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Aging Management for Nuclear Power Plants

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Aging Management for Nuclear Power Plants
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Preface

Regulatory document RD-334, *Aging Management for Nuclear Power Plants* sets out the requirements of the Canadian Nuclear Safety Commission (CNSC) for managing aging of structures, systems, and components (SSCs) of a nuclear power plant (NPP).

Managing aging for nuclear power plants means ensuring the availability of required safety functions throughout the service life of the plant, with account taken of changes that occur with time and use. Aging management requires addressing both physical aging of SSCs, resulting in degradation of their performance characteristics, and obsolescence of SSCs. Aging management applies to SSCs that can, directly or indirectly, have an adverse effect on the safe operation of the NPP.

Aging management is the engineering, operational, inspection, and maintenance actions that control, within acceptable limits, the effects of physical aging and obsolescence of SSCs occurring over time or with use. An aging management program (AMP) is a set of policies, processes, procedures, arrangements, and activities for managing the aging of SSCs of an NPP. Effective aging management ensures reliability and availability of required safety functions throughout the service life of the NPP, in accordance with the licensing basis.

This regulatory document is intended for use by licensees and applicants in establishing, implementing, and improving AMPs for NPPs. Requirements are specified to provide assurance that aging management is properly taken into account in the different phases of an NPP's lifecycle; i.e., in design, fabrication and construction, commissioning, operation (including long-term operation and extended shutdown), and decommissioning.

Requirements are provided for the establishment, implementation, and improvement of AMPs through application of a systematic and integrated approach, including organizational arrangements, data management, SSC selection, aging evaluation and condition assessment processes, AMP documentation, interfaces with other supporting program areas, and AMP review and improvement.

The requirements outlined in this regulatory document are consistent with international guidelines, including *Ageing Management for Nuclear Power Plants*, Safety Guide NS-G-2.12, and *Safe Long Term Operation of Nuclear Power Plants*, Safety Report Series No. 57, both from the International Atomic Energy Agency (IAEA), and the *Glossary of Nuclear Power Plant Ageing* from the Organisation for Economic Cooperation and Development (OECD) Nuclear Energy Agency.

Where appropriate, this regulatory document may be applied to nuclear facilities other than NPPs, with due consideration of the differences compare to those of an NPP in hazard potential and complexity of affected systems.

It is not the intent of this document to override the requirements of other codes and standards but rather to provide the expected framework within which codes and standards are applied to provide assurance that physical aging and obsolescence of SSCs are effectively managed.

This document addresses issues and features that control and enhance nuclear safety. Other health, safety, and environmental considerations may dictate adherence to additional standards. It is the licensee's or applicant's responsibility to identify and comply with all other applicable legislation or standards.

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Aging Management for Nuclear Power Plants

1. Introduction

1.1 Purpose

This regulatory document sets out the requirements of the Canadian Nuclear Safety Commission (CNSC) for managing aging of structures, systems, and components (SSCs) of a nuclear power plant (NPP).

Managing aging for nuclear power plants means ensuring the availability of required safety functions throughout the service life of the plant, with account taken of changes that occur with time and use. Aging management requires addressing both physical aging of SSCs, resulting in degradation of their performance characteristics, and obsolescence of SSCs. Aging management applies to SSCs that can, directly or indirectly, have an adverse effect on the safe operation of the NPP.

This regulatory document is intended for use by licensees and applicants in establishing, implementing, and improving aging management programs (AMPs) for NPPs.

1.2 Scope

This regulatory document sets out CNSC requirements to provide assurance that aging management is appropriately and proactively considered in the different phases of an NPP's lifecycle. The lifecycle phases can apply to individual SSCs as well as the entire NPP. Specific requirements are also provided for establishment, implementation, and improvement of AMPs through application of a systematic and integrated approach.

It is not the intent of this document to override the requirements of other codes and standards but rather to provide a framework within which codes and standards can be applied to provide assurance that physical aging and obsolescence of SSCs are effectively managed.

Where appropriate, this regulatory document may be applied to nuclear facilities other than NPPs, with due consideration of the differences compared to those of an NPP in hazard potential and complexity of affected systems.

