IAEA Safety Standards

for protecting people and the environment

Ageing Management for Research Reactors

Specific Safety Guide

No. SSG-10 (Rev. 1)

IAEA

International Atomic Energy Agency

IAEA SAFETY STANDARDS AND RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards.

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety. The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

Information on the IAEA's safety standards programme is available on the IAEA Internet site

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The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at: Vienna International Centre, PO Box 100, 1400 Vienna, Austria.

All users of IAEA safety standards are invited to inform the IAEA of experience in their use (e.g. as a basis for national regulations, for safety reviews and for training courses) for the purpose of ensuring that they continue to meet users' needs. Information may be provided via the IAEA Internet site or by post, as above, or by email to Official.Mail@iaea.org.

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The IAEA provides for the application of the standards and, under the terms of Articles III and VIII.C of its Statute, makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

Reports on safety in nuclear activities are issued as **Safety Reports**, which provide practical examples and detailed methods that can be used in support of the safety standards.

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Security related publications are issued in the **IAEA Nuclear Security Series**.

The **IAEA Nuclear Energy Series** comprises informational publications to encourage and assist research on, and the development and practical application of, nuclear energy for peaceful purposes. It includes reports and guides on the status of and advances in technology, and on experience, good practices and practical examples in the areas of nuclear power, the nuclear fuel cycle, radioactive waste management and decommissioning.

AGEING MANAGEMENT
FOR RESEARCH REACTORS

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world''.

IAEA SAFETY STANDARDS SERIES No. SSG-10 (Rev. 1)

AGEING MANAGEMENT FOR RESEARCH REACTORS

SPECIFIC SAFETY GUIDE

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FOREWORD

by Rafael Mariano Grossi
Director General

The IAEA's Statute authorizes it to "establish…standards of safety for protection of health and minimization of danger to life and property". These are standards that the IAEA must apply to its own operations, and that States can apply through their national regulations.

The IAEA started its safety standards programme in 1958 and there have been many developments since. As Director General, I am committed to ensuring that the IAEA maintains and improves upon this integrated, comprehensive and consistent set of up to date, user friendly and fit for purpose safety standards of high quality. Their proper application in the use of nuclear science and technology should offer a high level of protection for people and the environment across the world and provide the confidence necessary to allow for the ongoing use of nuclear technology for the benefit of all.

Safety is a national responsibility underpinned by a number of international conventions. The IAEA safety standards form a basis for these legal instruments and serve as a global reference to help parties meet their obligations. While safety standards are not legally binding on Member States, they are widely applied. They have become an indispensable reference point and a common denominator for the vast majority of Member States that have adopted these standards for use in national regulations to enhance safety in nuclear power generation, research reactors and fuel cycle facilities as well as in nuclear applications in medicine, industry, agriculture and research.

The IAEA safety standards are based on the practical experience of its Member States and produced through international consensus. The involvement of the members of the Safety Standards Committees, the Nuclear Security Guidance Committee and the Commission on Safety Standards is particularly important, and I am grateful to all those who contribute their knowledge and expertise to this endeavour.

The IAEA also uses these safety standards when it assists Member States through its review missions and advisory services. This helps Member States in the application of the standards and enables valuable experience and insight to be shared. Feedback from these missions and services, and lessons identified from events and experience in the use and application of the safety standards, are taken into account during their periodic revision.

I believe the IAEA safety standards and their application make an invaluable contribution to ensuring a high level of safety in the use of nuclear technology. I encourage all Member States to promote and apply these standards, and to work with the IAEA to uphold their quality now and in the future.

THE IAEA SAFETY STANDARDS

BACKGROUND

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive substances have many beneficial applications, ranging from power generation to uses in medicine, industry and agriculture. The radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled.

Activities such as the medical uses of radiation, the operation of nuclear installations, the production, transport and use of radioactive material, and the management of radioactive waste must therefore be subject to standards of safety.

Regulating safety is a national responsibility. However, radiation risks may transcend national borders, and international cooperation serves to promote and enhance safety globally by exchanging experience and by improving capabilities to control hazards, to prevent accidents, to respond to emergencies and to mitigate any harmful consequences.

States have an obligation of diligence and duty of care, and are expected to fulfil their national and international undertakings and obligations.

International safety standards provide support for States in meeting their obligations under general principles of international law, such as those relating to environmental protection. International safety standards also promote and assure confidence in safety and facilitate international commerce and trade.

A global nuclear safety regime is in place and is being continuously improved. IAEA safety standards, which support the implementation of binding international instruments and national safety infrastructures, are a cornerstone of this global regime. The IAEA safety standards constitute a useful tool for contracting parties to assess their performance under these international conventions.

THE IAEA SAFETY STANDARDS

The status of the IAEA safety standards derives from the IAEA's Statute, which authorizes the IAEA to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property, and to provide for their application.

With a view to ensuring the protection of people and the environment from harmful effects of ionizing radiation, the IAEA safety standards establish fundamental safety principles, requirements and measures to control the radiation exposure of people and the release of radioactive material to the environment, to restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation, and to mitigate the consequences of such events if they were to occur. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste.

Safety measures and security measures[1] have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. They are issued in the IAEA Safety Standards Series, which has three categories (see Fig. 1).

Safety Fundamentals

Safety Fundamentals present the fundamental safety objective and principles of protection and safety, and provide the basis for the safety requirements.

Safety Requirements

An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. If the requirements are not met, measures must be taken to reach or restore the required level of safety. The format and style of the requirements facilitate their use for the establishment, in a harmonized manner, of a national regulatory framework. Requirements, including numbered 'overarching' requirements, are expressed as 'shall' statements. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it

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[1] See also publications issued in the IAEA Nuclear Security Series.

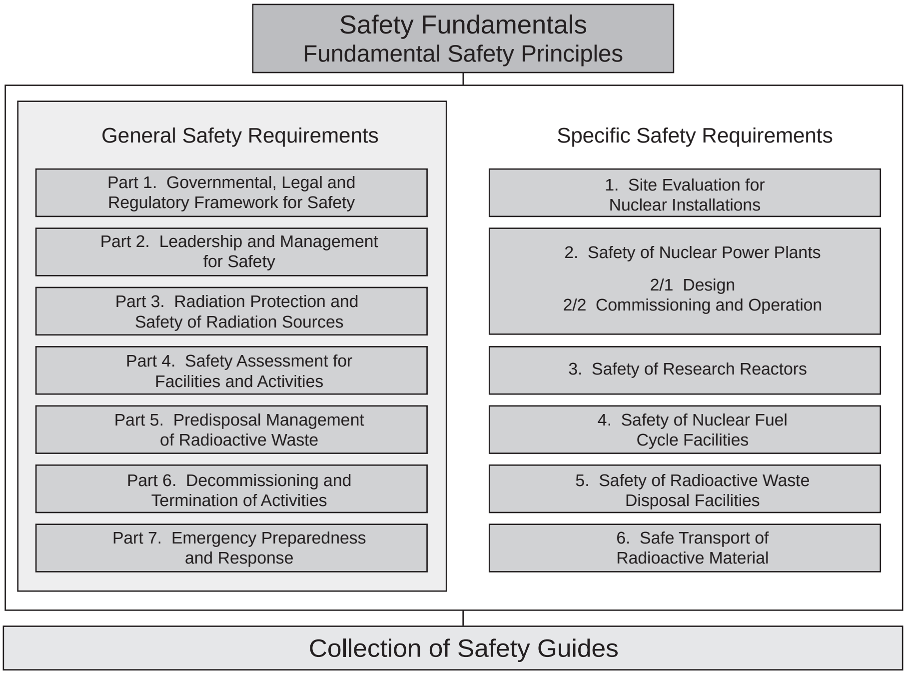

FIG. 1. The long term structure of the IAEA Safety Standards Series.

is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as ‘should’ statements.

APPLICATION OF THE IAEA SAFETY STANDARDS

The principal users of safety standards in IAEA Member States are regulatory bodies and other relevant national authorities. The IAEA safety standards are also used by co-sponsoring organizations and by many organizations that design, construct and operate nuclear facilities, as well as organizations involved in the use of radiation and radioactive sources.

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be used by States as a reference for their national regulations in respect of facilities and activities.

The IAEA's Statute makes the safety standards binding on the IAEA in relation to its own operations and also on States in relation to IAEA assisted operations.

The IAEA safety standards also form the basis for the IAEA's safety review services, and they are used by the IAEA in support of competence building, including the development of educational curricula and training courses.

International conventions contain requirements similar to those in the IAEA safety standards and make them binding on contracting parties. The IAEA safety standards, supplemented by international conventions, industry standards and detailed national requirements, establish a consistent basis for protecting people and the environment. There will also be some special aspects of safety that need to be assessed at the national level. For example, many of the IAEA safety standards, in particular those addressing aspects of safety in planning or design, are intended to apply primarily to new facilities and activities. The requirements established in the IAEA safety standards might not be fully met at some existing facilities that were built to earlier standards. The way in which IAEA safety standards are to be applied to such facilities is a decision for individual States.

The scientific considerations underlying the IAEA safety standards provide an objective basis for decisions concerning safety; however, decision makers must also make informed judgements and must determine how best to balance the benefits of an action or an activity against the associated radiation risks and any other detrimental impacts to which it gives rise.

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and five Safety Standards Committees, for emergency preparedness and response (EPReSC) (as of 2016), nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

All IAEA Member States may nominate experts for the Safety Standards Committees and may provide comments on draft standards. The membership of the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards.

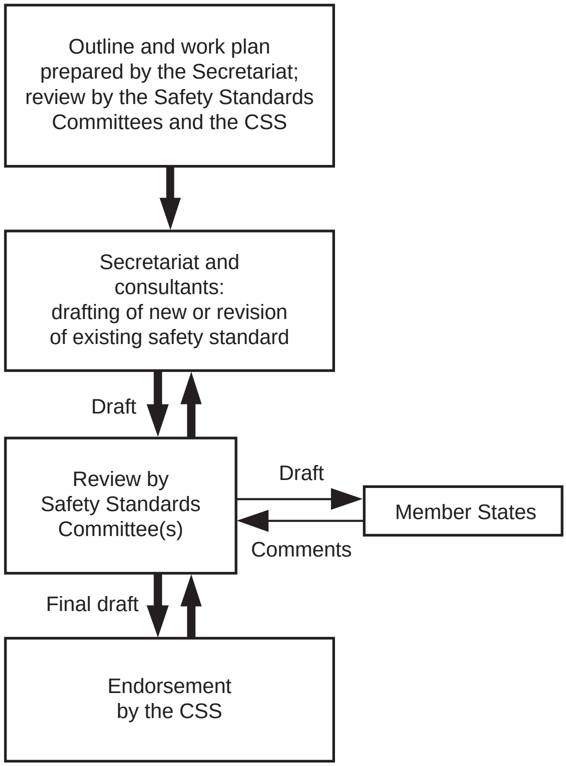

FIG. 2. The process for developing a new safety standard or revising an existing standard.

It articulates the mandate of the IAEA, the vision for the future application of the safety standards, policies and strategies, and corresponding functions and responsibilities.

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international expert bodies, notably the International Commission on Radiological Protection (ICRP), are taken into account in developing the IAEA safety standards. Some safety standards are developed in cooperation with other bodies in the United Nations system or other specialized agencies, including the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the International Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

INTERPRETATION OF THE TEXT

Safety related terms are to be understood as defined in the IAEA Nuclear Safety and Security Glossary (see https://www.iaea.org/resources/publications/iaea-nuclear-safety-and-security-glossary). Otherwise, words are used with the spellings and meanings assigned to them in the latest edition of The Concise Oxford Dictionary. For Safety Guides, the English version of the text is the authoritative version.

