Challenges of Hungarian nuclear NDT regarding existing plants and new-builds

P. Trampus
Trampus Consulting & Engineering, Hungary

Swedish Annual NDT Conference
Malmö, Sweden, 3-4. 04. 2017
Nuclear power in Hungary

In operation:

• 4 x 500 MW(e), Paks
  – VVER-440/V-213 (Russian design PWRs)
  – 1982/87 – 2012/17
  – After power uprate: 500 MW(e)
  – Service life extension: 2013/18 – 2032/37 (+20 years)

Under preparation:

• 2 x <1200 MW(e), same site
  – AES-2006 (Russian design PWRs)
  – 2026 – 2086

Nuclear capacity ensured for a century!
Paks NPP, Hungary
Operating units
VVER-440 reactor coolant system
Major challenge of operating units:  
Service life extension

Current status of life extension:

- new license for units 1 to 3 issued
- application for unit 4 submitted
Cornerstones of Paks NPP life extension: NDT challenges

- Aging Management (long-lived components)
  - Adoption of ASME BPVC XI requirements (ISI)
  - Inspection qualification of Class 1 components
- Time Limited Aging Analysis (TLAA)
- Environmental Qualification (I&C and electrical components)
- Design Basis Reconstitution (lack of construction documentation)
  - Construction review (compliance with ASME BPVC III requirements) → pre-condition for apply BPVC XI, too
Needs for ASME BPVC XI adoption

• Earlier NDT acceptance standards did not serve Fitness-for-Service (FFS) concept, i.e. *lifetime/integrity assessment*
  – expressed in equivalent reflector size (QC criteria)
  – no relation to fracture mechanics
• Inspection interval (reactor coolant system)
  – 4 years (NDT + hydrostatic test)
• Hydrostatic test of reactor coolant pressure boundary
  – 164 bar (originally 191 bar)
  – No added value

Consequences:
• Possible unnecessary repair works (QC criteria)
• Elongation of outage length (4 years)
• Component overloading (hydrostatic test) → fatigue
Acceptance standards

**Quality Control**
- Registration level
- Reference level (recording level)
- Acceptance level (QC)
- Acceptance level (FFS)

**Fitness-for-Service**
- Critical
- Not-allowable
- Allowable

**Former approach** (based on Russian standards)
- Evaluation based on flaw characteristics
- +12 dB Recording
- 100% PRR (FBH)

**Current approach** (based on ASME BPVC XI)
- Repair/replacement, or fracture mechanics analysis
- Acceptance standards
- 20% DAC (SDH)
- 100% DAC (SDH)
Objectives of ASME BPVC XI adoption

Overall objective
• Facilitate the implementation of
  – ISI
  – repair / replacement
  – fracture mechanics analysis
  of pressurized components where appropriate

Specific objectives
• Extend the 4-year ISI interval up to an 8-year one
• Provide an opportunity to compare ISI environment with worldwide acceptable safety requirements
• Strengthen a consent across Europe for Paks NPP service life extension (owner’s decision on life extension: 2002!)

Adoption: special situation - Paks NPP was not constructed in accordance with ASME BPVC III (Construction Code)
Construction review

- **Twofold objective**
  - Design basis reconstitution
  - Foundation of ASME XI adoption

- Reactor coolant boundary, SG secondary side, selected pipelines, vessels, heat exchangers, pumps, valves – Class 1, 2 and selected Class 3 components

- Independent expert review *(Registered Professional Engineer)*
  - Methodology: „provides solid basis”
  - Calculation results: „are correct”

- **Results:**
  - No significant non-compliances
  - Components reviewed meet ASME Construction Code requirements

**Adoption of ASME XI requirements was feasible!**
Implementation of ASME BPVC XI adoption

- Proven practice kept as much as possible
- New ISI program integrates the concept and requirements of Section XI
- More emphasis on ageing management
- NDT
  - supplemented by relevant examinations (e.g. attachments of welded components and pipes)
  - examinations outside the scope of Section XI remained (e.g. RPV base metal)
- ISI interval: 8 years (since 2016: 10 years due to C15)
- NDT procedures upgraded to comply with ASME BPVC V
- Inspection qualification - European approach (ENIQ)
- NDT personnel qualification / certification – EN 473, then ISO EN 9712
Inspection qualification