1.3 Relevant regulations

The following provisions of the *Nuclear Safety and Control Act* (NSCA; the Act) and the regulations made under the NSCA are relevant to this document:

- subsection 24(4) of the NSCA prohibits the Commission from issuing, renewing, amending or replacing a licence, "unless in the opinion of the Commission, the applicant (*a*) is qualified to carry on the activity that the licence will authorize the licensee to carry on, and (*b*) will, in carrying on that activity, make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of national security and measures required to implement international obligations to which Canada has agreed"
- paragraph 3(1)(*k*) of the *General Nuclear Safety and Control Regulations* states that "an application for a licence shall contain the following information: ... (*k*) the applicant's organizational management structure insofar as it may bear on the applicant's compliance

with the Act and the regulations made under the Act, including the internal allocation of functions, responsibilities and authority"

- subsection 12(1) of the *General Nuclear Safety and Control Regulations* states that "every licensee shall (*c*) take all reasonable precautions to protect the environment and the health and safety of persons and to maintain security of nuclear facilities and nuclear substances;" and "(*f*) take all reasonable precautions to control the release of radioactive nuclear substances or hazardous substances within the site of the licensed activity and into the environment as a result of the licensed activity"
- paragraphs 6(*d*), (*m*), and (*n*) of the *Class I Nuclear Facilities Regulations* state that "an application for a licence to operate a Class I nuclear facility shall contain", in addition to other information,
  "(*d*) the proposed measures, policies, methods and procedures for operating and maintaining the nuclear facility;
  "(*m*) the proposed responsibilities of and qualification requirements and training program for workers, including the procedures for the requalification of workers;
  "(*n*) the results that have been achieved in implementing the program for recruiting, training and qualifying workers in respect of the operation and maintenance of the nuclear facility"
- subsection 14(2) of the *Class I Nuclear Facilities Regulations* states that "every licensee who operates a Class I nuclear facility shall keep a record of (*a*) operating and maintenance procedures" and "(*c*) the results of the inspection and maintenance programs referred to in the licence"
- subsection 14(4) of the *Class I Nuclear Facilities Regulations* states that "every person who is required by [14(2) of those regulations] to keep a record [of the "operating and maintenance procedures" and "the results of the inspection and maintenance programs referred to in the licence"] shall retain the record for 10 years after the expiry date of the licence to abandon issued in respect of the Class I nuclear facility"

1.4 International standards

This regulatory document is consistent with the philosophy and technical content of modern codes and standards. In particular, this regulatory document is based in part on the following international publications:

- *Ageing Management for Nuclear Power Plants*, Safety Guide NS-G-2.12 from the International Atomic Energy Agency (IAEA) [1]
- *Safe Long Term Operation of Nuclear Power Plants*, Safety Report Series No. 57, from the IAEA [2]
- *Glossary of Nuclear Power Plant Ageing* from the Organisation for Economic Cooperation and Development (OECD) Nuclear Energy Agency [3]

2. General Requirements for Aging Management

Effective aging management ensures reliability and availability of required safety functions of SSCs throughout the service life of the NPP, in accordance with the licensing basis. Accordingly, two kinds of time-dependent changes must be addressed: degradation due to physical aging, and obsolescence.

Aging management activities shall be implemented proactively throughout the lifecycle of an NPP or SCC (e.g., in design, fabrication and construction, commissioning, operating, and decommissioning). Specific requirements for the different lifecycle phases are provided in section 3.0.

Licensees shall apply a systematic and integrated approach to establish, implement, and improve programs for managing aging and obsolescence of SSCs. Such an approach is illustrated in Figure 1. NPP management processes shall include requirements to ensure there is a documented overall integrated AMP framework for the NPP. SSC-specific AMPs shall be implemented in accordance with the overall integrated AMP framework, and shall address the attributes of an effective AMP as presented in Appendix A. Specific requirements for AMPs are provided in section 4.0.

