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Fitness for Service

Aging Management

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Preface

This regulatory document is part of the CNSC's Fitness for Service series of regulatory documents, which also covers reliability and maintenance programs for power reactor facilities. The full list of regulatory document series is included at the end of this document and can also be found on the CNSC's website at nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-documents

REGDOC-2.6.3, *Aging Management*, sets out the requirements of the CNSC for managing aging of structures, systems and components (SSCs) of a power reactor facility. It also provides guidance as to how these requirements may be met. This document replaces RD-334, *Aging Management for Nuclear Power Plants*, which was published in June 2011.

Aging management is the set of engineering, operational, inspection and maintenance actions that control, within acceptable limits, the effects of physical aging and obsolescence of SSCs that occur over time or with use. An aging management program or plan is a set of policies, processes, procedures, arrangements and activities for managing the aging of SSCs of a reactor facility. Effective aging management ensures that required safety functions are reliable and available throughout the service life of the facility, in accordance with the licensing basis.

This document is intended to form part of the licensing basis for a regulated facility or activity. It is intended for inclusion in licences as either part of the conditions and safety and control measures in a licence, or as part of the safety and control measures to be described in a licence application and the documents needed to support that application.

Important note: Where referenced in a licence either directly or indirectly (such as through licensee-referenced documents), this document is part of the licensing basis for a regulated facility or activity.

The licensing basis sets the boundary conditions for acceptable performance at a regulated facility or activity and establishes the basis for the CNSC's compliance program for that regulated facility or activity.

Where this document is part of the licensing basis, the word "shall" is used to express a requirement to be satisfied by the licensee or licence applicant. "Should" is used to express guidance or that which is advised. "May" is used to express an option or that which is advised or permissible within the limits of this regulatory document. "Can" is used to express possibility or capability.

Nothing contained in this document is to be construed as relieving any licensee from any other pertinent requirements. It is the licensee's responsibility to identify and comply with all applicable regulations and licence conditions.

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Aging Management

1. Introduction

1.1 Purpose

REGDOC-2.6.3, *Aging Management*, sets out the requirements of the CNSC for managing the aging of structures, systems and components (SSCs) of a power reactor facility. Guidance is also provided as to how these requirements may be met.

Managing the aging of a reactor facility means to ensure the availability of required safety functions throughout the facility's service life, with consideration given to changes that occur over time and with use. This requires addressing both physical aging and obsolescence of SSCs where this can, directly or indirectly, have an adverse effect on the safe operation of the reactor facility.

This document is intended for use by licensees and applicants in establishing, implementing and improving aging management (AM) programs and plans for reactor facilities.

1.2 Scope

Aging Management sets requirements to provide assurance that aging management is appropriately and proactively considered in the different phases of a reactor facility's lifecycle. The lifecycle phases can apply to individual SSCs as well as the entire reactor facility. Specific requirements are also provided for establishment, implementation and improvement of AM programs and plans through application of a systematic and integrated approach.

This document provides 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 document may be applied to other nuclear facilities, with due consideration of the differences compared to those of a power reactor facility in hazard potential and complexity of affected systems.

1.3 Relevant legislation

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

- Subsection 24(4) of the NSCA states that "No licence shall be issued, renewed, amended or replaced – and no authorization to transfer one given - unless, in the opinion of the Commission, the applicant or, in the case of an application for an authorization to transfer the licence, the transferee (*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"
- Paragraphs 12(1)(*c*) and (*f*) of the *General Nuclear Safety and Control Regulations* state 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"
- Paragraphs 14(2)(*a*) and (*c*) 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 this section to keep a record referred to in paragraph (2)(*a*) to (*d*) or (3)(*a*) to (*d*) 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 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 Concepts

2.1 Aging and obsolescence of structures, systems and components

Guidance

The SSCs of a reactor facility experience two kinds of time-dependent changes:

- physical aging, in which the physical and/or performance characteristics of SSCs degrade with time or use
- technology aging or obsolescence, in which SSCs become out-of-date relative to current knowledge, standards and technology

Over time, and if not properly managed, physical aging can reduce the ability of a structure, system or component to perform its safety functions within the limits and specifications assumed in the design basis and safety analysis. Several aging mechanisms can combine synergistically to cause unexpected or accelerated aging effects, or premature failure of a component or structural element. The aggregate of multiple degraded components or elements can significantly degrade the safety performance of a system or structure. For instance, while individual degraded components might meet their respective fitness-for-service criteria, the combined effect of all the multiple degraded components could still result in unacceptable safety performance of a system or facility.

Reactor facility safety can also be affected if obsolescence of SSCs is not identified and corrected before associated declines occur in their reliability or availability. This is more likely to apply to systems and components (particularly instrumentation and control) rather than the main structural elements of a facility (although there are examples of the latter, such as concrete expansion anchors). SSCs at risk of obsolescence need to be identified to ensure that an adequate supply of spare parts is available until an appropriate solution is found. The solution will depend on the particular circumstances, but may involve providing alternative components or items of equipment that can carry out the same safety duty. It could also involve redesigning the facility to remove the need for the obsolescent system or components.

Physical aging and obsolescence of SSCs can lead to increased probability of failure or common-cause failures, as well as reduced defence in depth. Other consequences may include:

- the need to de-rate the reactor power to maintain safety margins
- forced or unplanned outages
- significantly extended or more frequent maintenance outages
- additional inspections/monitoring of corrective maintenance and repairs
- increase in dose to the associated workers
- or, in extreme cases, the premature shutdown of a facility

Accordingly, both physical aging and obsolescence of SSCs in reactor facilities should be understood and managed effectively and proactively at each stage of the lifecycle of a reactor facility and its SSCs. This should begin with design, fabrication and construction and commissioning, and continue through operation (including extended or long-term operation, and during any extended shutdowns) and during decommissioning. Particular attention should be paid to aging phenomena that might affect the availability of SSCs that, directly or indirectly, have an adverse effect on the safe operation of the reactor facility. Attention should also be paid to aging effects on SSCs that do not have safety functions, but whose failure could prevent safety-related

SSCs from performing their intended functions for design-basis accidents, or that should be relied upon for design extension conditions. Specific requirements for the different lifecycle phases are provided in section 3.0.