The background and context of each standard in the IAEA Safety Standards Series and its objective, scope and structure are explained in Section 1, Introduction, of each publication.

Material for which there is no appropriate place in the body text (e.g. material that is subsidiary to or separate from the body text, is included in support of statements in the body text, or describes methods of calculation, procedures or limits and conditions) may be presented in appendices or annexes.

An appendix, if included, is considered to form an integral part of the safety standard. Material in an appendix has the same status as the body text, and the IAEA assumes authorship of it. Annexes and footnotes to the main text, if included, are used to provide practical examples or additional information or explanation. Annexes and footnotes are not integral parts of the main text. Annex material published by the IAEA is not necessarily issued under its authorship; material under other authorship may be presented in annexes to the safety standards. Extraneous material presented in annexes is excerpted and adapted as necessary to be generally useful.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. Requirements for the safety of research reactors, with particular emphasis on their design and operation, are established in IAEA Safety Standards Series No. SSR-3, Safety of Research Reactors [1].

1.2. This Safety Guide provides recommendations on ageing management for research reactors.

1.3. This Safety Guide was developed in parallel with seven other Safety Guides on the safety of research reactors, as follows:

(a) IAEA Safety Standards Series No. SSG-80, Commissioning of Research Reactors [2];
(b) IAEA Safety Standards Series No. SSG-81, Maintenance, Periodic Testing and Inspection of Research Reactors [3];
(c) IAEA Safety Standards Series No. SSG-82, Core Management and Fuel Handling for Research Reactors [4];
(d) IAEA Safety Standards Series No. SSG-83, Operational Limits and Conditions and Operating Procedures for Research Reactors [5];
(e) IAEA Safety Standards Series No. SSG-84, The Operating Organization and the Recruitment, Training and Qualification of Personnel for Research Reactors [6];
(f) IAEA Safety Standards Series No. SSG-85, Radiation Protection and Radioactive Waste Management in the Design and Operation of Research Reactors [7];
(g) IAEA Safety Standards Series No. SSG-37 (Rev. 1), Instrumentation and Control Systems and Software Important to Safety for Research Reactors [8].

1.4. Additional recommendations on the safety of research reactors are provided in IAEA Safety Standards Series Nos SSG-20 (Rev. 1), Safety Assessment for Research Reactors and Preparation of the Safety Analysis Report [9], and SSG-24 (Rev. 1), Safety in the Utilization and Modification of Research Reactors [10].

1.5. The terms used in this Safety Guide are to be understood as defined and explained in the IAEA Nuclear Safety and Security Glossary [11].

1.6. This Safety Guide supersedes IAEA Safety Standards Series No. SSG-10, Ageing Management for Research Reactors[1].

OBJECTIVE

1.7. The objective of this Safety Guide is to provide recommendations on ageing management for research reactors to meet the relevant requirements of SSR-3 [1], in particular Requirements 37 and 86.

1.8. The recommendations provided in this Safety Guide are aimed at operating organizations of research reactors, regulatory bodies and other organizations involved in a research reactor project.

SCOPE

1.9. This Safety Guide is primarily intended for use for heterogeneous, thermal spectrum research reactors that have a power rating of up to several tens of megawatts. For research reactors of higher power, specialized reactors (e.g. fast spectrum reactors) and reactors that have specialized facilities (e.g. hot or cold neutron sources, high pressure and high temperature loops), additional guidance may be needed. For such research reactors, the recommendations provided in IAEA Safety Standards Series No. SSG-48, Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants [12], might be more suitable. Homogeneous reactors and accelerator driven systems are outside the scope of this publication.

1.10. Some research reactors, critical assemblies and subcritical assemblies with a low hazard potential might need a less comprehensive ageing management programme. While all recommendations in this Safety Guide are to be considered, some might not be applicable to such research reactors, critical assemblies and subcritical assemblies (see Requirement 12 and paras 2.15–2.17 of SSR-3 [1], and IAEA Safety Standards Series No. SSG-22 (Rev. 1), Use of a Graded Approach in the Application of the Safety Requirements for Research Reactors [13]).

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[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Ageing Management for Research Reactors, IAEA Safety Standards Series No. SSG-10, IAEA, Vienna (2010).

1.11. In this Safety Guide, subcritical assemblies will be mentioned separately only if a specific recommendation is not relevant for, or is applicable only to, subcritical assemblies.

1.12. Ageing management is defined as engineering, operation and maintenance actions to control within acceptable limits the ageing degradation of structures, systems and components (SSCs). Ageing management includes activities such as repair, refurbishment and replacement of SSCs, which are similar to maintenance and testing activities at a research reactor or to other activities that are performed when a modification project takes place. However, effective management of ageing also involves (a) the use of a methodology that will detect and evaluate ageing effects as a consequence of the service conditions and (b) the application of countermeasures for prevention and mitigation of ageing effects.

1.13. This Safety Guide covers all aspects relating to the establishment, implementation and continuous improvement of an ageing management programme. As well as considering the physical ageing of SSCs important to safety, this Safety Guide provides recommendations on the safety aspects of managing technological obsolescence (non-physical ageing) of SSCs important to safety.

1.14. Although knowledge management and management of the succession of personnel are both important issues in relation to safety at research reactors, they are outside the scope of this Safety Guide. Recommendations relating to research reactor personnel are provided in SSG-84 [6].

STRUCTURE

1.15. Section 2 provides recommendations on the management system for a research reactor as it relates to ageing management. Section 3 presents the basic concepts and explanations of the terms used in this Safety Guide and an overview of ageing effects and their relation to safety at research reactors. Section 4 provides recommendations on proactive considerations on ageing during the various stages of the lifetime of a research reactor. Section 5 provides recommendations on the elements of a systematic programme for ageing management, and on implementation of the associated actions and activities. Section 6 provides recommendations on the management of obsolescence at a research reactor. Section 7 provides recommendations on the coordination of ageing management with other programmes and technical areas, such as maintenance, periodic testing and inspection; periodic safety review; equipment qualification; design basis reconstitution; configuration management; and continued safe operation.

1.16. Annex I presents information on degradation mechanisms and their effects for different categories of service conditions. Annex II provides an example of a typical SSC screening methodology for ageing management purposes for open pool, light water and heavy water moderated research reactors.

2. APPLICATION OF THE MANAGEMENT SYSTEM TO AGEING MANAGEMENT AT A RESEARCH REACTOR

2.1. A management system that integrates safety, health, environmental, security, quality, human-and-organizational-factor, societal and economic elements for the research reactor project is required to be developed (see Requirement 4 of SSR-3 [1]). The documentation of the management system should describe the system that controls the planning and implementation of all activities at the research reactor throughout its lifetime, including ageing management activities. Approval of the management system (or parts thereof) by the regulatory body may be required (see para. 4.12 of SSR-3 [1]).

2.2. In accordance with paras 4.13–4.20 of SSR-3 [1], the management system is required to cover four functional categories, as follows:

(a) Management responsibility: includes providing the means and management support needed to achieve the organization’s objectives (see paras 2.10 and 2.11 of this Safety Guide).
(b) Resource management: includes the measures needed to ensure that resources essential to the implementation of strategy and the achievement of the organization’s objectives are identified and made available (see paras 2.12 and 2.13 of this Safety Guide).
(c) Process implementation: includes those actions and tasks needed to achieve the goals of the organization (see paras 2.14–2.21 of this Safety Guide).
(d) Measurement, assessment and improvement of the management system: includes activities conducted to evaluate the effectiveness of management processes and work performance (see paras 2.22–2.25 of this Safety Guide).

General requirements for the management system are established in IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [14]. Specific recommendations are provided in IAEA Safety Standards Series No. GS-G-3.5, The Management System for Nuclear Installations [15], and practical guidance is provided in Ref. [16].

2.3. As part of the management system, a programme for ageing management should be established and implemented by the operating organization. For a new research reactor project, the ageing management programme should be established early in the design stage. The system should cover all items, services and processes important to safety and should include a means of controlling ageing management activities, thereby providing confidence that these activities are performed in accordance with established codes, standards, specifications, procedures and administrative controls, as required by para. 4.16 of SSR-3 [1].

2.4. In determining how the management system addresses ageing management at a research reactor, a graded approach in accordance with the relative importance to safety of each item or process is required to be used (see para. 4.7 of SSR-3 [1]).

2.5. The objective of the management system as applied to ageing management should be to ensure that the facility meets the requirements for safety as derived from the following:

(a) Regulatory requirements;
(b) Design requirements and assumptions;
(c) The safety analysis report (see Requirement 1 of SSR-3 [1]);
(d) The operational limits and conditions for the research reactor (see Requirement 71 of SSR-3 [1]);
(e) Periodic safety reviews;
(f) The administrative requirements associated with the management of the research reactor.

2.6. The management system is required to support the development, implementation, fostering and enhancement of a strong safety culture (see paras 1.5(b) and 4.9 of GSR Part 2 [14]). This safety culture should be applied in all aspects of the ageing management programme.

2.7. In implementing the management system, the operating organization should ensure that the ageing management programme includes the following:

(a) Planning and prioritizing work;
(b) Addressing regulatory requirements, codes and standards;
(c) Ensuring compliance with the operational limits and conditions and with the safety analysis report;
(d) Ensuring the availability of sufficient qualified personnel with suitable skills;
(e) Ensuring the availability of spare parts, special tools and equipment;

(f) Following up inspection and test results in a timely fashion;
(g) Establishing appropriate operating procedures following relevant standards, including procedures for assessing and correcting non-conforming items;
(h) Identifying, disseminating and using information on good practices from designers, manufacturers, contractors, suppliers and other operating organizations;
(i) Performing and adequately documenting the necessary inspections and tests;
(j) Performing root cause analyses of significant degradation of SSCs and incorporating lessons learned from experience.

2.8. The management system should include a description of the ageing management programme and associated operating procedures. Operating procedures should address all applicable ageing management activities specified in the management system for the research reactor.

2.9. The management system is required to include provisions to ensure that the ageing management activities are planned, performed and controlled in a manner that ensures effective communication and clear assignment of responsibility (see para. 4.14 of SSR-3 [1]).

MANAGEMENT RESPONSIBILITY FOR AGEING MANAGEMENT AT A RESEARCH REACTOR

2.10. The reactor management[2] should ensure that the management system provides a framework for managing, performing and assessing the activities necessary to prevent, detect, monitor, assess and mitigate ageing effects. The documentation of the management system should include descriptions of the organizational structure (see Requirement 68 of SSR-3 [1]) and the functional responsibilities, levels of authority, and interactions of those managing, performing and assessing the adequacy of ageing management activities. The documentation should also include other management measures, including planning, scheduling, resource allocation and human factors.

[2] The reactor management comprises members of the operating organization to whom the responsibility and the authority for directing the operation of the research reactor have been assigned.

2.11. The reactor management should ensure that ageing management activities are planned and performed, and their results recorded, in accordance with approved procedures included in the documentation of the management system.

RESOURCE MANAGEMENT FOR AGEING MANAGEMENT AT A RESEARCH REACTOR

2.12. Paragraph 4.15(c) of SSR-3 [1] states that "The management system shall ensure that: ...The equipment, tools, materials, hardware and software necessary to conduct the work in a safe manner are identified, provided, checked, and verified and maintained."

