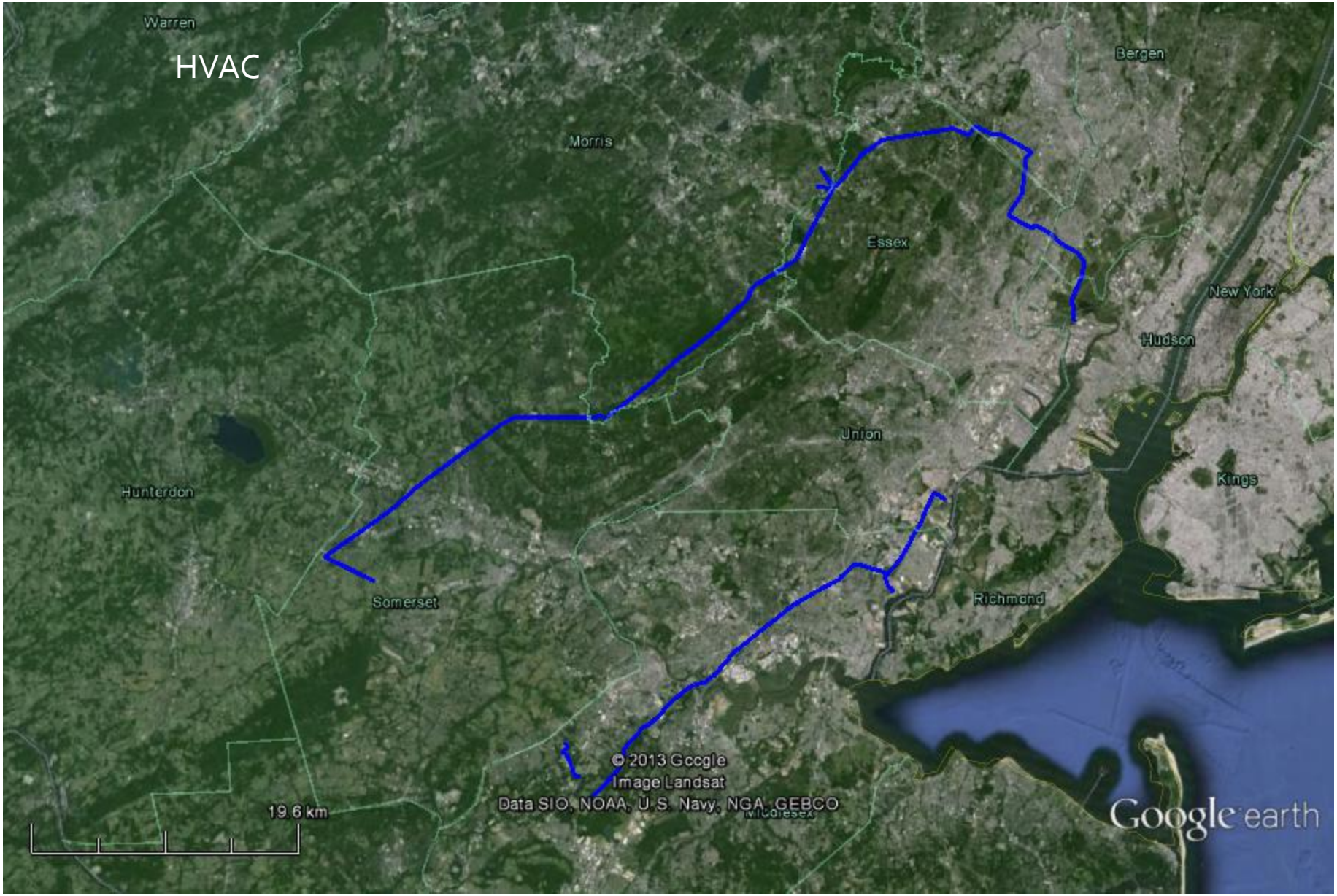




(3:26)

20:24
19-05-2014


PIPELINE
Warren
Morris
Bergen
Essex
New York
Hudson
Union
Kings
Hunterdon
Somerset
Richmond
© 2013 Google
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
19.6 km
Google earth


HVAC
Warren
Morris
Bergen
Essex
New York
Hudson
Union
Kings
Hunterdon
Somerset
Richmond
Middlesex
© 2013 Google
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
19.6 km
Google earth