2.2 Systematic and integrated approach to aging management

Guidance

Effective aging management uses a systematic approach providing an integrated framework for coordinating all supporting programs and activities associated with the understanding, control, monitoring and mitigation of aging effects at the facility. This approach (see figure 1) is an adaptation of Deming's "PLAN-DO-CHECK-ACT" cycle related to the aging management of an SSC[1] :

1. Effective aging management of a system, structure or component relies upon an understanding of how it ages. This understanding involves consideration of the design basis (including applicable codes and standards), safety analysis, safety functions, design and fabrication, materials, operation and maintenance history, generic and facility-specific operating experience, relevant research results, and identification of potential obsolescence concerns.
2. The PLAN activity involves coordinating, integrating, and modifying existing programs and activities that relate to managing the aging and obsolescence of a system, structure or component, and if necessary, developing new programs.
3. The DO activity is the minimization of expected degradation of a system, structure or component through its prudent operation or use in accordance with operating procedures and technical specifications.
4. The CHECK activity is the timely detection and characterization of significant degradation through inspection and monitoring of a structure or component, and the assessment of observed degradation to determine the type and timing of corrective actions required.
5. The ACT activity is the timely mitigation and correction of component degradation through appropriate maintenance and design modifications, including component repair and replacement of a structure or component.

This process relies on the continuous improvement of an aging management program, based on improved understanding of component aging and on the results of self-assessment and peer reviews. The information obtained through this approach provides important inputs to existing facility programs, such as maintenance and operations.

In practice, effective aging management requires the involvement and support of many internal and external organizations, and essential facility programs and processes. Examples include:

- deterministic safety analysis
- probabilistic safety assessment
- design, engineering change control
- periodic and in-service inspection programs
- equipment reliability
- maintenance programs
- environmental qualification programs

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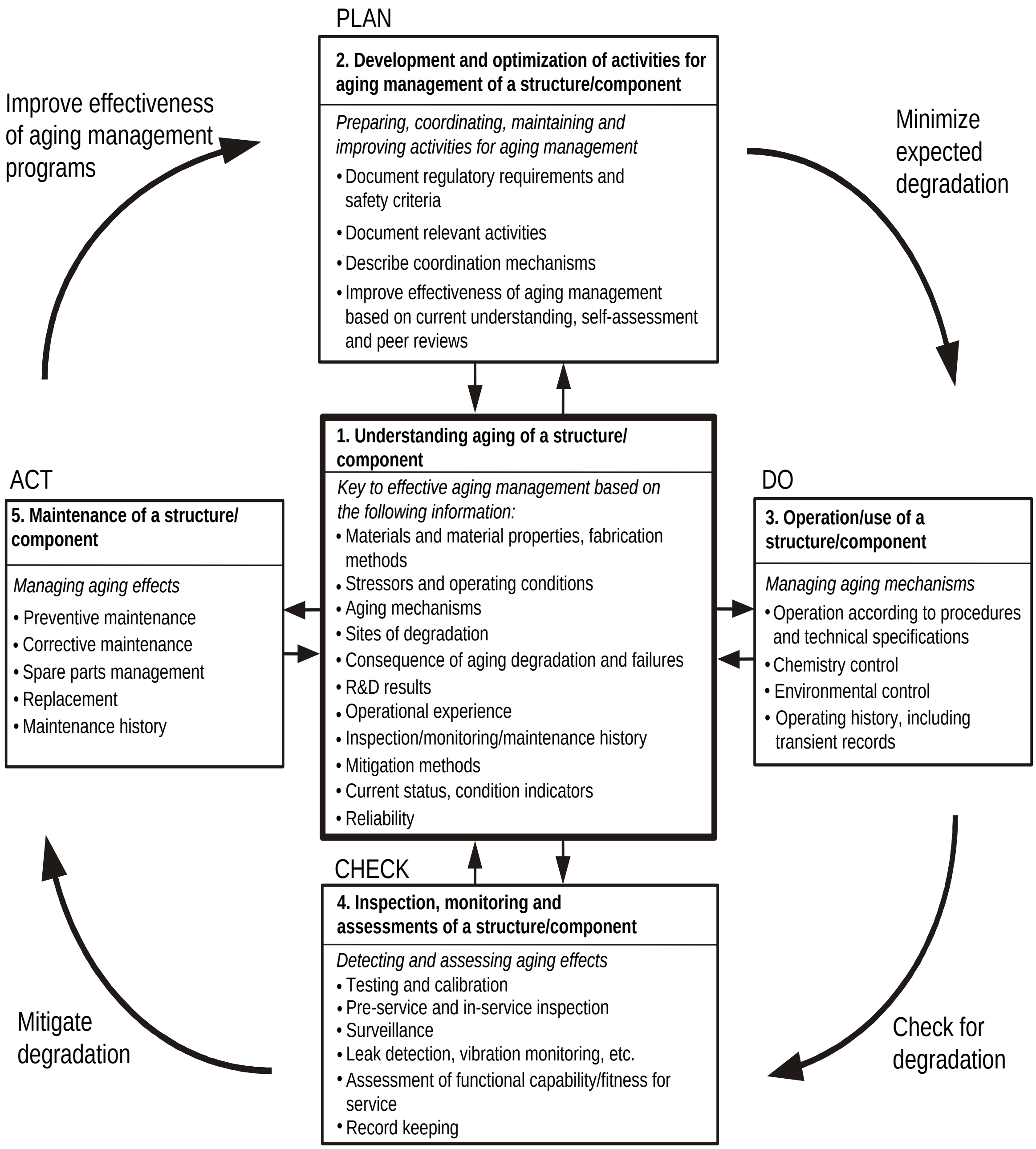
[1] IAEA Safety Report Series No. 57, *Safe Long Term Operation of Nuclear Power Plants*[2]

- system health monitoring programs
- operating procedures, chemistry programs
- operating experience, significant events analysis and research programs

See the References section, items 4–18, for applicable CNSC regulatory documents and CSA Group standards. While each of these facility programs and processes contribute to aging management, this is usually not their primary purpose or focus; none of these programs or processes, provide a complete program or process for managing the aging of SSCs.

Figure 1: A systematic and integrated approach to aging management [2]



Reliability and maintenance programs typically do not include passive, long-life SSCs (such as reactor assembly components, fuel channels, feeders, steam generators, pressure vessels and piping, structures and cables) that are difficult or impossible to replace or change except in an extended maintenance or refurbishment outage. Inspection and surveillance programs provide information used to confirm the current condition or fitness for service of these SSCs.

Lifecycle management plans are developed for structures and components, but do not typically consider the effects of other components or overall system safety performance. An important aspect is the determination of the impact of aging on facility safety, including safety margins as determined through an updated deterministic safety analysis, which requires a systematic and integrated approach to aging management.