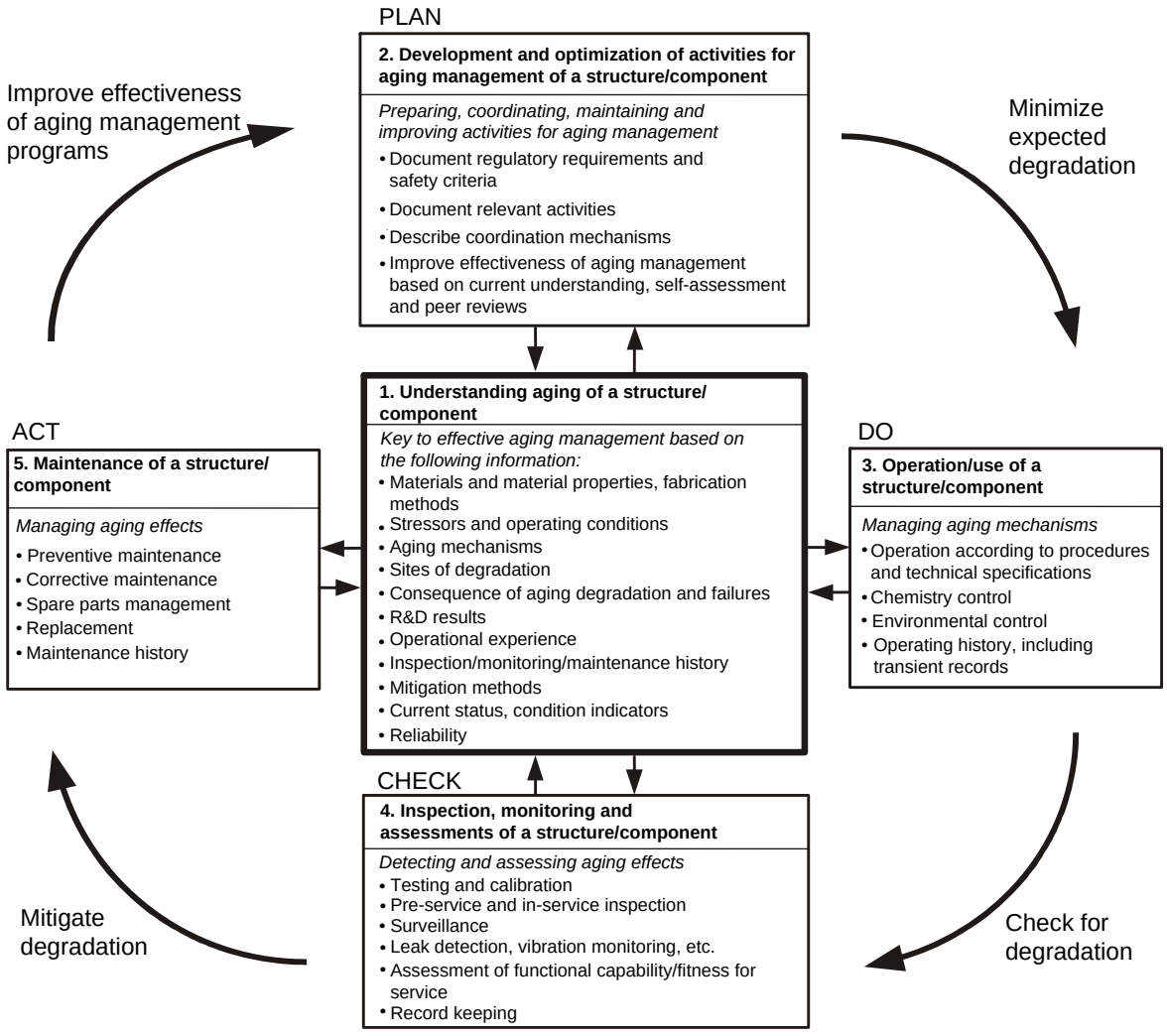

Figure 1: Systematic and integrated approach to manage aging [1].

3. Requirements for Proactive Management

The following subsections provide CNSC requirements for aging management activities during the lifecycle phases of an NPP. The lifecycle phases can apply to individual SSCs as well as the entire NPP.

3.1 Design

Appropriate measures shall be taken and design features shall be introduced in the design stage to facilitate effective aging management throughout the lifetime of the NPP. RD-337, *Design of New Nuclear Power Plants* [4] establishes design requirements for new NPPs.

Aging management shall also be considered in the design of modifications to existing operating plants, and for design changes related to modifications and repairs or replacements of individual SSCs.

The following aspects relating to aging management shall be taken into account:

1. apply a systematic approach at the design stage to ascertain the understanding of aging of SSCs, to evaluate effective approaches and design features for aging prevention, monitoring, and mitigation, and to establish AMPs for SSCs (see sections 4.3, 4.4, and 4.6)

2. consider the effects and interactions between mechanical, thermal, chemical, electrical, physical, biological and radiation stressors on materials properties, materials aging and degradation processes. In design documentation, demonstrate how past relevant generic aging issues, relevant aging management experience, and research results are addressed

3. define the safe service life or qualified life for SSCs in the design documentation, with an assessment of design margins that takes into account all known aging and wear mechanisms and potential degradation, including the effects of testing and maintenance processes. Identify SSCs that have shorter service life than the NPP life and provide management strategies in the design documentation

4. consider aging effects under design basis conditions, including transient conditions and postulated initiating event conditions, in the specifications for equipment qualification programs, e.g., environmental qualification and seismic qualification programs

5. include features in the plant layout and design of SSCs to facilitate inspection, testing, surveillance, maintenance, repair, and replacement activities, and to keep potential radiation exposures from these activities as low as reasonably achievable (ALARA)

6. specify the reference (baseline) and other pre-service, inaugural, or in-service inspection and test data that is required to be collected and documented for aging management purposes during fabrication, construction, commissioning, operation, and decommissioning

7. identify potential obsolescence issues for SSCs, evaluate effects on safety and reliability performance, and provide management strategies

8. in design document, specify any special process applied to fabrication (or manufacturing) and construction of SCCs that prevent, mitigate, or eliminate known aging mechanisms, for example, heat treatment, surface finishing, cure time, etc.