AC Mitigation
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Morris
Bergen
Essex
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Hudson
Union
Kings
Hunterdon
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Richmond
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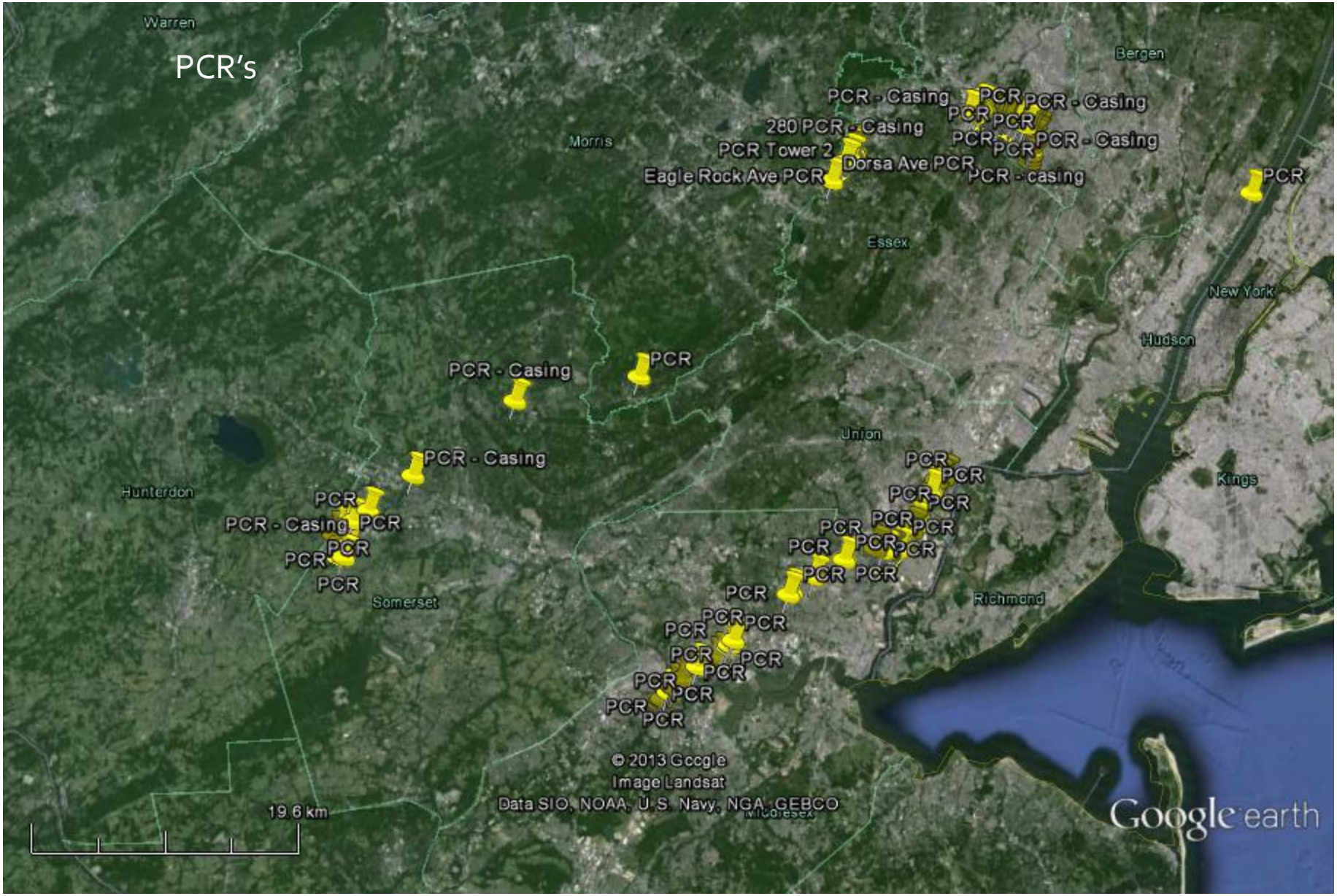
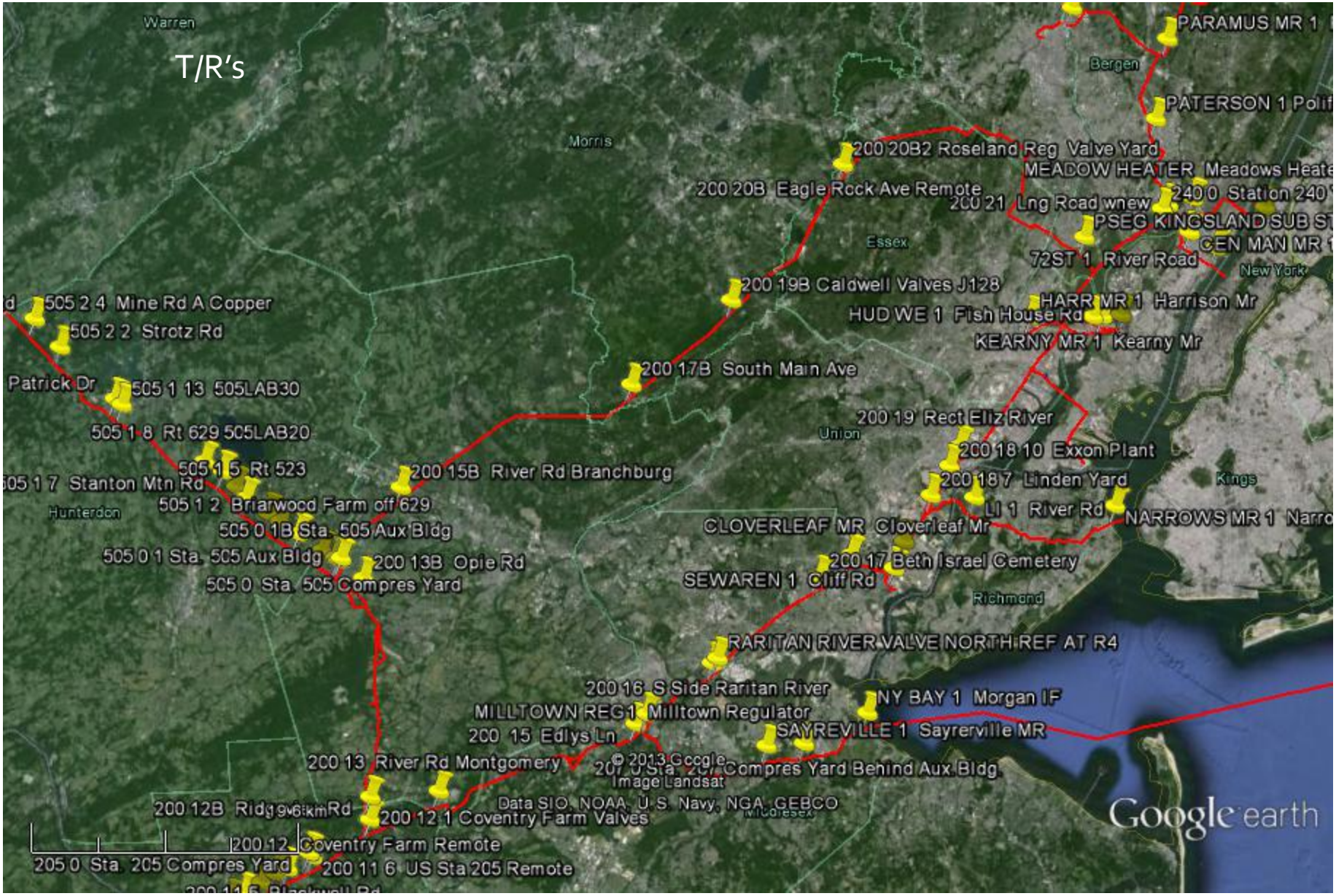
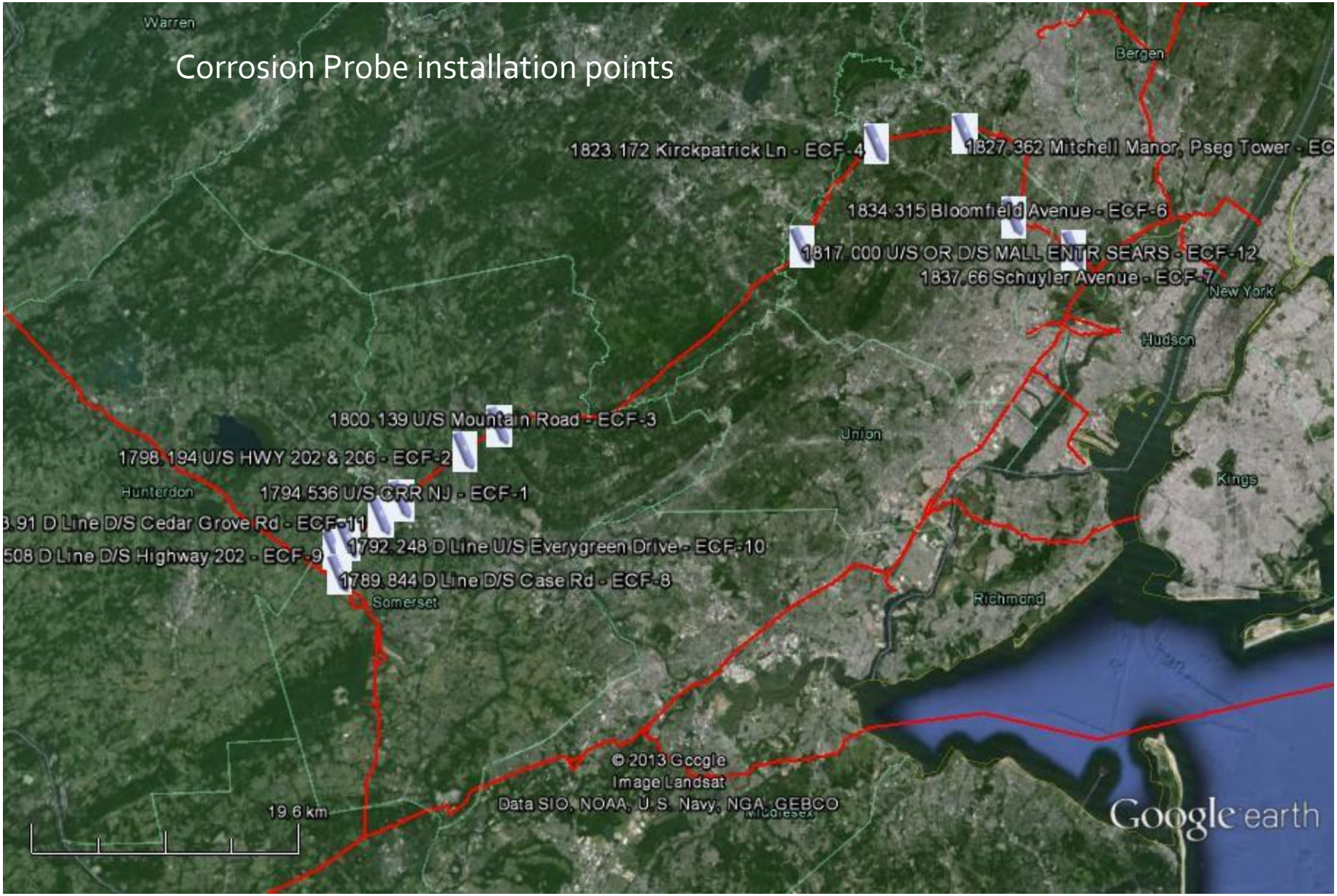
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
19.6 km
Google earth


