IAEA Safety Standards

for protecting people and the environment

Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants

Specific Safety Guide

No. SSG-48

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**.

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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 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 AND DEVELOPMENT OF A PROGRAMME FOR LONG TERM OPERATION OF NUCLEAR POWER PLANTS

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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-48

AGEING MANAGEMENT AND DEVELOPMENT OF A PROGRAMME FOR LONG TERM OPERATION OF NUCLEAR POWER PLANTS

SPECIFIC SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2018

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www.iaea.org/books

Printed by the IAEA in Austria
November 2018
STI/PUB/1814

IAEA Library Cataloguing in Publication Data

Names: International Atomic Energy Agency.
Title: Ageing management and development of a programme for long term operation of nuclear power plants / International Atomic Energy Agency.
Description: Vienna : International Atomic Energy Agency, 2018. | Series: IAEA safety standards series, ISSN 1020–525X ; no. SSG-48 | Includes bibliographical references.
Identifiers: IAEAL 18-01201 | ISBN 978–92–0–104318–4 (paperback : alk. paper)
Subjects: LCSH: Nuclear power plants — Maintainability. | Nuclear power plants — Safety measures. | Materials — Deterioration — Prevention.
Classification: UDC 621.039.58 | STI/PUB/1814

FOREWORD

by Yukiya Amano
Director General

The IAEA's Statute authorizes the Agency to "establish or adopt… standards of safety for protection of health and minimization of danger to life and property" — standards that the IAEA must use in its own operations, and which States can apply by means of their regulatory provisions for nuclear and radiation safety. The IAEA does this in consultation with the competent organs of the United Nations and with the specialized agencies concerned. A comprehensive set of high quality standards under regular review is a key element of a stable and sustainable global safety regime, as is the IAEA's assistance in their application.

The IAEA commenced its safety standards programme in 1958. The emphasis placed on quality, fitness for purpose and continuous improvement has led to the widespread use of the IAEA standards throughout the world. The Safety Standards Series now includes unified Fundamental Safety Principles, which represent an international consensus on what must constitute a high level of protection and safety. With the strong support of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its standards.

Standards are only effective if they are properly applied in practice. The IAEA's safety services encompass design, siting and engineering safety, operational safety, radiation safety, safe transport of radioactive material and safe management of radioactive waste, as well as governmental organization, regulatory matters and safety culture in organizations. These safety services assist Member States in the application of the standards and enable valuable experience and insights to be shared.

Regulating safety is a national responsibility, and many States have decided to adopt the IAEA's standards for use in their national regulations. For parties to the various international safety conventions, IAEA standards provide a consistent, reliable means of ensuring the effective fulfilment of obligations under the conventions. The standards are also applied by regulatory bodies and operators around the world to enhance safety in nuclear power generation and in nuclear applications in medicine, industry, agriculture and research.

Safety is not an end in itself but a prerequisite for the purpose of the protection of people in all States and of the environment — now and in the future. The risks associated with ionizing radiation must be assessed and controlled without unduly limiting the contribution of nuclear energy to equitable and sustainable development. Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them.

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.

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

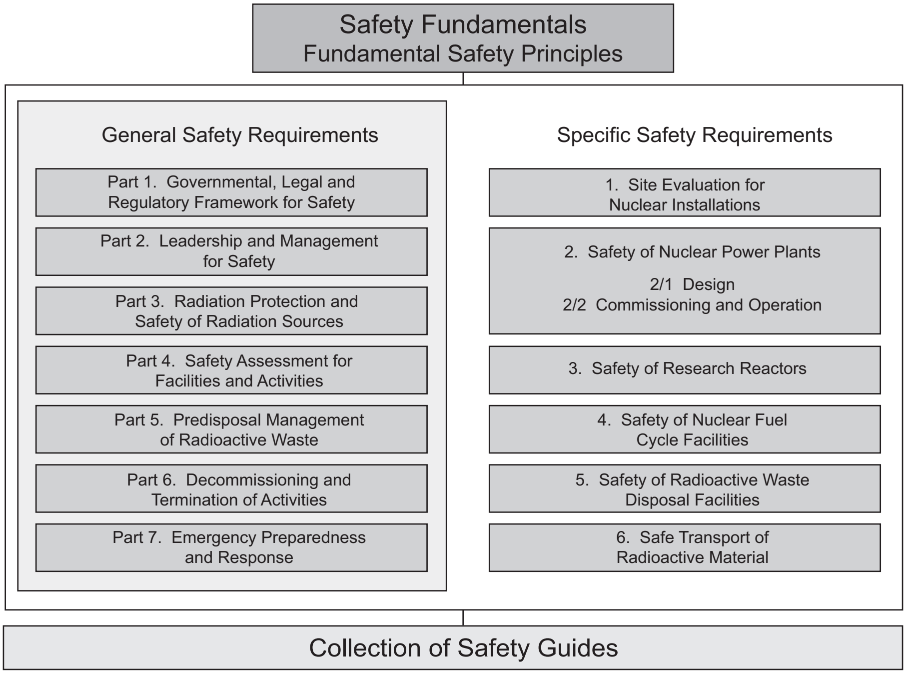

FIG. 1. The long term structure of the IAEA Safety Standards Series.

Safety Guides

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

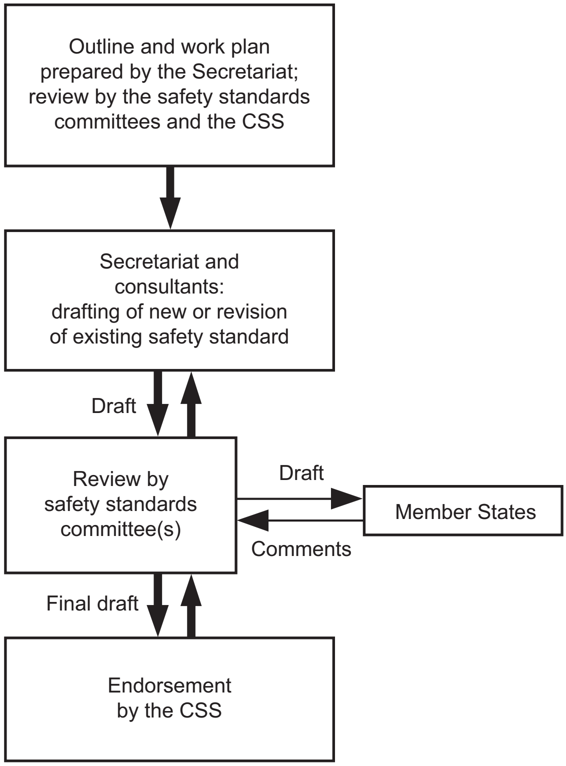

FIG. 2. The process for developing a new safety standard or revising an existing standard.

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. 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 Safety Glossary (see http://www-ns.iaea.org/standards/safety-glossary.htm). 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. This Safety Guide was prepared under the IAEA's programme for safety standards. The requirements for the design, commissioning and operation of nuclear power plants are established in IAEA Safety Standards Series Nos SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design [1], and SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation [2]. The requirements for safety assessment are established in IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [3]. IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety [4], addresses regulatory aspects throughout the operation of facilities and throughout the duration of associated activities and for any subsequent period of institutional control until there is no significant residual radiation hazard.

1.2. Ageing management for nuclear power plants is implemented to ensure that the effects of ageing will not prevent structures, systems and components (SSCs) from being able to accomplish their required safety functions throughout the lifetime of the nuclear power plant (including its decommissioning) and it takes account of changes that occur with time and use [1]. This requires addressing both the effects of physical ageing of SSCs, resulting in degradation of their performance characteristics, and the non-physical ageing (obsolescence) of SSCs (i.e. their becoming out of date in comparison with current knowledge, codes, standards and regulations, and technology).

1.3. Ageing management is most effective when it is properly carried out at all stages of the lifetime of a nuclear power plant.

1.4. Effective ageing management of SSCs is a key element of the safe and reliable operation of nuclear power plants. To assist its Member States in managing ageing effectively, the IAEA has developed the International Generic Ageing Lessons Learned (IGALL) programme (see Refs [5, 6]). In addition, the safety of nuclear power plants during long term operation has become more important owing to the steady increase in the number of operating organizations giving high priority to continuing the operation of nuclear power plants beyond the time frame originally anticipated for their operation.

1.5. This Safety Guide supplements and provides recommendations on meeting the requirements relating to ageing management and long term operation that are established in SSR-2/1 (Rev. 1) [1] and SSR-2/2 (Rev. 1) [2]. It identifies key elements of effective ageing management for nuclear power plants.

1.6. This publication revises and supersedes the Safety Guide on Ageing Management for Nuclear Power Plants issued in 2009, and also supersedes two Safety Reports issued by the IAEA in 1999 and 2007.[1] This revision takes into account developments in the ageing management of nuclear power plants worldwide and expands the scope to include provisions for maintaining the safety of nuclear power plants during long term operation.

1.7. IAEA Safety Standards Series No. SSG-25, Periodic Safety Review for Nuclear Power Plants [7], also provides recommendations on some aspects of physical ageing of SSCs but focuses more on non-physical ageing of SSCs. SSG-25 [7] also stresses the need to seek safety improvements and implement those improvements that are practicable if the plant is to continue to operate beyond the time frame originally anticipated for its operation.

OBJECTIVE

1.8. The objective of this Safety Guide is to provide recommendations for meeting Requirement 30 (Qualification of items important to safety) and Requirement 31 (Ageing management) of SSR-2/1 (Rev. 1) [1] and Requirement 14 (Ageing management) and Requirement 16 (Programme for long term operation) of SSR-2/2 (Rev. 1) [2].

1.9. This Safety Guide provides guidance for operating organizations on implementing and improving ageing management and on developing a programme for safe long term operation for nuclear power plants that, among other aspects, takes due account of ageing management.

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[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Ageing Management for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.12, IAEA, Vienna (2009).

INTERNATIONAL ATOMIC ENERGY AGENCY, Implementation and Review of a Nuclear Power Plant Ageing Management Programme, Safety Reports Series No. 15, IAEA, Vienna (1999).

INTERNATIONAL ATOMIC ENERGY AGENCY, Safe Long Term Operation of Nuclear Power Plants, Safety Reports Series No. 57, IAEA, Vienna (2007).

1.10. This Safety Guide may also be used by the regulatory body in preparing regulatory requirements, codes and standards and in verifying effective ageing management in nuclear power plants.

SCOPE

1.11. The recommendations provided in this Safety Guide are applicable for nuclear power plants throughout their entire lifetime (including their decommissioning), taking into account the different reactor designs existing worldwide.

1.12. This Safety Guide focuses mainly on managing the physical ageing of SSCs within the scope of ageing management ('in-scope SSCs'). It also provides recommendations on safety aspects of managing technological obsolescence and recommendations on the programme for safe long term operation of nuclear power plants with emphasis on ageing management related activities.

1.13. Other aspects relating to safe long term operation, such as obsolescence of knowledge (i.e. matters relating to knowledge management and human resources) and compliance with current regulatory requirements, codes and standards, as well as plant design, the environmental impact of long term operation, economic assessment and long term investment strategies, are outside the scope of this Safety Guide. They are addressed in other IAEA safety standards (see Refs [1, 7, 8]).

1.14. The recommendations in this Safety Guide also apply to facilities for spent fuel storage and radioactive waste management that are part of the nuclear power plant. The recommendations in this Safety Guide can also be used as a basis for ageing management at separate facilities for storage of spent nuclear fuel and for radioactive waste management. In this context, the recommendations provided in IAEA Safety Standards Series No. SSG-15, Storage of Spent Nuclear Fuel [9], should be followed.

STRUCTURE

1.15. Section 2 presents basic concepts of managing ageing and obsolescence as well as their implications for a programme for safe long term operation, which provide a common basis for the recommendations provided in Sections 3–7. Section 3 provides recommendations on ageing management of SSCs at each separate stage in the lifetime of a nuclear power plant. Section 4 provides recommendations on plant documentation and programmes relevant to ageing management and safe long term operation. Section 5 provides recommendations on managing ageing that are applicable throughout the entire lifetime of the nuclear power plant. Section 6 provides recommendations on the management of technological obsolescence at the operation stage. Section 7 provides recommendations on ageing related activities important to the safe long term operation of the nuclear power plant.

2. BASIC CONCEPTS

2.1. This section presents the basic concepts of ageing management, including their application to long term operation, which provide a common basis for the recommendations given in Sections 3–7 of this Safety Guide.

2.2. Physical ageing is a general process in which the physical characteristics of SSCs gradually deteriorate with time or use owing to physical degradation or chemical or biological processes (i.e. degradation mechanisms).

2.3. Non-physical ageing of SSCs is the process of their becoming out of date (i.e. obsolete) owing to the availability and evolution of knowledge and technology, and the associated changes in requirements, codes and standards.

2.4. In this Safety Guide, physical ageing is referred to as ‘ageing’, while non-physical ageing is referred to as ‘obsolescence’.

2.5. Evaluation of the consequences of the cumulative effects of both ageing and obsolescence on the safety of a nuclear power plant is a continuous process and is required to be assessed in a periodic safety review or an equivalent safety assessment under alternative arrangements (see paras 4.6–4.8) [2, 7].

AGEING MANAGEMENT

2.6. Effective ageing management throughout the lifetime of SSCs requires the use of a systematic approach to managing the effects of ageing that provides a framework for coordinating all activities relating to the understanding, prevention, detection, monitoring and mitigation of ageing effects on the plant’s structures and components. This approach is illustrated in Fig. 1, which is an adaptation of Deming's 'plan–do–check–act' cycle to the ageing management of SSCs.