9. specify required provisions for aging management in procurement documents for new facilities and SSCs, including documents from suppliers and other contractors (design institutions, vendors, manufacturers, inspection agencies, etc.)

3.1.1 Aging management content in safety analysis reports

The safety analysis for the NPP shall account for the cumulative effects of aging degradation of SSCs on overall systems and plant safety performance [5, 6].

Aging management shall be addressed in the safety analysis report for the NPP, including the following items:

1. an outline of the proactive strategy for aging management and prerequisites for its implementation

2. safety significant SSCs of the NPP that could be affected by aging

3. assumptions, methods, acceptance criteria, and data used to account for the effects of SSC aging in the safety analysis, including any time-limited assumptions and failure data for probabilistic safety assessments

4. critical service conditions, operational limits and conditions, and any other parameters to be monitored and/or controlled that affect aging assumptions used in safety analyses or equipment qualification

5. data and information to be collected for aging management in order to confirm safety analysis assumptions and acceptance criteria continue to be met

Periodic reviews of the safety analysis reports are to include operating experience and research findings with respect to aging and the implementation of the results of that analysis (see also section 3.4.1).

3.2 Fabrication, construction, and installation

Aging management shall be considered in the fabrication, construction, and installation processes for new NPPs, and the processes for modifications, repairs, and replacements of SSCs for existing operating NPPs.

Methods to ensure that fabrication (or manufacturing), construction, and installation processes do not adversely affect aging performance of SSCs shall be defined in relevant procedures.

Licensees are to ensure that:

1. current knowledge about relevant aging mechanisms, effects/degradation, and possible preventive and mitigation measures are taken into account in fabrication, construction, and installation of SSCs

2. relevant information on the factors affecting aging management and parameters influencing aging degradation is clearly specified in procurement documents and provided to SSC suppliers and contractors

3. suppliers and contractors adequately address factors affecting aging management

4. reference (baseline) data required for aging management are collected and documented

5. surveillance specimens for specific aging monitoring programs are made available and installed in accordance with design specifications

3.3 Commissioning

Aging management shall be considered in the commissioning activities for new NPPs, and projects for existing NPPs involving major repairs, replacements and modifications of SSCs.

Appropriate measures shall be taken to ensure that baseline data required for aging management of SSCs is recorded during commissioning. This includes mapping the actual service and environmental conditions in each critical spot of the plant or SSC.

Parameters influencing aging degradation shall be identified, monitored, and controlled during commissioning activities.

Critical service conditions and parameters, such as those considered in equipment qualification and aging assumptions in the design and safety analyses, shall be verified.

3.4 Operation

Licensees shall establish and implement processes, programs, and procedures to manage aging and obsolescence of SSCs to ensure that required safety functions are maintained during the plant operation phase. Specific additional information is provided in section 4.0.

Facility operations shall be monitored and recorded to demonstrate compliance with critical service conditions, operational limits and conditions (OLCs), and any other parameters that were identified (see section 3.1.1) as affecting aging assumptions used in safety analyses or equipment qualification.

In the event of operational changes or modifications to SSCs, a review of possible changes in environmental or process conditions (e.g., flow pattern, velocity, vibration) that could affect aging and failure of SSCs (see also section 3.1) shall be performed.

Corrective actions identified by AMP activities shall be managed within the NPP Corrective Action Program.

Measures shall be taken to ensure that spare or replacement parts and consumables are stored in appropriately controlled environments to preclude aging degradation due to their storage environment (e.g., high or low temperatures, moisture, chemical attack, dust accumulation), taking shelf life into account.

3.4.1 Review and update of safety analysis

As part of the safety analysis review and update, licensees shall account for the effects of SSC aging, research findings, and advances in knowledge and understanding of aging mechanisms, including an evaluation of the cumulative effects of SSC aging on overall system and plant safety performance, and on risk.

3.4.2 Long-term operation

A licensee may choose to implement a project for the purpose of long-term operation of the NPP beyond its assumed design life. In such cases, the licensee shall complete an in-depth review of the effects of aging on NPP safety and evaluate the effectiveness of AMPs for long-term operation in order to identify corrective actions and areas for improvement. Condition assessments are to be completed as part of the review of aging for long-term operation (see section 4.5).