The licensee’s management system processes should therefore include requirements to ensure there is a documented overall integrated AM program framework for the reactor facility. The integrated AM program framework should provide a comprehensive, umbrella-type program. Alternatively, the AM program framework could include a “road map” document that demonstrates how the current processes and programs meet requirements for effective aging management. Aging management does not necessarily replace existing programs but, on the basis of evaluation, modifies them (reduces, enhances, eliminates, or supplements them) to achieve a systematic, integrated program for effective aging management.

SSC-specific or mechanistic-based AM plans should be established and implemented in accordance with the licensee’s integrated AM program framework, and should address the attributes of an effective AM plan as presented in appendix A. The scope of the AM plans for SSCs should be commensurate with the importance to safety, design function and required performance of the SSCs, and its effect on the safe operation of the reactor facility.

Existing facility programs or practices that are credited as AM plans (such as equipment life cycle management plans, system health monitoring programs, water chemistry programs, inspection programs, and environmental qualification programs) should be evaluated against the attributes listed in appendix A. Programs or plans that do not include these attributes should be modified as appropriate. For example, existing system health, maintenance or inspection programs or practices may be adequate for the aging management of an SSC, provided they address the attributes listed in Appendix A.

Specific requirements for the licensee’s integrated AM program framework and associated AM plans are provided in section 4.0.

3. Proactive Strategy for Aging Management

Aging management activities shall be implemented proactively throughout the lifecycle of a reactor facility or SSC (e.g., in design, fabrication and construction, commissioning, operating, and decommissioning).

Guidance

This document emphasizes the need for proactive consideration of aging management during each lifecycle phase of a reactor facility: design, construction, commissioning, operation (including long-term operation and extended shutdowns) and decommissioning. The lifecycle phases can apply to individual SSCs as well as the entire reactor facility.

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 reactor facility.

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

Guidance

A proactive approach to aging management begins with the design phase during which important decisions having significant impact for preventing and managing aging effects are made.

RD/GD-337, *Design of New Nuclear Power Plants* [7] and its successor document[2] establish design requirements for new reactor facilities which include taking into account the effects of aging and wear of SSCs. This document applies to new facilities, as well as to future design changes, repairs and replacements that apply to operating facilities and SSCs.

The requirement to take appropriate measures, and to introduce design features – during the design stage – to facilitate effective aging management, complements the requirements in RD/GD-337. The following aspects related to aging management should be considered at the design stage:

1. apply a systematic approach at the design stage to ascertain the understanding of aging of SSCs, in order to evaluate effective approaches and design features for aging prevention, monitoring and mitigation, and to establish AM plans 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 lives than the nominal design 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
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

[2] The successor document is entitled REGDOC-2.5.2, *Design of Reactor Facilities: Nuclear Power Plants*

8. in design documents, specify any special process applied to fabrication (or manufacturing) and construction of SSCs that prevent, mitigate, or eliminate known aging mechanisms; e.g., heat treatment, surface finishing, curing regime
9. in design documents, specify critical environmental and operating conditions and any other parameters to be monitored and/or controlled that affect aging assumptions used in design
10. 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.)

Aging management is also to be considered in the design of modifications to existing operating facilities, and for the design of modifications, repairs, and replacements of individual SSCs. This does not preclude the use of like-for-like items for repairs and replacements; however, if failure or degraded performance of a structure, system or component is caused by premature aging, then consideration should be given to incorporating improvements that will prevent or slow down the aging effects. Aging management considerations for repairs and replacements may include, for example, selection of improved materials, increased piping wall thickness, stress relief of pipe bends, and the recording of baseline measurements.

3.1.1 Aging management content in safety analysis reports

The deterministic safety analysis for the reactor facility shall account for the cumulative effects of aging degradation of SSCs on overall systems and facility safety performance.

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).

Guidance

The deterministic safety analysis and probabilistic safety assessment for the reactor facility should be based on complete and accurate design and operational information and is to account for the cumulative effects of aging degradation of SSCs on overall systems and facility safety performance [3, 4]. For deterministic safety analysis, significant uncertainties in analysis or data relevant to aging assumptions, including those associated with reactor facility performance, operational measurements, and modelling parameters, should be identified and considered.

The safety analysis report for the reactor facility should address the following items relating to aging management:

1. an outline of the proactive strategy for aging management and prerequisites for its implementation
2. safety-significant SSCs of the reactor facility that could be affected by aging
3. assumptions, methods, acceptance criteria, and data used to account for the effects of the aging of SSCs in the safety analysis, including any time-limited assumptions and failure data for probabilistic safety assessments

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[3] RD-310, *Safety Analysis for Nuclear Power Plants* [4] and GD-310, *Guidance on Safety Analysis for Nuclear Power Plants* [5], or the successor document REGDOC-2.4.1, *Deterministic Safety Analysis*

[4] S-294, *Probabilistic Safety Assessment (PSA) for Nuclear Power Plants* [6] or its successor document REGDOC-2.4.2, *Probabilistic Safety Assessment (PSA) for Nuclear Power Plants*

4. critical service conditions, operational limits and conditions, and any other parameters to be monitored and/or controlled that affect aging assumptions used in deterministic safety analyses or equipment qualification
5. data and information to be collected for aging management in order to confirm that deterministic safety analysis assumptions and acceptance criteria continue to be met

3.2 Fabrication, construction, and installation

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

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.

Guidance

Fabrication and construction practices can have a significant effect on the aging resistance of SSCs, which often only become apparent much later in the operating life. Provisions to monitor, manage, and control aging degradation of SSCs should therefore be established and implemented, to ensure that the fabrication, construction, and installation processes do not adversely affect the aging resistance of SSCs. These provisions should take account of current aging management knowledge and experience, and other relevant factors affecting aging and aging management of SSCs.

The licensee should ensure the following items are taken into consideration:

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. prequalification and quality control / quality assurance during construction
3. relevant information on the factors affecting aging management and parameters influencing aging degradation is clearly specified in procurement documents and provided to SSCs suppliers and contractors
4. suppliers and contractors adequately address factors affecting aging management
5. reference (baseline) data required for aging management are collected and documented
6. 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 reactor facilities and in projects for existing facilities that involve 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.

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

Guidance

The following should be taken into account in commissioning activities:

1. relevant information on the factors affecting aging management and parameters influencing aging degradation should be identified, taken into account, monitored, and controlled in commissioning
2. required baseline or inaugural inspection data for aging management should be recorded
3. critical service conditions and parameters, such as those considered in equipment qualification and aging assumptions in safety analyses, should be verified as being in compliance with the design and safety
4. special attention should be paid to identification and recording of thermal and radiation hot spots, and to measurement of vibration levels

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 facility operation phase.