2.13. In accordance with para. 4.15 of SSR-3 [1], the operating organization is required to provide adequate resources (including human resources and financial resources) to execute the ageing management programme. The management of the operating organization, in particular the reactor manager[3], should participate in the ageing management programme by undertaking the following:

(a) Determining the necessary staff competences and arranging for training in accordance with Requirement 70 of SSR-3 [1];
(b) Preparing and issuing specifications and procedures to ensure that appropriate resources are provided for the ageing management programme;
(c) Having frequent personal contact with staff, including observing ageing management activities in progress;
(d) Supervising external personnel (including suppliers) who perform ageing management activities and ensuring that these personnel are adequately trained and qualified in accordance with para. 4.15(b) of SSR-3 [1];
(e) Supporting and participating in evaluations of the ageing of SSCs.

PROCESS IMPLEMENTATION FOR AGEING MANAGEMENT AT A RESEARCH REACTOR

2.14. The operating organization should nominate a person to be responsible and accountable for implementing the ageing management programme. This person

[3] The reactor manager is the member of the reactor management to whom the direct responsibility and authority for the safe operation of the reactor are assigned by the operating organization and whose primary duties constitute the discharge of this responsibility.

is usually the reactor manager or a member of the operating personnel acting on behalf of the reactor manager.

2.15. The management system should include a process to ensure that significant changes or failures of any SSCs important to safety are recorded and that the data are analysed and trends discerned to identify the causes of these changes or failures. Where the causes of failures have been determined, the information should be used to improve the ageing management programme.

2.16. The scope and frequency of tests and in-service inspections relevant to the ageing management programme should be specified, and they should be consistent with the operational limits and conditions and regulatory requirements. The management system should ensure that the process for recording and presenting test results enables easy comparison with the results of previous inspections and tests, to facilitate the detection of any changes and any deviations from reference values (baseline data).

2.17. The management system should include a process to ensure that monitoring and measurement methods are valid and are designed to provide evidence of conformity of SSCs to design requirements and evidence of satisfactory performance in service.

2.18. The management system should include a process to ensure that equipment used for monitoring, data collection, and inspections and tests is calibrated and that records are kept to demonstrate that this calibration is up to date.

2.19. The management system should include a process to ensure that inspections and tests relevant to the ageing management programme are performed by qualified personnel in accordance with Requirement 70 of SSR-3 [1], using procedures developed in accordance with Requirement 74 of SSR-3 [1].

2.20. The management system should include measures to ensure that ageing management activities are accomplished as specified in the appropriate procedures. Such measures should include the following:

(a) Reviews of procedures;
(b) Verification by inspection, witnessing and surveillance;
(c) Checks of non-conformances and implementation of corrective actions;
(d) Follow-up on the adequacy and timeliness of corrective actions.

2.21. The management system should include a process to ensure that records relevant to the performance of ageing management activities are controlled in accordance with Requirement 8 of GSR Part 2 [14] and Requirement 82 of SSR-3 [1]. This process should provide for the identification, approval, review, filing, retrieval and disposal of records and for the verification of results contained within these records.

MEASUREMENT, ASSESSMENT AND IMPROVEMENT OF THE MANAGEMENT SYSTEM FOR AGEING MANAGEMENT AT A RESEARCH REACTOR

2.22. Paragraph 4.20 of SSR-3 [1] states:

> "The effectiveness of the management system shall be regularly measured and assessed through independent assessments and self-assessments. Weaknesses in processes shall be identified and corrected. The operating organization shall evaluate the results of such assessments and shall determine and take the necessary actions for continuous improvements."

2.23. An independent assessment of the ageing management programme should be conducted. This task may be performed by the safety committee (see Requirement 6 of SSR-3 [1]) or by another competent body independent of line management of the research reactor. (See also para. 4.4 of this Safety Guide.)

2.24. Audits should be performed to determine the adequacy and effectiveness of all aspects of the implementation of the ageing management programme and of its compliance with the management system.

2.25. Performance indicators for the effectiveness of the ageing management programme should be developed. The effectiveness of the ageing management programme should be periodically evaluated, taking into account current knowledge and feedback from the implementation of the programme and the performance indicators, and the programme should be updated and adjusted, as appropriate.

3. THE EFFECTS OF AGEING ON THE SAFETY OF RESEARCH REACTORS

AGEING PROCESSES AT RESEARCH REACTORS

3.1. Ageing is defined as a general process in which the characteristics of SSCs gradually change with time or use [11]. Research reactors experience two types of time dependent change, as follows:

(a) Degradation (physical ageing) of SSCs; that is, gradual deterioration of their physical characteristics.
(b) Obsolescence (non-physical ageing) of SSCs; that is, their becoming out of date in comparison with current knowledge, regulations, codes and standards, and technology.

3.2. Physical ageing eventually leads to the degradation of SSCs that have been subject to normal service conditions. These conditions include the normal environmental conditions under which SSCs are expected to operate and anticipated operational occurrences under which SSCs are expected to continue functioning properly. The ageing effects on SSCs that respond to accident conditions (i.e. design basis accidents and design extension conditions) also need to be evaluated and considered in the ageing management programme.

3.3. Physical ageing (material degradation) might result in a reduction or loss of the ability of SSCs to function within their acceptance criteria (see para. 5.25). The safety and utilization of the facility could be affected unless preventive measures are implemented and timely appropriate corrective actions are taken.

3.4. Physical ageing could reduce the safety margins in the design of SSCs. The operating organization should ensure that reductions in these margins are detected, and corrective actions taken, before loss of functional capability occurs.

3.5. During the lifetime of a research reactor, advances will occur in technology, resulting in the introduction of new components or techniques. This might also result in difficulty in obtaining spare parts. The introduction of new components might also result in changes in failure modes (e.g. modern instrumentation contains microprocessors that have different failure modes than those of older components). Changes may also occur in regulatory requirements and in codes and standards, which could necessitate changes in hardware or software and might interfere with the operation of the research reactor. All these potential issues should be taken into account in the ageing management programme.

3.6. Operating personnel should have up to date knowledge of the operation of SSCs at the research reactor and their associated documentation; therefore, ongoing training should be provided for such personnel. Recommendations on training programmes and qualifications for research reactor personnel are provided in SSG-84 [6].

3.7. The evaluation of the cumulative effects of physical ageing and obsolescence on the safety of a research reactor is an ongoing process and these effects should be assessed at appropriate intervals in periodic safety reviews or equivalent systematic safety reassessment programmes such as peer reviews (see Requirement 86 of SSR-3 [1] and paras 7.6 and 7.7 of this Safety Guide).

3.8. The ageing management programme at a research reactor is required to be coordinated with other programmes at the research reactor, including maintenance, periodic testing and inspection programmes[4] (see para. 7.120 of SSR-3 [1]). The ageing management programme should take into account good operational practices, research and development (e.g. of material behaviour, radiation effects and chemistry) and should incorporate lessons learned from operating experience.

3.9. The ageing management programme is required to ensure that the safety functions of SSCs are fulfilled (see Requirement 86 of SSR-3 [1]). This includes the following:

(a) Shutting down the reactor and maintaining it in a safe shutdown state for all operational states and for design basis accidents. This includes, for example, ensuring the availability of the supplementary control room.
(b) Providing for adequate removal of heat after shutdown, in particular from the core, including during and after design basis accidents and, to the extent practicable, design extension conditions.
(c) Confining radioactive material to prevent or mitigate its unplanned release to the environment.

3.10. The ageing management programme should contain provisions for safety documents (e.g. safety analysis report, operational limits and conditions, operating procedures, emergency plan) that become outdated or obsolete. The operating

[4] Recommendations on programmes for maintenance, periodic testing and inspection of research reactors are provided in SSG-81 [3].

organization should ensure that such documents are periodically updated to reflect the actual status of the research reactor and to take into account feedback from operating experience. Such updates should be performed when a modification of an existing experimental device[5] is being introduced or a new experimental device is being installed.

AGEING AND DEFENCE IN DEPTH AT A RESEARCH REACTOR

3.11. The activities covered by this Safety Guide are directly related to the application of the concept of defence in depth, which in turn implements Principle 8 of IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles [17], which states that “**All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.**” The application of the concept of defence in depth to research reactors is described in paras 2.10–2.14 of SSR-3 [1]. Requirement 10 of SSR-3 [1] states that “**The design of a research reactor shall apply the concept of defence in depth. The levels of defence in depth shall be independent as far as is practicable.**”

3.12. The physical ageing of SSCs might increase the probability of common cause failures (i.e. the simultaneous degradation of physical barriers and redundant components), which could result in the impairment of one or more levels of defence in depth. Therefore, in the screening of SSCs for ageing management (see paras 5.4–5.8), no credit should be taken for component redundancy or diversity, on the basis that ageing effects should be regarded as a common cause failure mechanism and that diversity might not provide protection against all potential failures caused by common degradation mechanisms.

3.13. An essential aspect of the application of the concept of defence in depth is the implementation of multiple physical or functional barriers. The ageing process might affect defence in depth through the failure of one or more of these barriers (e.g. because of corrosion of the cladding material of fuel elements, corrosion of the reactor pool liner or corrosion of piping for primary cooling). An effective

[5] An experimental device is a device installed in or around a reactor to use the neutron flux and ionizing radiation from the reactor for research, development, isotope production or other purposes.

ageing management programme should provide for maintaining defence in depth through the following:

(a) Incorporation of good design features and sound engineering practices that provide safety margins, mainly through the use of design, technology and materials of high quality and reliability;
(b) Compliance with the operational limits and conditions;
(c) Execution of relevant tasks and activities in accordance with approved operating procedures and by following good practices.

SERVICE CONDITIONS AND AGEING AT A RESEARCH REACTOR

3.14. Service conditions are the major contributors to the ageing of SSCs through chemical and physical processes that affect material properties or functional capabilities. This should be taken into account by the operating organization when developing the ageing management programme for a research reactor. Service conditions include the following:

(a) Stress and/or strain;
(b) Temperature;
(c) Pressure;
(d) Chemistry regime;
(e) Environmental factors, such as radiation, high humidity or the presence and use of chemically active liquids and gases;
(f) Service wear, including changes in dimensions and the relative positions of individual parts of assemblies.

3.15. For research reactors with a low hazard potential and a power rating of up to several tens of kilowatts, and for subcritical assemblies and critical assemblies with a low hazard potential, many of the service conditions (e.g. thermal embrittlement, creep, fatigue (see para. 3.18)) are not severe. In such cases, the recommendations in this Safety Guide should be applied using a graded approach.

3.16. Limiting values for service conditions (e.g. the maximum temperature of fuel cladding; the pressure in cooling lines and across filters; the vibration levels of primary cooling pumps; the content of non-dissolved solids in water coolant; the water coolant chemistry parameters, such as electrical conductivity and pH) should be included in the limiting conditions for safe operation that are part of the operational limits and conditions for the research reactor. Further recommendations on the factors to be considered in establishing limiting conditions for safe operation of a research reactor are provided in appendix I to SSG-83 [5].

3.17. Three main categories of service conditions should be considered in the ageing management programme, as follows:

(a) Service conditions associated with normal operation;
(b) Service conditions associated with anticipated operational occurrences;
(c) Service conditions during postulated accident conditions, including conditions during periods when the SSC is not in service, such as when the reactor is shut down.