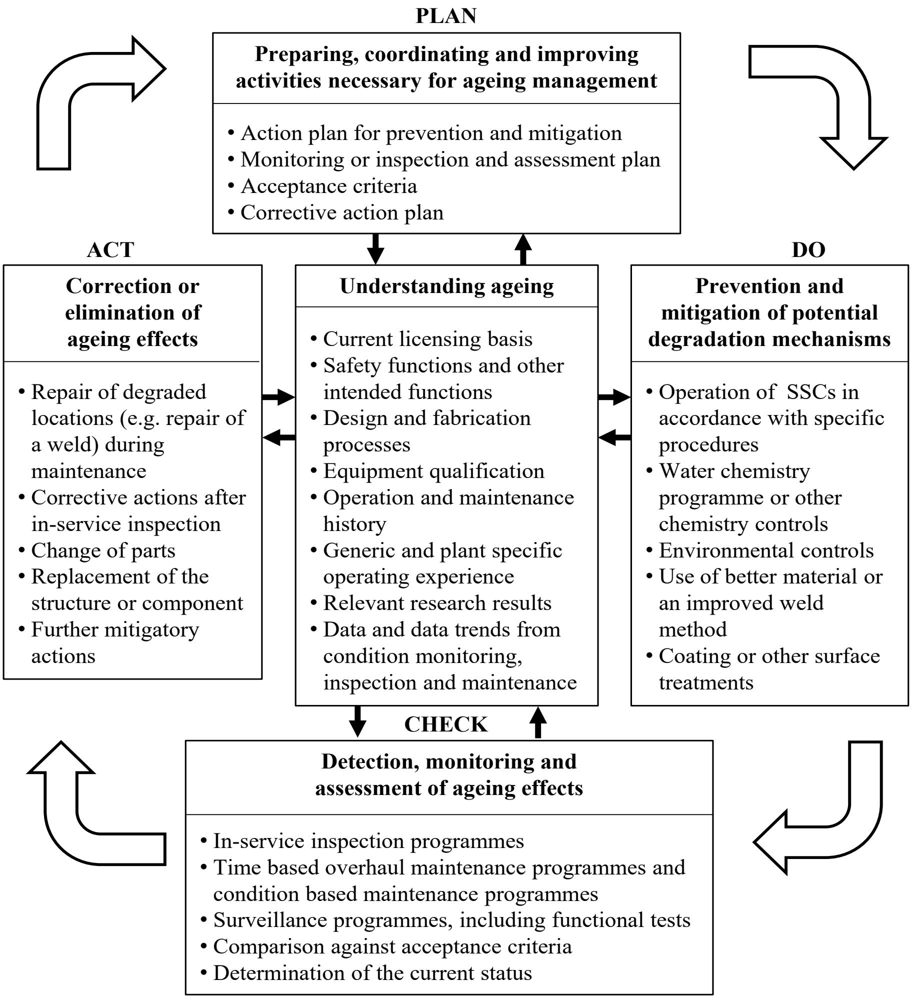

FIG. 1. Systematic approach to ageing management.

2.7. Understanding the ageing of SSCs, as illustrated in Fig. 1, is the key to effective ageing management. This understanding is derived from knowledge of:

(a) The current licensing basis[2] and anticipated updates to the licensing basis, where relevant (including regulatory requirements, codes and standards);
(b) The safety functions and other intended functions of the SSCs;
(c) The design and fabrication processes used (including the material, the material properties, adverse residual effects from fabrication methods, such as cold work or residual stresses in welds, specific service conditions, results from inspections and examinations, and testing in manufacturing);
(d) Equipment qualification (where applicable);
(e) The environmental conditions of the SSCs during any delayed construction period, as these may affect the ageing performance of the SSCs;
(f) The environmental conditions of the SSCs during operation and shutdown conditions, including, at a minimum, temperatures, humidity levels, aqueous parameters (e.g. water quality and levels of deleterious constituents) and neutron or gamma radiation fields;
(g) The operation, irradiation and maintenance histories of SSCs, including their commissioning, repair, modification and surveillance histories;
(h) Operating experience at the plant or at other nuclear power plants;
(i) Relevant research results;
(j) Data and data trends from condition monitoring, inspection and maintenance.

2.8. To maintain plant safety, the effects of ageing on SSCs (i.e. net changes in characteristics) should be detected in a timely manner, so as to be able to take appropriate actions to ensure that the required safety functions of SSCs are fulfilled over the entire lifetime of the nuclear power plant.

2.9. The 'plan' activity in Fig. 1 involves coordinating, integrating and modifying existing programmes and activities relating to the ageing management of SSCs, and developing new programmes if necessary.

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[2] The 'current licensing basis' is the set of regulatory requirements applicable to a specific plant, the operating organization's commitments to ensuring compliance with and operation within applicable regulatory requirements, and the plant specific design basis (including all modifications and additions to such commitments over the life of the licence). The current licensing basis also includes the plant specific design basis information as documented in a safety analysis report (which typically includes time limited ageing analyses), reports of periodic safety reviews and other plant documents.

2.10. Ageing management consists of design, operations and maintenance actions to prevent or to control, within acceptable limits, the ageing of SSCs. Ageing management is an interdisciplinary activity that involves engineering, maintenance, surveillance, equipment qualification, in-service inspection, safety analysis and other relevant plant programmes. IAEA Safety Standards Series No. NS-G-2.6, Maintenance, Surveillance and In-service Inspection in Nuclear Power Plants [10], provides guidance on maintenance, surveillance and inspection practices.

2.11. Ageing management covers all activities that aim to prevent or control ageing effects, within acceptable limits, throughout the entire lifetime of the nuclear power plant (i.e. design; fabrication or construction; commissioning; operation, including long term operation; and decommissioning, including long term shutdown), as described in Section 3.

2.12. The ageing of SSCs increases the probability of common cause failures (i.e. the degradation of two or more physical barriers or redundant structures and components), which could result in the impairment of one or more levels of protection provided by application of the defence in depth concept. Therefore, in setting the scope of ageing management for structures and components, no credit should be taken for redundancy among SSCs.

2.13. Ageing management programmes should be developed using a structured methodology, to ensure a consistent approach in implementing ageing management, as described in Section 5.

2.14. Existing plant programmes, including those for maintenance, equipment qualification, in-service inspection, surveillance and water chemistry, that can be credited where appropriate to manage ageing, ageing effects and degradation mechanisms are described in Section 4.

2.15. Where existing plant programmes are not sufficient, they should be improved or new ageing management programmes should be developed and implemented, as described in Section 5.

2.16. In practice, ageing effects and degradation mechanisms are studied and managed at the level of the structure or component. However, the ageing management programmes for individual structures or components may be integrated into an ageing management programme at the system and/or plant level.

2.17. The ‘do’ activity in Fig. 1 involves preventing and mitigating expected ageing effects and degradation mechanisms of SSCs by developing a specific operating procedure, a water chemistry programme or another chemistry or environmental control programme, and/or by means of other preventive and mitigatory actions.

2.18. Effective ageing management is in practice accomplished by coordinating existing plant programmes and processes (or elements thereof that are relevant to ageing), as well as external activities such as research and development, and by implementing, coordinating or taking credit for other specific actions, as described in Section 5.

2.19. The ‘check’ activity in Fig. 1 involves the timely detection and characterization of significant ageing effects and degradation mechanisms through the inspection and monitoring of structures and components and the assessment of observed ageing effects to determine the type and timing of any corrective actions required [8].

2.20. The ‘act’ activity in Fig. 1 involves the timely correction of ageing effects on structures and components and the introduction of further preventive or mitigatory actions through appropriate maintenance and design modifications, including the repair and replacement of structures and components.

2.21. The closed loop of Fig. 1 indicates the continuation and improvement of ageing management on the basis of feedback on relevant operating experience, results from research and development, and results of self-assessment and peer reviews, to help to ensure that emerging ageing issues will be addressed.

2.22. 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 capability of a structure or component to perform its intended function(s) throughout an assumed period of operation (see paras 5.64–5.69).

2.23. 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 a structure or component undergoes. The second parameter is the ageing effect associated with the first parameter, which could be the neutron embrittlement of vessel material, the cumulative fatigue usage factor or the thermal embrittlement of cast austenitic stainless steel, respectively. Both parameters should be evaluated and compared with a regulatory limit or criterion to determine the acceptability of the structure or component for continued service.

2.24. The effectiveness of ageing management should be periodically reviewed to maintain plant safety and to ensure feedback and continuous improvement (see paras 5.54–5.63).

MANAGEMENT OF OBSOLESCENCE

2.25. Nuclear power plant safety can be impaired if the obsolescence of SSCs is not identified in advance and corrective actions are not taken before the associated decrease in the reliability or availability of SSCs occurs.

2.26. Management of obsolescence is part of the general approach for enhancing nuclear power plant safety through ongoing improvements in both the performance of SSCs and safety management.

2.27. There are several types of obsolescence. The subject, manifestation, consequences and management approaches for three types of obsolescence are shown in Table 1.

2.28. Recommendations on the management of technological obsolescence (also called 'the obsolescence of technology') are provided in Section 6.

2.29. Conceptual aspects of obsolescence, such as obsolescence of knowledge and compliance with current regulations, codes and standards, are addressed in Requirements 5 and 12 of SSR-2/2 (Rev. 1) [2], which deal with safety policy and periodic safety review, and in safety factors 2 and 8 of SSG-25 [7], which deal with actual conditions of SSCs important to safety and safety performance. Recommendations on these aspects of obsolescence are not provided in this Safety Guide.

PROGRAMME FOR LONG TERM OPERATION

2.30. Long term operation of a nuclear power plant is operation beyond an established time frame defined by the licence term, the original plant design, relevant standards or national regulations. Long term operation should be justified by safety assessment and, depending on the State, this justification may take place within a broader regulatory process, such as licence renewal or a

TABLE 1. TYPES OF OBSOLESCENCE

Subject of obsolescence	Manifestation	Consequences	Management
Technology	Lack of spare parts and technical support Lack of suppliers Lack of industrial capabilities	Declining plant performance and safety due to increasing failure rates and decreasing reliability	Systematic identification of useful service life and anticipated obsolescence of SSCs Provision of spare parts for planned service life and timely replacement of parts Long term agreements with suppliers Development of equivalent structures or components
Regulations, codes and standards	Deviations from current regulations, codes and standards for structures, components and software Design weaknesses (e.g. in equipment qualification, separation, diversity or capabilities for severe accident management)	Plant safety level below current regulations, codes and standards (e.g. weaknesses in defence in depth or higher risk of core damage (frequency))	Systematic reassessment of plant safety against current regulations, codes and standards (e.g. through periodic safety review) and appropriate upgrading, back fitting or modernization
Knowledge	Knowledge of current regulations, codes and standards and technology relevant to SSCs not kept current	Opportunities to enhance plant safety missed	Continuous updating of knowledge and improvement of its application

periodic safety review (see SSG-25 [7]). Among the topics covered by the safety assessment, specific consideration should be given to adequate management of the ageing processes that can affect the SSCs within the scope of the evaluation for long term operation and to ensuring that those SSCs will retain their capability to perform their intended safety functions throughout the planned period of long term operation.

2.31. The plant programme for long term operation is a set of activities, including evaluations, assessments, maintenance, inspections and testing, aimed at justifying and demonstrating plant safety for the planned period of long term operation. The programme for long term operation should be based on national regulatory requirements, should consider international best practices, operating experience and research findings and should include an implementation plan, as described in Section 7.

2.32. If a decision is taken to pursue long term operation, justification of the adequacy of ageing management for the planned period of long term operation should be provided, based on the results of the periodic safety reviews [7] or the results of an adequate evaluation process (that includes scope setting, ageing management review, and revalidation of time limited ageing analyses, as described in this Safety Guide), and this justification should be evaluated for adequacy by the regulatory body.

3. AGEING MANAGEMENT THROUGHOUT THE LIFETIME OF THE NUCLEAR POWER PLANT

3.1. The ageing of in-scope SSCs (see paras 5.14–5.21) should be managed with foresight and anticipation throughout the entire lifetime of the plant (i.e. design, construction, commissioning, operation (including long term operation and suspended operation) and decommissioning), with consideration given to the associated techniques, costs and exposure of workers. The management of ageing effects should be considered during all associated activities, such as engineering, procurement, fabrication, transport and installation.

3.2. Regulatory requirements for ageing management should be established and guidance should be developed to ensure that the operating organization of the nuclear power plant implements effective ageing management at each stage of the lifetime of the nuclear power plant.

3.3. Requirements on the use of operating experience and results from research and development are established in Requirement 6 of SSR-2/1 (Rev. 1) [1], in Requirement 24 of SSR-2/2 (Rev. 1) [2] and in GSR Part 4 (Rev. 1) [3]. Specifically for ageing management and long term operation, such activities should focus on:

(a) Ensuring that all levels of the analysis are either performed, or are specified and accepted, by qualified experts within the operating organization to ensure that specific aspects relating to ageing management and long term operation are taken into account;
(b) Improving the understanding of ageing effects for all in-scope SSCs by analysis of operating experience from the nuclear power plant, from other nuclear power plants and from other industries, when relevant, and by analysis of results from research and development;
(c) Applying lessons identified in order to update and improve the ageing management.

3.4. The operating organization, in cooperation with the design organization and equipment suppliers, should ensure that proactive strategies for ageing management are established, especially at the stages of design, construction and commissioning. Such strategies should take into account the latest knowledge of ageing effects and degradation mechanisms. Reference [11] provides more detailed information on proactive ageing management strategies for nuclear power plants.

3.5. The roles of all organizations that participate in the ageing management of SSCs at different stages and in different activities should be properly defined and coordinated.

3.6. Ageing management activities should be overseen by the regulatory body throughout the lifetime of the nuclear power plant.

DESIGN

3.7. At the plant design stage and for licensing review, it should be demonstrated that ageing has been adequately taken into account.

3.8. Appropriate measures should be taken, such as the introduction of specific features in the design stage to facilitate effective ageing management throughout the operation stage of the plant. Such measures should also be applied to modifications and to the replacement of structures or components. Requirements 30 and 31 of SSR-2/1 (Rev. 1) [1] establish the design related requirements on ageing management of SSCs important to safety.