The review shall demonstrate that:

1. all SSCs that can, directly or indirectly, have an adverse effect on the safe operation of the NPP are evaluated for the proposed period of long-term operation

2. the effects of aging will continue to be identified and managed for these SSCs during the planned period of long-term operation

3. all safety analyses involving time-limited assumptions are validated for the proposed period of long-term operation to ensure that the aging effects will be effectively managed (i.e., to demonstrate that the intended function of an SSC will remain within the design safety margins throughout the planned period of long-term operation)

The results of the review of aging management for long-term operation shall be documented, and the findings shall be addressed.

3.4.3 Extended shutdowns

Extended shutdowns are reactor shutdowns lasting for a period exceeding one year, and exclude shutdowns for regular maintenance outages. During extended shutdowns, SSCs may need to be placed in temporary lay-up or safe-storage states which require supplementary measures and controls to prevent aging degradation.

Licensees shall review and, where necessary, revise SSC-specific AMPs to ensure that relevant factors affecting aging degradation are taken into account for SSCs placed in lay-up or safe-storage states during extended shutdowns. Required provisions for aging management shall be defined in the system lay-up specifications or preservation plans, including requirements for any condition assessments to be completed prior to the return to service of an NPP following an extended shutdown (see section 4.5).

3.5 Decommissioning

Licensees shall establish and implement aging management activities in decommissioning plans and procedures for those SSCs that are required to remain available and functional during decommissioning.

4. Integrated Aging Management

Licensees shall apply a systematic and integrated approach to establish, implement, and improve appropriate programs to manage aging and obsolescence of SSCs. NPP management processes shall include requirements to ensure there is a documented overall integrated AMP framework for the NPP that addresses the following elements:

- organizational arrangements
- data collection and record keeping
- screening and selection process for aging management
- evaluations for aging management
- condition assessments
- SSC-specific AMPs
- management of obsolescence
- interfaces with other supporting plant programs
- implementation of AMPs
- review and improvement of AMPs

SSC-specific AMPs shall be implemented in accordance with the overall integrated AMP framework.

Detailed requirements are provided in the following sections. Alternative approaches may be acceptable, provided these elements are addressed in an equivalent manner that is demonstrated to be effective in managing aging.

4.1 Organizational arrangements for effective aging management

The NPP management processes shall include requirements to ensure that appropriate organizational arrangements are established to facilitate the effective implementation of AMPs, including consideration of the following aspects:

1. established policy and objectives of the overall integrated AMP framework, allocated resources (such as human, financial, training, tools, and equipment), and processes to monitor the program to ensure that it is meeting its objectives

2. defined responsibilities for the implementation of aging management activities

3. provision for training to operations, maintenance, engineering, and other pertinent staff to ensure they have an adequate awareness and understanding of aging management concepts and program requirements

4. external organizations required for specific services related to aging management, such as specialized inspections, assessments, research, and standards development.

4.2 Data collection and record keeping system to support aging management

The licensee shall have an appropriate data collection and record keeping system to support aging management activities and provide a basis for decisions on the type and timing of aging management actions. Data and records relevant to aging management shall include:

1. reference (baseline) data on the design, fabrication, and construction of the plant or SSC and conditions at the beginning of the service life, including results of equipment qualification tests, inspections, commissioning tests, and mappings of environmental conditions during commissioning

2. data on the operating history of the plant, service conditions for SSCs (including transient data), chemistry conditions, SSC condition indicators, event reports, and data on the testing of availability and failure of SSCs

3. results of in-service inspections and material surveillance, including inspection specifications and results, as well as findings that exceed reporting levels

4. data on the maintenance history, including data on the monitoring of the condition and maintenance of components and structures, assessments of aging related failures or significant degradation of SSCs, including results of root cause analyses

5. records of SSC aging evaluations and condition assessments, AMP performance indicators, internal and external operating experience, and research results

Data entered into the system shall be auditable, to demonstrate an adequate verification of the data entered, detailed description of the basis for any conclusion, and all applicable references to source information.

4.3 Screening and selection of structures, systems and components

A documented screening and selection process shall be used to establish the list of SSCs to be included in the scope of the overall integrated AMP framework; i.e., SSCs susceptible to aging degradation or aging effects that can, directly or indirectly, have an adverse effect on the safe operation of the NPP. This process shall include SSCs that do not have safety functions but whose failure could prevent other safety-related SSCs from performing their intended functions.

The documentation for the screening and selection process includes the methodology, information sources, and criteria used, along with the final list of SSC elements and components in related categories with potential aging mechanisms and sites of concern.

