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EPD FOR MONITORING CREEP DAMAGE IN HT PRESSURE VESSELS:

CURRENT PROGRESS

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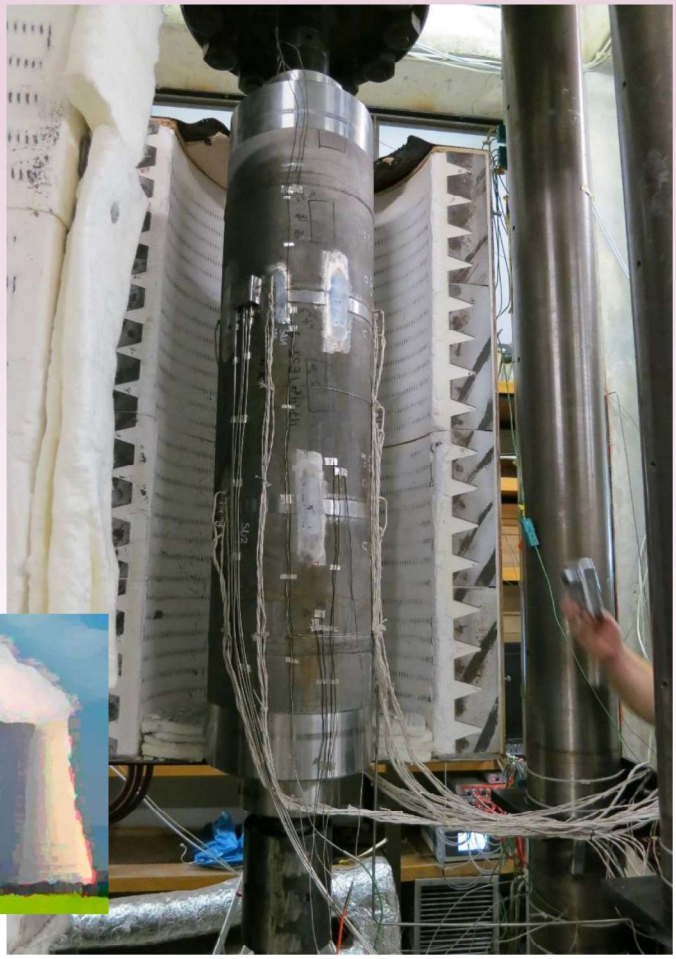


POTENTIAL DROP (PD), (EPD)

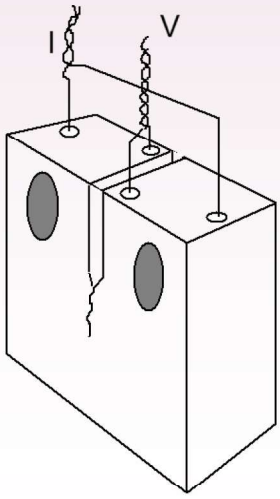
Electromagnetic method for crack measurement in conductive materials – long history of use

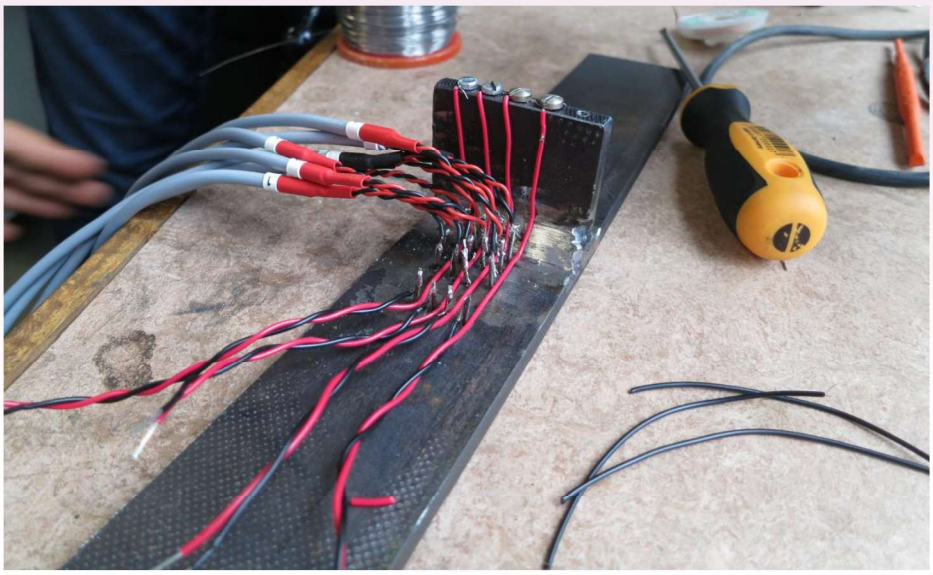
(ASTM 647 EPD Annex)

