## **AMP 146 CANDU/PHWR INSPECTION PROGRAMMES (VERSION 2021)**

**Programme Description**

Inspection programmes in CANDU and pressurized heavy water reactor (PHWR) nuclear power plants include the Periodic Inspection Programme (PIP) and the In-Service Inspection (ISI) programmes. The PIP is used by certain plants to refer to the inspection programmes mandatorily required by national requirements (e.g., CSA N285.4 “Periodic Inspection of CANDU Nuclear Power Plant Components” [1], CSA N285.5 “Periodic Inspection of CANDU Nuclear Power Plant Containment Components” [2]) for nuclear process systems and special safety systems. ISI refers to an augmented inspection programme implemented by the plant operator (such as FAC ISI [3]) or required by the Regulator (such as Inspection of Deaerators and Hot Water Storage Tanks).

The inspection programmes are developed and implemented to ensure that ageing effects are discovered and corrected (repair or replacement) to ensure structural integrity of the component.

The programmes have been shown to be generally effective in managing ageing effects in CANDU and PHWR nuclear power plants.

**Evaluation and Technical Basis**

1. ***Scope of the ageing management programme based on understanding ageing:***

Periodic inspection is considered to include the fluid boundary portions of components, piping, and supports that comprise systems containing fluid that directly transports heat from nuclear fuel, and systems essential for the safe shutdown of the reactor or the safe cooling of the fuel, as well as other systems or components whose failure could jeopardize the integrity of the aforementioned systems. The extent of systems and components selected for inspection in PIP are based on a screening and Inspection Category (A, B, C1 & C2), considering magnitude of failure (classified as Small, Medium and Large Failure size based on the energy release rate), and safety margin (in term of stress ratio and fatigue cumulative usage factor in Level A and B loading condition).

The containment components subject to periodic inspection include metallic containment boundary components, components required for suppressing or reducing pressure within the containment boundary, and fluid boundaries of systems that form extensions to the containment boundary. Extent of components selected for inspection and determination of inspection methods are based on assessment of the service loads (loads during normal reactor operation) and functional loads (loads generated when containment system is required to perform its safety function), as well as understanding of degradation mechanisms. The inspection programmes (PIP and ISI) include areas subject to inspection, inspection techniques to be used, frequency of inspection, evaluation of inspection results and disposition, as well as repair and replacement requirements.

Periodic Inspection Programme allows sampling schemes for single and multi-unit stations to reduce inspection effort and dose. Samples include the most significant acceptable indications discovered during the inaugural inspection, areas most likely to experience degradation; and areas having the most severe conditions of service in terms of stresses, particularly cyclic stresses. In particular, Clause 7.4.7 of CSA N285.4 [1] establishes requirements for the inspection of systems potentially susceptible to corrosion and erosion.

The results from each inspection are evaluated to determine compliance with the acceptance criteria of, for example [1-2, 4-6].

Supplementary inspection requirements for Fuel Channel Pressure Tubes, Fuel Channel Feeder Pipes, and Steam Generators are discussed in [1], AMP 139, AMP 140, and AMP 116, respectively.

1. ***Preventive actions to minimize and control ageing degradation:***

This is a condition monitoring programme. It does not implement preventive actions. However, if unacceptable indications and deterioration are found in inspection, additional inspections, expansion of inspection scope, and increase in inspection frequency, are considered.

If actual service loading exceeds Level B service loading specified in design specification, or a component is operated outside its design basis, additional inspections are considered. If inspection results reveal deficiency of the water chemistry control programme, updating water chemistry control programme is considered.

1. ***Detection of ageing effects:***

The programmes detect degradation of components by using non-destructive examinations (NDE) methods in one or more of the following groups:

1. Visual — this includes inspection for determining corrosion, erosion, distortion, position, alignment, wear, leakage, defects, fractures, and deterioration by methods such as direct visual inspection and inspection using visual aids (e.g., telescope, closed-circuit television);
2. Dimensional — this includes inspection for determining size, configuration, distortion, wear, alignment, corrosion, and erosion by direct measurement (e.g., use of calipers/gauges) and indirect measurement (e.g., use of ultrasonic and electronic methods);
3. Surface and volumetric — this includes inspection for determining discontinuities by methods such as liquid penetrant, magnetic particle, ultrasonic, radiographic, and eddy current; and
4. Integrative — this includes monitoring overall system or component integrity using leak detection, and acoustic emission and strain measurement.