Facility operations shall be monitored and recorded to demonstrate compliance with critical service conditions, operational limits and conditions, 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., temperature, flow pattern, velocity, vibration, radiation) that could affect aging and failure of SSCs (see section 3.1) shall be performed.

Corrective actions identified by AM plan activities shall be managed within the reactor facility's corrective action program.

Measures shall be taken to store spare or replacement parts and consumables in appropriately controlled environments (i.e., with appropriate temperatures and moisture levels, and to prevent chemical attack or dust accumulation), taking shelf life into account, in order to preclude aging degradation.

Guidance

During the facility operating phase, licensees are expected to establish and implement an overall facility AM program framework that ensures the coordination and communication between all relevant facility and external programs for managing aging and obsolescence of SSCs. A systematic approach (including appropriate organizational arrangements, data collection and record keeping, SSC screening and aging evaluations) should be applied in order to ensure:

1. all SSCs that are susceptible to aging effects or obsolescence that can, directly or indirectly, have an adverse effect on the safe operation of the reactor facility are identified
2. aging effects of SSCs and potential impacts on safety functions due to aging and obsolescence are systematically identified, evaluated and documented
3. effective actions for preventing, monitoring and mitigating aging are evaluated and implemented to ensure that the required SSCs and safety functions will not be impaired

during normal operation and design-basis accident conditions, as well as those relied on for design extension conditions

Additional detail is provided in section 4.0.

Critical service conditions, operational limits and conditions, and other parameters identified as affecting aging assumptions used in safety analyses, design or equipment qualification should be monitored and recorded to ensure compliance, and to provide for timely detection, reporting and evaluation of unexpected service conditions – so that corrective actions can be taken before reactor facility safety is negatively impacted.

Procedures should be in place to ensure that any changes to system operations or design modifications are reviewed for the effect on environment or process conditions (e.g., temperature, flow pattern, velocity, vibration, radiation fluence) of SSCs, including neighbouring or connected SSCs, such that they do not introduce a detrimental aging effect or new failure mechanism. In such cases, AM plans should be updated accordingly.

Procedures should be in place to ensure that if a new aging mechanism is discovered (e.g., through feedback from inspections, surveillance, operating experience or research findings), an appropriate aging management review is carried out.

3.4.1 Review and update of safety analysis

As part of the deterministic safety analysis review and update, licensees shall account for the effects of the aging of SSCs, research findings, and advances in knowledge and understanding of aging mechanisms. This shall include an evaluation of the cumulative effects of the aging of SSCs on overall system and facility safety performance, as well as on risk insights using probabilistic safety assessments.

Guidance

The deterministic safety analysis should be periodically reviewed and updated to account for changes in reactor facility configuration and conditions, operating parameters and procedures, research findings, and advances in knowledge and understanding of physical phenomena.

Data and information collected from AM plans should be reviewed to confirm that deterministic safety analysis assumptions, credited parameters and predictions remain valid, and that limiting criteria and required design margins continue to be met as the facility ages.

The probabilistic safety assessment should be updated periodically, as per S-294, *Probabilistic Safety Assessment (PSA) for Nuclear Power Plants* [6], or its successor document[5], using the data and information collected from AM plans as much as practicable.

3.4.2 Long-term operation

The licensee shall complete an in-depth review of the effects of aging on reactor facility safety and evaluate the effectiveness of AM plans for long-term operation in order to identify corrective

[5] The successor document is entitled REGDOC-2.4.2, *Probabilistic Safety Assessment (PSA) for Nuclear Power Plants.*

actions and areas for improvement. Condition assessments shall 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 reactor facility 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 deterministic 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.

Guidance

A review of the actual condition of SSCs and of the management of aging for long-term operation should be conducted in accordance with RD-360, *Life Extension of Nuclear Power Plants* [18] or its successor document[6], and IAEA Specific Safety Guide SSG-25, *Periodic Safety Review of Nuclear Power Plants* [19]. Additional guidance on the conduct of aging management review for safe long-term operation is provided in IAEA Safety Report Series No. 57, *Safe Long Term Operation of Nuclear Power Plants* [2] and IAEA Safety Report Series No. 82, *Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL)* [20].

3.4.3 Extended shutdowns

Licensees shall review and, where necessary, revise SSC-specific AM plans 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 system lay-up specifications or preservation plans, including requirements for any condition assessments to be completed prior to the return to service of a reactor facility following an extended shutdown (see section 4.5).

Guidance

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

The review and revision to SSC-specific aging management processes may take into consideration the differences in hazard potential and operating conditions between the temporary lay-up or safe storage states and the normal operating states.

[6] The successor document is entitled REGDOC-2.3.3, *Operating Performance: Integrated Safety Reviews.*

Provisions for aging management should include defining any requirements for a condition assessment or any other aging management activities. Not all condition assessments in the scope of the aging management program need to be completed prior to return to service from an extended shutdown. The scope of the condition assessments should be based on the lay-up conditions, the results and time since the last condition assessment and the duration of the shutdown.

The provisions for aging management, including scope of condition assessments, should be reassessed if the duration of the shutdown is greatly extended beyond what was originally anticipated (for example, due to unforeseen issues or delays in the return to service).

3.5 Decommissioning

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

Guidance

During the transition period from reactor unit shutdown to decommissioning and, where required, to facilitate decommissioning, appropriate aging management arrangements need to be continued to ensure that required SSCs remain available and functional. The stabilization activities phase (SAP) and storage and surveillance phase (SSP) may be considered as a subset of decommissioning, where attention must be paid to any equipment related to irradiated fuel bay operations, shutdown cooling, and core defuelling activities (fuelling machines and fuel transfer system equipment). This may require implementing relatively long-term aging management provisions for certain SSCs; for example, containment and spent fuel bay systems, fire protection systems, lifting equipment and monitoring equipment. Such provisions must be consistent with licensing requirements.

AM plans may no longer be required for specific SSCs after they are permanently taken out of service, and the residual risks are low and acceptable. For example, for reactor components this could be after the reactor is de-fuelled and drained, and placed into safe storage. However, AM plans would be required for those SSCs needed to monitor or secure the activated / contaminated reactor components (e.g. fire protection, monitoring equipment, security equipment).

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. Reactor facility management processes shall include requirements to ensure there is a documented overall integrated AM program framework for the reactor facility that addresses the following elements:

1. organizational arrangements
2. data collection and record keeping
3. screening and selection process for aging management
4. evaluations for aging management
5. condition assessments
6. SSC-specific AM plans
7. management of obsolescence
8. interfaces with other supporting facility programs

9. implementation of AM program and plans
10. review and improvement of AM program and plans

SSC-specific AM plans shall be implemented in accordance with the overall integrated AM program framework.

