Improving NDE Reliability through Performance Demonstration and Attention to Human Factors

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Effectiveness and reliability of nondestructive examination

- History of improvement in NDE qualification
  - Today: performance-based qualification
  - PDI and SGMP
  - Three-party agreement on IGSCC
  - Evidence of NDE shortcomings
  - Starting point: administrative qualification

- Technology development

Performance issues in the field

Guideline to improve performance

Summary
History of improvement
The starting point: administrative qualification

• Qualification up to 1983
  – Personnel: qualified according to ASNT requirements
    • American Society for Nondestructive Testing documents ASNT-TC-1A and, later, CP-189
    • Employer-specific written tests and limited practical tests, not related to specific procedures
  – Equipment: none
  – Procedures: none

ASME Section XI:
  • Had to be able to calibrate
  • Limited guidance on equipment selection
History of improvement

Early 1980s: Growing evidence of poor capability

- Programme for Inspection of Steel Components (PISC)
  - International program (included NRC)
  - PISC-1 showed poor performance by ASME Code techniques for RPV examination
- Pipe Inspection Round Robin (PIRR)
  - Large study by NRC-RES
  - Piping (stainless, ferritic, cast stainless)
  - Showed poor performance on stainless and cast
- BWR recirculation piping at Nine Mile Point
  - Pipes leaked; cracks not detected
History of improvement

1980s: Growing evidence of SG Degradation

- PWR Steam Generator Tubing
  - Leaker outages were common
  - Many forms of degradation were prevalent
**History of improvement**

**Mid-1980s:**

**Shift to performance-based qualification**

- Pipes removed from Nine Mile Point Unit 1
  - Collaboration between NRC and EPRI
    - Blind UT examination by several vendors and utilities
    - Poor result: many missed cracks, many false calls
- The original IGSCC qualification program
  - I&E Bulletins 82-03 and 83-02
  - Three-Party Agreement between NRC, EPRI, and BWROG
  - Defined the qualification test
    - Chiefly addressed personnel
    - Three-year requalification requirement
History of improvement

Late 1980s:
ASME adopts performance-based qualification

- Evidence mounts indicating inadequacy of Code approach
  
  **NRC and industry involved at every step**
  
  - EPRI round robin test of depth sizing capability (1983) shows poor performance
  - No one can pass the new IGSCC qualification using basic Code techniques
  - PIRR analysis completed and published
  - PISC-2 shows poor performance for Code techniques on piping
  - Everyone recognizes inability to create an effective “cookbook” procedure

- 1989: ASME publishes Appendix VIII to Section XI
  
  - Defines and requires formal performance demonstration
History of improvement

1990s: Implementation of Appendix VIII

• US utilities formed the Performance Demonstration Initiative (PDI) to implement Appendix VIII
  – Built mockups and administrative structure
  
  **NRC involvement at every step**
  • Stainless piping, ferritic piping, RPV welds, nozzles, bolting
  – Adoption through 10CFR50 rulemaking
    • Slightly different from Appendix VIII as written
      – In building the program, PDI and NRC found and remedied difficulties that the Code authors hadn’t foreseen
History of improvement

1990s:
Implementation of SGMP Performance Demonstration

- US utilities developed protocol
  - Technique and personnel qualification
    - PWR SG Examination Guidelines
      - Appendix G and H
    - Performance criteria for tube integrity
      - Operational leakage
      - Structural
      - Accident induced leakage
  - Adoption through NEI 97-06
    - Industry steam generator program description
      - Adopted by all U.S. PWR utilities
History of improvement

2000s: Qualification today

- NRC and PDI meet twice each year to maintain alignment
- Appendix VIII and PDI have expanded
  - Weld overlays
  - Dissimilar metal welds
- All qualifications are comprehensive
  - Procedure, equipment, and personnel
  - Flaw detection, length sizing, and depth sizing
- Diverse program
  - Accommodates manual, semi-automated, automated
  - Accommodates conventional and phased array UT
  - Generic procedures available to all
  - Recognized by regulators in many nations
History of improvement

2000s: Qualification today

- NRC and SGMP meet twice each year to maintain alignment and technical issues
- NEI 97-06 steam generator program elements were adopted into U.S. PWR plant technical specifications
  - Became imposed by law
- Qualifications are comprehensive
  - Eddy Current
    - Bobbin, array, and rotating coil
  - Ultrasonics
    - Rotating element
- Diverse program
  - Sample selection
  - Inspection
  - Human performance
  - Personnel qualification
  - Site specific training and demonstration
  - Tube integrity
History of improvement

2000s: Qualification today

- SGMP imposed multiple requirements to address human factors
  - Two party analysis
  - Resolution process
  - Independent QDA (third party oversight role)
  - Automated analysis demonstration protocol
    - Creation of AAPDD for initial qualification of automated software
  - Analyst feedback loop
    - Individual analyst review of overcalls and missed indications
  - Structured analysis guidelines content
  - Site specific performance demonstration
    - Written and practical exam conducted prior to each inspection
      - Based upon site specific degradation and techniques
  - Data quality parameters
    - Probe manufacturing
    - Collected data
- Use of both pulled tube data and laboratory grown stress corrosion cracks for qualification of inspection techniques
History of improvement