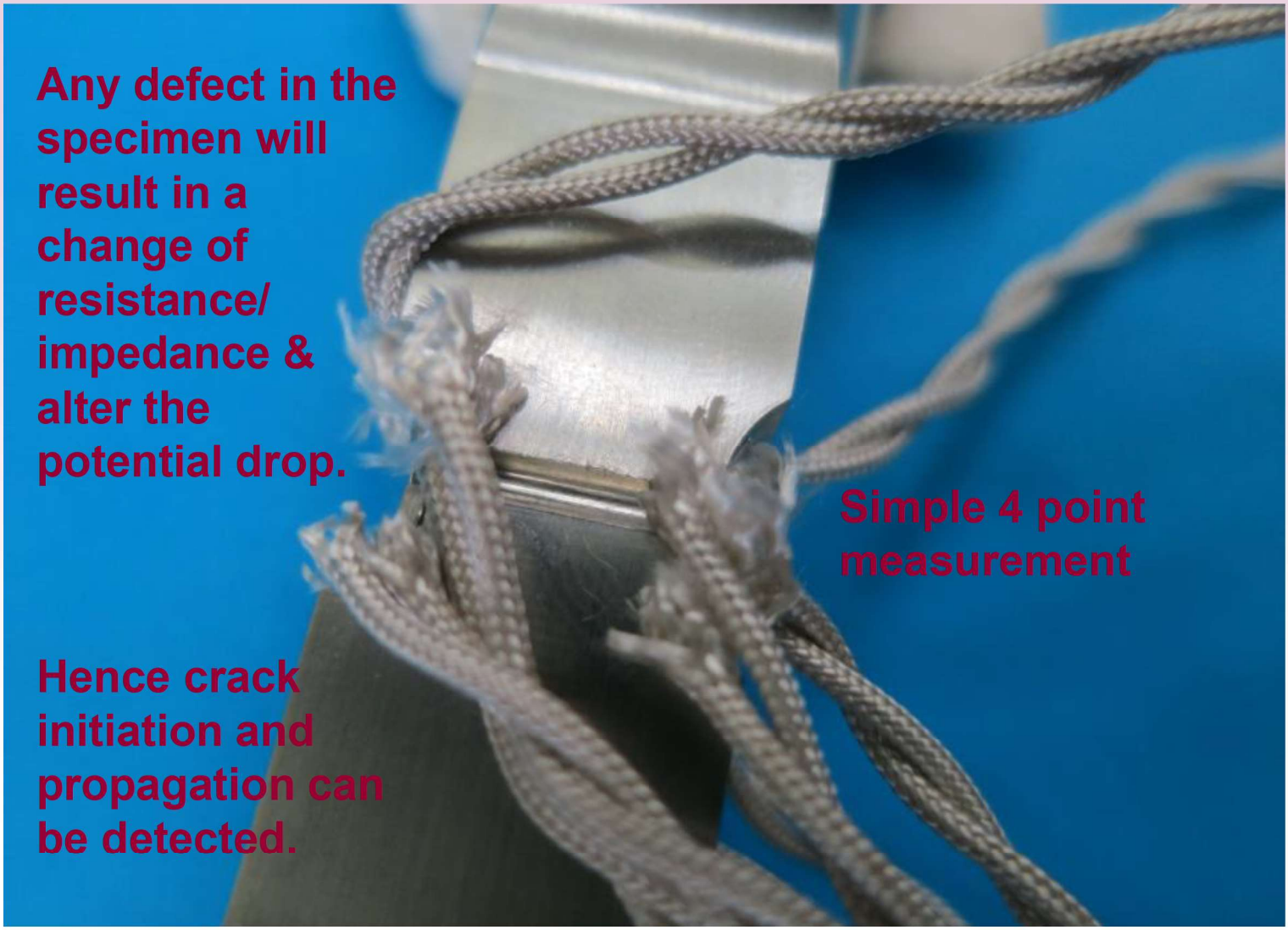
Two variants of EPD

Alternating current potential drop (ACPD)
Direct current potential drop (DCPD)

Passage of a current through specimen, interacts with resistance (DCPD) or impedance (ACPD) to generate a potential drop across specimen






Any defect in the specimen will result in a change of resistance/ impedance & alter the potential drop.
Simple 4 point measurement
Hence crack initiation and propagation can be detected.

Materials (metals) testing

Fracture toughness measurements, fatigue testing, thermal fatigue, stress corrosion cracking, crack initiation, fretting fatigue, impact testing (AC), crack closure studies and stress measurement (AC), case depth determination, porosity detection.

Continuous monitoring

multiple channel monitoring of airframe and vehicle, industrial plant, large structures, bridges etc.