3.9. In the design stage, it should be ensured that:

(a) The operational states and accident conditions for the plant are taken into account in the equipment qualification programme.
(b) The environmental conditions in operational states and accident conditions are taken into account in the design.
(c) All potential ageing effects and degradation mechanisms for SSCs that will perform passive and active functions are identified, evaluated and taken into account in the design. Examples of ageing effects and degradation mechanisms are provided in Ref. [5].
(d) Relevant experience (including experience from the construction, commissioning, operation and decommissioning of nuclear power plants) and research results are reviewed and taken into account in the design.
(e) Appropriate materials with adequate ageing resistant properties are used.
(f) Materials testing programmes are in place for the periodic monitoring of ageing effects during the operation of the plant, taking into account the need for accessibility of the structures and components.
(g) Provisions for on-line monitoring are in place, particularly when this would provide forewarning of degradation leading to the failure of SSCs and when the consequences of failure could be important to safety.
(h) Relevant actions are taken to make inspections and maintenance possible for SSCs throughout the lifetime of the nuclear power plant.
(i) Provisions for relevant preventive and/or mitigatory measures (e.g. appropriate chemistry programmes) are considered.

3.10. In the design and procurement documents for a new nuclear power plant or new SSCs, the operating organization should specify requirements that facilitate ageing management, including the specification of information to be included in documentation from vendors, contractors, suppliers and manufacturers.

3.11. Ageing management should be addressed in the safety analysis report and other licensing documents. The description of ageing management in the safety analysis report should include general information on the following topics [12]:

(a) The strategy for ageing management and prerequisites for its implementation;

(b) Identification of all SSCs that could be affected by ageing and are in the scope of the ageing management;
(c) Proposals for appropriate materials monitoring and sampling programmes in cases where it is found that ageing effects might occur that could affect the capability of SSCs to perform their intended functions throughout the lifetime of the plant;
(d) Ageing management for different types of in-scope SSCs (e.g. concrete structures, mechanical components and equipment, electrical equipment and cables, and instrumentation and control equipment and cables) and the means to monitor their degradation;
(e) Design inputs for equipment qualification (see paras 4.23–4.31) of the in-scope SSCs, including required equipment and equipment functions that need to be qualified for service conditions in normal operation and associated with postulated initiating events;
(f) General principles stating how the environment of an SSC is to be maintained within specified service conditions (e.g. by means of proper location of ventilation, insulation of hot SSCs, radiation shielding, damping of vibrations, avoiding submerged conditions, and proper selection of cable routes);
(g) Appropriate consideration of the analysis of feedback on operating experience with respect to ageing.

3.12. The operating organization should establish a specific equipment qualification programme, including consideration of the ageing of SSCs, that meets Requirement 30 of SSR-2/1 (Rev. 1) [1] and Requirement 13 of SSR-2/2 (Rev. 1) [2].

FABRICATION AND CONSTRUCTION

3.13. The operating organization should ensure that suppliers adequately address factors affecting ageing management and that sufficient information and data on fabrication are provided to the operating organization, so that the operating organization can take this information into account in developing ageing management programmes, including operating and maintenance procedures.

3.14. The operating organization should ensure that:

(a) Current knowledge about relevant potential ageing effects and degradation mechanisms as well as possible preventive and/or mitigatory measures are taken into account in the fabrication and construction of in-scope SSCs by manufacturers;

(b) The transport and storage conditions of manufactured equipment are appropriate for the prevention of premature ageing effects and/or of conditions that can promote subsequent ageing;
(c) All relevant reference (baseline) data are collected and documented (e.g. information and data on material chemistry and material properties);
(d) Sufficient surveillance specimens for specific ageing monitoring programmes (to cover possible periods of long term operation) are made available and can be obtained in accordance with design specifications;
(e) Equipment qualification tests carried out by the manufacturer are in compliance with the applicable equipment qualification programme.

3.15. If a delayed construction period has occurred at the plant, the operating organization should identify and document the environmental conditions that could affect the physical condition of SSCs and their long term ageing behaviour, and should make any necessary modifications to the ageing management programme for the SSCs.

COMMISSIONING

3.16. The operating organization should establish a programme for measuring and recording baseline data relevant to ageing management for all in-scope SSCs. This programme should include mapping the actual environmental conditions in each critical location of the plant to ensure that they are in compliance with the design.

3.17. The operating organization should verify that the actual environmental conditions are consistent with those considered in the design of SSCs. Special attention should be paid to the identification of 'hot spots' in terms of temperature and levels of radiation and to the measurement of vibration levels. All parameters that can influence degradation mechanisms should be identified as early as possible, monitored if possible and tracked throughout the operation of the plant.

3.18. The operating organization should collect baseline data and should also confirm that critical service conditions (as used in equipment qualification) are in compliance with the design. Analyses of such data should be subject to review by the regulatory body.

3.19. The operating organization should ensure that SSCs are not subjected to unnecessary stresses by tests performed during commissioning 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 may have been caused by the improper execution of testing.

OPERATION

3.20. A systematic approach (see Fig. 1) should be applied to managing the ageing and obsolescence of SSCs to ensure that required intended functions are maintained at all times during the operation stage of the nuclear power plant.

3.21. The operating organization should ensure that programmes and documentation relevant to the management of ageing (see Sections 4 and 5) and technological obsolescence (see Section 6) are implemented during the operation stage. Where necessary, new programmes and documentation should be developed or existing programmes and documentation should be reviewed and modified to ensure that they will be effective for managing ageing.

3.22. The operating organization should ensure that specific operating procedures for the water chemistry programme or other environmental control programmes and other preventive or mitigatory actions with respect to ageing are followed.

3.23. Specific parameters of concern should be monitored and recorded during plant operations to demonstrate compliance with critical service conditions, operational limits and conditions, and any other parameters that were identified as affecting ageing assumptions used in safety analyses or equipment qualification.

3.24. The operating organization should ensure the timely detection and characterization of significant ageing effects through the inspection and monitoring of in-scope structures or components, and the assessment of observed ageing effects to determine the type and timing of any actions required.

3.25. The operating organization, in cooperation with design organizations, should ensure that corrective actions are taken to prevent or mitigate ageing effects of structures or components through the appropriate maintenance, repair and replacement or modification of a structure or component, and/or through appropriate changes to relevant plant operations, programmes and documentation.

3.26. In the event of operational changes or modifications to SSCs, the operating organization should ensure that a review is performed of possible changes in environmental or process conditions (e.g. temperature, flow pattern, velocity, vibration, radiation and hot spots) that could affect ageing or lead to the failure of SSCs. If necessary, an ageing management review should be completed for the affected SSCs.

3.27. The availability of spare parts or replacement parts and the shelf life of spare parts or consumables should be continuously monitored and controlled (see paras 6.6 and 6.7).

3.28. Where spare parts or consumables could be vulnerable to degradation mechanisms owing to their storage environment (e.g. high or low temperatures, moisture, chemical attack and dust accumulation), measures should be taken to ensure that they are stored in an appropriately controlled environment.

3.29. For major SSCs important to safety, the operating organization should consider preparing contingency plans or exceptional maintenance plans to deal with their potential ageing effects or their failure caused by potential ageing effects and degradation mechanisms.

3.30. Evaluation of relevant operating experience and research and development programmes should be continuously performed to support better understanding of degradation mechanisms and their ageing effects and to improve the ageing management programmes. If a new ageing effect or degradation mechanism is discovered (e.g. through feedback of operating experience or research and development), the operating organization should perform an appropriate ageing management review and should implement additional ageing management as necessary.

LONG TERM OPERATION

3.31. If long term operation is contemplated, the operating organization should establish policy documents, dedicated organizational structures and action plans to perform evaluations for long term operation well before the plant enters into long term operation. The operating organization should specify subjects for evaluation for long term operation and should assess the current physical status of relevant SSCs during the preparation phase for long term operation (see paras 7.3–7.15).

3.32. The operating organization should detail how the physical status of structures or components will be managed consistent with the current licensing basis for the planned period of long term operation.

3.33. Concerning ageing management, the operating organization should review and validate the existing programmes and processes (or elements thereof) relevant to ageing for all in-scope structures or components.

3.34. For in-scope structures or components, the operating organization should identify all time limited ageing analyses and should demonstrate either that all these analyses will remain valid for the planned period of long term operation, or that the structures or components will be replaced, or that further operation, maintenance or ageing management actions will be implemented.

3.35. Since long term operation is operation beyond the originally established time frame and evaluations for long term operation are based on assumptions, the operating organization should periodically perform the following activities to validate or correct the ageing related assumptions so that plant safety during long term operation is ensured and improved:

(a) Evaluation of operating experience at the plant or at other nuclear power plants, after entering long term operation;
(b) Analysis of trends in ageing effects;
(c) Review of the effectiveness of the ageing management programmes and existing plant programmes for long term operation;
(d) Incorporation of relevant research and development results;
(e) Evaluation of the need for new research and development.

3.36. Decisions concerning ageing management and long term operation should take due account of the potential implications for the subsequent decommissioning stage.

SUSPENDED OPERATION

3.37. Suspended operation is plant shutdown lasting for a period that generally exceeds one year; it excludes regular outages for maintenance. During suspended operation, SSCs may need to be placed in temporary lay-up or safe storage states that require supplementary measures and controls to minimize or prevent ageing effects.

3.38. The operating organization should review and, where necessary, revise the ageing management programmes to ensure that relevant factors affecting ageing are taken into account for SSCs placed in lay-up or safe storage states during suspended operation.

3.39. Required provisions for ageing management should be defined in specifications or preservation plans for SSCs in lay-up, including requirements for any condition assessments to be completed prior to the return to service of the plant after a period of suspended operation.

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

DECOMMISSIONING

3.41. There may be a transition period between the permanent shutdown of operations at the reactor and the implementation of the approved final decommissioning plan, during which appropriate ageing management arrangements should be put in place to ensure that required SSCs remain available and functional. This may necessitate the implementation of relatively long term ageing management provisions for certain SSCs, such as containment and spent fuel pool systems, fire protection systems, lifting equipment and monitoring equipment. Such provisions should be consistent with national regulations.

3.42. The operating organization should establish and implement ageing management activities in decommissioning plans and procedures for SSCs that are required to remain available and functional during decommissioning (e.g. ensuring the long term integrity of SSCs to prevent their deterioration and to allow the safe dismantling, handling and transport of components until the completion of decommissioning; monitoring SSCs to ensure the integrity of the containment and to ensure that there are no significant radioactive releases during the transition period until completion of decommissioning; ensuring the integrity of subsurface infrastructure components; monitoring for the potential spread of contamination from previous releases, particularly the transport of radionuclides in groundwater; and conducting effective measures to minimize the spread of contamination).

4. RELEVANT PLANT DOCUMENTATION AND PROGRAMMES

4.1. The following nuclear power plant documentation and programmes relevant to ageing management and, where relevant, evaluation for long term operation (also called ‘preconditions for long term operation’) should be in place at the plant:

(a) The safety analysis report and other current licensing basis documents;
(b) Configuration and modification management programmes, including design basis documentation;
(c) Plant programmes relevant to ageing management;
(d) Plant programmes relevant to long term operation;
(e) The corrective action programme;
(f) Time limited ageing analyses, in accordance with paras 5.64–5.69.

4.2. Each plant programme and analysis should be properly documented in safety analysis reports or in other current licensing basis documents, which should clearly and adequately describe the current licensing basis or the current design basis requirements for operation of the nuclear power plant.

SAFETY ANALYSIS REPORT AND OTHER CURRENT LICENSING BASIS DOCUMENTS

4.3. The policy on ageing management and the justification for long term operation should be properly documented in the current licensing basis, in particular in documents such as the safety analysis report, reports of periodic safety reviews (if applicable) or other licensing basis documents.

4.4. The safety analysis report should be kept up to date to reflect the results of the ageing management review [12].

4.5. The safety analysis report or other licensing documents should provide descriptions of activities in support of safe long term operation to ensure that the operating organization maintains the necessary information to reflect the current status of the plant and addresses new issues as they arise.

4.6. A periodic safety review is a systematic, comprehensive assessment of the plant's safety [2]. The content and the scope of the periodic safety review should be consistent with the recommendations provided in SSG-25 [7]. Some of the 14 safety factors described in SSG-25 [7] have a strong link with ageing management. The operating organization should consider in particular:

(a) The adequacy of the design of the nuclear power plant (safety factor 1) and its documentation, by assessment against the current licensing basis and national and international standards, requirements and practices.
(b) Thorough documentation of the actual condition of each SSC important to safety (safety factor 2). Knowledge of any existing or anticipated obsolescence of plant systems and equipment should be considered part of this safety factor.
(c) Whether qualification of equipment important to safety (safety factor 3) is being maintained through an adequate programme that includes maintenance, inspection and testing and that provides assurance that safety functions will be maintained at least until the next periodic safety review.
(d) The effects of ageing on nuclear power plant safety, the effectiveness of ageing management programmes and the need for improvements to ageing management programmes, as well as the obsolescence of technology used in the nuclear power plant (safety factor 4).

4.7. If national requirements do not require periodic safety review, an alternative systematic comprehensive safety assessment that meets the objectives of the periodic safety review is recommended to be performed [7].

4.8. The assessment should also consider the safety performance indicators of the plant, plant specific operating experience, operating experience from other nuclear power plants, and national and international research findings, which can reveal previously unknown weaknesses in safety.

CONFIGURATION AND MODIFICATION MANAGEMENT PROGRAMMES, INCLUDING DESIGN BASIS DOCUMENTATION

4.9. As the preparation of the plant for safe long term operation usually includes a number of important safety modifications and refurbishments, the plant should follow a configuration management programme or modification management programme [1, 2, 13] that reflects the evolving status of the plant.

4.10. All modifications to SSCs, releases of process software, operational limits and conditions, set points, instructions and procedures should be properly documented and retained in an auditable and retrievable form. All safety significant modifications should be included in the safety analysis report [12–14].