3.18. Service conditions lead to degradation of materials through, for example, one or more of the following degradation mechanisms:

(a) A change in physical proprieties (e.g. swelling; chemical decomposition; changes in material strength, ductility or resistivity);
(b) Irradiation and thermal embrittlement;
(c) Creep;
(d) Fatigue, including thermal fatigue;
(e) Corrosion, including galvanic corrosion, corrosion erosion and corrosion assisted cracking;
(f) Wear (e.g. fretting) and wear assisted cracking (e.g. fretting fatigue).

3.19. Further information on the categories of service conditions and the associated degradation mechanisms can be found in section 3 of Ref. [18]. Annex I to this Safety Guide describes the effect of ageing for different categories of service conditions.

4. AGEING MANAGEMENT CONSIDERATIONS IN DIFFERENT STAGES OF THE LIFETIME OF A RESEARCH REACTOR

4.1. Ageing management of SSCs important to safety should be implemented proactively (i.e. with foresight and anticipation) throughout the lifetime of the research reactor; that is, in design, fabrication and construction, commissioning, operation (including utilization and modification), and decommissioning.

Particular consideration is required to be given to ageing management for periods of extended shutdown (see para. 7.123 of SSR-3 [1]).

4.2. The operating organization should be able to demonstrate that regulatory requirements for ageing management are met and that issues relevant to the ageing of a research reactor are clearly identified and documented in the safety analysis report and supporting documents throughout the lifetime of the reactor. The safety analysis report should include (or should reference documents that contain) information that confirms that all materials of SSCs important to safety have been selected to withstand the service conditions to which they are subject, without unacceptable degradation of the performance of their intended safety functions. The safety analysis report should also describe the in-service inspection programme, including information on SSCs to be inspected, as well as the inspection frequency and acceptance criteria. Further recommendations on the preparation and content of safety analysis reports for research reactors are provided in the appendix to SSG-20 (Rev. 1) [9].

4.3. Feedback from relevant operating experience at other reactors, including nuclear power plants, should be used by the operating organization in evaluating the ageing management measures proposed by designers, manufacturers and suppliers.

4.4. An independent review of the ageing management programme and any subsequent modifications to this programme at various stages throughout the lifetime of the research reactor should be performed by the safety committee or other competent body. Any proposed modifications to the ageing management programme should be submitted to the regulatory body for review and assessment, in accordance with regulatory requirements. Paragraphs 3.7–3.12 of SSG-24 (Rev. 1) [10] provide further recommendations on the categorization of research reactor modifications.

AGEING MANAGEMENT CONSIDERATIONS IN THE DESIGN OF A RESEARCH REACTOR

4.5. Requirement 37 of SSR-3 [1] states:

> "**The design life of items important to safety at a research reactor facility shall be determined. Appropriate margins shall be provided in the design to take due account of relevant mechanisms of ageing, such as neutron embrittlement and wear-out, and of the potential for age related degradation, to ensure the capability of items important to**

safety to perform their necessary safety functions in operational states and accident conditions in case of demand throughout their design life. The life cycles of the technology utilized and the possible obsolescence of the technology shall be considered.”

4.6. Paragraph 6.112 of SSR-3 [1] states:

> “The design for a research reactor shall take due account of physical ageing, the effects of wear and tear and obsolescence in all operational states for which a component is credited, including testing, maintenance, and operational states during and following a postulated initiating event.”

4.7. Paragraph 6.113 of SSR-3 [1] states:

> “An ageing management programme that includes inspection and periodic testing of materials shall be put in place, and the results that are obtained in this programme shall be used in reviewing the adequacy of the design at appropriate intervals.”

4.8. Paragraph 6.114 of SSR-3 [1] states:

> “The design shall include provisions for the necessary monitoring, testing, sampling and inspection for the detection, assessment, prevention and mitigation of ageing effects. The ageing management of the research reactor facility shall include the management of obsolete structures, systems and components and the management of spare parts.”

4.9. In the design of, and any modification to, a research reactor, including installation of new experimental devices or changes to existing equipment, consideration should be given to the needs of the operating organization with regard to ageing management and reactor utilization. Further recommendations are provided in SSG-24 (Rev. 1) [10].

4.10. The design of, and any modification to, a research reactor or experimental device should facilitate inspections and testing aimed at detecting degradation mechanisms and their ageing effects on SSCs, while ensuring that the radiation exposure of inspection personnel is as low as reasonably achievable. Particular consideration should be given to SSCs that are difficult to inspect or maintain. Further recommendations on design for inspectability are provided in paras 4.17 and 4.18 of SSG-81 [3].

4.11. The operating organization should document the ageing management programme and should thereby be able to demonstrate that ageing management has been adequately addressed in the design for the entire lifetime of the research reactor.

4.12. In the procurement of SSCs, the operating organization should include specifications to facilitate ageing management, including information to be included in documents received from suppliers (see also para. 7.7 of SSR-3 [1]).

Reactor design considerations

4.13. Ageing effects are required to be taken into account in equipment qualification activities, with consideration given to all environmental conditions established in the design basis including anticipated operational occurrences and design basis accidents (see paras 6.82–6.84 of SSR-3 [1]).

4.14. All potential degradation mechanisms for passive and active SSCs that could affect the ability of the SSCs to perform the necessary safety functions during their design life should be identified, evaluated and taken into account. In doing this, the importance of the SSCs to safety should be identified, and account should be taken of the specific service conditions, intended mode of operation, expected service life and ease of replacement.

4.15. Relevant experience of ageing management from nuclear installations (including other research reactors and nuclear power plants) and other industrial installations, as well as research results, should be reviewed and taken into account in the design of a research reactor. Consideration should also be given to the combined effects of several degradation mechanisms acting simultaneously.

4.16. In the design of a research reactor, consideration should be given to the use of advanced materials with greater ageing resistance (e.g. materials with a high resistance to corrosion, high strength, or resistance to neutron and thermal embrittlement). Consideration should also be given to the combined effects of several degradation mechanisms acting simultaneously and to the use of compatible materials, especially materials used for welding.

4.17. In the design of a research reactor, consideration should be given to maintenance activities and material testing programmes, including surveillance specimens, that will be needed to monitor ageing effects.

4.18. Ageing management should be included in the general design criteria and should address the following:

(a) Different types of SSC important to safety (e.g. concrete structures, mechanical components and equipment, electrical equipment and instrumentation, control equipment and cables) and measures to monitor their potential degradation;
(b) The means by which environmental conditions to which SSCs are exposed are to be maintained within specified service conditions (e.g. location of ventilation, insulation of hot SSCs, radiation shielding, damping of vibrations, avoidance of submerged conditions, selection of cable routes);
(c) Appropriate monitoring and sampling programmes for materials in cases where it is found that ageing effects might affect the capability of SSCs to perform their safety function throughout the lifetime of the reactor.

AGEING MANAGEMENT CONSIDERATIONS IN THE FABRICATION AND CONSTRUCTION OF A RESEARCH REACTOR

4.19. The operating organization of a research reactor should ensure the following:

(a) Relevant information on factors affecting ageing management, including service conditions, is provided to manufacturers of SSCs. The operating organization should conduct audits of the manufacturer's management system to ensure that this information is properly taken into account in the fabrication and construction of SSCs.
(b) Current knowledge about relevant degradation mechanisms as well as possible mitigation measures is taken into account in the fabrication and construction of SSCs.
(c) Reference (baseline) data, including manufacturing and inspection records, as well as records on shipment and storage conditions, are collected and documented.
(d) Surveillance specimens for specific ageing monitoring programmes are made available and installed in accordance with design specifications.
(e) Environmental conditions are appropriate to minimize any degradation of SSCs in storage, undergoing installation or otherwise not in service (including periodic energizing, functional operation or lubrication to prevent degradation while in storage, if necessary). If a delayed construction period has occurred, the operating organization should identify and document the environmental conditions that could affect the physical condition of SSCs and their long term ageing behaviour.

AGEING MANAGEMENT CONSIDERATIONS IN THE COMMISSIONING OF A RESEARCH REACTOR

4.20. The operating organization should establish a systematic programme for measuring and recording baseline data relevant to ageing management for SSCs important to safety. This includes mapping the actual environmental conditions at each critical location within the research reactor to ensure that they conform with the design specifications.

4.21. Special attention should be paid to the identification of hot spots in terms of temperature and dose rate, to the measurement of vibration levels, and to the characterization of thermal insulation or electrical isolation. All parameters that can influence degradation mechanisms should be identified during commissioning and should be tracked throughout the lifetime of the research reactor. Acceptance criteria for these parameters should be established. Further recommendations are provided in SSG-80 [2].

4.22. The operating organization should ensure that tests performed during commissioning of a research reactor do not subject SSCs to stresses that are not accounted for in the design or that could cause premature ageing. The operating organization should properly document the testing and record the test results during commissioning to allow investigation of any subsequent cases of premature ageing that might have been caused by improper testing.

AGEING MANAGEMENT CONSIDERATIONS IN THE OPERATION OF A RESEARCH REACTOR

4.23. The following issues should be taken into account in implementing the ageing management programme for a research reactor:

(a) Support for the ageing management programme by the management of the operating organization;
(b) Early implementation of an ageing management programme;
(c) A proactive approach based on an adequate understanding of SSC ageing, rather than a reactive approach responding to SSC failures;
(d) Optimal operation of SSCs to slow down the rate of degradation mechanisms;
(e) Proper implementation of maintenance and testing activities in accordance with operational limits and conditions, design requirements and manufacturers’ recommendations, and following approved operating procedures;

(f) Minimization of human performance factors that might lead to premature degradation, through enhancement of staff motivation, sense of ownership and awareness, and understanding of the basic concepts of ageing management;
(g) Availability and use of correct operating procedures, tools and materials, and of a sufficient number of qualified staff for a given task;
(h) Appropriate storage of spare parts and consumables susceptible to ageing to minimize degradation while in storage and to control their shelf life properly;
(i) Availability of the necessary competences for dealing with complex ageing issues;
(j) Effective internal and external communication;
(k) Feedback of operating experience (both generic and plant specific operating experience, including operating experience from non-nuclear plants) to learn from relevant ageing related events (see Requirement 88 of SSR-3 [1]);
(l) Follow-up of possible degradation trends in SSCs between successive periodic testing where possible;
(m) Use of databases on SSC reliability and maintenance histories;
(n) Use of adequate and qualified methods of non-destructive testing and ageing monitoring for early detection of flaws possibly resulting from intensive use of equipment.

4.24. The operating organization should identify and address the following common weaknesses of an ageing management programme:

(a) Insufficient understanding and predictability of ageing at the time of design and construction of a research reactor;
(b) Premature ageing of SSCs in research reactors (i.e. ageing effects that occur earlier than expected) caused by non-compliance with the management system, unforeseen ageing phenomena, or operation of SSCs beyond their design specifications or in service conditions that are more severe than the normal environmental conditions.

4.25. The operating organization should identify and justify possible changes in operational conditions (e.g. radiation levels, flow distribution, coolant velocity, vibration) that could cause accelerated or premature ageing and failure of some SSCs, in the event of the following:

(a) Uprating of the reactor power (examples of significant ageing effects due to power uprating include radiation degradation of the reactor vessel and core

components, flow accelerated corrosion and vibration of primary system piping);
(b) Installation of new experimental devices or changes in the utilization programme;
(c) Implementation of modifications, including changes to the safety analysis;
(d) Replacement of SSCs.

4.26. If a new degradation mechanism is discovered (e.g. through feedback from operating experience or from research), the operating organization should perform an appropriate review of the ageing management programme to determine the effects, if any, on SSCs important to safety that are subject to similar service conditions. The operating organization should then implement appropriate ageing management measures.