Depth sizing

Uses hand held probes (generally AC) for in-field crack depth measurement.

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Application of EPD to creep damage in pressure vessels

5 year study, ETD Ltd, UCL, Matelect Ltd

P91 Q&T martensitic steel, widely employed, 700 DegC, Type IV cracking in weld HAZ zones

Continuous/Online monitoring

Multiple channel monitoring of zones along welds in tubular specimens under pressure/temperature.

First time AC & DC have been combined in one system to ascertain benefits/strengths

Offline NDE

Use of newly developed area scanning EPD kit for defect development at outages.

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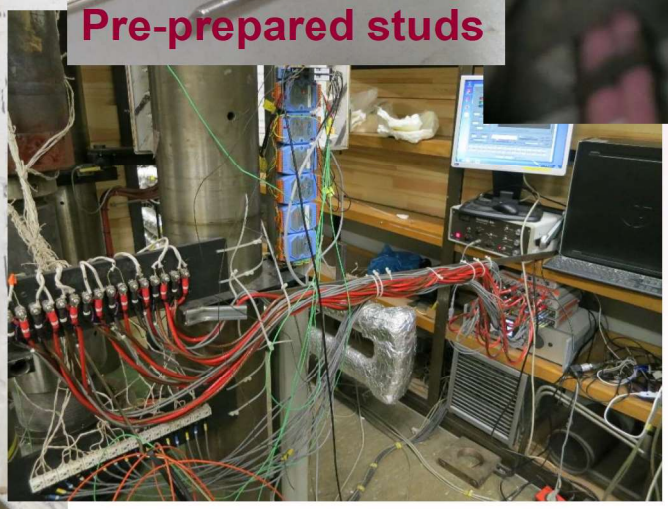
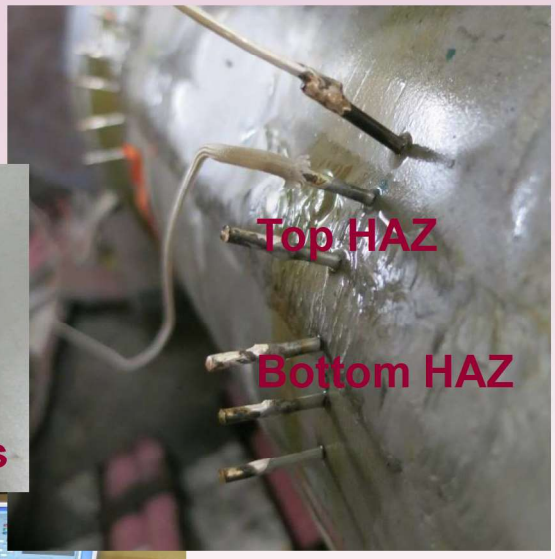
Continuous/Online monitoring P91/P92 pressure vessels