4.4 Evaluations for aging management

The NPP management processes and procedures shall include requirements for conducting, documenting, and keeping records of evaluations for aging management. The evaluations address the following elements:

1. understanding aging
2. preventive actions to minimize and control aging degradation
3. methods for detection, monitoring, and trending of aging effects
4. methods for mitigating aging effects and corrective actions

4.4.1 Understanding aging

NPP management processes shall include requirements for the evaluation of the current understanding of aging for the selected SSCs. The evaluation identifies:

1. SSC design and licensing basis requirements relevant to aging and aging management (including applicable codes and standards, safety analysis, safety functions, and consequences of failure)

2. SSC materials, service conditions, stressors, degradation sites, aging mechanisms and effects

3. indicators of SSC physical or functional condition (condition indicators)

4. anticipated obsolescence issues

5. quantitative or qualitative models for predicting relevant aging effects, and any gaps in the understanding

6. SSC life-limiting conditions and acceptance criteria against which the need for corrective action is evaluated

7. a list of data needs for the assessment of SSC aging (including any deficiencies in the availability and quality of existing records)

4.4.2 Preventive actions to minimize and control aging degradation

Methods to prevent and control aging degradation shall be evaluated to establish appropriate actions that can be taken. The evaluation identifies:

1. preventive actions to be taken in the design, selection of materials and coatings, fabrication and construction practices, commissioning, service conditions, and preventive operation and maintenance practices

2. parameters to be monitored or inspected to ensure the preventive actions are effective

3. service conditions (environmental conditions and operating conditions) to be maintained and operating practices aimed at slowing down potential degradation of the structure or component

4.4.3 Methods for detection, monitoring, and trending aging effects

The effectiveness of methods for timely detection and characterization of aging degradation shall be evaluated, with account taken of relevant operating experience and research results, to establish appropriate strategies and requirements for inspection, surveillance, testing, sampling, and monitoring programs for aging of SSCs. The evaluation identifies:

1. parameters and condition indicators for detecting, monitoring, and trending aging degradation of the structure or component

2. effective technology (inspection, testing, surveillance, and monitoring methods) for detecting aging effects before failure of the SSC with sufficient sensitivity, reliability, and accuracy

3. data to be collected to facilitate assessment of SSC aging

4. data evaluation techniques for recognizing significant degradation and for predicting future performance of the SSC (including data analysis and trending)

4.4.4 Methods for mitigating aging effects and corrective actions

The effectiveness of methods for timely mitigation and correction of detected active aging effects and degradation shall be evaluated to establish appropriate strategies and requirements for preventive and corrective maintenance, repairs, replacements (including refurbishment and periodic replacement of items), and/or design modifications.

4.5 Condition assessments

NPP management processes shall include requirements to evaluate the actual condition of an SSC at the initiation of the SSC-specific AMP and at periodic intervals throughout the service life of the NPP or SSC as required to validate AMP effectiveness.

The condition assessments provide information on:

1. the current performance and condition of the SSC, including assessment of any aging related failures or indications of significant material degradation, previously unidentified aging mechanisms or effects, and comparisons against predictions for the aging mechanisms and acceptance criteria

2. estimation of future performance, aging degradation, and residual service life, where feasible, of the SSC (i.e., the length of time the SSC is likely to meet its function and performance requirements)

3. recommended follow-up or prevention, monitoring, and mitigation measures to be completed and/or incorporated into the AMP, including appropriate intervals for follow-on condition assessments and areas for further research and development

The procedure for conducting condition assessments and the results shall be documented.

4.6 SSC-specific aging management programs

NPP management processes shall include requirements to develop, document, and maintain a specific program for the aging management of SSCs (or groups of structures and components) selected by the screening process, or alternatively a program for managing a specific aging mechanism or effect.

The SSC-specific AMP shall be commensurate with the importance to safety, design function and required performance of the SSC, and its effect on the safe operation of the NPP.

The effectiveness of existing practices needs to be confirmed in light of completed aging evaluations and condition assessments (see sections 4.4 and 4.5) and the applicable recommendations for the SSC-specific AMP need to be implemented.

The SSC-specific AMPs shall be documented and address the attributes of an effective AMP as listed in Appendix A.

4.7 Management of technological obsolescence

The licensee shall establish a program for management of technological obsolescence.

The provisions for the management of obsolescence shall be documented, and included in the overall integrated AMP framework or as part of SSC-specific AMPs.