Improvement of POD through the years

• Stainless steel pipe examination (mean POD, several studies)

Today: Performance-based qualification

1980s: Administrative qualification
History of improvement

Improvement of POD through the years

• Steam generator performance has improved due to:
  – Better probe technology
  – Improved human performance
  – Process controls
  – Steam generator replacement
    • Improved materials

Today: Performance-based qualification
Technology development has been a key to this improvement in NDE reliability

- 1980s
  - Specialized probes for IGSCC
- 1980s
  - Early automated systems
- 1990s
  - Improved software for data analysis
  - Two party analysis for SG tubing
  - Surface riding rotating coil probes for SG tubing
- 2000s
  - Advanced automated systems made possible by rapid advances in computing and microelectronics
  - Array probes for SG tubing
  - Computer auto analysis for SG tubing
  - Phased array technology
    - Mid-2000s: portable phased array systems
    - Today: every piping and dissimilar metal UT procedure qualification in 2008 will be phased array

*Note that phased array technology improves coverage and productivity for some applications, but is not always more accurate than conventional UT*
Looking ahead: Industry is working to develop or improve NDE capability in many areas

- NDE of dissimilar metal weld mitigations
- NDE of welds and overlays with poor surface conditions
- Cast stainless steel
- Detection of SCC at earlier, slower phases of growth
- Guided waves, for large-area components and for buried piping
- NDE for high-density polyethylene piping
- NDE for concrete

And supporting it all:

- Workforce expansion and improvement
  - More focused training
  - Making data presentation more intuitive
Agenda

• Effectiveness and reliability of ultrasonic examination
• Performance issues in the field
  – Review of recent NDE issues in the field
  – The errors are in human performance
• Guideline to improve performance
• Summary
## Summary of the OE

<table>
<thead>
<tr>
<th>Outage</th>
<th>OE</th>
<th>Nature of issue</th>
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<tbody>
<tr>
<td>Susquehanna 1 2004</td>
<td>Surface condition</td>
<td>Performance (surface condition)</td>
</tr>
<tr>
<td>DC Cook 1 2005</td>
<td>Surface condition</td>
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</tr>
<tr>
<td>Millstone 3 2005</td>
<td>Surface condition Confirmatory NDE</td>
<td>Performance (surface condition)</td>
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<tr>
<td>Farley 2007</td>
<td>Access limitation Manual confirmation</td>
<td>Performance (communication)</td>
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<tr>
<td>Pilgrim 2007</td>
<td>Care in data analysis</td>
<td>Performance (analyst bias)</td>
</tr>
<tr>
<td>Duane Arnold 2007</td>
<td>Surface condition Care in data analysis</td>
<td>Performance (surface condition)</td>
</tr>
<tr>
<td>Crystal River 2008</td>
<td>Surface condition</td>
<td>Performance (surface condition)</td>
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<tr>
<td>St Lucie 1 2008</td>
<td>Be prepared with augmented technique</td>
<td>Performance (contingency readiness)</td>
</tr>
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Lesson: Procedure execution

- PDI qualified procedures produce high quality, reliable results when properly executed
  - Use the right probes and prepare the surface
  - Ensure surface contact meets procedural requirements
  - Document all areas of poor surface condition and all areas of scan limitation, and don’t take coverage credit there
  - Follow all the steps of data analysis before reaching a conclusion
Agenda

• Effectiveness and reliability of ultrasonic examination
• Performance issues in the field
• Guideline to improve performance
  – Background information and human factors discussion
  – Guidance for utilities
  – Guidance for vendors
  – Collaboration between utility and vendor
  – Implementation through NEI 03-08
• Summary
Guideline for implementation of ultrasonic examinations

• EPRI is preparing a guideline for the use of utilities in preparing for, and executing, ultrasonic examinations
  – Collects the lessons learned from field implementation issues
  – Addresses the key underlying factors
    • Human factors
    • Utility and vendor planning for the outage
    • Procedure compliance
    • Surface preparation
Guideline for implementation of ultrasonic examinations

• Schedule and focus
  – Publication Summer 2009
  – Guidance is applicable to any ultrasonic examination
  – For dissimilar metal welds, the guidance includes implementation categories according to NEI 03-08
    • Contains needed guidance for owner to develop and implement a surface condition assessment process and other good practices
    • Utilities commit to following the guidance
    • Deviations will be reported both to industry Issue Programs and to NRC
    • Compliance due within two outages after publication
Agenda

• Effectiveness and reliability of ultrasonic examination
• Performance issues in the field
• Guideline to improve performance
• Summary
Summary

• The effectiveness and reliability of examinations are high

• Recent issues in field implementation have resulted from human factors

• Tools are in place to improve the human element
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