4.11. To provide a formal process to maintain design integrity, the plant should establish an organizational entity (e.g. a unit or a member of staff) that has overall responsibility for the design process, that approves design changes and that is responsible for ensuring that the knowledge of the design basis is maintained [14].

4.12. The management system should contain the processes and activities relating to the configuration management programme and the modification management programme.

4.13. The design basis documentation, including design basis requirements and supporting design basis information, should be owned by, or accessible to, the operating organization to support appropriate configuration management and modification management and to allow identification of the time limited ageing analyses for the plant.

4.14. The design basis information and any changes to it should be included in the safety analysis report or separate design basis documentation [13, 14].

4.15. If design basis documentation is not complete or is obsolete, an appropriate programme for reconstitution of the design basis should be implemented.

PLANT PROGRAMMES

4.16. The following existing plant programmes are essential to ageing management and evaluations for long term operation:

(a) Maintenance programmes;
(b) Equipment qualification programmes;
(c) In-service inspection programmes;
(d) Surveillance programmes;
(e) Water chemistry programmes.

4.17. Existing programmes that are credited for ageing management and used in evaluations for long term operation should be consistent with the nine attributes listed in Table 2, in Section 5.

4.18. Such existing programmes should be part of the management system of the operating organization.

Maintenance programmes

4.19. Maintenance programmes that are consistent with NS-G-2.6 [10] should be in place and should be properly implemented for ageing management and for the evaluations for long term operation of applicable in-scope SSCs.

4.20. The maintenance programmes should clearly specify their links with the ageing management programmes, including the frequency of maintenance activities and specific information on the tasks and their evaluation and on the retention of records.

4.21. The plant maintenance programmes should be assessed to ensure that in-scope SSCs are capable of performing their intended functions throughout operation, including the planned period of long term operation.

4.22. The results of the assessments should be used to improve the existing maintenance programmes. The documentation of the assessments should cover all maintenance activities and should provide technical references to support findings and conclusions.

Equipment qualification programme

4.23. An equipment qualification programme should be in place to ensure that the qualified status of in-scope SSCs is achieved and maintained in order to meet Requirement 30 of SSR-2/1 (Rev. 1) [1] and Requirement 13 of SSR-2/2 (Rev. 1) [2].

4.24. In this Safety Guide, 'environmental qualification' means the part of equipment qualification that focuses on qualification of the equipment for temperature, pressure, humidity, contact with chemicals, radiation exposure, meteorological conditions, submergence and ageing mechanisms as conditions that could affect the proper functioning of the equipment.

4.25. Environmental qualification should demonstrate that, at the end of its qualified life, the equipment will still be capable of performing its intended function(s) under the full range of specified service conditions.

4.26. Environmental qualification should establish the qualified life of the equipment, within which ageing effects would not prevent satisfactory performance of the equipment if a postulated accident were to occur within the established operating period (possibly including long term operation).

4.27. Monitoring of actual environmental conditions should be implemented in order to get additional information necessary for the assessment of ageing effects on the equipment in its actual operating environment.

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

4.29. The qualification status of equipment should be properly documented and maintained throughout the lifetime of the plant. The documentation relating to equipment qualification, which is typically part of the equipment qualification programme, should include:

(a) A master list of qualified equipment;
(b) Results of temperature monitoring and radiation monitoring in the plant;
(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 (for the evaluation for long term operation) or reports of another suitable equivalent analysis.

4.30. The review of equipment qualification should include an assessment of the effectiveness of the plant's equipment qualification programme in accordance with Requirement 13 of SSR-2/2 (Rev. 1) [2]. The review should also consider the effects of ageing on equipment during service and the effects of possible changes in environmental conditions during normal operation and postulated accident conditions since the equipment qualification programme was implemented.

4.31. Details of recommended practices, processes and methods relating to equipment qualification are given in Ref. [15].

In-service inspection programmes

4.32. In-service inspection programmes that are consistent with NS-G-2.6 [10] should be in place and properly implemented for ageing management and for evaluations for the long term operation of applicable in-scope SSCs, including consideration of baseline data.

4.33. In-service inspection procedures should be effective in detecting degradation, and it should be demonstrated that ageing effects will be adequately detected with the proposed inspection or monitoring technique.

4.34. The results of in-service inspection should be documented such that a trending analysis can be carried out using the results obtained from sequential inspections at the same location.

4.35. In-service inspection results that indicate notable degradation (e.g. if the degradation is greater than expected or if it approaches the acceptance criteria) should be evaluated to ensure that the extent of degradation at similar locations is appropriately determined. SSCs in redundant subsystems should be inspected independently to detect possible differences in their ageing behaviour.

4.36. A list or database should be developed and maintained to document the adequacy of non-destructive examination in detecting, characterizing and trending the degradation of structures or components. The database should provide the technical bases to support the findings and the conclusions necessary to support ageing management decisions.

Surveillance programmes

4.37. Surveillance programmes, including functional tests, that are consistent with NS-G-2.6 [10] should be in place and properly implemented for ageing management and evaluations for the long term operation of applicable in-scope SSCs.

4.38. The surveillance programmes should confirm the provisions for safe operation that were considered in the design and assessed in construction and commissioning, and which are verified throughout operation.

4.39. The surveillance programmes should continue to supply data from monitoring relevant parameters to be used in assessing the service life of SSCs for the planned period of long term operation, for example through existing or additionally installed means of measuring temperature and pressure or through additional diagnostic systems.

4.40. The surveillance programmes should verify that the safety margins for long term operation are adequate and provide a high tolerance for anticipated operational occurrences, errors and malfunctions.

4.41. Particular attention should be paid to the following:

(a) The integrity of the barriers between radioactive material and the environment (i.e. the primary pressure boundary and the containment);
(b) The availability of safety systems such as the reactor protection system, the safety system actuation systems and the safety system support features [16];
(c) The availability of items whose failure could adversely affect safety;
(d) Functional testing in accordance with Requirement 31 of SSR-2/2 (Rev. 1) [2] to ensure that the tested SSCs are capable of performing their intended functions.

4.42. Surveillance programmes using representative material samples (e.g. material specimens for surveillance of the reactor pressure vessel, cable samples and corrosion coupons) should be reviewed and extended or supplemented for ageing within the period of long term operation, if necessary.

4.43. The documentation on the relevant initial conditions of the material samples used for surveillance should be identified, the adequacy of the information should be assessed and the documentation should be supplemented as necessary.

4.44. Appropriate testing procedures and evaluation methods should be considered for defining the set of specimens to be included in the supplementary material surveillance programme for the reactor pressure vessel, if necessary, in particular for alternative assessments such as the master curve approach for assessing fracture toughness.

Water chemistry programme

4.45. A water chemistry programme is essential for the safe operation of a nuclear power plant and should be in place [17]. The programme should ensure that degradation due to stressors in water chemistry does not impact the capability of

SSCs to perform their intended functions, in accordance with the assumptions and the intent of the design. The water chemistry programme should prevent and/or minimize the harmful effects of chemical impurities and corrosion on SSCs.

4.46. The operating organization should ensure that the plant water chemistry programme is effective in maintaining the water quality required by the technical specifications.

4.47. The water chemistry programme should specify the scheduling and the analytical methods used to monitor chemistry (some programmes use automated on-line monitoring equipment; others use wet chemical methods) and the means of verification of the effectiveness of the chemistry programme.

4.48. The water chemistry programme should also provide the necessary chemical and radiochemical environment to ensure safe long term operation and the integrity of structures or components within the scope of ageing management and evaluations for long term operation.

CORRECTIVE ACTION PROGRAMME

4.49. A corrective action programme should be put in place to ensure that conditions adverse to quality, such as ageing related degradation, are identified and that corrective actions commensurate with the significance of the issue are specified and implemented [8].

4.50. The corrective action programme should document occurrences of identified ageing related degradation (conditions adverse to quality) and the methods used to address the degradation, such as evaluation and acceptance, evaluation and monitoring, repair, or replacement. Such information should be taken into account as plant specific operating experience.

4.51. The corrective action programme should document the modifications to ageing management programmes, system configuration or plant operations that are made to manage the occurrence or the severity of the ageing effect.

4.52. The corrective action programme and the associated plant specific operating experience should be routinely reviewed by individuals responsible for the relevant ageing management programme. The review should determine whether ageing management programmes need to be enhanced to ensure that the corrective action programme is effective in managing the ageing effects for which it is credited.

4.53. If it is determined, through the evaluation of the corrective action programme and the associated plant specific operating experience, that the ageing management programmes do not adequately manage the effects of ageing, modifications to the existing ageing management programmes should be specified and implemented or new ageing management programmes should be developed, as appropriate.

5. MANAGEMENT OF AGEING

ORGANIZATIONAL ARRANGEMENTS

5.1. For the implementation of the plant programme for ageing management, the policy and objectives of the programme should be established, and the necessary resources (e.g. human resources, financial resources, tools and equipment, and external resources) should be identified and allocated. The organizational arrangements, such as the organizational structure and the policies of the operating organization should meet national requirements and IAEA safety standards [2, 8, 18–20], and should be in accordance with national practices.

5.2. Suitable organizational and functional arrangements should be established, such as those shown in Fig. 2, in which all necessary members of staff of the operating organization of the plant and of external organizations are involved with and support ageing management.

5.3. An authorized organizational entity (e.g. an ageing management unit, manager or task force) should be assigned responsibilities for ageing management, as specified in para. 5.4. This ageing management entity should work closely with other organizational units at the plant, such as the operations, maintenance, engineering and management system units. Interdisciplinary ageing management teams consisting of members of different units of the plant and external experts may be established if necessary, on either a permanent or ad hoc basis.

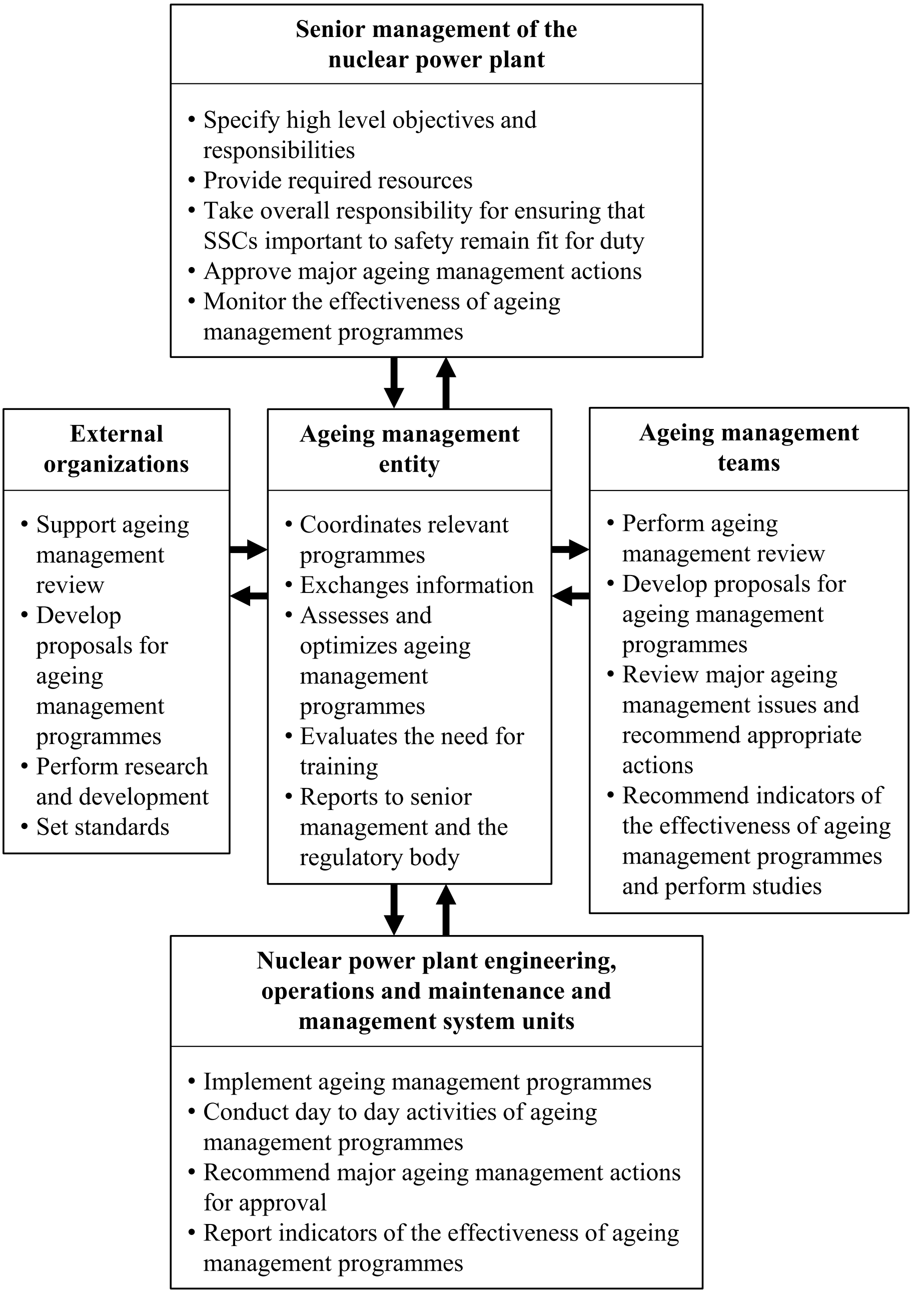


FIG. 2. Organizational arrangements in support of ageing management.

5.4. The responsibilities of the ageing management entity should include:

(a) Development of the plant's ageing management programme;
(b) Coordination of existing and new plant programmes that are relevant to ageing management;
(c) Systematic monitoring of relevant operating experience and research and development results, and evaluation of their applicability to the plant;
(d) Direction of interdisciplinary ageing management teams for managing complex ageing issues;
(e) Assessment and optimization of ageing management programmes;
(f) Dealing with external technical support organizations;
(g) Evaluation of further training needs;
(h) Performance of periodic self-assessments;
(i) Improvement of activities relating to ageing management.