The sensitivity of the NDE inspection methods prescribed by the programmes should be appropriate for the component and / or degradation effects being inspected.

Inspection can reveal cracking, erosion, corrosion, leakage, wear, relaxation of fitted connections, changes in clearances/settings, physical displacements, loose or missing parts, debris, or loss of integrity at bolted or welded connections.

1. ***Monitoring and trending of ageing effects:***

Periodic inspection is a practice for detecting and monitoring deterioration. This involves comparison and thus it is necessary to have a baseline from which to start. An inaugural inspection stipulated in [1-2,4] is thus conducted and covers all areas intended to receive subsequent periodic inspection.

When an indication is found during inspection to exceed the acceptance standards, it may be left as is, subject to approval by the regulatory authority, provided that a monitoring programme is established for periodic evaluation.

Overall system or component integrity can also be monitored by using leak detection, or acoustic emission, or strain measurement.

1. ***Mitigating ageing effects:***

This is a type of condition monitoring programme. The inspection results are evaluated to determine the need for mitigating actions. For example, methods for water chemistry control are established to control and monitor any adverse effects of the water chemistry conditions on the ageing effect. The programme description and evaluation and technical basis of monitoring and maintaining reactor coolant chemistry are addressed in AMP 103.

1. ***Acceptance criteria:***
2. Indications that show no detectable change since the previous inspection are considered acceptable.
3. Indications that show material erosion or corrosion losses and loss rates that do not exceed the limits specified for the design of the component, piping, or support, at the end of the next periodic inspection interval, are considered acceptable.
4. Unless otherwise specified, the acceptance criteria in accordance with national regulations or governing documents, such as [1-2,4,6], will apply.

Conditions that do not comply with the general acceptance criteria mentioned above may be considered acceptable provided that the fitness-for-service of the component has been demonstrated, to the satisfaction of the regulatory authority, until the end of the next periodic inspection interval.

1. ***Corrective actions:***

The inspection results are evaluated based on documents approved by national regulations and approved fitness-for service guidelines to determine the need for corrective action. If required, a corrective action plan, which includes removal of surface indications, repair, replacement, operation with restrictions, or mitigating actions, is developed and implemented.

1. ***Operating experience feedback and feedback of research and development results:***

This AMP addresses the industry-wide generic experience. Relevant plant-specific operating experience is considered in the development of the plant AMP to ensure the AMP is adequate for the plant. The plant implements a feedback process to periodically evaluate plant and industry-wide operating experience and research and development (R&D) results, and, as necessary, either modifies the plant AMP or takes additional actions (e.g. develop a new plant-specific AMP) to ensure the continued effectiveness of the ageing management.

A mechanism that ensures timely feedback of operating experience as well as research and development results, and provides objective evidence that they are taken into account in the AMP.

PIP and ISI have been widely used over a long period, and have been shown to be generally effective in managing ageing effects for components and their integral attachments in CANDU and PHWR nuclear power plants.

Component specific information on operating experience feedback and on feedback of R&D results is given in [7-17]. Some specific examples of operating experience of component degradation are given in [18].

This programme includes provisions for continuing review of plant-specific and industry-wide operating experience, and research and development results, such that impact on the programme is evaluated and any necessary actions or modifications to the programme are performed.

CSA standard N285.7 [19] defines requirements for the periodic inspection of balance of plant pressure retaining systems, components, and supports that form part of a CANDU nuclear power plant using a risk informed in-service inspection (RI-ISI) methodology. The scope of this standard covers plant systems that are not addressed by CSA N285.4 and N285.5. This standard, which was first published in 2015, is being phased into reactor operating licenses in Canada.

1. ***Quality management:***

Site quality assurance procedures, review and approval processes, and administrative controls are implemented in accordance with the different national regulatory requirements (e.g., CSA N286-05 [20]).

### References

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