The HOIS recommended practice for in-service computed radiography of pipes

WCNDT 2012, Durban, SA. April 2012

Dr Stephen F Burch,
ESR Technology, Oxfordshire, UK
steve.burch@esrtechnology.com
HOIS Joint Industry Project (JIP)

• HOIS is a well established JIP & forum for improved NDE in the oil and gas industry
  – Focus on upstream applications
• Members comprise:
  – Oil and Gas producers
  – NDT service/vendor companies
  – NDT equipment vendors
  – A regulatory authority (UK HSE)
• Managed by ESR Technology
• Now has 39 members
• More information from www.hois2000.com
Computed Radiography (CR) in the oil and gas industry

- **In-service inspection of pipes**
  - Flaws of interest generally corrosion & erosion
  - Can be internal or external
  - Corrosion product often present for external flaws
  - External insulation often present

- **Drivers:**
  - No need for dark room/chemical disposal required for film
  - Reduced exposure times compared with film
  - Ease of dimensional measurements

- **Most widespread application is combination of tangential & double wall double image (DWDI)**
  - Can then measure through-wall extent of corrosion
Potential issues for in-service CR

• No relevant international standards
• Lack of quality control
  – IQI values not specified for in-service inspection
  – Variable exposures, source positioning, source selection
  – Subjective assessment of image quality
• Lack of understanding of CR equipment by users
  – CR equipment more complex than film!
  – Range of different scanners and imaging plates
  – Effects of different user selectable parameters not well understood
    • Gain/sensitivity
    • Pixel size
    • Other parameters (e.g. scanning speed)
  – Not clear what is needed to achieve acceptable image quality
HOIS Project on CR recommended practice for ISI

• Early HOIS sponsored blind trial of CR for ISI gave unexpectedly poor results (2003)
• Follow-up showed this to be due to limitations in procedures used, not the inherent capabilities of the equipment.
• Productive collaboration with CR experts at BAM, Berlin.
  – Professor Uwe Ewert & Dr Uwe Zscherpel
• Several practical CR trials to develop and validate the recommended practice
• HOIS Recommended Practice
  – Published in January 2010 – available for download from www.hoispublications.com
• Now being progressed to form basis of prEN 16407
HOIS CR Recommended Practice: Scope

• For **wall loss** in-service inspection of pipes only
  – Corrosion/erosion flaws
  – NOT cracks

• **Techniques covered:**
  – DWDI and/or tangential radiography
  – DWSI

• **Two quality classes**
  – Standard quality
  – Higher quality for more demanding applications such as inspection of fine pitting
HOIS CR recommended practice - key sections

• Radiation Sources
  – Focus on isotope sources as these are nearly always used for in-service inspection
  – Types of source
  – Source selection
  – Size and strength of sources

• Recommended Source to Detector Distances
  – DWSI
  – DWDI
  – Tangential Inspection

• CR Image Quality criteria
  – Normalised Signal-to-noise ratio (SNR_N)
  – Target single-wire IQI values

• Guidance on exposure times
Isotope source selection for tangential radiography

- Limits are similar for CR & radiographic film

- Example: 2" sch 80 pipe has a max path of 35mm (much greater than twice the wall thickness)

<table>
<thead>
<tr>
<th>Isotope source</th>
<th>Approximate maximum tangential path (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard quality (for generalised wall loss)</td>
</tr>
<tr>
<td>Se 75</td>
<td>55</td>
</tr>
<tr>
<td>Ir 192</td>
<td>85</td>
</tr>
<tr>
<td>Co 60</td>
<td>140</td>
</tr>
</tbody>
</table>
Source to detector distances (SDD) for DWDI

• Setting the SDD involves a trade-off between image sharpness and exposure time
• For wall-loss applications, image unsharpness can be larger than for weld radiography
• After much discussion, recommend distances based on geometric unsharpness, $U_g$, projected onto a plane on the source side of pipe
  – Standard quality: $U_g = 0.6$ mm
  – Higher quality: $U_g = 0.3$ mm
• Above values in reasonable accordance with current practice
• SDD for higher quality is twice the SDD for standard quality
CR image quality

• With CR, apparently “acceptable” images can be obtained with very short exposure times
• But these images can be “noisy” and may not have acceptable sensitivity for flaw detection and reliable sizing
• Objective measures of CR image quality are needed to ensure adequate flaw sensitivity
• CR image quality measures considered:
  – Image signal to noise ratio
  – CR image grey level (target grey-level values)
  – Wire IQIs
Image quality measures: Signal-to-noise ratio

