Application of IAEA Methodology in the Pilot Study to Develop a Technical Justification for ISI of RPV Weld

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Technical Justification

- Technical Justification in the context of IAEA Qualification Methodology
  - "The documented evidence which supports the assessment of the proposed non-destructive inspection system capabilities justifying selection of the essential parameters.... The extent of practical trials needed...."
  - Citing of relevant evidence
  - Complementing and extending practical trial results
  - Providing basis for designing effective test piece trials
  - Providing basis for selecting essential parameters
Available evidence

- Theoretical
  - Logical structure of the procedure
  - Mathematical models
  - Physical reasoning
- Practical
  - results from qualifications of similar techniques
  - Experimental evidence
  - Plant experience

Assessment of the procedure capability

Integral Relationship between Technical Specification and Technical Justification
Role of Technical Justification

- The Technical Justification and the Technical Specification are linked in fundamental ways
- Assessment of the TJ against the TS may require an iterative process
- Objective of preliminary assessment of the TJ
  - Evaluate the capabilities of the proposed procedure
  - Assess the methods used to develop the Technical specification
  - Compare the capabilities of procedure using available evidence
    - Databases of performance of similar techniques
    - Physical reasoning
    - Specific data on procedure performance
  - Develop recommendations on how to proceed

Application for the Pilot Study

- Technical Specification defines
  - Flaws to be detected
    - Type
  - Flaw parameters to be characterized
    - Size
    - Location
    - Shape
    - Remaining ligament to the surface
  - Inspection Reliability
    - Examples;
      - Probability of detection and correct rejection
      - Minimum ligament to be measured
Reliability Goals

- A very high level of ISI reliability should be established through the combination of Technical Justification and practical trials to show the NDT system is capable of detection, characterization and size estimation of flaws equal to or greater than the target flaw size.

- A reasonable level of ISI reliability should also be established through the combination of Technical Justification and practical trials which shows the NDT system is capable of detection, characterization and size estimation of flaws less than the target flaw size.

Establishing Performance Criteria for Qualification

- Objective is to minimize chance for error in flaw detection and evaluation
- \[ P(\text{error}) = P(\text{flaw of concern is present}) \]
  \[ = P(\text{flaw is missed}) \]
  \[ + P(\text{flaw is detected})P(\text{critically undersized}) \]
- \[ P(\text{error}) = P(\text{flaw is present}) \]
  \[ \times (1 - POD + POD \times (1 - PCR)) \]
- PCR = conditional probability: \( P(\text{Correct rejection|detection}) \)
- \[ P(\text{error}) = POD \times PCR \times P(\text{flaw is present}) \]
Establishing Performance Criteria for Qualification

- Therefore, we must assess
  - Detection performance
  - Characterization (undersizing)
  - Probability a flaw of concern could exist
    - Loads
    - Material properties
    - Regulations
    - Codes
    - Service experience

Preliminary Calculation of Permissible Flaw Sizes

Permissible sizes of surface defects in weld No 4 of WWER-1000 reactor vessel

<table>
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<tr>
<th>a/c</th>
<th>0.0</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>[a], mm</td>
<td>3.6</td>
<td>4.1</td>
<td>4.5</td>
<td>5.1</td>
<td>5.9</td>
<td>6.8</td>
<td>8.0</td>
<td>8.3</td>
<td>8.2</td>
<td>8.2</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Analysis provided by V. Piminov, OKB Gidropress
Permissible Flaw Sizes

Probability that a 6 mm flaw will beReported as Size x or Smaller

Effect of Sizing Error
Preliminary Assessment of Proposed Procedure Capability & Reliability

- A preliminary assessment of the procedure capability and reliability was performed
- Available databases of performance in practical trials was used to assess the likely performance of the proposed procedure to meet the proposed technical specification goals
- Experience with performance of similar techniques in industry practice was also considered

Capability
- Procedure is consistent with industry practice for RPV examination
- Similar techniques and essential parameters were qualified to Appendix VIII
- Target flaw size of 4-8 mm could be detected with specified probability

Reliability
- Flaw sizing accuracy demands were at limit of the state-of-the-art for 4-8 mm flaws
  - Likely sizing error could result in critical undersizing and therefore, false acceptance of large flaw
- P(Correct rejection) criteria not likely to be met
Refinement of Technical Specification

- Re-examine technical approach to calculating target flaw size
- Consider plant specific conditions
  - Fluence & material properties
  - Preheating of ECCS water
  - Cladding effects
  - Analytical methods
- Target flaw size increased to 21 mm as a result of these refinements

Probability that a 21 mm flaw will be Reported as Size $x$ or Smaller
Effect of Sizing Error
Probability that a 15 mm flaw will be reported as Size x or Smaller

Effect of Sizing Error

Conclusions and lessons Learned

- Extensive analysis is required to arrive at realistic specification of target flaw
- Preliminary Technical Justification process was an integral part of refining the approach
- Refining the Technical Justification and Technical Specification can be an iterative process
- Teamwork was essential for making progress
- Revised specification expected to be within capability and reliability of proposed procedure
- Experimental trials will confirm specific situation and fill in areas where databases lack evidence specific to the situation