4.27. For SSCs important to safety, the operating organization should consider preparing contingency maintenance plans to deal with the potential ageing effects or failure of these SSCs caused by potential degradation mechanisms.

AGEING MANAGEMENT CONSIDERATIONS IN THE UTILIZATION AND MODIFICATION OF A RESEARCH REACTOR

4.28. Research reactors are frequently modified to incorporate new experimental devices or to improve the efficiency of normal operation. In addition, the frequency of testing and repair may also need to be changed owing to ageing or obsolescence of SSCs. The operating organization should consider the impact of these factors on the maintenance programme and the ageing management programme. Consideration should be given to reactor modifications, including temporary ones, with regard to the possible acceleration of ageing phenomena or the appearance of phenomena that have not previously been considered.

4.29. The operating organization should ensure that appropriate cooling is provided for experimental devices and reactor structures such as thermal columns and concrete shields, as well as power, instrumentation and control cables, located in unventilated hot areas.

4.30. In the development of the ageing management programme, the operating organization should ensure that particular consideration is given to the following:

(a) Experimental devices operating at high temperature gradients, high temperatures and/or pressures causing creep and fatigue of materials;

(b) Beam ports and beam tubes;
(c) Degradation of mechanical properties of experimental devices due to radiation induced embrittlement or due to vibration induced by water flow;
(d) The irradiation of capsules containing materials (e.g. copper, mercury) that can cause corrosion in aluminium alloys.

4.31. The documentation for a research reactor might become obsolete due to modifications or to changes in the reactor utilization programme (e.g. owing to installation of a new experimental device or changes to an existing experiment). The updating of operating procedures, drawings and other technical documentation should be included in the ageing management programme.

AGEING MANAGEMENT CONSIDERATIONS IN THE EXTENDED SHUTDOWN OF A RESEARCH REACTOR

4.32. Paragraph 7.123 of SSR-3 [1] states that "The operating organization shall take appropriate measures during an extended shutdown to ensure that materials and components do not seriously degrade." To meet this requirement, the following measures should be implemented:

(a) Unloading the fuel elements from the reactor core to storage racks as appropriate;
(b) Removing components for lay-up or safe storage in an appropriate controlled environment;
(c) Maintaining water chemistry within specifications and maintaining appropriate environmental conditions (e.g. humidity, temperature) to prevent accelerated ageing (e.g. corrosion).

4.33. Further information on safety considerations for research reactors in extended shutdown is provided in Ref. [19]. Periods of extended shutdown should be used for additional inspections that are not included in the operational limits and conditions for SSCs during normal operation (e.g. because the core cannot be unloaded or the beryllium reflector cannot be dismantled). Such additional inspections include the following:

(a) Inspection of the reactor vessel or core support structure;
(b) Inspection of the core structure internals, including connection bolts;
(c) Dimensional control and alignment of the core internals and reactivity control mechanisms;

(d) Inspection of bellows, strainers, valves and other piping of SSCs important to safety;
(e) Inspection of beam ports.

4.34. The operating organization should review and, where necessary, revise the ageing management programme to ensure that relevant factors affecting ageing are taken into account for SSCs that are out of service, in lay-up or in safe storage states during extended shutdown. Particular consideration should be given to inspections for degradation of structures (including biological shielding) and mechanical and electrical SSCs. Documentation and software should also be evaluated for obsolescence.

AGEING MANAGEMENT CONSIDERATIONS IN PLANNING FOR DECOMMISSIONING OF A RESEARCH REACTOR

4.35. Appropriate arrangements should be made by the operating organization to ensure that the equipment and SSCs (e.g. means of confinement, radiation monitoring, long term cooling, lifting equipment, condition monitoring equipment) needed for decommissioning remain available and functional. During the planning process for decommissioning, the ageing management programme should be reviewed to identify elements of the programme that will remain in effect after the research reactor has been shut down.

5. AGEING MANAGEMENT PROGRAMMES FOR RESEARCH REACTORS

5.1. With regard to the design of research reactors, para. 6.113 of SSR-3 [1] states:

> “An ageing management programme that includes inspection and periodic testing of materials shall be put in place, and the results that are obtained in this programme shall be used in reviewing the adequacy of the design at appropriate intervals.”

5.2. With regard to the operation of research reactors, Requirement 86 of SSR-3 [1] states:

> "**The operating organization for a research reactor facility shall ensure that an effective ageing management programme is implemented to manage the ageing of items important to safety so that the required safety functions of structures, systems and components are fulfilled over the entire operating lifetime of the research reactor.**"

5.3. The ageing management programme for a research reactor should be aimed at identifying and implementing effective and appropriate ageing management actions and practices that provide for prevention, timely detection and mitigation of ageing effects on SSCs. A systematic ageing management programme should be applied, comprising the following elements:

(a) Screening of SSCs for the ageing management programme;
(b) Identification and understanding of degradation mechanisms;
(c) Minimization of ageing effects;
(d) Detection, monitoring and identification of trends in ageing effects;
(e) Mitigation of ageing effects;
(f) Acceptance criteria;
(g) Corrective actions;
(h) Review and improvement of the ageing management programme;
(i) Record keeping.

SCREENING OF STRUCTURES, SYSTEMS AND COMPONENTS AT A RESEARCH REACTOR FOR THE AGEING MANAGEMENT PROGRAMME

5.4. A research reactor has a large number and variety of SSCs, some of which are more important to safety than others. There are also considerable differences in the extent to which these SSCs are susceptible to degradation mechanisms. It is neither practicable nor necessary to evaluate and quantify the extent of ageing effects on every individual SSC. A systematic approach should therefore be applied to focus resources on those SSCs, including experimental devices, that are susceptible to degradation mechanisms and whose failure could have a negative impact on the safe operation of the research reactor.

5.5. The following safety based approach should be applied to the screening of SSCs for the ageing management programme:

(a) First level screening: The existing list of SSCs important to safety, which should have been developed during the design stage, should be reviewed for completeness (see Annex II). If such a list is not available, first level screening should be performed to identify those SSCs that are important to safety on the basis of whether a failure could lead (directly or indirectly) to the loss or impairment of a safety function.
(b) Second level screening: For each SSC identified as being important to safety, the specific structural elements[6] and components that are important to safety should be identified (i.e. those whose failure could lead (directly or indirectly) to the loss or impairment of a safety function).
(c) Third level screening: From the list of structural elements and components important to safety, those for which degradation mechanisms have the potential to cause component failure should be identified, and a justification should be provided for any components that are excluded.

An outline of this screening process is given in Fig. 1.

5.6. Alternative screening methodologies (e.g. approaches based on probabilistic safety assessment (see Requirement 16 and para. 6.29 of SSR-3 [1])) may also be acceptable. The specific screening methodology used should be justified and documented.

5.7. Annex II provides an example list of SSCs to be considered in the ageing management programme for open pool, light water research reactors and heavy water moderated research reactors. The ageing management programme for a specific research reactor should not be limited to the SSCs presented in Annex II; the SSCs specific to the individual research reactor should also be considered.

5.8. In the screening of SSCs for the ageing management programme, consideration should be given to all operational states for which a component is credited. These SSCs should be identified by applying the approach set out in para. 5.5. Consideration should be given to grouping similar components (e.g. valves, pumps, small diameter piping) that operate in comparable service conditions (e.g. pressure, temperature, water chemistry).

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[6] Structural elements include both simple structures and elements of complex structures. The term ‘structural element’ is used only for this screening process. In subsequent paragraphs, structural elements are again referred to as ‘structures’.

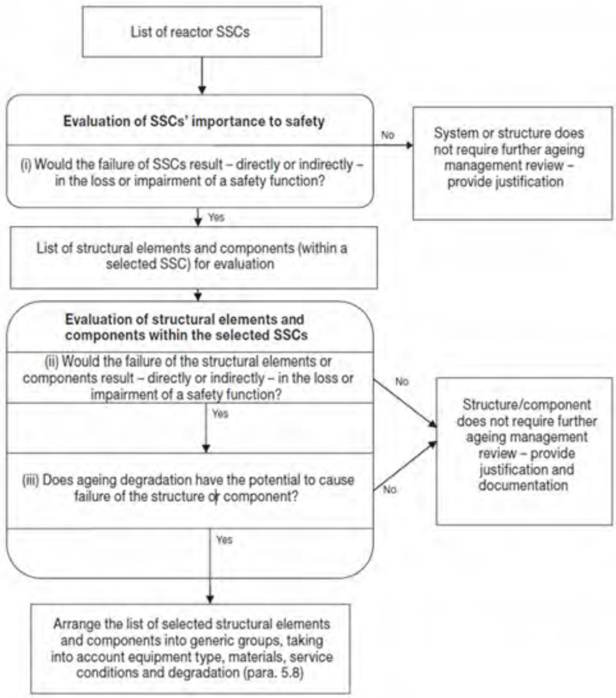

FIG. 1. Outline of the process for screening structures, systems and components (SSCs) for ageing management.

IDENTIFICATION AND UNDERSTANDING OF DEGRADATION MECHANISMS AT A RESEARCH REACTOR

5.9. To understand the ageing effects on an SSC, the degradation mechanisms should be identified and understood. This will then enable effective prevention, monitoring and mitigation of the ageing effects.

5.10. Interactions between materials, and service conditions, should be assessed to identify degradation mechanisms. This assessment should be performed using analytical or empirical models for evaluating previous ageing effects and predicting future degradation.

5.11. Existing methods for inspection, testing, surveillance, monitoring and assessment should be evaluated, taking into account relevant operating experience and research results, to determine whether these methods are effective for timely detection of ageing effects before failure of the structure or component occurs.

MINIMIZATION OF AGEING EFFECTS AT A RESEARCH REACTOR

5.12. Preventive and mitigatory actions should be taken to minimize or limit the effects of ageing. Preventive and mitigatory actions are required to be determined during the design stage of the research reactor (see para. 6.114 of SSR-3 [1]). The actions should be continually improved, with account taken of relevant operating experience and research results, and should include the following:

(a) An assessment of the effectiveness of current maintenance and refurbishment methods and practices (including periodic replacement of parts and consumables) to control the ageing of SSCs;
(b) Establishment of appropriate operating conditions and implementation of practices that minimize the ageing of SSCs;
(c) Changes in design, materials or environmental conditions, where appropriate, to minimize the ageing of SSCs.

5.13. Periodic reviews should be undertaken at appropriate intervals to monitor the effects of ageing and determine the effectiveness of actions and practices for minimizing the ageing of SSCs. The information obtained in periodic reviews should be documented. If the effectiveness of the preventive actions is determined to be unacceptable, appropriate corrective actions should be implemented.

DETECTION, MONITORING AND IDENTIFICATION OF TRENDS IN AGEING EFFECTS AT A RESEARCH REACTOR

5.14. An assessment of the various methods for examining SSCs should be performed to select those methods that are appropriate for detecting the effects of the identified degradation mechanisms. Such methods could include the following:

(a) Inspections;
(b) Monitoring;
(c) Performance tests;
(d) Periodic testing;
(e) Non-destructive testing, including visual examination.

5.15. The results of the examinations should be evaluated using baseline data collected in previous examinations, or acceptance criteria, to assess the condition[7] of the SSCs and whether they are acceptable for continued safe operation or whether remedial measures or corrective actions need to be taken. The examination results should be added to the baseline data for use in subsequent examinations, and records should be kept of any remedial measures or corrective actions.