5.5. The management of complex ageing issues may require an interdisciplinary approach. The members of the ageing management teams (see Fig. 2) should include experts from operations, maintenance, engineering, equipment qualification, design, and research and development, depending on the evaluations necessary. If necessary, external organizations should be requested to provide expert services on specific topics, such as condition assessments, research and standards development.

5.6. Responsibilities for the implementation of ageing management programmes and for reporting on the performance of SSCs should be defined and allocated within the operating organization (e.g. operations, maintenance and engineering units).

5.7. Training on the effects of ageing on SSCs should be provided for personnel involved in operations, maintenance and engineering to enable them to make an informed and effective contribution to ageing management.

5.8. Relevant plant and industry operating experience should be systematically collected and evaluated and should be used to improve the ageing management programmes.

DATA COLLECTION AND RECORD KEEPING

5.9. A data collection and record keeping system should be in place as a necessary base for the support of ageing management. Examples of data that should be included in the data collection and record keeping system are described in Ref. [21].

5.10. The data collection and record keeping system should be established in the early stages of the lifetime of the plant (ideally, data should be collected from the construction stage onwards) in order to provide information for the following activities:

(a) Identification of fabrication, construction and environmental conditions that could adversely affect the ageing of SSCs, including any periods of delayed construction or suspended operation;
(b) Identification of relevant fabrication records, such as heat treatment history and certified reports on material tests;
(c) Identification and evaluation of degradation, failures and malfunctions of components caused by ageing effects;
(d) Decisions on the type and timing of maintenance actions, including calibration, repair, refurbishment and replacement;
(e) Optimization of operating conditions and practices that prevent or minimize ageing effects;
(f) Identification of all ageing effects before they jeopardize plant safety or reduce the service life of SSCs;
(g) Records of configuration and modification management, maintenance, surveillance and in-service inspection results, as well as chemistry control records.

5.11. To facilitate obtaining the necessary quality and quantity of ageing related data from plant operation, maintenance and engineering, representatives of the operations, maintenance and engineering units should be involved in the development and maintenance of the data collection and record keeping system.

5.12. Design documentation, including documentation from suppliers, should be made available, as this is essential in supporting effective ageing management.

5.13. The use of available generic data should be considered until the plant has developed its own data from the construction stage onwards.

SCOPE SETTING FOR STRUCTURES, SYSTEMS AND COMPONENTS

5.14. A systematic scope setting (also called ‘scoping’) process to identify SSCs subject to ageing management should be developed and implemented.

5.15. A list or database of all SSCs at the nuclear power plant (such as a master list of SSCs) should be made available before the scope setting process is commenced.

5.16. The following SSCs should be included in the scope of ageing management:

(a) SSCs important to safety that are necessary to fulfil the fundamental safety functions [1]:
- Control of reactivity;
- Removal of heat from the reactor and from the fuel store;
- Confinement of radioactive material, shielding against radiation and control of planned radioactive releases, and limitation of accidental radioactive releases.

(b) Other SSCs whose failure may prevent SSCs important to safety from fulfilling their intended functions. Examples of such potential failures are:
- Missile impact from rotating machines;
- Failures of lifting equipment;
- Flooding;
- High energy line break;
- Leakage of liquids (e.g. from piping or other pressure boundary components).

(c) Other SSCs that are credited in the safety analyses (deterministic and probabilistic) as performing the function of coping with certain types of event, consistent with national regulatory requirements, such as:
- SSCs needed to cope with internal events (e.g. internal fire and internal flooding);
- SSCs needed to cope with external hazards (e.g. extreme weather conditions, earthquakes, tsunamis, external flooding, tornados and external fire);
- SSCs needed to cope with specific regulated events (e.g. pressurized thermal shock, anticipated transient without scram and station blackout);
- SSCs needed to cope with design extension conditions [1] or to mitigate the consequences of severe accidents.

5.17. Structures and components that satisfy both of the following conditions can be excluded from the scope of ageing management:

(a) Structures and components subject to periodic replacement or to a scheduled refurbishment plan on the basis of predefined rules (based on a manufacturer’s recommendation or other basis and not on an assessment

of the condition of the structure or component, which would comprise implementation of ageing management for the structure or component); and
(b) Structures and components that are not required by national regulatory requirements to be included in the scope.

5.18. If an SSC within the scope is directly connected to an SSC out of the scope, clear definitions of the boundaries between them should be established.

5.19. In addition to the analysis of plant documentation, dedicated plant walkdowns should be used to check the completeness of the list of SSCs whose failure may prevent SSCs important to safety from performing their intended functions.

5.20. Since the subsequent process is carried out at the level of a structure or component (or its subcomponent), all structures or components and their subcomponents within the scope for ageing management should be identified. If the components or structures within a group have similar functions and similar materials and are in a similar environment, that group may be defined as a structure or component 'commodity group'.

5.21. After the scope setting process, a clear distinction between SSCs within the scope and those out of the scope should be evident. A typical scope setting process is illustrated in Fig. 3.

AGEING MANAGEMENT REVIEW

5.22. An ageing management review for in-scope SSCs should be performed to ensure and demonstrate that ageing will be effectively managed.

5.23. The ageing management review should systematically assess ageing effects and the related degradation mechanisms that have been experienced or are anticipated. The assessment should include an evaluation of the impact of the ageing effect on the in-scope SSCs' capability to perform their intended functions as specified in para. 5.16, including consideration of the current condition of the SSC.

5.24. Relevant applicable lessons relating to ageing provide a good reference basis for the ageing management review [5] but should not be used in place of a plant specific ageing management review.

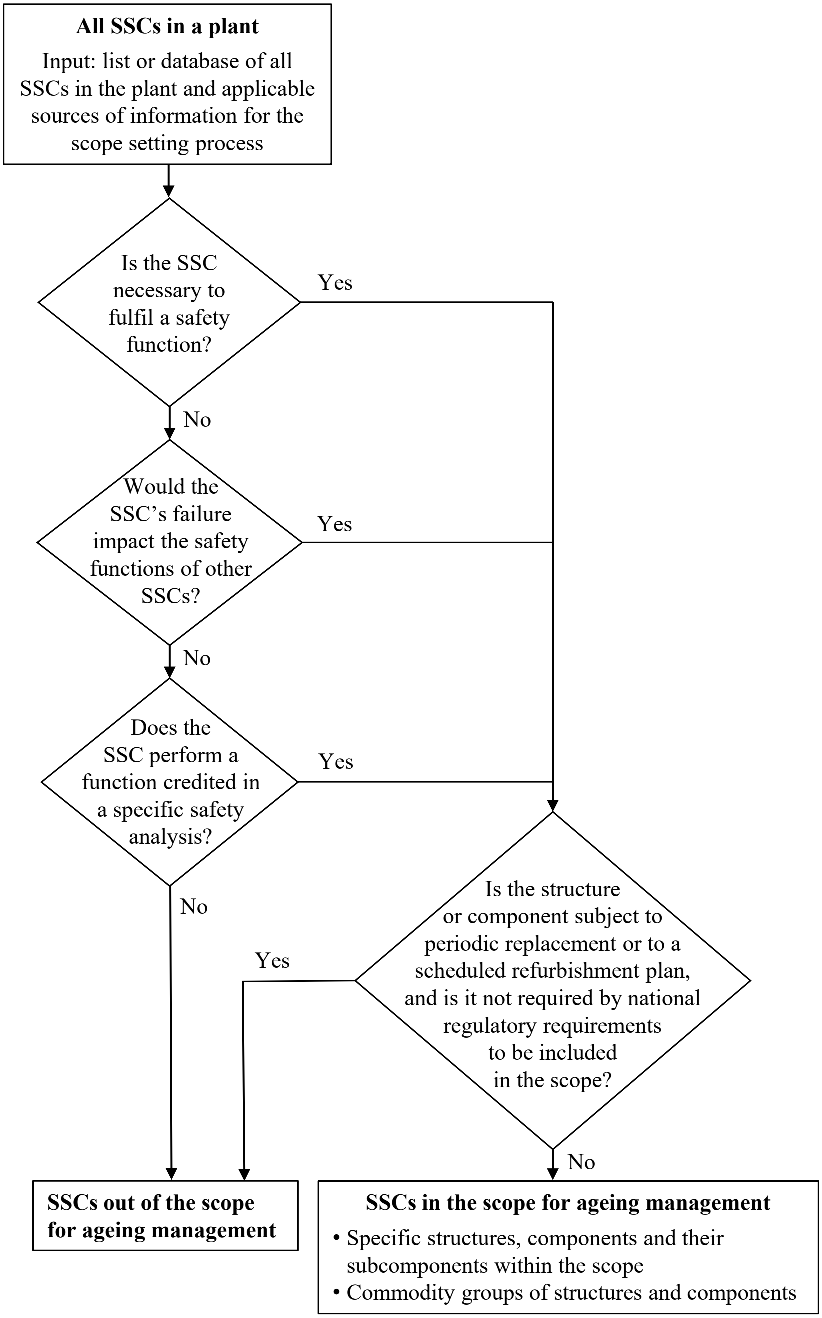


FIG. 3. Scope setting process for ageing management.

5.25. A process to identify relevant ageing effects and degradation mechanisms for each structure or component should be established, and the programmes to manage the identified ageing effects and degradation mechanisms should be in place (see Fig. 4). This process should cover the following steps:

(1) Time limited ageing analyses associated with these structures or components should be evaluated to determine the continued validity of the analyses for the intended period of operation. Results of the evaluation of the time limited ageing analyses should be taken into account in the ageing management review.
(2) All relevant ageing effects and degradation mechanisms should be identified.
(3) If the ageing of structures or components is managed by existing ageing management programmes, it should be verified that the ageing management programmes are consistent with the nine attributes shown in Table 2.
(4) If the ageing of structures or components is managed by other plant programmes, such as maintenance, it should be verified that these programmes are consistent with the nine attributes shown in Table 2.
(5) If the ageing of structures or components is not managed by any existing programme, a new programme should be established or existing programmes should be modified or improved (e.g. by extending the scope of an ageing management programme) or a specific action (e.g. a new time limited ageing analysis, replacement of the structure or component, or further analysis) should be taken.
(6) If the qualified lifetime of equipment important to safety expires, such equipment should be requalified or replaced at the expiration of its present qualification.

5.26. An ageing management review should be performed for each in-scope structure or component or commodity group of structures or components and should consist of the following essential elements:

(a) Assessment of the current condition of the structure or component;
(b) Identification of ageing effects and degradation mechanisms on the basis of fundamental knowledge for understanding ageing (e.g. the design basis, materials, the environment and stressors; see 'Understanding ageing' in Fig. 1);
(c) Identification of the appropriate programme for ageing management;
(d) Reporting of the ageing management review to demonstrate that the ageing effects and degradation mechanisms are being managed effectively.

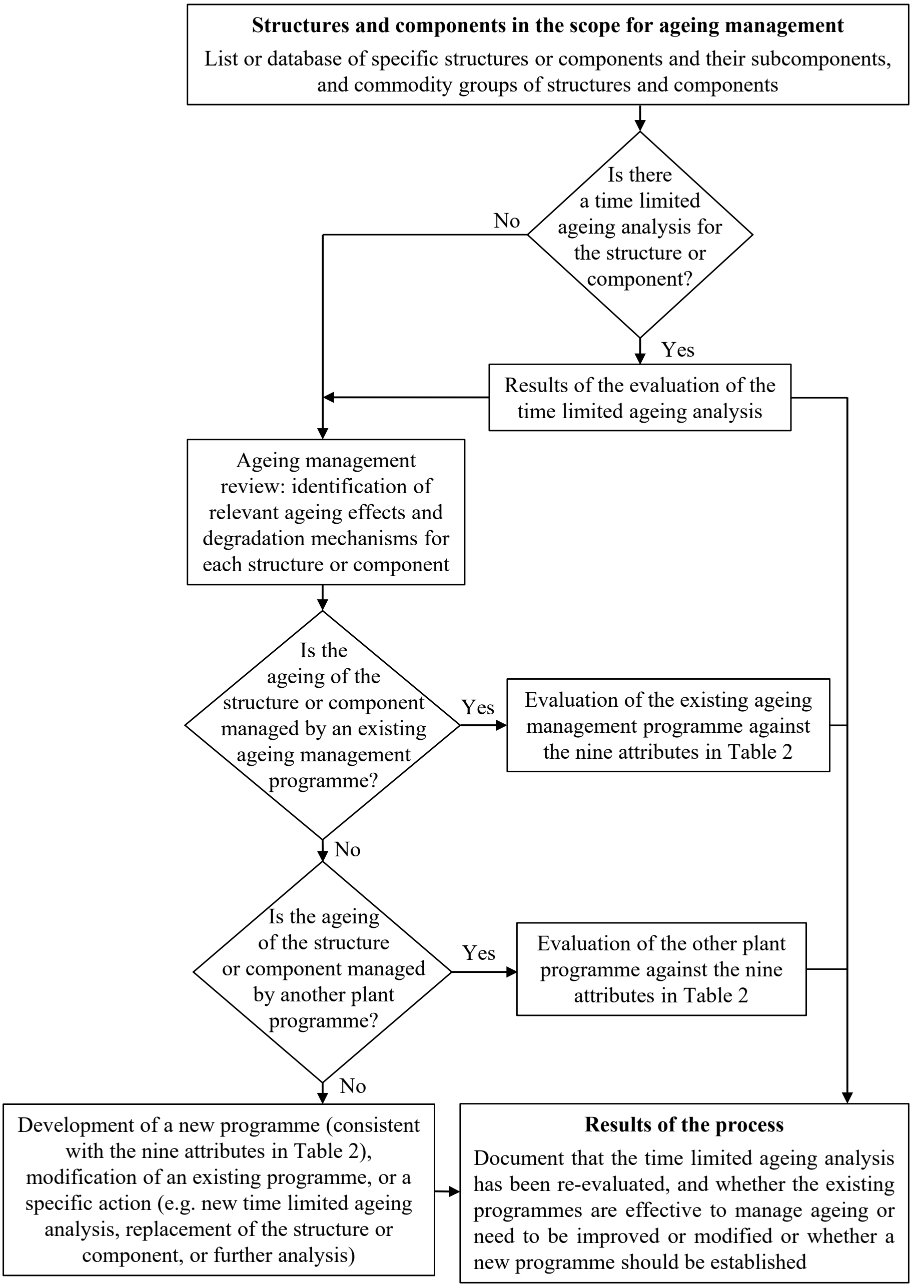


FIG. 4. Process for identifying programmes to manage the ageing of structures or components.