• Concept of normalised signal-to-noise ratio (SNR_N) given in EN 14784-1 & 2

• Can be used to measure objectively the quality of CR images
  – Select areas for analysis with no significant image variations caused by the component (e.g. pipe centre line avoiding any areas of corrosion)

• Advantages:
  – Provides quantitative measure of CR image quality
  – Can be applied to tangential radiography (using pipe centre line or free beam areas)

• Limitations:
  – Does not take account of radiographic contrast of CR image
  – Needs measurement of basic spatial resolution (BSR) of IP/scanner using duplex wire IQIs
HOIS CR recommended practice – SNR_N targets

• Double wall techniques:
  – Standard image quality:
    • SNR_N \geq 50 \text{ on pipe centre-line}
    • Similar to IP5 film class, e.g. D7 film with density = 2
  – Higher image quality:
    • SNR_N \geq 80 \text{ on pipe centre-line}
    • Similar to IP3 film class, e.g. D4 film with density = 2

• Tangential techniques
  – Follow above if pipe centre line available for SNR_N measurement
  – Use free beam if not, but aim for higher values
SNR_N as a function of exposure for different scanners/IPs

- Wide variations in exposure times need to achieve specified SNR_N values.
Image quality measures: Single-wire IQIs

- Used as standard for radiography of welds
- Can also be applied for in-service radiography of wall-loss flaws

Advantages:
- Easy to apply. No special software needed
- Takes account of radiographic image contrast

Issues:
- Not appropriate for tangential radiography
- IQI may obscure flaws of interest
- Ensure that IQI is placed centrally in image – not right at edge
- Target values need to be established experimentally
- Some subjectivity in assessment of wire values
Target values for IQI wires for wall loss CR

• Experimental trials to determine IQI wire numbers for CR images collected in accordance with the recommended practice

• Number of IQI wires visible will depend on:
  – Image quality class (standard/high)
  – Wall thickness of pipe
  – Presence of any liquid product in pipe
  – Source used (Ir 192, Se75 etc)

• Large number of experimental measurements needed
Trial results for DWDI IQI values for Ir 192

- Apply to empty and product filled pipes
- Note experimental scatter. RP uses solid lines shown
Validation of RP – repeat blind POD trial

• Original CR POD trial in 2003 gave comparatively poor performance
  – POD ~ 60%
  – Procedure used was not fully developed for the DWDI application

• Repeat CR trial on same specimens in 2007 in accordance with HOIS CR recommended practice
  – Used DWSI to detect flaws (quicker than DWDI)
  – POD ~ 98%

• Clear improvement
Recent HOIS CR activities

• Further CR trials for in-service inspection
  – External corrosion scabs – highlights limited coverage of tangential technique (shots at \( \sim 5^\circ \) increments needed to find deepest point)
  – Effects of dry pipe insulation

• Some initial investigations of CR for weld inspection
  – Main interest of members is for site radiography of new welds
  – Use isotope sources and relevant double-wall techniques
  – Significantly higher quality required

• Some interest in DR flat panels for site radiography
  – Near real-time imaging
  – Shorter exposure times than for CR
CR pros and cons for in-service inspection

• Main CR advantages
  – Avoids need for dark room and chemical disposal
  – Re-usable IPs (cost savings)
  – Adequate image quality for erosion/corrosion
  – On-screen measurements of dimensions (tangential)
  – Greater exposure tolerance than film (higher dynamic range)
  – Electronic images can be readily transmitted and stored
  – Potentially shorter exposure times (often not a significant factor)

• Main CR limitations
  – High capital cost of equipment
  – High complexity of equipment compared with film (many user adjustments – effects not well understood)
  – Scanner/IP related large-scale non-uniformities in image brightness (e.g. banding/shading)
  – Limits to achievable SNR due to IP/scanner induced fixed pattern noise
  – IP's can be damaged quite easily and become "used" (scratches etc)
Conclusions

• There is a need for improved quality control for in-service inspection of wall-loss using CR

• A recommended practice has been developed by the HOIS JIP:
  – Download from www.hoispublications.com

• Draft EN standards prEN16407-1 & -2 have just been issued for public comment in EU.
Acknowledgements

• The HOIS JIP is thanked for funding this work
• Members of the HOIS JIP are thanked for useful discussions and feedback during the preparation of the CR recommended practice
• The following are thanked for hosting, supply of equipment and participation in the HOIS CR experimental trials
  – Aker Solutions, AGR EMI team, NDT Services
  – DÜRR NDT, FujiFilm, GE Inspection Technologies
  – Malcolm Miller, Shell for leading the second blind trial
Thank you for your attention

Any questions?
Thank you for your attention

Any questions?