Pre-prepared studs





Top HAZ

Bottom HAZ

Possible connection issues

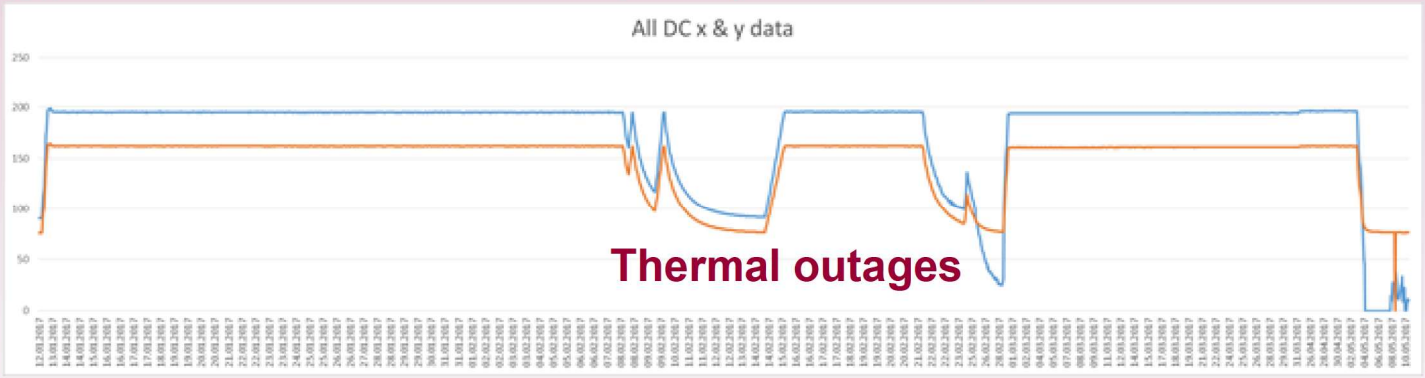
Materials for wiring & insulation - long term oxidation could lead to rise in Ω

SS studs
Ag wiring
Silica braid
Welded &
Soldered

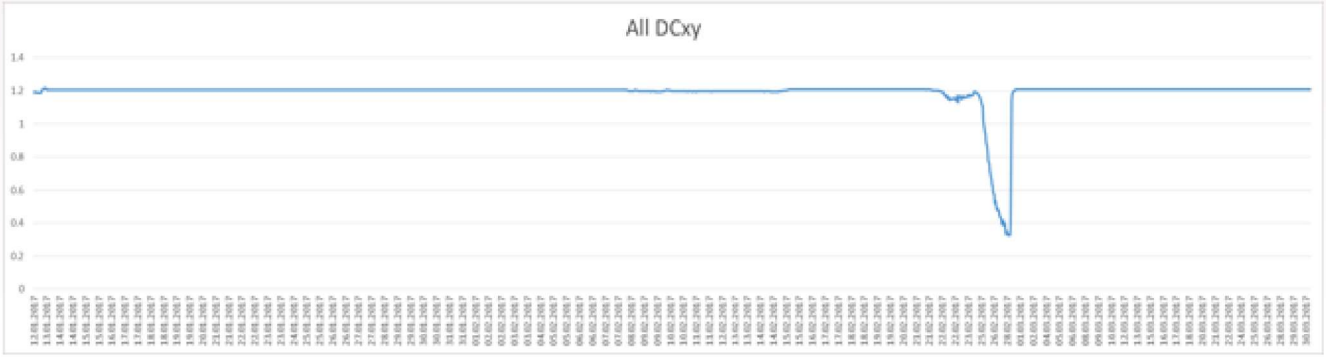
After 2000 hrs

DC Results:

typical mid life raw data plot (2 months)