4.8 Interfaces with other supporting programs

All supporting programs and activities that are credited as an integral part of the NPP aging management shall be identified, and their interfaces and information requirements defined in the overall integrated AMP framework document, including safety analysis 56, 6], maintenance [7], and reliability programs [8].

4.9 Implementation of AMPs

The overall integrated AMP framework and SSC-specific AMPs and major actions relating to aging management shall be implemented under the licensee's management system for the facility. The implementation shall provide a systematic aging management process, based on understanding of aging, consisting of the following aging management tasks (see Figure 1):

- planning activities including documentation of applicable regulatory requirements and safety and reliability criteria, relevant programs and activities
- operation within operating guidelines aimed at minimizing the rate of degradation
- inspection and monitoring activities aimed at timely detection and assessment of aging degradation
- maintenance activities aimed at mitigating aging effects and corrective actions for unacceptable degradation

The implementation of AMPs includes periodic reporting on the performance of SSCs and on the indicators of effectiveness of the integrated AMP framework and SSC-specific AMPs.

Data identified in the AMP shall be collected and recorded to provide a basis for decisions on the type and timing of aging management actions.

4.10 Review and improvement

The effectiveness of the overall integrated AMP framework and SSC-specific AMPs shall be periodically reviewed using feedback from the program and performance indicators.

The licensee shall update the AMPs and interfacing programs, and their implementation, to improve their effectiveness based on the results of the review as appropriate.

Glossary

acceptance criteria
Specified bounds on the value of a functional indicator or condition indicator used to assess the ability of a structure, system, or component (SSC) to perform its design function.

aging
A general process in which characteristics of an SSC gradually change over time or with use. This process may proceed by a single aging mechanism or by a combination of several aging mechanisms. Non-physical aging is the process of becoming out-of-date (obsolete) owing to the evolution of knowledge and technology and associated changes in codes and standards. Physical aging is due to physical, mechanical, thermal, electrical, chemical, irradiation and/or biological processes (aging mechanisms).

aging degradation
Aging effects that could impair the ability of an SSC to function within its acceptance criteria.

aging effects
Net changes in the characteristics of an SSC that occur with time or use and are due to aging mechanisms.

aging management
Engineering, operations, inspection, and maintenance actions to control, within acceptable limits, the effects of physical aging and obsolescence of SSCs.

aging management program (AMP)
A set of policies, processes, procedures, arrangements, and activities that provides direction for managing the aging of an NPP's SSCs.

aging mechanism
A specific process that gradually changes characteristics of an SSC with time or use, such as thermal or radiation embrittlement, corrosion, fatigue, creep, erosion, etc.

assumed design life
The period of operation that was originally anticipated at the design phase for the NPP. It is used as a reference or target for planning activities including the design of SSCs that can affect the safe operation of the NPP.

commissioning
Process consisting of activities intended to demonstrate that installed SSCs and equipment perform in accordance with their specifications and design intent before they are put into service.

common cause failure
A concurrent failure of two or more structures, systems, or components due to a single specific event or cause, such as natural phenomena (earthquakes, tornadoes, floods, etc.), design deficiency, manufacturing flaws, operation and maintenance errors, human-induced destructive events, aging effects and others.

condition assessment
An assessment performed to determine current performance and condition of an SSC (including assessment of any age-related failures or indications of significant material degradation), and to predict future performance, extent and rate of aging degradation, and residual service life of the SSC.

condition indicator
A characteristic of an SSC that can be observed, measured, or trended to infer or directly indicate the current and future ability of an SSC to function within acceptance criteria.

defence in depth
The application of more than one protective measure for a given safety objective, such that the objective is achieved even if one of the protective measures fails.

design basis
The range of conditions and events taken explicitly into account in the design of a facility, according to established criteria, such that the facility can withstand them without exceeding authorized limits by the planned operation of safety systems.

failure
The inability or interruption of ability of an SSC to function within acceptance criteria.

functional indicator
A condition indicator that is a direct indication of the current ability of an SSC to function within acceptance criteria.

licensing basis
For a regulated facility or activity, the set of requirements and documents comprising:
(i) the regulatory requirements set out in the applicable laws and regulations
(ii) the conditions and safety and control measures described in the facility's or activity's licence and the documents directly referenced in that licence
(iii) the safety and control measures described in the licence application and the documents needed to support that licence application.

long-term operation
Operation beyond the assumed design life of the NPP, which has been justified by the results of an integrated safety review taking into consideration the conditions of SSCs, life-limiting processes, and a review of the plant design and operational measures in place against modern codes and practices.

maintenance
The organized activities, both administrative and technical, of keeping structures, systems, and components in good operating condition, including both preventive and corrective (or repair) aspects.