PCR's
Warren
Morris
Bergen
Essex
Hudson
New York
Union
Kings
Richmond
Hunterdon
Somerset
PCR - Casing
280 PCR - Casing
PCR Tower 2
Eagle Rock Ave PCR
Dorsa Ave PCR
PCR - casing
PCR
© 2013 Google
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
19.6 km
Google earth


T/R's
Warren
Morris
Essex
Bergen
Hunterdon
Union
Kings
Richmond
New York
PARAMUS MR 1
PATERSON 1 Polif
200 20B2 Roseland Reg Valve Yard
MEADOW HEATER Meadows Heate
200 20B Eagle Rock Ave Remote
200 21 Lng Road wnew
2400 Station 240
PSEG KINGSLAND SUB ST
CEN MAN MR
72ST 1 River Road
200 19B Caldwell Valves J128
HARR MR 1 Harrison Mr
HUD WE 1 Fish House Rd
KEARNY MR 1 Kearny Mr
505 2 4 Mine Rd A Copper
505 2 2 Strotz Rd
Patrick Dr
505 1 13 505LAB30
200 17B South Main Ave
505 1 8 Rt 629 505LAB20
200 19 Rect Eliz River
200 18 10 Exxon Plant
505 1 5 Rt 523
200 15B River Rd Branchburg
505 1 7 Stanton Mtn Rd
200 18 7 Linden Yard
LI 1 River Rd
505 1 2 Briarwood Farm off 629
CLOVERLEAF MR Cloverleaf Mr
NARROWS MR 1 Narro
505 0 1B Sta 505 Aux Bldg
505 0 1 Sta 505 Aux Bldg
200 13B Opie Rd
200 17 Beth Israel Cemetery
505 0 Sta 505 Compres Yard
SEWAREN 1 Cliff Rd
RARITAN RIVER VALVE NORTH REF AT R4
200 16 S Side Raritan River
NY BAY 1 Morgan IF
MILLTOWN REG 1 Milltown Regulator
200 15 Edlys Ln
SAYREVILLE 1 Sayrerville MR
200 13 River Rd Montgomery
© 2013 Google
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
200 12B Ridg Rd
200 12 1 Coventry Farm Valves
200 12 Coventry Farm Remote
205 0 Sta 205 Compres Yard
200 11 6 US Sta 205 Remote
Google earth


Corrosion Probe installation points
Warren
Bergen
1823.172 Kirckpatrick Ln - ECF-4
1827.362 Mitchell Manor, Pseg Tower - EC
1834.315 Bloomfield Avenue - ECF-6
1817.000 U/S OR D/S MALL ENTR SEARS - ECF-12
1837.66 Schuyler Avenue - ECF-7
New York
Hudson
1800.139 U/S Mountain Road - ECF-3
Union
1798.194 U/S HWY 202 & 206 - ECF-2
Hunterdon
1794.536 U/S CRR NJ - ECF-1
Kings
.91 D Line D/S Cedar Grove Rd - ECF-11
508 D Line D/S Highway 202 - ECF-9
1792.248 D Line U/S Everygreen Drive - ECF-10
1789.844 D Line D/S Case Rd - ECF-8
Somerset
Richmond
© 2013 Google
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
19.6 km
Google earth