Guidance

The integrated AM program framework should provide a comprehensive, umbrella-type program or, alternatively, a “road map” document that demonstrates how the current processes and programs meet the requirements for effective aging management. The integrated AM program framework would be subject to CNSC compliance program inspections and reviews.

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 reactor facility management processes shall include requirements to ensure that appropriate organizational arrangements are established to facilitate the effective implementation of AM plans.

Guidance

The following aspects should be considered:

1. established policy and objectives of the overall integrated AM program framework, allocated resources (such as human, financial, training, tools, and equipment), and processes to monitor the program to ensure it is meeting its objectives
2. defined responsibilities for the implementation of aging management activities
3. provision of training and mentoring to operations, maintenance, engineering, and other pertinent staff to ensure they have adequate awareness and understanding of aging management concepts and program requirements
4. external organizations, if/when 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 to provide a basis for decisions on the type and timing of aging management actions.

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 to trace all applicable sources of information.

Guidance

A data collection and record keeping system should be established early in the life of a reactor facility to support the AM plans. Data and records relevant to aging management include:

1. reference (baseline) data on the design, fabrication, and construction of the facility or SSCs and conditions at the beginning of the service life, including results of equipment qualification tests, inspections, commissioning tests, and mappings of environmental conditions during construction and commissioning
2. data on the operating history of the facility, 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, performance indicators of AM plans' effectiveness, SSC health indicators, internal and external operating experience, and research results

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 AM program framework. This process shall include SSCs susceptible to aging degradation or aging effects that can, directly or indirectly, have an adverse effect on the safe operation of the reactor facility. The process shall include SSCs that do not have safety functions, but whose failure could prevent safety-related SSCs from performing their intended functions.

Guidance

The screening and selection requirements in section 4.3 are commensurate with RD/GD-210, *Maintenance Programs for Nuclear Power Plants* [16], which covers all SSCs within the bounds of the facility. The selection process for aging management will include long-lived passive SSCs that may not be covered by maintenance programs. The screening and selection requirements for aging management are intentionally broader in scope than those of RD/GD-98, *Reliability Programs for Nuclear Power Plants* [15], which focuses on reliability performance of primarily active components in systems important to safety.

The screening and selection process for SSCs should follow a safety-based approach. The following list is an example of such considerations:

1. from a comprehensive list of all SSCs, identify those whose malfunction or failure could lead directly or indirectly to the loss or impairment of a safety function
2. ensure that the list includes all SSCs whose degradation may challenge or affect the assumptions made in the safety analyses
3. ensure that the list includes all SSCs relied upon for design extension conditions (for example, emergency filtered containment vent, provisions for emergency water makeup, equipment to mitigate hydrogen and combustible gases, and dedicated instrumentation for beyond-design-basis accidents)

4. for each SSC, identify those structural elements and components whose failure could lead directly or indirectly to the loss or impairment of a safety function. This may include consideration of surrounding or neighbouring structures, piping, components and supports that are not safety-related, but whose failure could affect a safety-related item
5. from the list of structural elements and components, identify those for which aging degradation has the potential to cause component failure; provide justification for the excluded components

This screening and selection process should consider relevant operating experience and research findings.

For SSCs that are not included in the AM plan, appropriate provisions should be implemented to ensure their safety significance will not change throughout the facility's life because of degradation due to aging.

The documentation of the screening and selection process should include the information sources and any criteria used, and arrange the final list of elements and components into related categories.

The records produced should be identified as permanent records.

4.4 Evaluations for aging management

The reactor facility's 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

The procedure for conducting the evaluations for aging management shall be documented, as well as the results of the evaluations.

Guidance

A recommended methodology is to conduct an evaluation of relevant information and then document the findings (see Appendix B).

The results of operating experience, research and development, and available previous aging evaluations (both generic and facility-specific) can be used in the evaluations. Relevant applicable aging management reviews (i.e., those prepared by the licensee, suppliers or support organizations) should be used to minimize duplication of effort, if available. Appropriate references should be made, and an explanation of the use of these references should be provided.

The results of the evaluations should summarize the pertinent aging issues and effectiveness of current practices, such as existing lifecycle management plans, and system health monitoring, inspection and maintenance programs. They should also provide recommendations for activities in the SSC aging management plan and for facility-supporting programs in design, operation, monitoring, and maintenance, and identify areas for further research and development.

4.4.1 Understanding of aging

Reactor facility management processes shall include requirements for the evaluation of the current understanding of aging for the selected structure, system or component.

Guidance

The current understanding of aging for the selected structure, system or component should be documented based on an evaluation of possible and actual aging mechanisms. The evaluation is to consider the effects of aging degradation on SSC safety function, the effect on the ability of other SSCs to perform their intended safety functions, and other consequences of failure.

The evaluation should identify:

1. SSC design and licensing basis requirements relevant to aging and aging management (including applicable codes and standards, deterministic safety analysis, safety functions, and consequences of failure)
2. SSC materials, service conditions, stressors, degradation sites, aging mechanisms and effects
3. indicators of the physical or functional condition of SSCs (condition indicators)
4. anticipated obsolescence issues
5. quantitative or qualitative models for predicting relevant aging effects, and any gaps in 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 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.

Guidance

The evaluation should identify:

1. preventive actions to be taken in design, selection of materials and coatings, fabrication and construction practices, commissioning, service conditions, and preventive operation and maintenance practices (including specifications for SSC lay-up conditions)
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 detecting, monitoring, and trending aging effects

Methods for the detection, monitoring, and trending of aging effects shall be evaluated to establish appropriate actions that can be taken.

Guidance

The evaluation should identify:

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 – with sufficient sensitivity, reliability, and accuracy – before SSCs fail
3. data to be collected to facilitate assessment of the aging of SSCs
4. data evaluation techniques (including data analysis and trending) for recognizing significant degradation and for predicting future performance of the SSCs

National and international operating experience should be considered in the evaluation. The evaluation of technology and methods should consider the need for the detection of unexpected degradation, depending on how critical the SSC is to safety. For example, while inspections to deal with known degradation mechanisms may incidentally result in discovery of unexpected degradation, there is no assurance that unexpected degradation will always be detected. Surveillance programs involving the removal of items (e.g., pressure tubes, material coupons) can assist in discovery of degradation mechanisms that were not previously known.

As well, it is known that measurements of degradation on specific components can demonstrate a large variation even for similar items (e.g., feeder pipe wall thinning, pressure tube flaws). The evaluation should take into account the need for an appropriate level of statistical confidence that significant degradation will not go undetected.