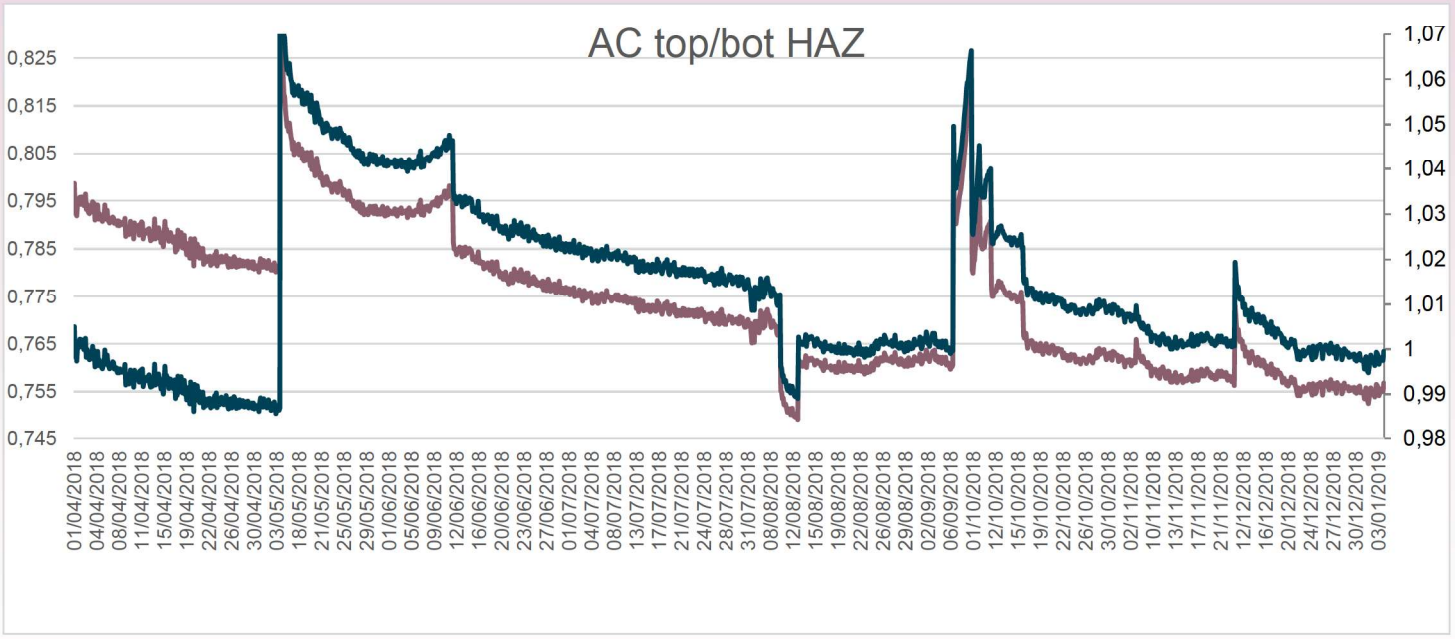


after conventional normalisation (active/ref)



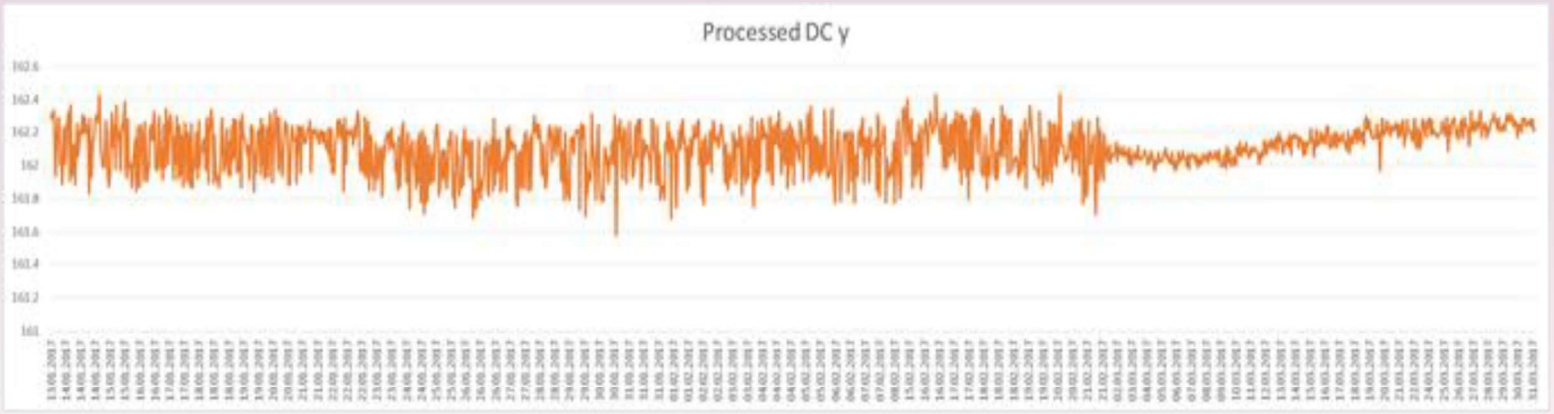
AC results:

typical mid-life raw data plot (10 months)



Large transients - pressure changes (& temperature!)

Results – after filtering/processing

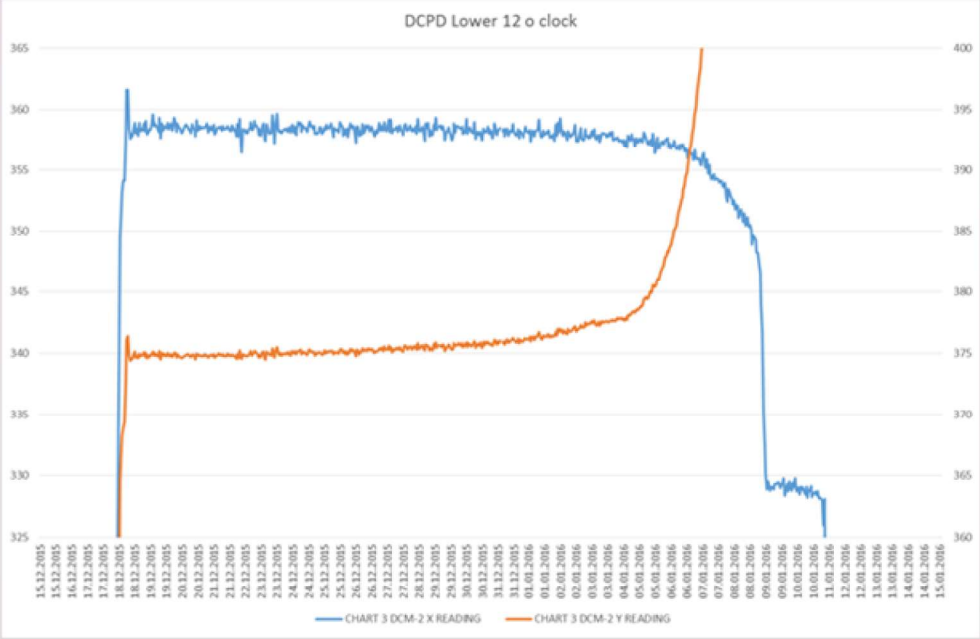


Transients removed

Data re-scaled

Subtle long term changes in EPD visible

Results – typical end of life response (DC)



Subtantial signal rises across "active" HAZ

but drops across adjacent – current flow affected

Notion of a "signature" developed

Results – associated ACPD

Both HAZ channels drop until final fracture

Probable effect of strain on ferritics/permeability

AC/DC results – notion of "signature"

DC – active channel rises as expected

Responds to remaining thickness

DC – adjacent channel drops

Caused by "shielding" effect – changes I flow

AC – both channels drop

Consequence of ACPD response to local strain

AC – final rise when crack is through-thickness

Confirmed over 5 separate vessel tests (2014-19)