TABLE 2. GENERIC ATTRIBUTES OF AN EFFECTIVE AGEING MANAGEMENT PROGRAMME

Attribute		Description
1.	Scope of the ageing management programme based on understanding ageing	Structures (including structural elements) and components subject to ageing management Understanding of ageing phenomena (significant degradation mechanisms, susceptible sites): — Structure or component materials, service conditions, stressors, degradation sites, degradation mechanisms and ageing effects — Structure or component condition indicators and acceptance criteria — Quantitative or qualitative predictive models of relevant ageing phenomena
2.	Preventive actions to minimize and control ageing effects	Specification of preventive actions Determination of service conditions (i.e. environmental conditions and operating conditions) to be maintained and operating practices aimed at precluding potential degradation of the structure or component
3.	Detection of ageing effects	Specification of parameters to be monitored or inspected Effective technology (inspection, testing and monitoring methods) for detecting ageing effects before failure of the structure or component
4.	Monitoring and trending of ageing effects	Condition indicators and parameters monitored Data collected to facilitate assessment of structure or component ageing Assessment methods (including data analysis and trending)
5.	Mitigation of ageing effects	Operations, maintenance, repair and replacement actions to mitigate detected ageing effects and/or degradation of the structure or component
6.	Acceptance criteria	Acceptance criteria against which the need for corrective actions is evaluated
7.	Corrective actions	Corrective actions if a structure or component fails to meet the acceptance criteria

TABLE 2. GENERIC ATTRIBUTES OF AN EFFECTIVE AGEING MANAGEMENT PROGRAMME (cont.)

Attribute		Description
8.	Operating experience feedback and feedback of research and development results	Mechanism that ensures timely feedback of operating experience and research and development results (if applicable) and provides objective evidence that they are taken into account in the ageing management programme
9.	Quality management	Administrative controls that document the implementation of the ageing management programme and actions taken
		Indicators to facilitate evaluation and improvement of the ageing management programme
		Confirmation (verification) process for ensuring that preventive actions are adequate and appropriate and that all corrective actions have been completed and are effective
		Record keeping practices to be followed

Identification of relevant ageing effects and degradation mechanisms of structures or components

5.27. All relevant ageing effects and degradation mechanisms for each in-scope structure or component should be identified on the basis of the understanding of ageing set out in paras 5.28 and 5.29.

5.28. A comprehensive understanding of structures or components and their ageing effects and degradation mechanisms and how these can affect the capability of an SSC to perform its function(s) should be a prerequisite for the systematic ageing management process shown in Fig. 1. This understanding should be based on:

(a) The design, including the SSC's intended function(s) and applicable regulatory requirements, codes and standards, the design basis and design documents, including safety analyses;
(b) The fabrication of the SSC, including material properties, manufacturing conditions that may affect ageing and service conditions;

(c) The operation and maintenance history of the SSC, including commissioning, operational transients and events, power uprating, modifications and replacements;
(d) Stressors on the structure or component (including loads on the structure or component and the environmental conditions inside and outside the structure or component);
(e) Results of in-service inspections and surveillance;
(f) Operating experience, results of research and development, and any post-service examinations;
(g) Results from walkdowns, inspections and condition assessments, if available;
(h) Results of the evaluation of time limited ageing analyses.

5.29. The identification process should take into account knowledge of the characteristics of the ageing effect (e.g. necessary conditions under which the effect occurs and rates of degradation), the related degradation mechanisms and their impact on the structure or component's intended function(s).

Identification of the appropriate programme for ageing management

5.30. Appropriate methods to detect, monitor, prevent and mitigate ageing effects and degradation mechanisms for each structure or component should be specified.

5.31. Existing ageing management programmes and other plant programmes should be evaluated for consistency with the nine attributes in Table 2 to determine whether they are effective in detecting, monitoring and preventing or mitigating ageing effects and degradation mechanisms in the structures or components for which the programme is credited.

5.32. If existing ageing management programmes and other plant programmes are not sufficiently effective, the existing programme should be improved or modified or a new programme should be developed, consistent with the nine attributes in Table 2.

Reporting on the ageing management review

5.33. Once the approach for managing ageing effects and degradation mechanisms has been determined, documentation should be prepared that logically demonstrates that the ageing effects will be adequately managed.

5.34. All information and conclusions with regard to the scope of ageing management review should be documented, including:

(a) A description and justification of the methods used to determine the structures or components that are subject to an ageing management review;
(b) An identification and listing of structures or components subject to an ageing management review and their intended function(s);
(c) The information sources used to accomplish the above, and any description necessary to clarify their use.

5.35. The methodology and results of the ageing management review should be documented and should also provide information on the following:

(a) The current performance and condition of the structure or component, including assessment of any indications of significant ageing effects;
(b) The ageing effects and degradation mechanisms requiring management;
(c) Understanding ageing, monitoring of ageing and prevention or mitigation of ageing effects;
(d) The specific programmes or activities that will manage the ageing effects and degradation mechanisms for each structure, component or commodity grouping subject to an ageing management review, and the need for the development of new programmes;
(e) How the programmes and activities will manage the ageing effects and degradation mechanisms, considering the current condition of the structure or component;
(f) The estimated future performance, ageing effects and service life of the structure or component, when feasible;
(g) How the results of the ageing management review should be applied in plant operation, maintenance and design.

5.36. If the ageing management review takes account of IGALL [5], then the demonstration should provide a justification that generic references from the nuclear industry are applicable to the plant concerned, based on plant specific features, plant operating and maintenance history, and/or industry developments since the selected references were issued.

AGEING MANAGEMENT PROGRAMMES

5.37. The identified ageing effects and degradation mechanisms that require ageing management should be managed using existing ageing management programmes or existing plant programmes (possibly with improvements or modifications), or new programmes should be developed. These programmes should be coordinated, implemented and periodically reviewed for improvements as indicated in Fig. 5.

5.38. Each ageing management programme should be consistent with the generic attributes of an effective ageing management programme listed in Table 2.

5.39. Plant programmes or processes used to manage ageing effects and ageing management programmes should include one or more of four types of activity:

(a) Prevention activities, which preclude the ageing effect from occurring;
(b) Mitigation activities, which attempt to slow the ageing effects;
(c) Condition monitoring activities, including inspection and examination for the presence and extent of ageing effects, or surveillance using test samples or coupons intended to mimic the performance of the structure or component;
(d) Performance monitoring activities, which test the capability of a structure or component to perform its intended function(s).

5.40. If necessary, more than one type of activity should be implemented to ensure that ageing effects are adequately managed and that the intended function(s) of the structure or component are maintained. For example, managing the internal corrosion of piping may rely on a mitigation programme (water chemistry) to minimize susceptibility to corrosion and a condition monitoring programme (ultrasonic inspection) to verify that the corrosion is insignificant.

5.41. If the programme used to manage ageing effects involves inspection by sampling from a specific population of structures or components, the programme should describe and justify the methods used for selecting the samples to be inspected and the sample size, and should demonstrate that the sampling is adequate to provide reasonable assurance that ageing effects on the structure or component will not prevent the performance of its intended function(s) throughout its lifetime.

5.42. Information and example summaries of ageing management programmes specific to structures or components and specific to degradation mechanisms are provided in Refs [5, 22].

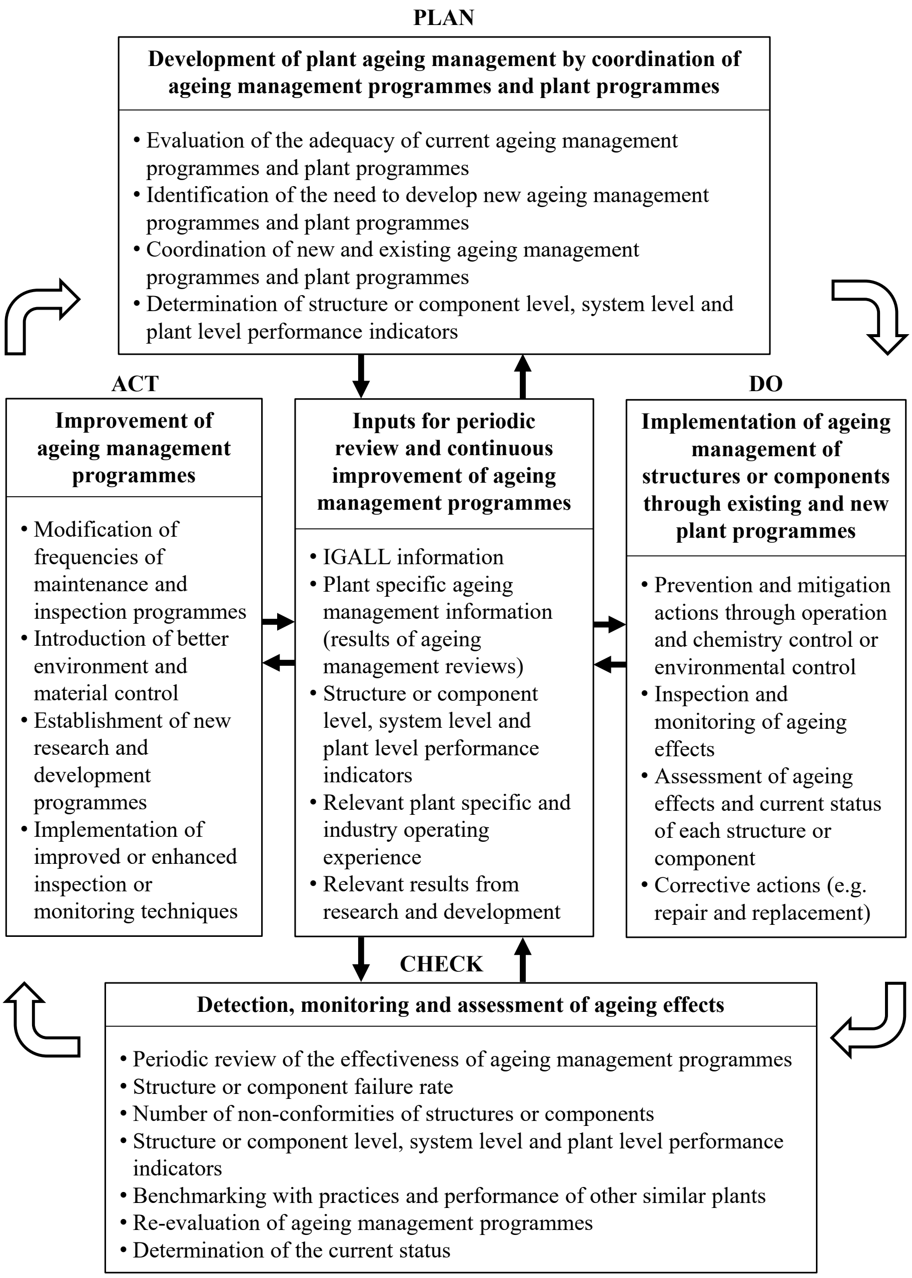


FIG. 5. Development, implementation, review and improvement of ageing management programmes.

Development of ageing management programmes

5.43. Ageing management programmes specific to ageing effects and degradation mechanisms or specific to structures and components should be developed. Existing plant programmes should be coordinated and maintained to cover the activities indicated in para. 5.39. If necessary, a new programme that includes or supplements these activities should be developed. Such existing or newly developed programmes can be at different levels of detail (e.g. structure or component level, commodity group level or system level) depending on their complexity and importance to safety.

5.44. Whether an ageing management programme is structure or component specific or degradation mechanism specific, specific actions relating to the detection, monitoring and prevention or mitigation of ageing effects should be specified within each ageing management programme. Such specific actions may include plant programmes for maintenance, equipment qualification, in-service inspection, testing and surveillance, as well as for controlling operating conditions.

5.45. The development of the ageing management programmes should be based on the results of the ageing management review.

5.46. All programmes developed should comply with relevant national regulatory requirements, codes and standards and the ageing management policy of the plant (see para. 4.3) and should be consistent with the nine attributes in Table 2. If a programme is of such a nature that it does not meet all nine attributes, its use should be properly justified and the justification should be documented.

5.47. Appropriate acceptance criteria for the inspection and monitoring of ageing effects should be established for ageing management programmes and should be based on the design basis or on the technical requirements for the structure or component, and the relevant regulatory requirements, codes and standards, so that a corrective action can be implemented sufficiently before loss of the intended function(s) of the structure or component. The need for sufficient margins should be taken into account in these acceptance criteria.

5.48. Particular attention should be paid when developing ageing management programmes to ensuring that the programme has in place provisions to prevent, detect, evaluate and mitigate the ageing effects of anticipated degradation mechanisms, based on the findings from the ageing management review.

5.49. Information on the current status of in-scope structures or components should be collected for subsequent review of the effectiveness of the ageing management programmes. Performance indicators representing the effectiveness of the ageing management programmes should be developed along with the development of the ageing management programmes (see para. 5.56).

5.50. The structure or component specific or the degradation mechanism specific ageing management programmes provided in Refs [5, 22] should be considered as guidance for the development of ageing management programmes.

Implementation of ageing management programmes

5.51. The ageing management programmes should be implemented in a timely manner to ensure that the intended functions of structures or components continue to be performed.

5.52. Detailed implementation procedures that describe preventive and mitigatory actions, monitoring or inspection and assessment actions, acceptance criteria, and corrective actions should be established and shared among the different units of the nuclear power plant (e.g. operations, maintenance and engineering units) that are responsible for implementing ageing management programmes.

