Lessons learned – a regulator’s view

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Contents

- NDT in the context of the nuclear safety case
- The basics of highest reliability NDT
- Why design for inspectability is so important
- Some examples of lessons learned
Liverpool

London

Cheltenham

370 specialist staff
How ONR Regulates

COMPLIANCE

36 Standard Licence Conditions

ASSESSMENT

Safety Assessment Principles for Nuclear Facilities
2014 Edition
Revision 0

Technical Assessment Guides

RELEVANT GOOD PRACTICE
Structural Integrity Safety Case

DESIGN (Normal & Upset Conditions)
- Appropriate materials
- Configuration
- Fracture Mechanics
- Environment
- Hazards
- Degradation

MANUFACTURE
- Forgings, Welds, Castings
- High quality
- Mechanical Testing
- Chemical measurements
- Quality Assurance
- NDT

COMMISSIONING
- Pressure Test
- Confirming NDT

OPERATION
- Operating Rules
- Monitoring
- ISI NDT
- Repair

CONFIRM SAFETY FUNCTION OF THE COMPONENT CAN BE DELIVERED
NDT reliability issues

Important nuclear safety decisions are made on the basis of NDT results:
- Repair/replacement of components (can be harmful to the plant)
- Plant shutdown, extended outages
- Early closure of reactors

Good margins are important:
- Detection (signal to noise ratio, clear signals)
- Characterisation
- Accept/reject criteria
- Recognises uncertainties

Conservative approach:
- Selection of NDT methods
- Mature methods/techniques
- Physical principles understood
- Engineering solution rather than NDT

Continuity of results
What is better NDT?
Fit for purpose
NDT reliability issues

- Optimise conditions for NDT ✓
- Develop clever techniques to overcome poor conditions X

### Engineering principles: integrity of metal components and structures: design

<table>
<thead>
<tr>
<th>Providing for examination</th>
<th>EMC.8</th>
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</table>

Geometry and access arrangements should have regard to the need for examination.

### Engineering principles: integrity of metal components and structures: manufacture and installation

<table>
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<tr>
<th>Materials</th>
<th>EMC.13</th>
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Materials employed in manufacture and installation should be shown to be suitable for the purpose of enabling an adequate design to be manufactured, operated, examined and maintained throughout the life of the facility.

Apply ALARP
Design for inspectability

- UK gas-cooled reactors not, in general, designed with inspection in mind
  - Novel techniques often applied
  - Complex deployment techniques
- Components designed to ASME III often cannot meet the ASME XI NDE requirements
  - Component geometry
  - Physical access
  - Materials (cast stainless steel)
- ASME Code Case N-711-1
  - Revision of inspection volume to consider degradation effects.
Initial design not optimised for ultrasonic inspection. Design modified to provide a 250mm straight section on the ends of the bends.

UK EPR Main Coolant Lines
Highest reliability components

• Safety case claims for components and structures the likelihood of gross failure is so low it may be discounted, but if failure did occur the consequences would be extreme

• Additional measures (beyond codes and standards) required to assure the integrity (including NDT)

<table>
<thead>
<tr>
<th>Engineering principles: integrity of metal components and structures: highest reliability components and structures</th>
<th>Safety case and assessment</th>
<th>EMC.1</th>
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<tbody>
<tr>
<td>The safety case should be especially robust and the corresponding assessment suitably demanding, in order that a properly informed engineering judgement can be made that:</td>
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<tr>
<td>(a) the metal component or structure is as defect-free as possible; and</td>
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<td>(b) the metal component or structure is tolerant of defects.</td>
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as defect-free as possible
• Objective based manufacturing NDT to meet specific safety case needs
• Design considerations for NDT: ‘Design for inspectability’
• Qualified NDT performed in manufacture.
• Repeat NDT
• Enhanced quality assurance/control
High Reliability NDT: Inspection Qualification

• The elements of the inspection qualification process that ONR is seeking are:
  – Objective Based
  – Procedure qualified using technical justification and practical trials
  – Personnel qualified against a specific NDT procedure using blind trials

• These elements are found in the ENIQ Methodology

• Founded on the Sizewell B ‘Validation’ approach
New UK nuclear build

Generic Design Assessment

Important phase for de-risking subsequent licensing, construction and operation

Licensing

Construction

Operation
Doel 3/Tihange 2 Hydrogen Flakes

- Around 10,000 defects identified in the RPV forgings in 2012, understood to be present at manufacture.
- Significant NDT failure applying ASME based procedures – difficult to establish the root cause.
- The Sizewell B RPV forgings were subject to several qualified mechanised inspections.
- EDF were able to provide good evidence that hydrogen flakes were not present in Sizewell B RPV
Boiler spines

Feed Header
- 20” transducer collar – Three rings, each consisting of 52 transducers arranged in groups of 13 elements in 4 quadrants

Mounting Blocks

ESR

4 cable pairs connecting transducer collar to Teletest Ultrasonic unit located outside of boiler pod

Teletest Ultrasonic Unit

Ethernet cable

Laptop running Teletest Software
Corrosion under insulation

• The issue isn't specifically related to NDT (but NDT plays an important part!) but it is a very relevant lesson
• Management and risk assessment of all supporting equipment is key to operations
• Careful design and operation of plant is key and is bolstered by good design of inspections at a suitable frequency.
• Requirement to continuously review the situation (corrosion doesn’t go away)
Conclusions

• There is a golden opportunity for every nuclear operator at the design stage to ensure the design will cater for appropriate fit for purpose NDT and high reliability where required.

• It is possible in most instances to use a combination of engineering and NDT methods to back-fit inspection techniques to otherwise un-inspected components but this is often extremely costly and time consuming and often sparks significant interest by ONR.

• Expect the unexpected – a common re-occurring lesson for everyone. As a nuclear regulator, we still see cases of unexpected degradation – hence why a conservative approach based on sensible classification of components is what we always expect as an approach.
Thank you