AC/DC-EPD – tentative conclusions

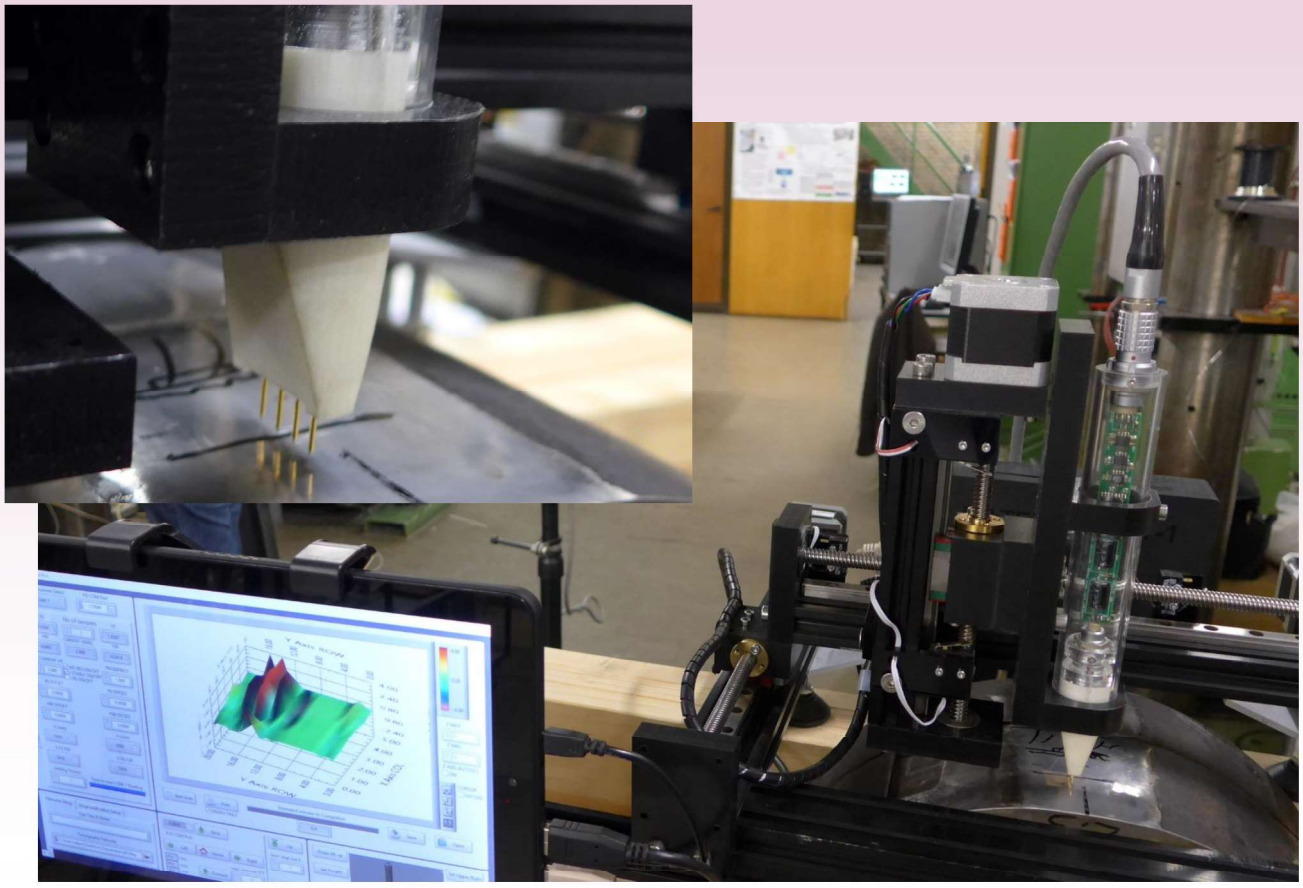
Establishment of a reliable dual-EPD testing methodology suitable for long term use

Improved sensitivity to subtle changes which might signify creep damage development via "signature" notion

Provides 2-3 weeks (conservatively) warning of impending failure, but 6-12 months for subtle damage development

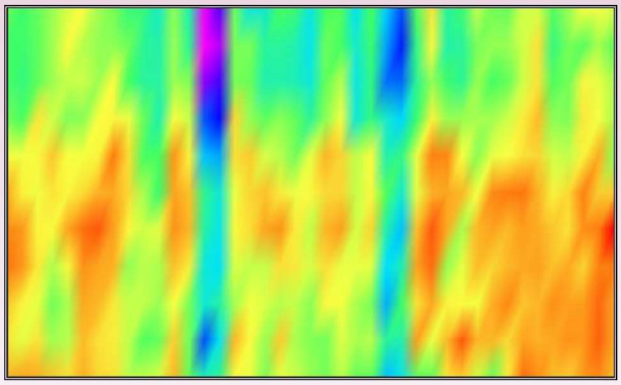
Two tests successfully stopped before surface breaking defect developed. Damage development now linked to on-going microstructural/EM study