5.53. As part of the implementation of the ageing management programmes, appropriate data should be collected and recorded to provide a basis for decisions on the type and timing of ageing management actions.

Review and improvement of ageing management programmes

5.54. The effectiveness of ageing management programmes should be periodically evaluated in the light of current knowledge and feedback from the programme and the performance indicators and should be updated and adjusted as appropriate. Relevant knowledge includes information on the operation of the structure or component, surveillance and maintenance histories, information from the results of research and development, and operating experience from other nuclear facilities.

5.55. Ageing management programmes should be part of the management system of the operating organization.

5.56. To evaluate the effectiveness of the ageing management programmes, performance indicators should be developed and used by the operating organization. Examples of such performance indicators are:

(a) Material condition with respect to acceptance criteria;
(b) Trends of data relating to failure and degradation;
(c) Percentage of recurrent ageing driven failures and instances of degradation;
(d) Status of compliance with inspection programmes;
(e) Newly discovered ageing effects and degradation mechanisms;
(f) Newly developed ageing management programmes.

5.57. Responsible units and other internal or external organizations involved in ageing management should share data and information newly acquired through the implementation of ageing management programmes. Consideration should be given to connecting these data with the existing plant databases, such as the master equipment and component list. Such units and organizations should meet periodically to review these data and information and to discuss whether modification of an ageing management programme or development of a new ageing management programme is necessary.

5.58. The qualified life of equipment should be reassessed during its lifetime, with account taken of progress in the knowledge of degradation mechanisms. If the qualified life of equipment is to be increased, a thorough safety demonstration should be provided by the operating organization.

5.59. The management of the operating organization should provide for the performance review and improvement of ageing management programmes. The result of such reviews should be made available to the regulatory body for review and assessment if required by national regulatory requirements.

5.60. Consideration should be given to arranging for peer reviews of ageing management programmes to obtain an independent assessment in order to establish whether the ageing management programmes are consistent with generally accepted practices [5] and to identify areas for improvement.

5.61. An in-depth review of ageing management should be performed periodically, for example as part of periodic safety review [7] or as part of the safety review for long term operation (see Section 7), in order to assess the effects of ageing on plant safety and to evaluate the effectiveness of plant programmes and practices used to support ageing management throughout plant operation, including long term operation if applicable.

5.62. The in-depth review should demonstrate that ageing effects will continue to be identified and effectively managed for each structure or component throughout the entire period of operation of the plant, including long term operation if applicable. Requirements for modifications to existing plant programmes or the development of any new programmes should be specified and applied. The results of this in-depth review should be documented, and the findings, including any corrective actions and areas for improvement, should be addressed in a timely manner.

5.63. Adequately funded research and development programmes should be put in place to respond to any new ageing issues and to provide for continuous improvement of (a) the understanding and predictability of degradation mechanisms and the causes of ageing and (b) the associated monitoring and mitigation methods or practices. A strategic approach should be taken to promoting relevant long term research and development programmes.

TIME LIMITED AGEING ANALYSES

5.64. Time limited ageing analyses should meet all six of the following criteria [5]:

(1) Time limited ageing analyses should involve SSCs within the scope for ageing management. Scope setting is described in paras 5.14–5.21 and illustrated in Fig. 3.
(2) Time limited ageing analyses should consider ageing effects. Ageing effects include, but are not limited to: loss of material, changes in dimension, changes in material properties, loss of toughness, loss of pre-stress, settlement, cracking, and loss of dielectric properties.
(3) Time limited ageing analyses should involve time limited assumptions defined by the current operating term. The specified operating term should be explicit in the analysis. Simple assertion that a component is designed for a particular service life or for the lifetime of the plant 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.
(4) Time limited ageing analysis should have been determined to be relevant by the operating organization in making a safety determination as required by national regulations. 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

plant when, in the absence of the analyses, the operating organization might have reached a different safety conclusion or taken a different safety action.

(5) Time limited ageing analyses should involve conclusions or provide the basis for conclusions relating to the capability of SSCs to perform their intended functions.

(6) Time limited ageing analyses should be contained or incorporated by reference in the current licensing basis. The current licensing basis includes the technical specifications and the design basis information, or the commitments of the operating organization documented in the plant specific documents contained or incorporated by reference in the current licensing basis, including, but not limited to: safety analysis reports, regulatory safety evaluation reports, the fire protection plan or hazard analysis, correspondence with the regulatory body, the documentation of the management system, and topical reports included as references in the safety analysis reports. If a code of record is in the safety analysis report for a particular group of structures or components, the reference material should include all the calculations called for by that code of record for those structures or components.

5.65. Safety analyses that meet all criteria except for criterion 6 of para. 5.64, and which have been developed in Member States to demonstrate preparedness for the intended period of operation, should also be considered as time limited ageing analyses. Further examples of time limited ageing analyses for different reactor technologies are provided in Ref. [5].

5.66. 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 of the time dependent parameter (e.g. the projected neutron fluence) should then be used to evaluate certain analysis parameters, such as the adjusted nil ductility temperature or the fracture toughness.

5.67. The validity of time limited ageing analyses over the intended period of operation should be ascertained by demonstrating satisfaction against one of the following criteria [5]:

(a) The analysis should remain 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 should have been projected to the end of the intended period of operation. The value of the analysis parameter value 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 the regulatory limit or criterion.

(c) The effects of ageing on the intended function(s) of the structure or component should be adequately managed for the intended period of operation. The value of the analysis parameter should be managed (using an ageing management programme) to ensure that ageing effects are adequately managed and that the value of the analysis parameter will continue to meet the regulatory limit or criterion throughout the intended period of operation.

5.68. If the time limited ageing analyses cannot be found acceptable using the criteria in para. 5.67, then corrective actions should be implemented. Depending on the specific analysis, corrective actions could include:

(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.

5.69. Results of the evaluation of time limited ageing analyses should be used as an input for ageing management review.

DOCUMENTATION OF AGEING MANAGEMENT

5.70. The assumptions, activities, evaluations, assessments and results of the evaluation of the plant programme for ageing management should be documented in accordance with national regulatory requirements as well as in accordance with IAEA safety standards [2, 8]. The documentation should be developed and retained in an auditable and retrievable form.

5.71. The documentation should also include the following to demonstrate that ageing effects will be managed during the planned operating period:

(a) A description of plant programmes and documentation relevant to ageing management;
(b) A list of commitments or plans for the improvement or development of plant programmes and documentation relevant to ageing management.

5.72. The documentation should include an update of the safety analysis report reflecting the assumptions, activities and results of the plant programme for ageing management.

5.73. The assumptions, activities, evaluations, assessments and results of the plant programme for ageing management should also be reflected in the reports of periodic safety reviews, if applicable.

5.74. If a periodic safety review is to be used to justify long term operation or licence renewal, the safety assessment performed, as defined in SSG-25 [7], should take account of the intended operating period.

6. MANAGEMENT OF TECHNOLOGICAL OBSOLESCENCE

6.1. Technological obsolescence of the SSCs in the plant should be managed through a dedicated plant programme with foresight and anticipation and should be resolved before any associated decrease in reliability and availability occur.

6.2. A technological obsolescence programme should be prepared and implemented to address all SSCs important to safety and the spare parts required to maintain those SSCs.

6.3. The technological obsolescence programme should involve the participation of the engineering, maintenance, operations and work planning units, plant senior management and supply chain organizations.

6.4. The technological obsolescence programme should be made available to the regulatory body for review and assessment at a level of detail defined by national regulatory requirements.

6.5. The technological obsolescence programme should be consistent with the nine attributes set out in Table 2, as applicable.

6.6. The technological obsolescence programme should include three basic steps (see Fig. 6):

(1) The operating organization should identify the installed SSCs important to safety that are technologically obsolete or will become obsolete in the upcoming years.
(2) The identified equipment should be prioritized on the basis of the safety and criticality significance of the obsolete equipment (i.e. its impact on the plant safety).
(3) The operating organization should develop and implement effective replacement solutions in a timely manner. Solutions to manage technological obsolescence are illustrated in Fig. 7 and are described in the IGALL technological obsolescence programme [5].

6.7. For the identification of obsolete equipment and parts, the following activities should be performed:

(a) Collection of data on structures and components, usually from plant asset management systems (equipment databases with information on manufacturers and parts);
(b) Determination of whether the manufacturer still provides replacement equipment and spare parts.

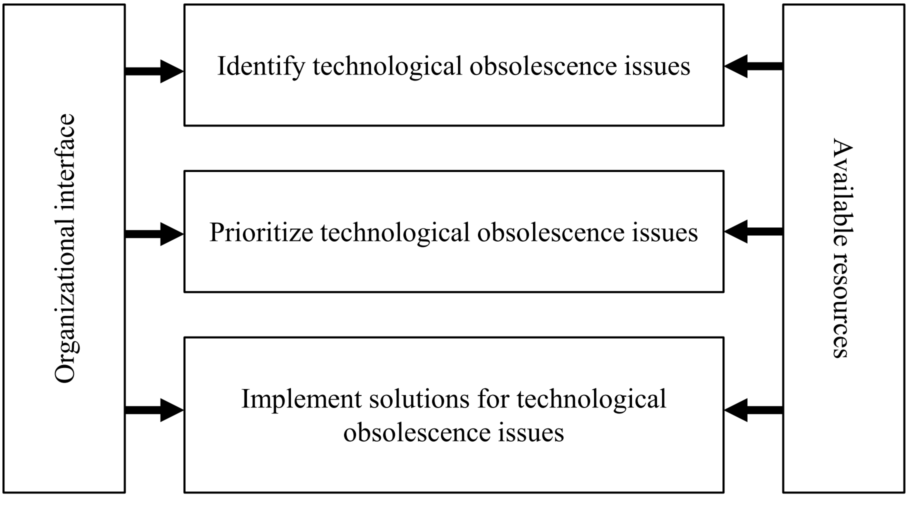


FIG. 6. Basic steps of the generic proactive process to manage obsolescence.

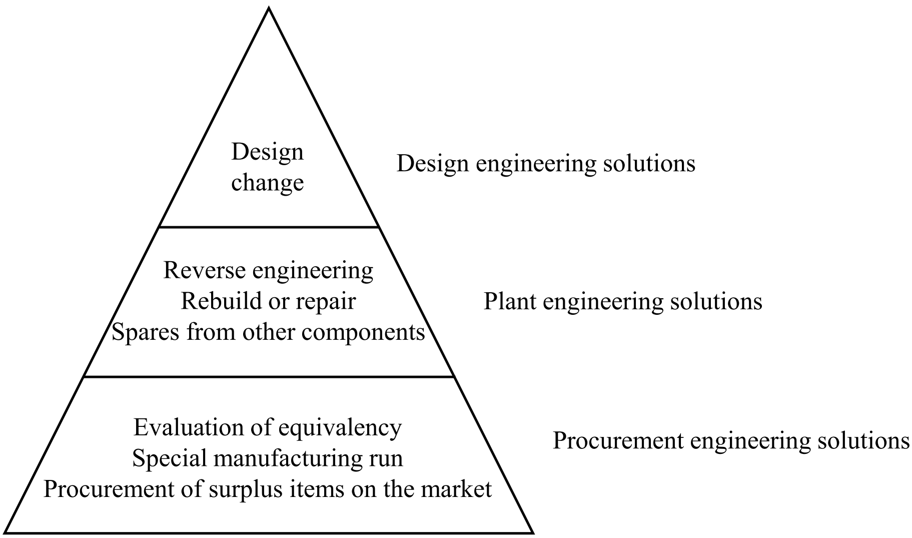


FIG. 7. Solutions to manage technological obsolescence.

6.8. For the prioritization (see step 2 of para. 6.6), suitable criteria should be used, such as: safety relevance; plant demand; quantity in stock; safety classification of components; failure history; reliability of structures or components; work order information; stock history; and uncertainty (spare parts with insufficient data).

6.9. Training should be conducted on obsolescence to educate personnel involved in understanding obsolescence management.

6.10. The operating organization should exchange information and should participate in collaboration within the nuclear industry and should make use of industry tools to identify and resolve common occurrences of technological obsolescence.

6.11. The operating organization should periodically assess the effectiveness of the technological obsolescence programme and should continuously seek to improve performance and efficiency. Self-assessments should be performed concerning the obsolescence programme, its implementation and its effectiveness, and any lessons learned should be acted on.

6.12. Detailed information on the technological obsolescence programme is provided in Ref. [5].

7. PROGRAMME FOR LONG TERM OPERATION

7.1. Requirement 16 of SSR-2/2 (Rev. 1) [2] establishes requirements for the programme for long term operation.

7.2. Requirements for long term operation should be specified within the national regulatory framework. They should cover, as appropriate, interfaces with the requirements for periodic safety review [7].