• A systematic assessment by all necessary methods in order to provide reliable confirmation that the NDT system (procedure, equipment and personnel) is capable of the required performance under realistic conditions

• Different approaches exist:
  – ASME BPVC XI Appendix VIII (Performance Demonstration)
  – ENIQ (European Network for Inspection and Qualification)
  – IAEA Methodology (for VVERs)
Inspection qualification at Hungary

• Started in 2001, in accordance with ENIQ methodology
• NDT system qualification consists of that of procedure, equipment and personnel
• The qualifications completed so far covered mainly **procedure** and **equipment** qualifications
• As for **personnel**, the qualifications according to ISO EN 9712 (and SNT-TC-1A) considered and approved
### Current status of inspection qualification

<table>
<thead>
<tr>
<th>Subject</th>
<th>NDT equipment</th>
<th>NDT procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SG:</strong> primary collector base metal, welds (UT, ET*), tubing (ET), bolts (MT), threaded holes (ET), DMW (UT)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>RPV:</strong> welds, base metal, nozzle inner radii (ID/OD UT), cladding (ET), DMW (ID/OD UT), bolts (UT, ET), threaded holes (ET)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Pressurizer: DMW (UT)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Main coolant pipeline: welds (UT*)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Main circulating pump: bolts (MT, ET), threaded holes (ET)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Small bore pipe (PT)</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

* Personnel qualification
Time Limited Ageing Analysis

Key issue:
Pressurized Thermal Shock (PTS) analysis

- RPV design limitations – high neutron flux
- Cr-Mo-V alloyed RPV steel – high radiation resistance
- Surveillance program – high lead factor
- Life limiting area: circumferential weld in core region \( (0.68 F_{\text{max}}) \)
**Major steps of PTS analysis**

- **PTS transient identification**
  - deterministic (engineering judgment), probabilistic ($f > 10^{-5}$/year)
- **Thermal-hydraulic calculations**
  - RELAP5/mod3.2, ATHLET, REMIX (flow stagnation)
- **Neutron fluence calculations**
  - KARATE and MCNP for RPV wall and surveillance position
- **Evaluation of irradiation effects on RPV materials**
  - surveillance program, trend curves
- **ISI results**
  - target flaw size and position
  - cladding integrity
- **Structural analysis**
- **Calculation of allowable service life**
Hungarian Regulatory Guide:

- Surface / **subsurface** crack \((a/c = 1/3)\)
- Normal to principal stress in BM, circumferential in WM
- \(a = 1/4 \ t\) or **less if NDT system is qualified** (according to ENIQ) \((a = \text{target flaw size} \approx 0.1 \ t)\)
- Subsurface crack allowed to use if:
  - integrity of cladding is demonstrated by NDT
  - mechanical properties of cladding are known
RPV’s NDT qualification

Qualification Phase I (UT)

Qualification Phase II (UT)

Qualification Phase III (nozzle inner radii, UT)

Qualification Phase IV (cladding ET)

Inner zone

Outer zone

Cladding / BM, WM interface
Further items

• Hungarian standards (2013)
  – MSZ 27003 – Section III
  – MSZ 27011 – Section XI
  – MSZ 27020 – Operation & Maintenance Code (OMC)

Translations

• Registered Professional Engineer equivalent: established (2012)

• Authorized Inspection Agency, Inspector, Supervisor: pending
Paks new-builds requirements

Nuclear Safety Rules say:

• Design standards applied should be accepted in the nuclear industry
  – standards have to be defined in advance, and their applicability should be justified

• Components manufacturing:
  – third party inspection (Authorized Inspection Agency, AIA)
  – regulatory inspection

has to be ensured
Paks new-builds challenges

- Relevant Russian standard: PNAE G-7 series (25-30 years old)
- New standards for components manufacturing and inspection:
  - NP-084-15 (for ISI) – shows similarity to ASME BPVC XI (!)
  - NP-089-15 (for manufacturing) – no relevance to inspection (?)
- ISO 9712 is not widely used
- Inspection qualification (ENIQ methodology) is not used
- Comparison of relevant sections of ASME BPVC and of PNAE G-7 series is quite difficult due to fundamental differences in structure of the codes / standards
- Substantial gap between Hungarian regulatory requirements and Russian regulatory documents / practice