management system
A set of interrelated or interacting elements (system) for establishing policies and objectives and enabling the objectives to be achieved in an efficient and effective way. The management system integrates all elements of an organization into one coherent system to enable all of the organization's objectives to be achieved. These elements include the structure, resources, and processes. Personnel, equipment, and organizational culture as well as the documented policies and processes are parts of the management system. The organization's processes have to address the totality of the requirements on the organization as established in, for example, IAEA safety standards and other international codes and standards.

nuclear power plant (NPP)
Any nuclear fission reactor installation that has been constructed to generate electricity on a commercial scale and is a Class 1A nuclear facility, as defined in the *Class I Nuclear Facilities Regulations*.

operational limits and conditions
The set of limits and conditions that can be monitored by, or on behalf of, the operator and can be controlled by the operator.

root cause analysis
An objective, structured, systematic and comprehensive analysis that is designed to determine the underlying reason(s) for a situation or event, and that is conducted with the level of effort that is consistent with the safety significance of the event.

safety functions
A specific purpose that must be accomplished by an SSC for safety, including those necessary to prevent accident conditions and to mitigate the consequences of accident conditions.

safety systems
Systems provided to ensure the safe shutdown of the reactor or the residual heat removal from the core, or to limit the consequences of anticipated operational occurrences and design basis accidents.

service life
The period from initial operation to final withdrawal from service of an SSC.

stressor
An agent or stimulus stemming from pre-service and service conditions that can produce immediate or gradual aging degradation of an SSC. Examples include heat, steam, chemicals, radiation, and electrical cycling.

structures, systems, or components (SSCs)
A general term encompassing all of the elements (items) of a facility or activity that contribute to protection and safety, except human factors. Structures are the passive elements: buildings, vessels, shielding, etc. A system comprises several components, assembled in such a way as to perform a specific (active) function. A component is a discrete element of a system. Examples are wires, transistors, integrated circuits, motors, relays, solenoids, pipes, fittings, pumps, tanks, and valves.

testing
The observation or measurement of condition or functional indicators under controlled conditions to verify that the current performance of an SSC conforms to acceptance criteria.

time-limited assumptions
Assumptions used in certain plant- or SSC-specific safety or design analyses that are based on an explicitly specified length of plant or SSC life; for example, metal fatigue calculation, pressurized thermal shock (PTS) analysis, radiation-induced deformation and embrittlement, thermal aging, loss of material, and equipment qualification of electrical equipment, instrumentation and control (I&C) equipment, and cables are included in the analyses.

References

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3. Organisation for Economic Cooperation and Development (OECD) Nuclear Energy Agency; *Glossary of Nuclear Power Plant Ageing*, Paris, France, 1999
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Appendix A: Attributes of an Effective Aging Management Program

Table 1: Attributes of an effective AMP (adapted from IAEA NS-G-2.12 [1]).

No.	Attribute	Description
1	Scope of the AMP based on understanding aging	Systems, structures (including structural elements) and components subject to aging management Understanding of aging phenomena (significant aging mechanisms, susceptible sites): • design and licensing basis requirements relevant to aging • SSC materials, service conditions, stressors, degradation sites, aging mechanisms and effects • SSC condition indicators and acceptance criteria • quantitative or qualitative predictive models of relevant aging phenomena
2	Preventive actions to minimize and control aging degradation	Identification of preventive actions Identification of parameters to be monitored or inspected Service conditions (i.e. environmental conditions and operating conditions) to be maintained and operating practices aimed at slowing down potential degradation of the structure or component
3	Detection of aging effects	Effective technology (inspection, testing and monitoring methods) for detecting aging effects before failure of the SSC
4	Monitoring and trending of aging effects	Condition indicators and parameters to be monitored Data to be collected to facilitate assessment of structure or component aging Assessment methods (including data analysis and trending)
5	Mitigating aging effects	Operations, maintenance, repair and replacement actions to mitigate detected aging effects / degradation of SSCs
6	Acceptance criteria	Acceptance criteria against which the need for corrective action is evaluated
7	Corrective actions	Corrective actions if a component fails to meet the acceptance criteria

8	Operating experience feedback and feedback of R&D results	Mechanism that ensures timely feedback of operating experience and R&D results (if applicable), and provides objective evidence that they are taken into account in the AMP
9	Quality management	Organizational roles and responsibilities Administrative controls that document the implementation of the AMP and actions taken Indicators to facilitate evaluation and improvement of the AMP Confirmation (verification) process for ensuring that preventive actions are adequate and appropriate and all corrective actions have been completed and are effective Record keeping practices to be followed References