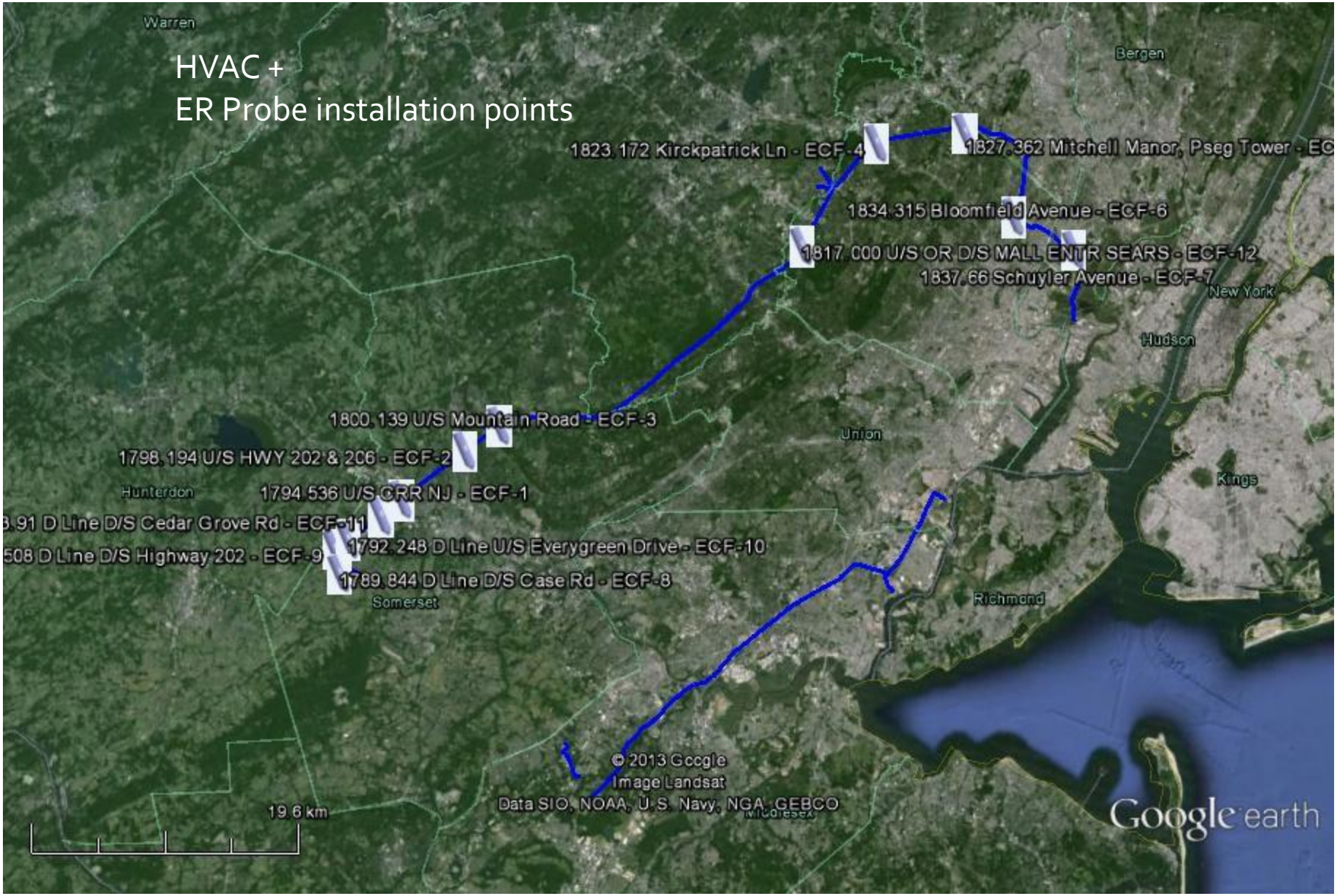

HVAC +
ER Probe installation points
1823.172 Kirckpatrick Ln - ECF-4
1827.362 Mitchell Manor, Pseg Tower - EC
1834.315 Bloomfield Avenue - ECF-6
1817.000 U/S OR D/S MALL ENTR SEARS - ECF-12
1837.66 Schuyler Avenue - ECF-7
1800.139 U/S Mountain Road - ECF-3
1798.194 U/S HWY 202 & 206 - ECF-2
1794.536 U/S CRR NJ - ECF-1
1792.248 D Line U/S Everygreen Drive - ECF-10
1789.844 D Line D/S Case Rd - ECF-8
Warren
Bergen
New York
Hudson
Union
Kings
Richmond
Hunterdon
Somerset
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Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
19.6 km
Google earth

Points & Postulates

- Corrosion rate probes can be applied with success for verification of cathodic protection effectiveness in problematic areas (AC/DC interference, complex piping systems, difficulties with achieving CP criterion etc.)

- If combined with simultaneous electrical fingerprint measurements (current densities, potentials, spread resistance), the corrosion rate probes can be a very powerful tool in establishing cause of corrosion and verify corrective actions.

- The concept is readily made part of a Remote Monitoring System through which corrosion rate measurements simplifies the monitoring process and reveals risk areas where potentials do not apply.