5.16. The capability and feasibility of detection methods should be periodically evaluated to check their adequacy (including whether they are sufficiently sensitive, reliable and accurate).

5.17. The frequency of examination of an SSC for ageing management should be in accordance with the recommendations of the designer, manufacturer and/or supplier. The frequency may be adjusted on the basis of the likelihood of failure of the SSC and on the basis of experience, including experience from similar facilities. Any proposed changes to the frequency of examinations should be justified.

5.18. Inspection activities should include the following:

(a) Observation of the condition of SSCs (e.g. leaks, noise, vibration); this is normally done during periodic walkdowns of the research reactor.
(b) Sampling of water coolant for chemical[8] or radiochemical analysis.

5.19. Ageing effects may be detected by a change in measurable operating parameters (e.g. control rod drop time, water chemistry parameters, temperature, flow rate, pressure). Parameters that can be used to predict ageing effects should be routinely monitored (either on-line or periodically). Readings should be assessed, and trends identified, in order to predict the onset of ageing effects in a timely manner.

5.20. Ageing effects can be detected by checking the performance of SSCs. The results of performance tests undertaken as part of the maintenance programme should be periodically examined for evidence of trends that indicate ageing effects.

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[7] Condition assessment of an SSC is an assessment to determine the SSC’s current performance and condition (including assessment of any ageing related failures or indications of significant material degradation) and to predict its expected future performance, future ageing effects and residual service life.

[8] Use of electrochemical techniques for on-line monitoring of corrosion is also suitable for low temperature environments such as research reactor pools.

TABLE 1. NON-DESTRUCTIVE TESTING METHODS AND ASSOCIATED TECHNIQUES

Method	Type of defect	Techniques
Visual examination	Scratches, wear, cracks, corrosion or erosion of surfaces	Television cameras, underwater telescopes, binoculars and mirrors
Surface examination	Surface or near surface flaws or discontinuities	Liquid penetrant and magnetic particles
Volumetric examination	Depth or size of a surface breaking or subsurface flaw	Radiographic, ultrasonic and eddy current techniques

5.21. The results of periodic testing performed to verify compliance with the operational limits and conditions should be evaluated to detect and correct abnormal conditions before they give rise to significant consequences with regard to the ageing of SSCs that could be important to safety.

5.22. Non-destructive testing methods should also be used to detect ageing of SSCs. Various non-destructive testing methods and their capabilities, together with the associated techniques, are presented in Table 1. Further information on non-destructive testing methods and techniques that can be used to detect ageing of SSCs in research reactors can be found in Ref. [20]. The non-destructive testing methods, procedures and personnel may be subject to approval by the regulatory body.

MITIGATION OF AGEING EFFECTS AT A RESEARCH REACTOR

5.23. Once ageing effects have been detected or predicted, methods for mitigation of ageing effects should be evaluated, and mitigating actions should be taken. The effectiveness of existing methods and practices for mitigating ageing effects on an SSC should be evaluated, with account taken of relevant operating experience and research results. Methods and practices to be evaluated should include maintenance, refurbishment and periodic replacement of components; modification of SSCs; and alteration of operating conditions and practices that might affect the rate of ageing degradation.

5.24. Although preventive and mitigatory actions are conceptually different, some preventive actions (e.g. maintaining water chemistry parameters within specifications) are also mitigatory actions.

ACCEPTANCE CRITERIA FOR AGEING MANAGEMENT AT A RESEARCH REACTOR

5.25. Appropriate acceptance criteria for the inspection and monitoring of ageing effects on SSCs should be established and should be based on the design basis for items important to safety (see Requirement 17 of SSR-3 [1]) or on the technical requirements for the structure or component, as well as on the relevant regulatory requirements, codes and standards, so that a corrective action can be implemented before loss of the intended function of the structure or component. The need for sufficient margins should be taken into account in these acceptance criteria.

CORRECTIVE ACTIONS FOR AGEING MANAGEMENT AT A RESEARCH REACTOR

5.26. The operating organization of a research reactor should ensure that corrective actions are taken when ageing effects are identified, for example by replacing or refurbishing the affected SSC. The corrective actions should be commensurate with the safety significance of the ageing effects, and their implementation should ensure that SSCs meet the acceptance criteria for continued safe operation.

REVIEW AND IMPROVEMENT OF THE AGEING MANAGEMENT PROGRAMME AT A RESEARCH REACTOR

5.27. The reactor management should establish provisions for reviewing the effectiveness of the ageing management programme and implementing improvements, as necessary. Ageing evaluations and condition assessments should be periodically reviewed and updated, and the effectiveness of ageing management activities for individual SSCs should be periodically evaluated to take into account current knowledge and performance indicators, and should be adjusted as appropriate. Information should be acquired from experience with the operation of SSCs, from surveillance and maintenance records, from lessons from other similar facilities, and from the results of research. New degradation mechanisms or unexpected degradation locations may be identified from analysis of an incident occurring at another research reactor.

5.28. The reactor management should ensure that a review of the performance of SSCs, indicating the effectiveness of the ageing management programme in monitoring ageing trends and identifying any weaknesses and opportunities for improvement, is performed at an appropriate frequency. The results of the performance reviews should be evaluated, analysed and used to define corrective actions and to update the ageing management programme, as appropriate.

5.29. The result of reviews of the ageing management programme and of the assessments of SSCs, including inspection results and proposed updates, should be submitted to the safety committee (or another competent body) for review and, if required, to the regulatory body for review and assessment.

5.30. The operating organization should consider arranging for peer reviews of the ageing management programme to obtain an independent assessment in order to establish whether the ageing management programme is consistent with accepted practices and to identify areas for improvement (see also paras 7.6 and 7.7 of this Safety Guide).

RECORD KEEPING FOR AGEING MANAGEMENT AT A RESEARCH REACTOR

5.31. The operating organization is required to establish a data collection and record keeping system (see Requirement 82 of SSR-3 [1]), which should be described in the safety analysis report (see Requirement 1 of SSR-3 [1]). This system should include information for the following ageing management activities:

(a) Identification and evaluation of degradation, failures and malfunctions of SSCs caused by ageing effects;
(b) Prediction of the future performance of SSCs, which is necessary for continued safe and reliable operation of the research reactor;
(c) Decisions on the type and timing of preventive maintenance actions, including calibration, repair, modification, refurbishment and replacement, and decisions on revisions to the ageing management programme;
(d) Optimization of service conditions and practices that reduce degradation of SSCs;
(e) Identification of emerging ageing effects before they jeopardize the safety, reliability and service life of SSCs or the operating lifetime of the research reactor.

5.32. The information on ageing management may be divided into the following three categories:

(a) Baseline information, consisting of data on the design of the reactor and/or of the SSCs and on the conditions at the beginning of the service life of the SSCs;
(b) Reactor operating records, covering service conditions of the SSCs, including transient data, and data on the availability, testing and failure of SSCs;
(c) Maintenance records, including information on the condition of the SSCs.

All records should be retained as specified in the operational limits and conditions.

6. MANAGEMENT OF OBSOLESCENCE AT RESEARCH REACTORS

6.1. Obsolescence (non-physical ageing) occurs when SSCs become out of date in comparison with current technology, knowledge, standards or regulations, or when documentation becomes out of date. Paragraph 6.114 of SSR-3 [1] states that “The ageing management of the research reactor facility shall include the management of obsolete structures, systems and components”. Recommendations on managing the obsolescence of instrumentation and control systems, including software, are provided in SSG-37 (Rev. 1) [8].

6.2. Obsolescence of SSCs important to safety should be managed proactively (i.e. with foresight and anticipation) throughout their service life. Obsolescence of SSCs should be identified, and corrective actions should be taken before the occurrence of any decline in safety, reliability or availability of a research reactor.

6.3. The operating organization should establish activities for the management of obsolescence throughout the lifetime of the research reactor. These activities should be reviewed by the safety committee (or other competent body) and should be submitted to the regulatory body for review and assessment, if required by national regulations. Conditions that can lead to obsolescence and that can thus affect reactor safety include the following:

(a) Changes in technology, including software and hardware;
(b) Changes in regulations, codes or standards;

(c) Documentation becoming out of date (e.g. if it is not correctly updated following modifications of SSCs or changes in the utilization programme).

Table 2 summarizes these conditions and their effects and recommends actions to be considered for managing obsolescence.

6.4. The reactor management should ensure that attention is paid to the management of obsolescence of technology (which, in general, occurs in systems such as electrical and instrumentation systems and the radiation monitoring system).

6.5. The management of obsolescence should include the review and updating of the documentation for the reactor (e.g. the safety analysis report, operational limits and conditions, emergency plan, radiation protection programme, operating procedures). The documentation for a research reactor should be updated when changes in regulations or standards occur, to prevent its obsolescence.

TABLE 2. TYPES OF OBSOLESCENCE, ASSOCIATED AGEING EFFECTS AND RECOMMENDED AGEING MANAGEMENT ACTIONS

Conditions	Ageing effects	Ageing management actions
Changes in technology (safety systems)	Incompatibility between old and new equipment Unavailability of suppliers Shortage or lack of spare parts	Ensure systematic identification of useful service life and anticipated obsolescence Prioritize the identified equipment on the basis of safety significance Prepare a modification project for future replacement of obsolete SSCs Provide spare parts for the planned service life or identify alternative suppliers
Changes in standards or regulations, advances in knowledge	Outdated knowledge of practices, standards or regulations Deviations from current standards or regulations	Ensure compliance with current standards and regulations Consider the modification of SSCs important to safety, as necessary Participate in industry forums to exchange information on obsolescence management
Documentation becoming out of date	Lack of the information needed for safe operation	Establish an effective management system, including configuration management and updating of documents

7. INTERFACES BETWEEN AGEING MANAGEMENT AND OTHER PROGRAMMES AND TECHNICAL AREAS AT A RESEARCH REACTOR

7.1. Paragraph 7.120 of SSR-3 [1] states that (footnote omitted) “The ageing management programme shall be coordinated with, and be consistent with, other relevant programmes, including the programmes for in-service inspections, periodic safety review and maintenance.”

7.2. The following programmes and technical areas interface with, or are closely related to, the ageing management programme at a research reactor:

(a) Maintenance, periodic testing and inspection;
(b) Periodic safety review;
(c) Equipment qualification;
(d) Reconstitution of the design basis for SSCs;
(e) Configuration management;
(f) Time limited ageing analysis;
(g) Continued safe operation;
(h) Post-service surveillance and testing;
(i) Operational limits and conditions;
(j) The interfaces between safety and nuclear security.

INTERFACE BETWEEN AGEING MANAGEMENT AND MAINTENANCE, PERIODIC TESTING AND INSPECTION AT A RESEARCH REACTOR

7.3. The objective of maintenance, periodic testing and inspection programmes is to ensure that SSCs function in accordance with the design requirements and intent, as well as in compliance with the safety analysis report and the operational limits and conditions. The activities in these programmes are closely related to those that should be established in the ageing management programme, for example as follows:

(a) Preventive maintenance, consisting of regularly scheduled inspections, testing, servicing, overhauls and replacement activities, to detect and prevent incipient failures and to ensure the continuing capability of SSCs to perform their intended functions.

(b) Corrective maintenance, consisting of repair and replacement of damaged or worn SSCs.
(c) Periodic testing, to ensure compliance with the operational limits and conditions.
(d) Inspection, consisting of examinations of SSCs for ageing effects, to determine whether they are acceptable for continued safe operation or whether corrective actions should be taken. Inspection also refers to non-routine examination for assessment of ageing effects.