Where it is critical to life management activities or to fitness-for-service calculations, or where significant changes in inspection techniques are to be implemented, parallel measurements or comparison with existing qualified techniques should be conducted. This is to ensure proper calibration and to correct any bias.

The evaluation should also include an assessment of the safety risks to the facility and workers from the data collection activities.

4.4.4 Methods for mitigating aging effects and corrective actions

Methods for mitigating aging effects shall be evaluated to establish appropriate corrective actions that can be taken.

Guidance

The evaluation should identify:

- operations, maintenance, repair and replacement actions to allow timely mitigation of detected aging effects or degradation
- acceptance criteria against which the need for corrective action is evaluated
- corrective actions if a component fails to meet the acceptance criteria

The effectiveness of existing methods and practices for mitigating aging degradation should take account of relevant operating experience and research results.

4.5 Condition assessments

Reactor facility management processes shall include requirements to evaluate the actual condition of a structure, system or component at the initiation of the SSC-specific AM plan and at periodic intervals throughout the service life of the reactor facility or structure, system or component, as required, to validate the AM plan’s effectiveness. The procedure for conducting condition assessments and the results shall be documented.

Guidance

Condition assessments are used to establish the actual condition of an SSC, usually at the initiation of the SSC-specific AM plan, and certain times during the service life of the reactor facility or SSC as required for validating the AM plan’s effectiveness. For example, condition assessments are also completed as part of the review of aging for extended or long-term operation (see section 3.4.2), and may be required before a reactor facility returns to service after an extended shutdown period or SSC lay-up (see section 3.4.3).

The condition assessments should provide information on:

- 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
- estimation of future performance, degradation due to aging, 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)
- recommended follow-up or prevention, monitoring, and mitigation measures to be completed and/or incorporated into the AM plan, including appropriate intervals for follow-up condition assessments and areas for further research and development

Condition assessments of SSCs may be conducted as part of the evaluations for aging management (see section 4.4).

4.6 SSC-specific aging management plans

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

The SSC-specific AM plans shall be documented and address the attributes of an effective AM plan as listed in appendix A.

Guidance

The AM plan should specify what range of outcomes they can reasonably accommodate, and take into account the ability to adjust the plans to outcomes outside of that range.

The scope of the SSC-specific AM plan should be commensurate with the importance to safety, design function and required performance of the structure, system or component, and its effect on the safe operation of the reactor facility. For example, the critical life-limiting SSCs of current

CANDU reactors – such as fuel channels, heat transport feeder piping and steam generators – will have detailed lifecycle management plans as part of their SSC-specific AM plans. AM plans may not necessarily be specific to SSCs, but could instead focus on degradation mechanisms or operational requirements to control or predict degradation; for example, plans or programs for managing flow-accelerated corrosion, water chemistry and fatigue monitoring.

Each SSC-specific AM plan should cover the nine attributes of an effective program (see appendix A). Existing facility programs that are credited as should be evaluated against the attributes listed in appendix A. Programs that do not include these attributes should be modified as appropriate. For example, existing life cycle management plans, system health monitoring, maintenance or inspection programs or practices may be eligible as the AM plan of an SSC, provided they address the attributes listed in appendix A.

The required attributes of SSC-specific AM plans are typically implemented through several facility programs. Recognizing this, the documentation of an SSC-specific AM plan should provide, for each attribute, a summary description of the SSC-specific application of the relevant facility program(s) and references to reactor facility documents containing the supporting basis/evidence.

It is up to the reactor facility licensee to identify its AM plan performance indicators. This could include the program health indicators currently used in system health reports. Other examples of indicators include:

- material condition with respect to acceptance criteria
- trends of data relating to failure and degradation
- comparison of preventive and corrective maintenance efforts (e.g., in terms of person-years or cost)
- number of recurrent failures and instances of degradation
- status of compliance with inspection programs

The AM plan document should also include a summary page that highlights the key information useful for understanding and managing aging, including materials, degradation sites, aging stressors and environment, aging mechanisms and effects, inspection and monitoring requirements and methods, mitigation methods, regulatory requirements, and acceptance criteria.

Additional information and summaries of SSC-specific AM plans are provided in IAEA Safety Report Series No. 82, *Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL)*. [20].

4.7 Management of obsolescence

The licensee shall have a managed process for obsolescence. The provisions for the management of obsolescence shall be documented in the licensee’s management system.

Guidance

The program for management of obsolescence should address the following:

- spare parts supplies for planned service life
- long-term arrangements for manufacturers and spare parts suppliers, and for required technical support

- availability of documentation to support maintenance and replacement of SSCs
- availability of documentation and technology to support development of equivalent SSCs, if needed
- arrangements for modernization and technology updates

4.8 Interfaces with other supporting programs

All supporting programs and activities that are credited as an integral part of the reactor facility's aging management shall be identified, and their interfaces and information requirements defined in the overall integrated AM program framework document.

Guidance

The integrated AM program framework should also identify the aging management information that needs to be provided as inputs into other facility programs and activities, including safety analysis [7, 8], maintenance [9], and reliability programs [10]. As an example, section 3.4.1 includes a requirement for data and information collected from the AM plan to be reviewed within the program for the periodic review and update of the deterministic safety analysis.

4.9 Implementation of aging management programs

The overall integrated AM program framework and SSC-specific AM plans and major actions related to aging management shall be implemented under the licensee's management system for the facility.

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

Guidance

The implementation of AM plans should provide a systematic aging management process, based on an 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

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[7] RD-310, *Safety Analysis for Nuclear Power Plants* [4] and GD-310, *Guidance on Safety Analysis for Nuclear Power Plants* [5], or the successor document, REGDOC-2.4.1, *Deterministic Safety Analysis*

[8] S-294, *Probabilistic Safety Assessment (PSA) for Nuclear Power Plants* [6] or its successor document REGDOC-2.4.2, *Probabilistic Safety Assessment for Nuclear Power Plants*

[9] RD/GD-210, *Maintenance Programs for Nuclear Power Plants* [16]

[10] RD/GD-98, *Reliability Programs for Nuclear Power Plants* [15]

4.10 Review and improvement

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

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

Guidance

The reviews should be conducted on a regular periodic basis and documented. Program reviews should include consideration of the operating performance, inspection and maintenance histories, results of condition assessments, event reports, information from the results of research and development, self assessments, and operating experience, current issues, and future actions. Recommendations and corrective actions for AM plans and supporting programs should be implemented in a timely manner, as appropriate. Aging management is a specific area reported on in the CNSC’s annual nuclear power industry safety performance reports.

Consideration should be given to arranging for peer reviews of AM plans to obtain an independent assessment, to establish if they are consistent with generally accepted practices and to identify areas for improvement.