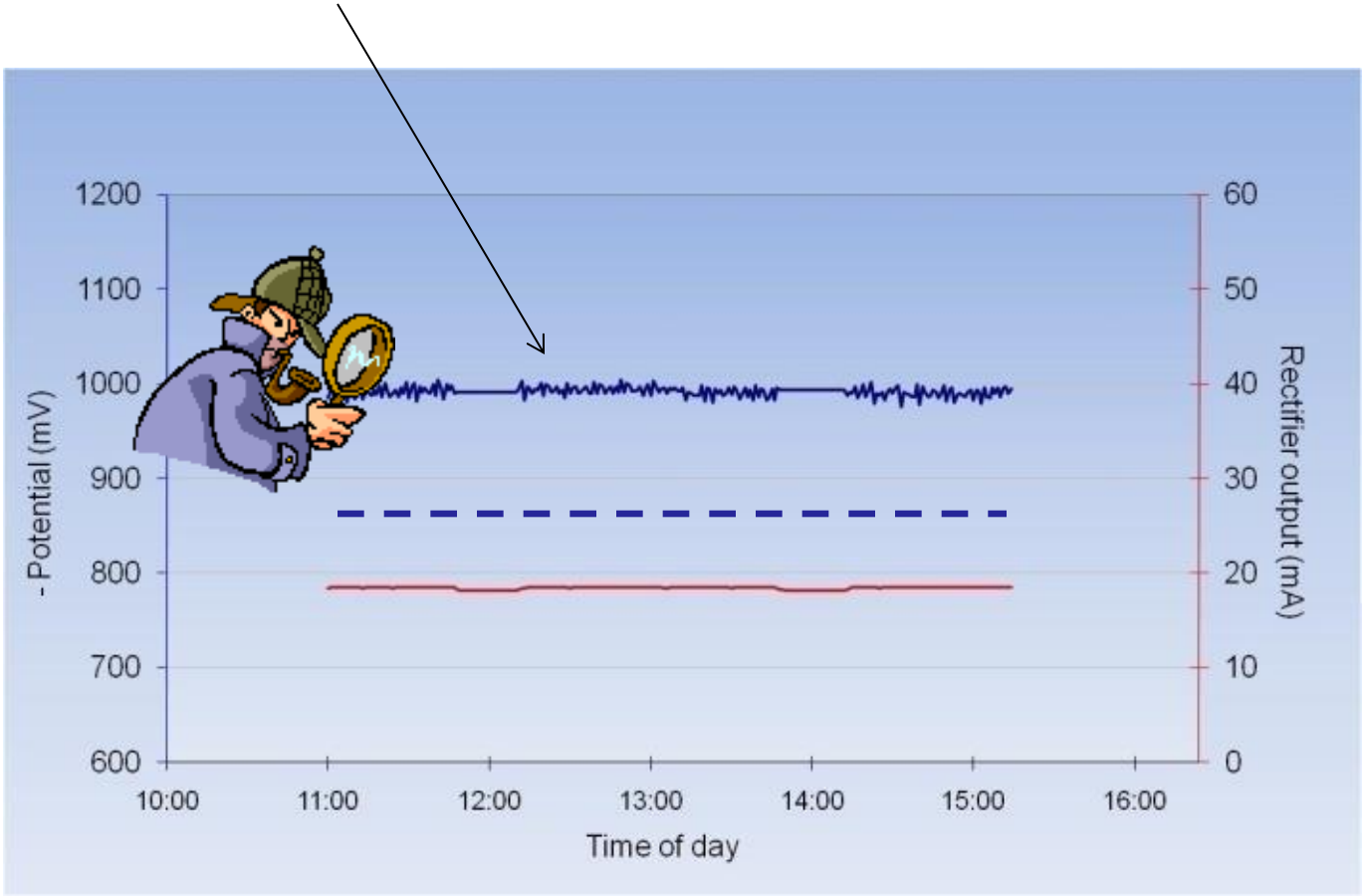
Functional Components Inspection Intervals

Component	Without Remote Monitoring	With Remote Monitoring
Transformer Rectifier	3 months	3 years
Galvanic Anode	3 months	3 years
Bonds	3 months	3 years
AC discharge devices	12 months	3 years

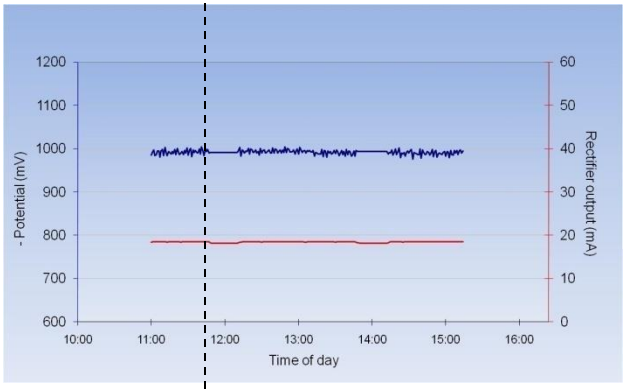
Saving money on maintenance budget!

Cathodic Protection Potential

Why keep starring when nothing happens?



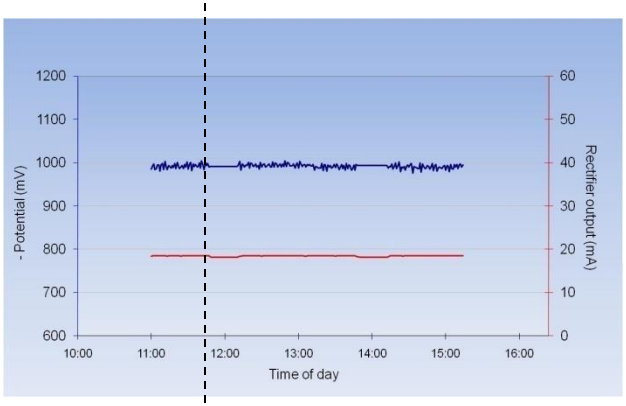
Coating Integrity Monitor



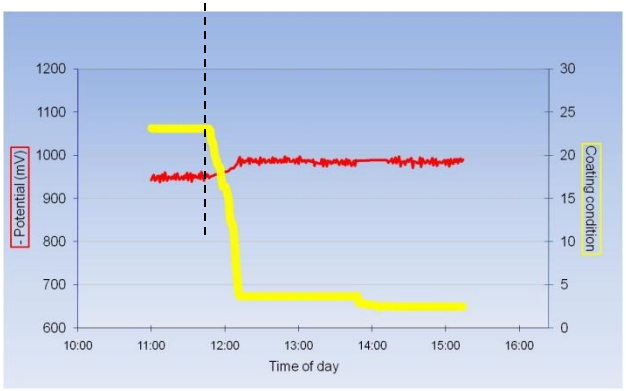
Plot showing conventional cathodic protection monitoring data throughout a detrimental third party damage.

Who would have guessed that this day around noon a highway crash barrier was hammered right down in the head of a pipeline leaving a large crack and a dent?

Coating Integrity Monitor



Plot showing conventional cathodic protection monitoring data throughout a detrimental third party damage.



Plot showing the MetriCorr Pipeline Integrity Monitor data throughout a detrimental third party damage.