7.4. Further recommendations on the interrelationship between maintenance, periodic testing and inspection and their relationship to ageing management for research reactors are provided in SSG-81 [3].

7.5. The maintenance programme should be evaluated and, if necessary, updated on the basis of the findings of the ageing management programme. The maintenance frequency, testing methods and procedures, and repair methods and procedures may need to be adjusted with time, as inadequate maintenance in conjunction with service conditions, as well as improper maintenance, might accelerate ageing effects on SSCs.

INTERFACE BETWEEN AGEING MANAGEMENT AND PERIODIC SAFETY REVIEW OF A RESEARCH REACTOR

7.6. Paragraph 4.25 of SSR-3 [1] states:

> "Systematic periodic safety reviews of the research reactor in accordance with the regulatory requirements shall be performed throughout its operating lifetime, with account taken of operating experience, the cumulative effects of ageing, applicable safety standards and safety information from all relevant sources."

In the periodic safety review, the operating organization should assess the effectiveness of the ageing management programme and the need for improvements. The objectives of this assessment should include the following:

(a) To determine whether the research reactor or individual SSCs important to safety can be operated safely for a specified future period (e.g. the period between the current safety review and the next one);
(b) To provide inputs for improvement of the scope, frequency and procedures for maintenance, surveillance and inspection, for updating of the safety

analysis, and for modifications of service conditions or design (including possible changes to the design basis of SSCs).

7.7. In performing a periodic safety review, self-assessment or audits by the operating organization, or peer reviews, the information provided in Ref. [19] should be taken into account. Reference [19] covers the preparation, execution, reporting and follow-up of safety reviews of research reactors, including long term safety reviews when ageing of a research reactor may be a concern.

INTERFACE BETWEEN AGEING MANAGEMENT AND EQUIPMENT QUALIFICATION AT A RESEARCH REACTOR

7.8. Requirement 29 of SSR-3 [1] states:

> "**A qualification programme shall be implemented for a research reactor facility to verify that items important to safety are capable of performing their intended functions when necessary, and in the prevailing environmental conditions, throughout their design life, with due account taken of reactor conditions during maintenance and testing.**"

The programme should also include the list of equipment that should be qualified (see also annex I to SSR-3 [1]), the process of qualification (i.e. testing, analysis, use of operating experience, or a combination), and frequency of qualification.

7.9. The qualification programme is required to include the environmental conditions for which equipment is qualified (see para. 6.82 of SSR-3 [1]). Environmental conditions include temperature, pressure, humidity, contact with chemicals, radiation exposure, meteorological conditions, submergence, and degradation mechanisms that could affect the proper functioning of the equipment. Monitoring of actual environmental conditions should be implemented to obtain additional information necessary for the assessment of ageing effects on the equipment in its actual operating environment.

7.10. Equipment qualification should establish the qualified life[9] of equipment, in which ageing effects and environmental conditions have been taken into

[9] Qualified life is the period for which an SSC has been demonstrated, through testing, analysis or experience, to be capable of functioning within acceptance criteria during specific operating conditions while retaining the ability to perform its safety functions in accident conditions for a design basis accident or a design basis earthquake [11].

account. The qualified life of equipment should be reassessed during its lifetime, taking into account new knowledge and understanding of degradation mechanisms and the actual operating environment of the equipment. If the qualified life is to be increased, a thorough safety demonstration should be provided by the operating organization.

7.11. The status of qualified equipment should be properly documented and maintained throughout the lifetime of the research reactor. The documentation relating to equipment qualification, which is typically part of the equipment qualification programme, should include the following:

(a) A list of all qualified equipment;
(b) Results of monitoring of environmental conditions, such as temperature, humidity and radiation levels in the research reactor;
(c) The evaluation report for equipment qualification;
(d) Test reports relating to equipment qualification;
(e) Reports of time limited ageing analyses relating to equipment qualification, or reports of a suitable equivalent analysis.

7.12. The operating organization of a research reactor should periodically review the equipment qualification programme, including an assessment of the effectiveness of the programme. The review should consider the effects of ageing on equipment during service and the effects of possible changes in environmental conditions (during normal operation and in postulated accident conditions) since the equipment qualification programme was implemented.

7.13. Recommendations on practices, processes and methods relating to equipment qualification are provided in IAEA Safety Standards Series No. SSG-69, Equipment Qualification for Nuclear Installations [21]. Specific recommendations on equipment qualification for seismic design are given in IAEA Safety Standards Series No. SSG-67, Seismic Design for Nuclear Installations [22]. Recommendations on equipment qualification for instrumentation and control systems of research reactors are provided in SSG-37 (Rev. 1) [8].

INTERFACE BETWEEN AGEING MANAGEMENT AND RECONSTITUTION OF THE DESIGN BASIS FOR STRUCTURES, SYSTEMS AND COMPONENTS AT A RESEARCH REACTOR

7.14. The design basis for SSCs is the information that identifies the specific functions to be performed and the controlling design parameters and specific values, or ranges of values, for these parameters. The design basis should be reconstituted if it has not been supplied in full to the operating organization or if it is not adequately documented. This is particularly important when a new experiment with major safety significance is installed or when SSCs have been significantly modified and/or might become vulnerable to degradation mechanisms. The ageing management programme should be used to demonstrate that, irrespective of ageing effects, the design basis for SSCs important to safety remains valid.

INTERFACE BETWEEN AGEING MANAGEMENT AND CONFIGURATION MANAGEMENT AT A RESEARCH REACTOR

7.15. Configuration management is the process of identifying and documenting the characteristics of SSCs (including computer systems and software) at a research reactor and of ensuring that changes to these characteristics are properly developed, assessed, approved, issued, implemented, verified, recorded and incorporated into the facility documentation. The operating organization, within its management system (see Section 2), should establish a configuration management process aimed at ensuring that changes to characteristics of SSCs due to ageing are properly assessed, recorded and incorporated into the documentation of the research reactor.

TIME LIMITED AGEING ANALYSES AT A RESEARCH REACTOR

7.16. Time limited ageing analyses (also called safety analyses that use time limited assumptions) should demonstrate that the analysed ageing effects will not adversely affect the ability of the structure or component to perform its intended function throughout an assumed period of operation.

7.17. Time limited ageing analyses involve two types of parameter. The first parameter is the time dependent variable used in the analysis. Examples of this parameter are the neutron fluence, the operating time or the number of thermal cycles experienced by a structure or component. The second parameter is the ageing effect associated with the first parameter, which could be the neutron embrittlement, the thermal embrittlement of cast austenitic stainless steel or the cumulative fatigue usage factor, respectively. Both parameters should be evaluated and compared with established acceptance criteria to determine the acceptability of the structure or component for continued service.

7.18. Time limited ageing analyses should meet the following criteria:

(a) Time limited ageing analyses should involve all SSCs within the scope of the ageing management programme (see paras 5.4–5.8).
(b) Time limited ageing analyses should consider ageing effects. Such effects include loss of material, changes in dimension, changes in material properties, loss of toughness, loss of pre-stress in concrete structures, settlement, cracking and loss of dielectric properties.
(c) Time limited ageing analyses should involve time limited assumptions defined by a period of operation that is specified in the analysis. A simple assertion that a component is designed for a particular service life or facility lifetime is not sufficient. Any such assertion should be supported by calculations or other analyses that explicitly include a time limit or a time based assumption.
(d) Time limited ageing analyses should be determined by the operating organization to be of relevance[10] in making a safety determination in accordance with regulatory requirements.
(e) Time limited ageing analyses should produce conclusions (or provide the basis for conclusions) relating to the capability of the SSC to perform its intended function.
(f) Time limited ageing analyses should be referenced in the current licensing basis. The licensing basis includes the technical specifications and documents contained within or incorporated by reference in the licensing basis. Examples of such documents include the safety analysis report and supporting reports and calculations for SSCs needed by codes and standards referenced in the safety analysis report, the fire hazard analysis or fire protection plan, the documentation of the management system, and relevant correspondence and reports issued by the regulatory body.

Safety analyses that meet the criteria in (a)–(e) above, and which have been developed to demonstrate preparedness for the intended period of operation, should be also considered as time limited ageing analyses.

[10] Relevancy is a determination that the operating organization makes on the basis of a review of the information available. A calculation or analysis is relevant if it can be shown to have a direct bearing on the action taken as a result of the analysis performed. Analyses are also relevant if they provide the basis for the safety determination for the facility where, in the absence of the analyses, the operating organization might have reached a different safety conclusion or taken a different safety action.

7.19. Time limited ageing analyses should be evaluated using a projected value of the time dependent parameter, for example through a calculation of the neutron fluence for a certain operating period. This projected value should then be used to evaluate analysis parameters, such as the adjusted nil-ductility temperature or the fracture toughness.

7.20. The validity of time limited ageing analyses over the intended period of operation should be assessed through a demonstration of one of the following criteria:

(a) The analysis remains valid for the intended period of operation. The time dependent parameter value for the intended operating period should not exceed the time dependent parameter value used in the existing analysis.
(b) The analysis has been projected to the end of the intended period of operation. The value of the analysis parameter should be changed on the basis of the time dependent parameter projected for the intended operating period, and the value of the analysis parameter should continue to meet acceptance criteria.
(c) The effects of ageing on the intended function of the structure or component will be adequately managed for the intended period of operation. The value of the analysis parameter should be set (as part of the ageing management programme) to ensure that ageing effects are adequately managed and that the value of the analysis parameter will continue to meet the acceptance criteria throughout the intended period of operation.

7.21. If the validity of the time limited ageing analyses cannot be demonstrated using any of the criteria listed in para. 7.20, then corrective actions should be implemented. Depending on the specific analysis, these corrective actions could include the following:

(a) Refinement of the analysis to remove excess conservatism;
(b) Implementation of further actions in operations, maintenance or the ageing management programme;
(c) Modification, repair or replacement of the structure or component.

7.22. The results of the evaluation of time limited ageing analyses should be used as an input for the review of the ageing management programme.

INTERFACE BETWEEN AGEING MANAGEMENT AND THE CONTINUED SAFE OPERATION OF A RESEARCH REACTOR

7.23. With proper implementation of the ageing management programme, the lifetime of a research reactor may be extended. The lifetime of a research reactor is usually determined by the reactor's continued usefulness and by its operational costs. To assess the continued safe operation of a research reactor, data from the ageing management programme should be analysed and the following actions should be performed:

(a) A safety review of the reactor should be performed, including inspections, to establish the actual status of SSCs.
(b) An overview of potential refurbishment needs should be developed by establishing a comprehensive list of SSCs.
(c) SSCs important to safety should be selected and relevant degradation mechanisms should be identified in order to perform a preliminary evaluation.
(d) The technical and economic feasibility of a refurbishment programme should be established.

7.24. Before commencing a large scale refurbishment project, a strategic plan (or other equivalent study) should be prepared. In addition to commercial and utilization issues, this plan should consider safety issues, such as compliance with regulatory requirements, as well as the technical status of SSCs and experimental devices that are not part of the refurbishment project.

INTERFACE BETWEEN AGEING MANAGEMENT AND POST-SERVICE SURVEILLANCE AND TESTING AT A RESEARCH REACTOR

7.25. After final shutdown of a research reactor and before its decommissioning, a post-service surveillance and testing programme should be implemented to detect and assess continuing ageing effects. This programme should continue for as long as SSCs important to safety remain in operation and decommissioning has not yet been completed.