Whenever an AM plan’s deficiency is identified, the licensee should assess its significance and, where appropriate, conduct a causal analysis and take corrective actions. AM plans should be adjusted as appropriate in response to the new information. When a component fails to meet the acceptance criteria, the cause of the component failure should be identified and reviewed, in order to determine corrective actions that should be implemented in a timely manner to prevent recurrences. Lead times to plan and implement options can be a significant factor in aging management planning. Therefore, it is recommended for AM plans to identify when work should be started, with regard given to when critical options are needed in order to manage the range of uncertainties. A confirmation process should be established to ensure that corrective actions have been completed and are effective.

Adequately funded research and development programs should be put in place to respond to any new aging issues and to provide for continuous improvement of the understanding and predictability of aging mechanisms and the causes of aging, and associated monitoring and mitigation methods or practices. A strategic approach should be made to promoting relevant long-term research and development programs.

Appendix A: Attributes of an Effective Aging Management Plan

Adapted from the International Atomic Energy Agency Safety Guide *Ageing Management of Nuclear Power Plants* NS-G 2.12 [1].

Attribute		Description
1	Scope of the aging management (AM) plan, based on understanding of aging	Systems, structures and components (SSCs) subject to aging management (structures include structural elements) 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 degradation due to aging	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 SSCs
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 research and development (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 AM plan
9	Quality management	Organizational roles and responsibilities Administrative controls that document the implementation of the AM plan and actions taken Indicators to facilitate evaluation and improvement of the AM plan 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

Appendix B: Sample Methodology for Aging Evaluation

Adapted from the International Atomic Energy Agency Safety Guide *Ageing Management of Nuclear Power Plants* NS-G 2.12 [1].

Understanding of aging

Design and specifications	Materials and material properties	Service conditions	Performance requirements	Operation and maintenance histories	Generic operating experience	Relevant research and development (R&D) results

Documentation of:

- current understanding of the aging of structures, systems and components (SSCs) (e.g., aging mechanisms and effects, sites of degradation, any analytical/empirical models for predicting SSC degradation, any gaps in understanding of aging)
- acceptance criteria including applicable regulatory or code requirements, set of limits and conditions defining the safe operation envelope
- list of data requirements for the assessment of SSC aging (including any deficiencies in availability and quality of existing records)

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Prevention of aging degradation

Evaluation of the effectiveness of methods and practices for prevention of aging degradation of the SSC

Documentation of the information, including:

- design, materials, fabrication (or manufacturing) and construction, operations and maintenance methods and practices to prevent aging degradation of the SSC
- operating conditions and practices that prevent or minimize the rate of aging degradation of the SSC

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Monitoring of aging degradation

Evaluation of monitoring methods, taking into account relevant operating experience and research results.

Documentation of the information, including:

- functional parameters and condition indicators for detecting, monitoring, and trending aging degradation of the SSC
- an assessment of the capability and practicability of existing monitoring techniques to measure these parameters and indicators with sufficient sensitivity, reliability, and accuracy
- data evaluation techniques for recognizing significant degradation and for predicting future performance of the SSC

↓

Mitigation of aging degradation

Evaluation of the effectiveness of existing methods and practices for mitigating aging degradation of the SSC.

Documentation of the information, including:

- maintenance methods and practices, condition monitoring (including refurbishment and periodic replacement of parts and consumables) to control aging degradation of the SSC
- operating conditions and practices that minimize the rate of aging degradation of the SSC
- possible modifications to design and materials of the component to control aging degradation of the SSC

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Report on aging management review

SSC-specific information on understanding, monitoring, and mitigating aging

Recommendations for the application of results of the aging management review in facility design, operation and maintenance, and for R&D to address gaps in knowledge and technology

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 to perform its design function.

aging
A general process in which characteristics of a structure, system or component 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 a structure, system or component to function within its acceptance criteria.

aging effects
Net changes in the characteristics of a structure, system or component that occur with time or use and are due to aging mechanisms.

aging management (AM)
Engineering, operations, inspection, and maintenance actions to control, within acceptable limits, the effects of physical aging and obsolescence of structures, systems and components.

aging management program or aging management plan (AM program/plan)
A set of policies, processes, procedures, arrangements, and activities that provides direction for managing the aging of a nuclear power plant’s structures, systems and components. In this document, AM program refers to the overall integrated aging management program or framework for the reactor facility. AM plan refers to a SSC-specific or mechanistic-based aging management plan.

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

commissioning
A process consisting of activities intended to demonstrate that installed structures, systems and components 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, or aging effects.

condition assessment
An assessment performed to determine the current performance and condition of a structure, system or component (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 structure, system or component.

condition indicator
A characteristic of a structure, system or component that can be observed, measured, or trended to infer or directly indicate the current and future ability of the structure, system or component 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.

design extension conditions
A subset of beyond-design-basis accidents that are considered in the design process of the facility in accordance with best-estimate methodology to keep releases of radioactive material within acceptable limits. Design extension conditions could include severe accident conditions.

extended shutdown
A reactor shutdown lasting for a period exceeding one year and excludes regular maintenance outages.

failure
The inability or interruption of ability of a structure, system or component to function within acceptance criteria.

functional indicator
A condition indicator that is a direct indication of the current ability of a structure, system or component to function within acceptance criteria.

licensing basis
A set of requirements and documents for a regulated facility or activity comprising:

- the regulatory requirements set out in the applicable laws and regulations
- the conditions and safety and control measures described in the facility's or activity's licence and the documents directly referenced in that licence
- 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 reactor facility, which has been justified by the results of safety assessment, considering life limiting processes and features for structures, systems and components.

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 efficiently and effectively. The management system integrates all elements of an organization into one coherent system to enable all organizational objectives to be achieved. These elements include the organization's structure, resources, and processes. Personnel, equipment, and organizational culture, as well as the documented policies and processes, are all 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.

obsolescence
With respect to structures, systems and components, the process of becoming out of date in comparison with current knowledge, standards and technology.

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.

reactor facility
Any fission reactor as described in the *Class I Nuclear Facilities Regulations*, including structures, systems and components:

- that are necessary for shutting down the reactor ensuring that it can be kept in a safe shutdown state
- that may contain radioactive material and which cannot be reliably isolated from the reactor
- whose failure can lead to a limiting accident for the reactor
- that are tightly integrated into the operation of the nuclear facility
- that are needed to maintain security and safeguards

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 a structure, system or component 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 a structure, system or component.

stressor
An agent or stimulus stemming from pre-service and service conditions that can produce immediate or gradual aging degradation of a structure, system or component. 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. 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 a structure, system or component conforms to acceptance criteria.