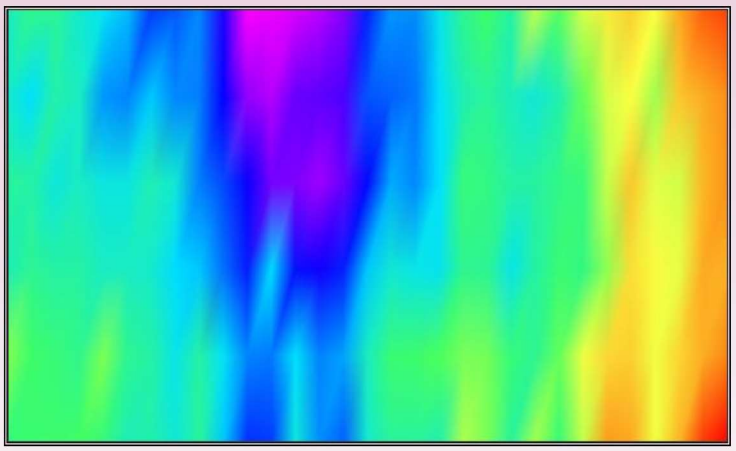
Offline NDE – developed rigidly held scanning probe

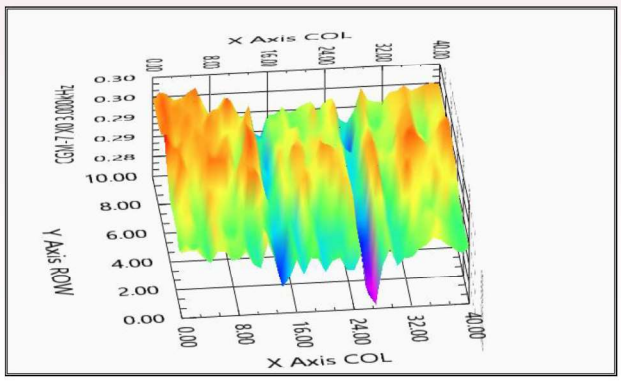


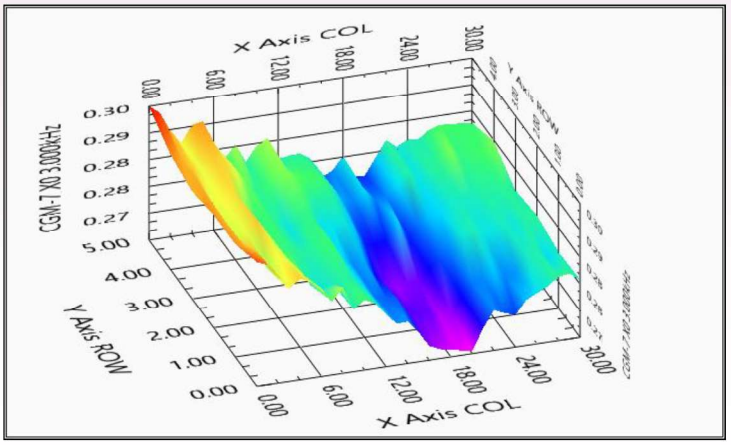
PDT – potential drop tomography

Vessel 1 scans









PDT – benefits

Provides far greater sensitivity than spot testing

Picks up subtle changes such as HAZ (strain/microstructure?)

Detected subsurface defects (ACPD should be insensitive?)

Reasons

Stability/reproducibility of geometry

Differential measurements – not absolute

Unexpected sub-surface/back-surface effects

Sadly off-line……

Future?

AC/DC-PD instrumentation

Software interpretation

On-line industry application

Thanks

colleagues at MPA Stuttgart

University of Manchester

Impact Powertech

Questions?