INTERFACE BETWEEN AGEING MANAGEMENT AND OPERATIONAL LIMITS AND CONDITIONS AT A RESEARCH REACTOR

7.26. Operational limits and conditions for a research reactor specify several service conditions, including limits on operating loads of SSCs or environmental conditions such as water chemistry parameters, that directly affect the ageing of SSCs. The ageing management programme should consider the effects of ageing degradation on the established operational limits and conditions and the effect of any violations of such conditions. Recommendations on establishing operational limits and conditions, including those relating to ageing, and on establishing operating procedures for research reactors, are provided in SSG-83 [5].

INTERFACES BETWEEN AGEING MANAGEMENT AND SAFETY AND NUCLEAR SECURITY AT A RESEARCH REACTOR

7.27. The ageing management programme should take into account any interfaces between safety and nuclear security arrangements (including physical and computer security arrangements), such as common power supplies to the equipment used for security and for ageing management purposes, access restrictions for activities relating to ageing management, and material movement that could block the views of security surveillance equipment.

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Annex I

EFFECT OF AGEING FOR DIFFERENT SERVICE CONDITIONS

I–1. The basic cause of ageing of a structure, system or component (SSC) is the service conditions, which support the actuation and progression of particular degradation mechanisms and, unless ageing is properly managed, lead to loss of the safety function capability of the SSC. Service conditions can be categorized as conditions associated with normal operation, conditions associated with anticipated operational occurrences, and environmental conditions.

I–2. The degradation mechanisms and possible effects of ageing due to selected service conditions associated with normal operation, selected service conditions associated with anticipated operational occurrences, and selected environmental conditions are summarized in Tables I–1, I–2 and I–3, respectively.

TABLE I–1. DEGRADATION MECHANISMS AND POSSIBLE EFFECTS OF AGEING DUE TO SELECTED SERVICE CONDITIONS ASSOCIATED WITH NORMAL OPERATION

Condition	Degradation mechanism	Possible effects or consequences
Radiation	Change of properties	Chemical decomposition Change of strength Change of ductility Swelling Change of resistivity Burnup
Temperature	Change of properties	Change of strength Change of resistivity Change of ductility
Stress (pressure)	Creep	Change of geometry (e.g. breakage, collapse)
Cycling of temperature, flow and/or load	Motion	Displacement Change of position or set point Loose connections Material damage (cracks)

TABLE I–1. DEGRADATION MECHANISMS AND POSSIBLE EFFECTS OF AGEING DUE TO SELECTED SERVICE CONDITIONS ASSOCIATED WITH NORMAL OPERATION (cont.)

Condition	Degradation mechanism	Possible effects or consequences
Flow induced vibrations	Fatigue	Breakage or collapse Deformation Material damage (cracks)
	Wear	Deterioration of surface Change of dimensions
Flow	Erosion	Change of strength
Fluids chemistry	Corrosion or galvanic action	Release of radioactivity Reduction of strength Deposition of particles Short circuits Leakage

TABLE I–2. DEGRADATION MECHANISMS AND POSSIBLE EFFECTS OF AGEING DUE TO SELECTED SERVICE CONDITIONS ASSOCIATED WITH ANTICIPATED OPERATIONAL OCCURRENCES

Condition	Degradation mechanism	Possible effects or consequences
Power excursion	Thermal and/or mechanical stresses	Deterioration of core components Accelerated ageing of core components
Unbalanced control rod positions	Thermal stresses	Reduction of strength Accelerated ageing
Power–flow mismatch (error in fuel loading)	Thermal stresses	Reduction of strength Accelerated ageing
Primary pump failure	Thermal and mechanical stresses	Accelerated ageing
Erroneous maintenance or operation	Mechanical damage and adverse chemical conditions	Deterioration of systems Corrosion Accelerated ageing

TABLE I–3. DEGRADATION MECHANISMS AND POSSIBLE EFFECTS OF AGEING DUE TO SELECTED ENVIRONMENTAL CONDITIONS

Condition	Degradation mechanism	Possible effects or consequences
Humidity and salinity	Corrosion	Leakage Release of radioactive material Reduction of strength Short circuits
Chemical agents	Chemical reactions	Corrosion Deterioration of SSCs
Wind, dust and sand	Erosion and deposition	Change of strength Deterioration of surface Malfunction of mechanical and electrical components

Annex II

EXAMPLE OF SCREENING OF RESEARCH REACTOR STRUCTURES, SYSTEMS AND COMPONENTS FOR AGEING MANAGEMENT PURPOSES

II–1. Table II–1 provides examples of screening of structures, systems and components (SSCs) of pool type, light water research reactors, as well as of heavy water moderated research reactors, for ageing management purposes. The table lists SSCs and indicates their importance to safety and their ease of replacement, as well as the relevant degradation mechanism.

TABLE II–1. TYPICAL RESEARCH REACTOR STRUCTURES, SYSTEMS AND COMPONENTS, TOGETHER WITH THEIR EASE OF REPLACEMENT AND POSSIBLE DEGRADATION MECHANISMS

Structure, system or component	Important to safety? [a]	Ease of replacement [b]	Degradation mechanisms [c]
Pool and reactor internals (for light water moderated reactors)			
Pool structure and vessel	Y	A/B	1, 2, 4, 5, 6
Core structure	Y	B	1, 4, 5, 6, 7
Reflector	Y	B/C	1, 4, 5
Control rods and mechanisms	Y	C	1, 4, 5
Shielding	Y	C	1, 5
Beam tubes	Y	B/C	1, 3, 5
Liner	Y	B/C	1, 3, 5
Fuel assemblies and storage in reactor pool	Y	C	1, 5
Reactor internals (for heavy water moderated reactors)			
Reactor tank	Y	A/B	1, 2, 5, 6

TABLE II–1. TYPICAL RESEARCH REACTOR STRUCTURES, SYSTEMS AND COMPONENTS, TOGETHER WITH THEIR EASE OF REPLACEMENT AND POSSIBLE DEGRADATION MECHANISMS (cont.)

Structure, system or component	Important to safety? [a]	Ease of replacement [b]	Degradation mechanisms [c]
Core structure	Y	B	1, 2, 5
Control rods and mechanisms	Y	C	1, 4, 5
Fuel assemblies	Y	C	1, 5
Cooling systems			
Primary	Y	B/C	1, 3, 4, 5, 6, 7
Pool	Y	A/B	1, 3, 4, 5, 6
Emergency	Y	B/C	3, 4, 5, 6
Make-up	N	C	5
Purification	Y	C	1, 2, 5
Secondary	N	C	4, 5, 6, 7
Hot water layer	Y	C	4, 5, 6
Heavy water storage	Y	B/C	5
Collection of heavy water leaks	Y	B/C	5
Cover gas circulation	Y	C	4, 5
Confinement/containment			
Structure	Y	A	2, 3, 4, 5
Biological shield	Y	A/B	1, 2, 3, 4, 5
Ventilation: normal	M	C	2, 5, 6
Ventilation: emergency	Y	B/C	5, 6

TABLE II–1. TYPICAL RESEARCH REACTOR STRUCTURES, SYSTEMS AND COMPONENTS, TOGETHER WITH THEIR EASE OF REPLACEMENT AND POSSIBLE DEGRADATION MECHANISMS (cont.)

Structure, system or component	Important to safety? [a]	Ease of replacement [b]	Degradation mechanisms [c]
Penetrations	Y	C	1, 2, 4, 5
Isolation system	Y	C	4, 5
Stack	Y	B/C	6
Controls and instrumentation			
Shutdown systems	Y	C	4, 5
Protection system	Y	B	4, 5
Control system	Y	C	2, 4, 6
Control console	M	B/C	2, 6
Radiation monitoring	Y	C	5
Process systems	M	B	4, 5, 6
Annunciators	Y	C	2, 4, 6
Instrumentation	M	C	1, 2, 4, 6
Cabling	M	B/C	1, 2, 5
Remote shutdown and remote monitoring	Y	C	5
Pneumatic system	M	C	4, 5
Data acquisition	M	C	4, 5
Seismic protection	Y	C	4, 5

TABLE II–1. TYPICAL RESEARCH REACTOR STRUCTURES, SYSTEMS AND COMPONENTS, TOGETHER WITH THEIR EASE OF REPLACEMENT AND POSSIBLE DEGRADATION MECHANISMS (cont.)

Structure, system or component	Important to safety? [a]	Ease of replacement [b]	Degradation mechanisms [c]
Auxiliaries			
Electrical power system	M	B	6
Emergency power system	Y	B/C	5, 6
Fire protection	Y	B	5
Lightning protection	M	B/C	5
Flood protection	M	C	5
Communications	M	C/D	5
Cranes	Y	B/C	4, 5
Handling and storage facilities	Y	D	5
Transfer casks and fuel casks	Y	B/C	1, 4, 5
Handling, storage and disposal of radioactive waste	Y	B/C	1, 2, 5, 6
Hot cells	M	B	1, 5, 6, 8
Compressed air	M	C	4, 5, 6
Laboratories	N	C	5, 6, 8
Heavy water auxiliaries, including recombination	Y	C	5, 6
Spare parts	M	B/C	8
Experimental devices			
Cold and hot sources	Y	B/C	1, 2, 3, 4, 5, 6

TABLE II–1. TYPICAL RESEARCH REACTOR STRUCTURES, SYSTEMS AND COMPONENTS, TOGETHER WITH THEIR EASE OF REPLACEMENT AND POSSIBLE DEGRADATION MECHANISMS (cont.)

Structure, system or component	Important to safety? [a]	Ease of replacement [b]	Degradation mechanisms [c]
Shielding	Y	C	1, 5
Rigs and loops	Y	B/C	1, 2, 3, 4, 5, 6
Beam tube lines	Y	C	1, 3, 4, 5
Isotope production facilities and irradiation facilities	M	C	1, 2, 3, 4, 5, 6
Rabbit systems	M	C	1, 5, 6
Thermal columns	M	C	1, 2, 3, 5
Dry irradiation rooms	N	C	1, 5
Reactor block			
Reflector	Y	A/B	1, 4, 5
Thermal shield	Y	A/B	1, 2, 5
Biological shield	Y	A/B	1, 2, 4, 5
Reactor block cooling system	Y	B	2, 5
Other factors (not structures, systems or components)			
Documentation			
— Design	M	B/C	10
— Safety analysis report	Y	B/C	9, 10
— Operational limits and conditions	Y	B/C	10

TABLE II–1. TYPICAL RESEARCH REACTOR STRUCTURES, SYSTEMS AND COMPONENTS, TOGETHER WITH THEIR EASE OF REPLACEMENT AND POSSIBLE DEGRADATION MECHANISMS (cont.)

Structure, system or component	Important to safety? [a]	Ease of replacement [b]	Degradation mechanisms [c]
Operating procedures	Y	B/C	10
Management system	Y	B/C	9, 10
Reviews and assessment	Y	C	9, 10
Industrial safety	N	B/C	8, 9
Licensing	Y	B/C	9

[a] Y: Yes; N: No; M: Maybe, depending on specific reactor design and features.
[b] A: Very difficult; B: Difficult or costly; C: Normal: D: Readily.
[c] 1: Changes of properties due to neutron irradiation.
2: Changes of properties due to temperature service conditions.
3: Stress or creep (due to pressure and temperature service conditions).
4: Motion, fatigue or wear (resulting from cycling of temperature, flow and/or load, or flow induced vibrations).
5: Corrosion.
6: Chemical processes.
7: Erosion.
8: Changes of technology.
9: Changes of regulations.
10: Obsolescence of documentation.

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