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

References

1. International Atomic Energy Agency (IAEA), Safety Standards Series, Safety Guide, No. NS-G 2.12, *Ageing Management for Nuclear Power Plants*, Vienna, 2009
2. IAEA, Safety Report Series No. 57, *Safe Long Term Operation of Nuclear Power Plants*, Vienna, 2008
3. Organisation for Economic Cooperation and Development, Nuclear Energy Agency; *Glossary of Nuclear Power Plant Ageing*, Paris, France, 1999
4. Canadian Nuclear Safety Commission (CNSC), RD-310, *Safety Analysis for Nuclear Power Plants*, Ottawa, 2008
5. CNSC, GD-310, *Guidance on Safety Analysis for Nuclear Power Plant*s, Ottawa, 2012
6. CNSC, S-294, *Probabilistic Safety Assessment (PSA) for Nuclear Power Plants*, Ottawa, 2005
7. CNSC, RD-337, *Design of New Nuclear Power Plants*, Ottawa, 2008
8. CSA Group, CSA N285.0, *General requirements for pressure-retaining systems and components in CANDU nuclear power plants*, Mississauga, 2012
9. CSA Group, CSA N286, *Management system requirements for nuclear facilities*, Mississauga, 2012
10. CSA Group, CSA N287.1, *General requirements for concrete containment structures for nuclear power plants*, Mississauga, 1993
11. CSA Group, CSA N291, *Requirements for safety-related structures for CANDU nuclear power plants*, Mississauga, 2008
12. CSA Group, CSA N285.4, *Periodic inspection of CANDU nuclear power plant components,* Mississauga, 2009
13. CSA Group, CSA N285.5, Periodic *inspection of CANDU nuclear power plant containment components*, Mississauga, 2008
14. CSA Group, CSA N287.7, *In-service examination and testing requirements for concrete containment structures for nuclear power plants*, Mississauga, 2008
15. CNSC, RD/GD-98, *Reliability Programs for Nuclear Power Plants*, Ottawa, 2012
16. CNSC, RD/GD-210, *Maintenance Programs for Nuclear Power Plants*, Ottawa, 2012
17. CSA Group, CSA N290.13, *Environmental qualification of equipment for CANDU nuclear power plants*, Mississauga, 2005
18. CNSC, RD-360, *Life Extension of Nuclear Power Plants*, Ottawa, 2008
19. IAEA, Safety Standards Series, Specific Safety Guide, SSG-25, *Periodic Safety Review for Nuclear Power Plants*, Vienna, 2013
20. IAEA, Safety Report Series No. 82, *Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL)*, Vienna, 2015

Additional Information

The following documents contain additional information that may be of interest to persons involved in designing and implementing an aging management program

1. International Atomic Energy Agency (IAEA), Safety Standards Series, Safety Requirements, NS-R-1, *Safety of Nuclear Power Plants: Design*, Vienna, 2000
2. IAEA, Safety Standards Series, Safety Guide, NS-G-2.6, *Maintenance, Surveillance and In-Service Inspection in Nuclear Power Plants*, Vienna, 2002
3. IAEA, Safety Standards Series, Safety Guide, NS-G-2.4, *The Operating Organization for Nuclear Power Plants*, Vienna, 2001
4. IAEA, Safety Standards Series, Safety Requirements, NS-R-2, *Safety of Nuclear Power Plants: Operation*, Vienna, 2000
5. IAEA, Safety Report Series No. 3, *Equipment Qualification in Operational Nuclear Power Plants: Upgrading, Preserving and Reviewing*, Vienna, 1998
6. IAEA, Safety Report Series No. 62, *Proactive Management of Ageing of Nuclear Power Plants*, Vienna, 2009
7. IAEA, Technical Document, TECDOC 1197, *Assessment and Management of Ageing of Major Nuclear Power Plant Components Important to Safety: CANDU Reactor Assemblies*, Vienna, 2001
8. IAEA, Technical Document, TECDOC 1188, *Assessment and Management of Ageing of Major Nuclear Power Plant Components Important to Safety: In-containment Instrumentation and Control cables, Volumes I & II*, Vienna, 2000
9. IAEA, Technical Document, TECDOC 1025, *Assessment and Management of Ageing of Major Nuclear Power Plant Components Important to Safety: Concrete Containment Buildings*, Vienna, 1998
10. IAEA, Technical Document, TECDOC 981, *Assessment and Management of Ageing of Major Nuclear Power Plant Components Important to Safety: Steam Generators*, Vienna, 1997
11. IAEA, Safety Report Series No. 15, *Implementation and Review of a Nuclear Power Plant Ageing Management Programme*, Vienna, 1999
12. United States Nuclear Regulatory Commission, NUREG-1801, *Generic Aging Lessons Learned (GALL) Report*, Volumes 1 and 2, Washington, DC, 2011
13. Institute of Nuclear Power Operations, INPO AP-913 Revision 1, *Equipment Reliability Process Description*, Atlanta, Georgia, 2001

CNSC Regulatory Document Series

Facilities and activities within the nuclear sector in Canada are regulated by the Canadian Nuclear Safety Commission (CNSC). In addition to the *Nuclear Safety and Control Act* and associated regulations, these facilities and activities may also be required to comply with other regulatory instruments such as regulatory documents or standards.

Effective April 2013, the CNSC's catalogue of existing and planned regulatory documents has been organized under three key categories and twenty-five series, as set out below. Regulatory documents produced by the CNSC fall under one of the following series:

1.0 Regulated facilities and activities

Series	1.1	Reactor facilities
	1.2	Class IB facilities
	1.3	Uranium mines and mills
	1.4	Class II facilities
	1.5	Certification of prescribed equipment
	1.6	Nuclear substances and radiation devices

2.0 Safety and control areas

Series	2.1	Management system
	2.2	Human performance management
	2.3	Operating performance
	2.4	Safety analysis
	2.5	Physical design
	2.6	Fitness for service
	2.7	Radiation protection
	2.8	Conventional health and safety
	2.9	Environmental protection
	2.10	Emergency management and fire protection
	2.11	Waste management
	2.12	Security
	2.13	Safeguards and non-proliferation
	2.14	Packaging and transport

3.0 Other regulatory areas

Series	3.1	Reporting requirements
	3.2	Public and Aboriginal engagement
	3.3	Financial guarantees
	3.4	Commission proceedings
	3.5	Information dissemination

Note: The regulatory document series may be adjusted periodically by the CNSC. Each regulatory document series listed above may contain multiple regulatory documents. For the latest list of regulatory documents, visit the CNSC's website at nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-documents