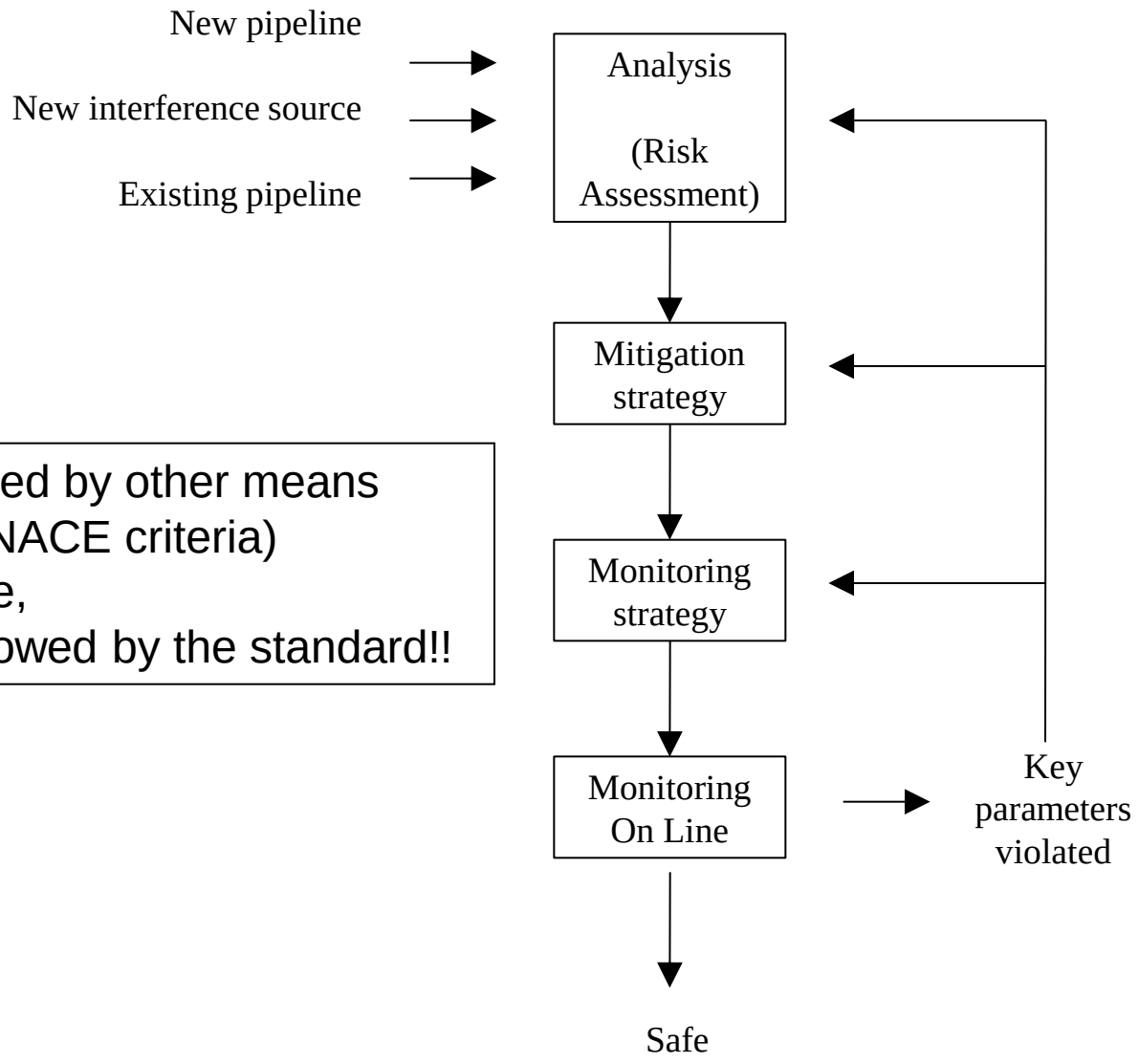
Who would have guessed that this day around noon a highway crash barrier was hammered right down in the head of a pipeline leaving a large crack and a dent?

Coating Resistance Monitoring

NACE -10065

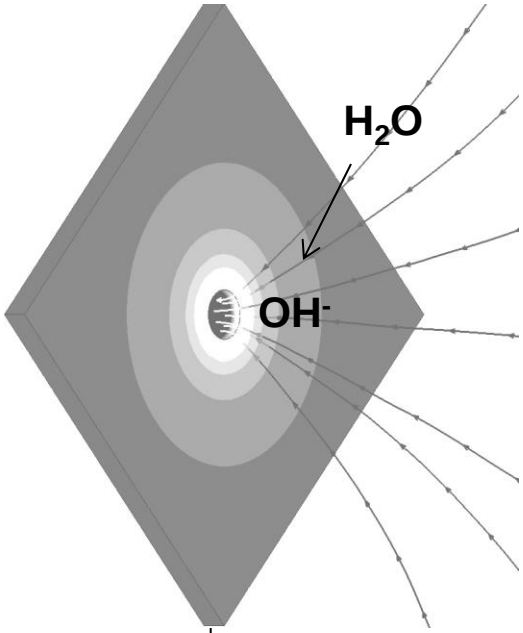
ON-LINE MONITORING OF AVERAGE COATING RESISTANCE WITH OFF-POTENTIAL MODE T/R's

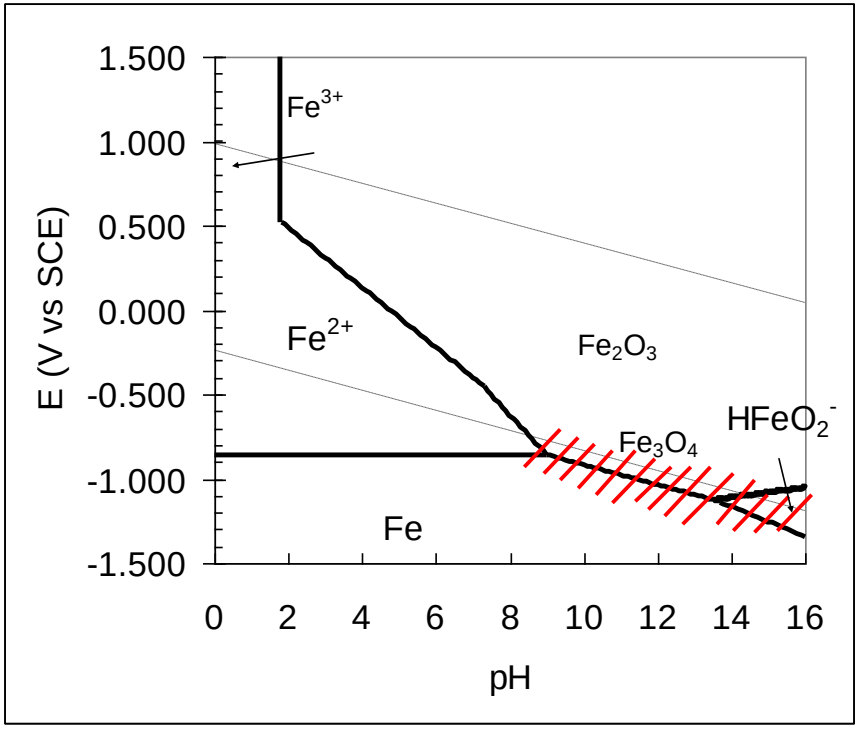
AC CORROSION EVALUATION PROCESS



If it can be demonstrated by other means
(than the established NACE criteria)
that the pipeline is safe,
then this should be allowed by the standard!!

AC CORROSION CHARACTERISTICS





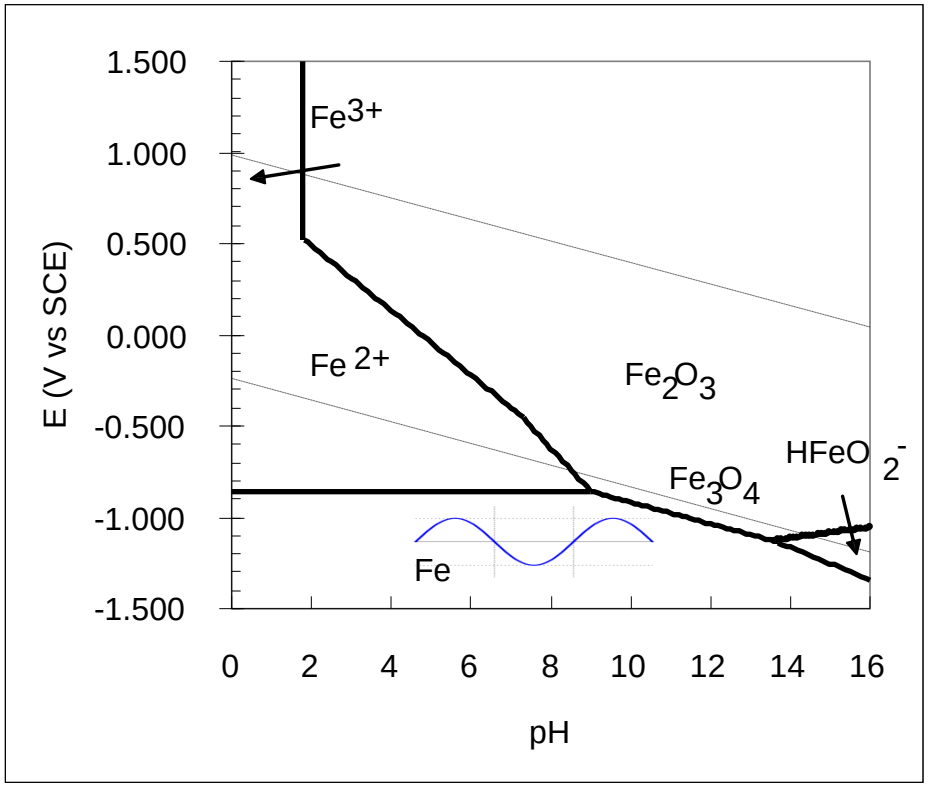
OH^- neutralisation (Mg/Ca)

Influx (I_{DC})

Accumulation (pH increase)

Out-flux (Diffusion – texture)

POURBAIX DIAGRAM AC CASE



$Fe \rightarrow Fe^{2+} + 2e^-$

$V_{corr} \cong I_{anodic}$?

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

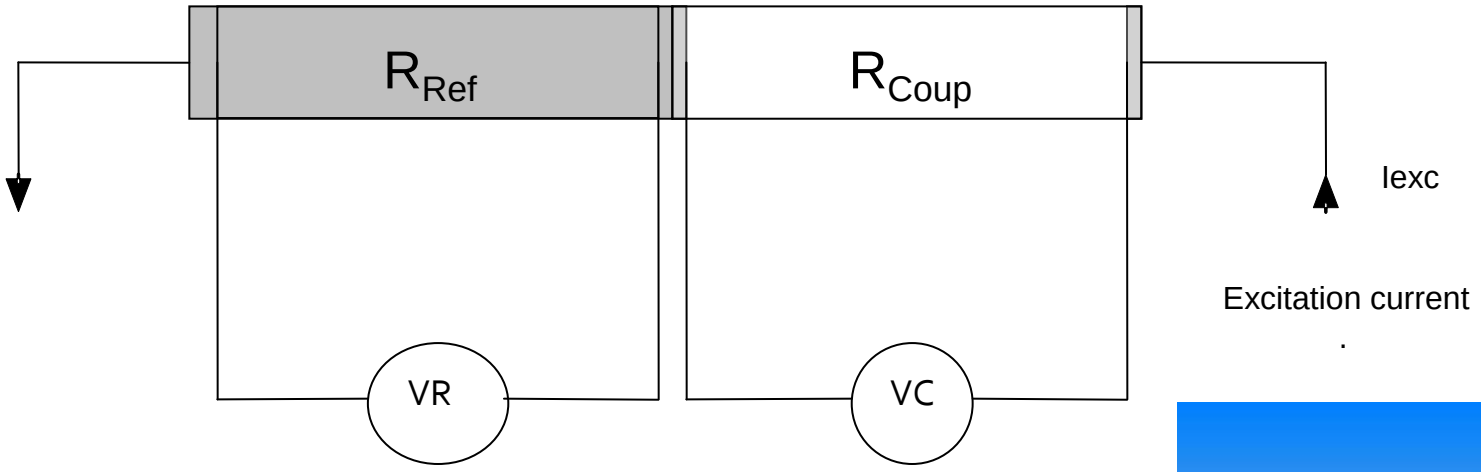
$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

~~Answer to the AC corrosion challenge: Increase the CP level~~ **Absolutely not**

Temperature compensation (1)

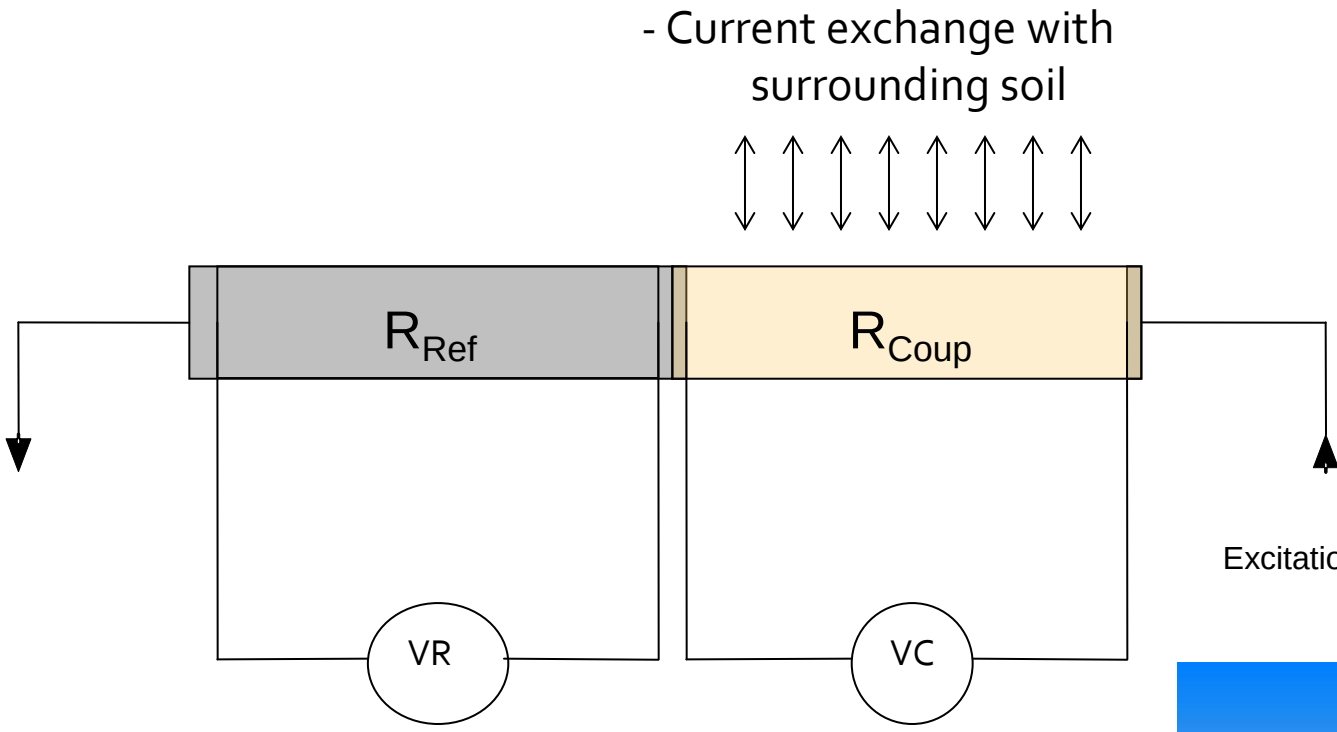
- assuming uniform temperature distribution between Ref and Coup

$$d(t) = d(t=0) \cdot \frac{R_R(t)}{R_C(t)} \cdot \frac{R_C(t=0)}{R_R(t=0)}$$



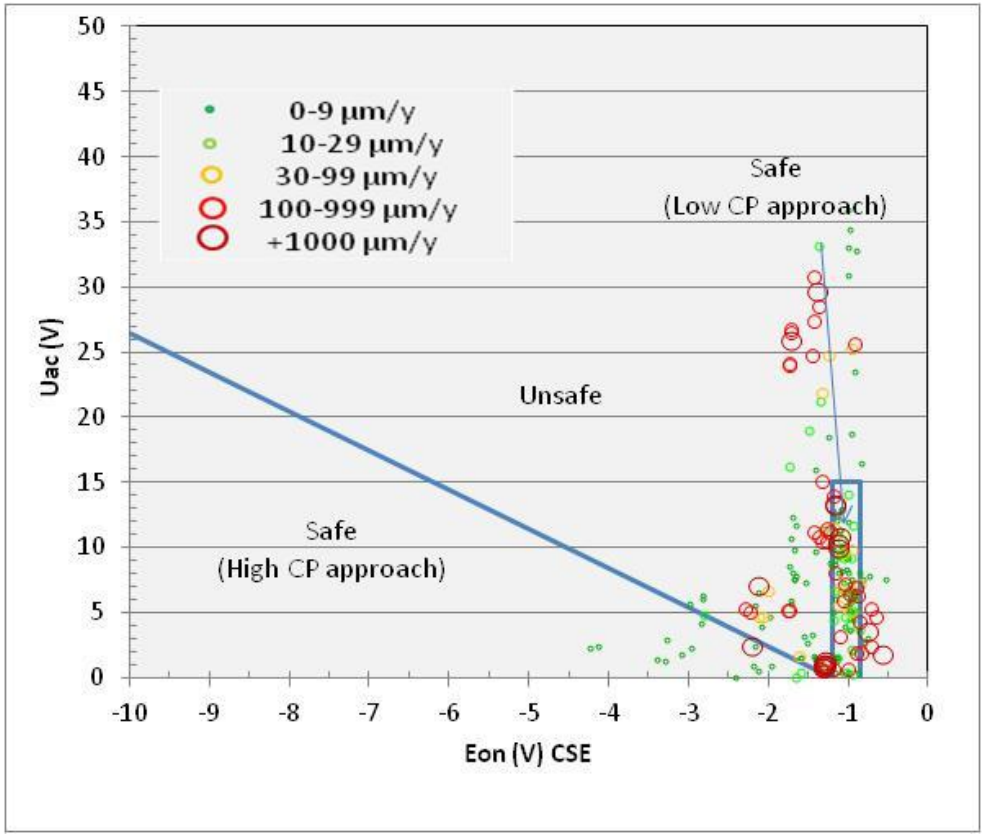
Temperature compensation (2)

Electrical heating on exposed part requires additional means for temperature compensation



CEN – EN 15280 Voltage CRITERIA

ALL DATA POINTS



CEN – EN 15280 CRITERIA

ALL DATA POINTS