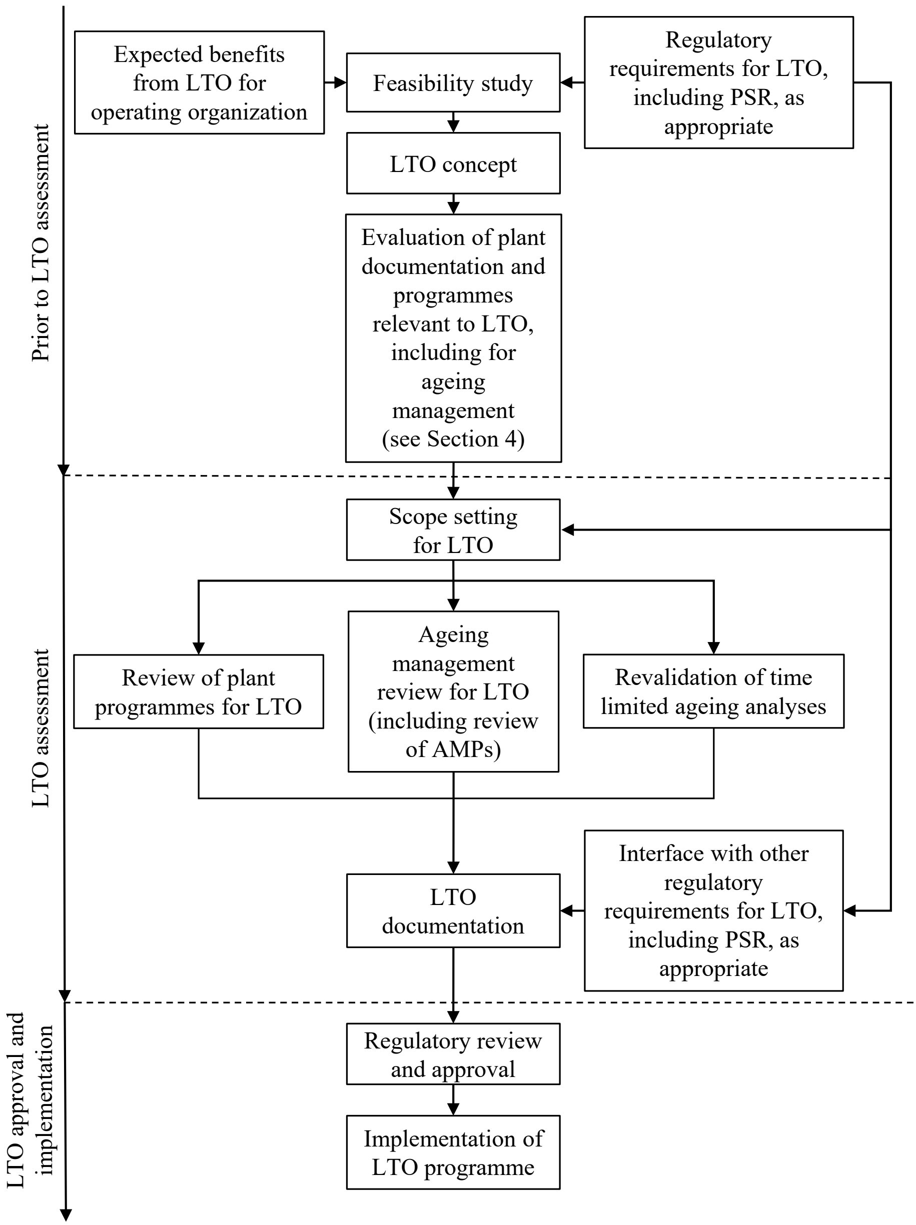
ORGANIZATIONAL ARRANGEMENTS

7.3. The operating organization should adopt a comprehensive project structure or similar organizational arrangements for the preparation and implementation of the programme for long term operation, which should take into account the arrangements for the management of physical ageing, as described in Section 5. The organizational arrangements for the management of physical ageing, including technological obsolescence, should be properly implemented and should be one of the prerequisites for a decision to pursue long term operation of the nuclear power plant.

7.4. In addition to the existing obligations associated with ageing management, the operating organization should clearly define the additional responsibilities and authorities associated with the preparation for, and implementation of, long term operation, after considering all the regulatory requirements relevant to long term operation. The operating organization should ensure that appropriate resources are available to support these assigned responsibilities and accountabilities.

PRINCIPLES OF AND APPROACH TO LONG TERM OPERATION

7.5. Major steps in the programme for long term operation, in particular for the ageing management of SSCs necessary to ensure safe long term operation, are illustrated in Fig. 8.



Note: AMP — ageing management programme; LTO — long term operation; PSR — periodic safety review.

FIG. 8. Major steps in a programme for long term operation.

7.6. The decision of an operating organization to pursue long term operation is typically based on an evaluation (feasibility study) that addresses the following:

(a) Strategic elements, such as the need for electrical power, an economic assessment and issues concerning diversity in supply, with due consideration that safety takes precedence over electricity production;
(b) Compliance with current codes, standards and regulations;
(c) The most recent relevant international standards and guidance;
(d) A technical assessment of the physical condition of the plant;
(e) An evaluation of past operating experience at the plant relating to ageing, obsolescence and other safety issues;
(f) Storage of spent nuclear fuel for long term operation;
(g) Radioactive waste management for long term operation;
(h) An assessment of the environmental impact of long term operation as required by national regulations.

7.7. A plant policy for long term operation should be established and should cover the principles of and concept (strategy) for long term operation. When a decision on long term operation is connected to a regulatory process, such as licence renewal or periodic safety review, the plant policy should take account of the related regulatory process.

7.8. The long term operation programme should be based on the following principles:

(a) Operational practices should meet national regulations, should follow international guidelines, as applicable, and should be adequate to ensure safe operation of the plant.
(b) The regulatory process should be adequate to ensure that safe operation of the nuclear power plant is maintained and should focus on ageing effects that need to be properly managed for the planned period of long term operation.
(c) The current licensing basis should provide an acceptable level of safety and should be carried over to the planned period of long term operation in the same manner and to the same extent, with the exception of any changes specific to long term operation.

7.9. The concept (strategy) for long term operation should address basic goals and objectives, milestones, activities, organizational roles and responsibilities, interactions with other major projects, and interactions with external organizations.

7.10. The operating organization's staff, in particular plant personnel, should be familiar with long term operation and should understand its principles and concept.

7.11. Ageing management review and evaluation of time limited ageing analyses should have been completed previously in accordance with the recommendations in paras 5.22–5.36 and 5.64–5.69, respectively; if not, such review and evaluation should be completed for long term operation.

7.12. Technological obsolescence should have been addressed previously in accordance with the recommendations in paras 6.1–6.11; if not, then it should be addressed for long term operation.

7.13. The assessment for long term operation should demonstrate, in particular, that ageing effects will be adequately managed so that the intended functions of the SSCs can be maintained consistent with the plant's current licensing basis for the planned period of long term operation.

7.14. The approach to the assessment prior to long term operation is outlined in Fig. 8. With regard to ageing, an overview of the major steps of the programme for long term operation should involve the following:

(a) Demonstration that ageing effects will continue to be identified and managed for each structure or component in the scope of long term operation for the planned period of long term operation (including feedback on operating experience and research and development findings).
(b) Review of time limited ageing analyses to ensure that the analyses continue to meet the criteria specified in para. 5.67.

7.15. The approach to an assessment for long term operation should also take into account the licensing processes and other licensing related requirements, such as the performance of a periodic safety review [7]. This is to ensure that any safety improvements required for long term operation will be addressed as part of the preparation for long term operation.

DEVELOPMENT OF A PROGRAMME FOR LONG TERM OPERATION

7.16. Ageing management for the period of long term operation should use the approach described in Section 5 and should account for the differences that will occur for the period of long term operation, for example longer operating times and higher neutron fluence levels. In addition, changes that will occur before the period of long term operation should be considered, including changes in regulatory requirements, codes and standards, knowledge and operating experience.

7.17. Time limited ageing analyses should be re-evaluated for the planned period of long term operation, and it should be demonstrated that they meet the criteria in para. 5.67.

7.18. The programme for long term operation should include the following activities, evaluations, assessments and results:

(a) The method of scope setting, the results obtained (structures or components within the scope and out of the scope of long term operation), and supporting technical justifications as outlined in paras 5.14–5.21.
(b) Demonstration that the programmes credited for long term operation support the conclusion that the intended functions of the SSCs and the required safety margins will be maintained. This demonstration should address the following topics:
    - A description of the intended functions of the structures or components;
    - Identification of applicable ageing effects and degradation mechanisms based on, for example, the materials used, the environment and operating experience;
    - Specification and description of operational programmes and ageing management programmes that manage the identified ageing effects;
    - Demonstration that these operational programmes and ageing management programmes (including new programmes) are effective.
(c) Demonstration that the review performed for the SSCs within the scope of long term operation is consistent with the process outlined in paras 5.22–5.36. A technical justification should be provided that:
    - Demonstrates that ageing effects will be adequately managed for each structure or component in such a way that the intended function(s) of the structure or component will be maintained throughout the planned period of long term operation in a manner that is consistent with the current licensing basis;
    - Ensures that operating experience and research findings are adequately reflected in assessing the ageing effects of structures or components that are in scope for long term operation and will continue to be taken into account during the entire period of long term operation.
(d) Demonstration that the time limited ageing analyses have been revalidated and that the evaluation includes:

— Identification of time limited ageing analyses in accordance with the definition specified in para. 5.64;
— Revalidation of each identified time limited ageing analysis in accordance with the recommendations provided in para. 7.28 to demonstrate that the intended function(s) of the structure or component will be maintained throughout the planned period of long term operation in a manner that is consistent with the current licensing basis.

(e) The implementation of the programme for long term operation, specifying the corrective actions for safe long term operation, and the schedule and commitments of the operating organization relating to long term operation.

7.19. The programme for long term operation should address the safety improvements required for safe long term operation, the schedule, and the commitments of the operating organization relating to long term operation.

SCOPE SETTING FOR STRUCTURES, SYSTEMS AND COMPONENTS FOR LONG TERM OPERATION

7.20. Scope setting for long term operation should follow the approach set out in paras 5.14–5.21 and should account for differences in regulatory requirements, codes and standards.

AGEING MANAGEMENT REVIEW FOR LONG TERM OPERATION

7.21. The ageing management review for long term operation should follow the approach set out in paras 5.22–5.36, accounting for differences in regulatory requirements, codes and standards, knowledge and operating experience for the period of long term operation.

7.22. The process set out in paras 5.30–5.32 should be used to identify programmes to manage the ageing of in-scope structures or components.

7.23. The ageing management review for long term operation should focus on the following issues:

(a) Whether any new ageing effect or degradation mechanism is anticipated in the course of the planned period of long term operation;

(b) Whether the significance, degradation rate or susceptible sites of degradation mechanisms are expected to change during the planned period of long term operation;
(c) Whether current relevant operating experience and research findings have been incorporated into ageing management programmes.

7.24. If the operating organization has not performed an ageing management review, the results of an ageing management review for long term operation should be used to identify or develop effective ageing management programmes in order to detect and mitigate those ageing effects identified in the ageing management review before the integrity and the functional capability of the SSCs are compromised.

7.25. The ageing management review should provide a clear demonstration that ageing effects will continue to be identified and managed for each structure or component in the scope of long term operation for the planned period of long term operation.

REVIEW OF PLANT PROGRAMMES AND AGEING MANAGEMENT PROGRAMMES FOR LONG TERM OPERATION

7.26. On the basis of the results of the ageing management review for long term operation, the existing plant programmes used for ageing management and existing ageing management programmes should be reviewed to ensure that they will remain effective in managing the effects identified for the planned period of long term operation. This review should identify programme modifications and/or new programmes necessary to ensure that the structures or components will be able to perform their intended functions for the planned period of long term operation.

7.27. Any existing and new plant programmes for long term operation should be reviewed to determine whether they are consistent with the nine attributes set out in Table 2. In addition, the plant documentation and programmes described in Section 4 should also be reviewed with respect to the planned period of long term operation.

REVALIDATION OF TIME LIMITED AGEING ANALYSES

7.28. Time limited ageing analyses should be reviewed to determine the continued acceptability of the analysed structure or component for the planned period of long term operation, in accordance with para. 5.67. The time dependent parameter should be determined from a re-evaluation or analysis of the operating history of the plant (including its projection to the end of the planned period of long term operation) to define a value of the parameter that applies to or bounds the expected value of the parameter at the end of the planned period of long term operation. The value of the time dependent parameter applicable to the period of long term operation should be used to re-evaluate the time limited ageing analyses, as described in para. 5.67.

DOCUMENTATION IN SUPPORT OF LONG TERM OPERATION

7.29. The assumptions, activities, evaluations, assessments and results of the plant programme for long term operation should be documented by the operating organization in accordance with national regulatory requirements as well as in accordance with the IAEA safety standards [2]. The documentation should be developed and retained in an auditable and retrievable form so that it provides a part of the technical basis for approval of long term operation.

7.30. The documentation should provide detailed information on each element outlined in paras 7.18 and 7.19 and any other information required by national regulatory requirements.

7.31. With regard to ageing management, the documentation should also include the following to demonstrate that ageing effects will be managed throughout the planned period of long term operation:

(a) A description of plant programmes and documentation relevant to ageing management throughout the planned period of long term operation;
(b) A list of commitments for the improvement or development of plant programmes and documentation relevant to ageing management throughout the period of long term operation, and information on the implementation of new ageing management programmes.

7.32. The methodology used to carry out the ageing management review for long term operation should be documented and justified.

7.33. All information and conclusions with regard to the scope of an ageing management review for long term operation should be documented, including:

(a) An identification and listing of SSCs subject to an ageing management review and their intended functions;
(b) A description and justification of the methods used to determine the structures or components that are subject to an ageing management review;
(c) The information sources used to accomplish the above, and any description necessary to clarify their use.

7.34. The results of the ageing management review for long term operation should be documented in an appropriate report. The report should address the understanding of ageing, the monitoring of ageing and the prevention and mitigation of ageing effects. In addition, recommendations should be provided for the application of the results of the ageing management review in plant operation, maintenance and design.

7.35. Documentation of the demonstration that ageing effects will be adequately managed during long term operation should include the following:

(a) Identification of the ageing effects and degradation mechanisms requiring management;
(b) Identification of the specific programmes or activities that will manage the ageing effects and degradation mechanisms for each structure, component or commodity grouping listed;
(c) A description of how the programmes and activities will manage the ageing effects and degradation mechanisms.

7.36. The documentation should include an update of the safety analysis report and other documents required by the licensing process reflecting the assumptions, activities and results of the plant programme for long term operation. The update to the safety analysis report should also include documentation of the revalidation of the time limited ageing analyses for the period of long term operation.

7.37. The assumptions, activities, evaluations, assessments and results of the plant programme for long term operation should also be reflected in the periodic safety review report, if applicable.

7.38. If the periodic safety review is used as a licensing tool, the safety assessment performed for safety factors 2–5 as defined in SSG-25 [7] should consider the entire planned period of long term operation.

REGULATORY REVIEW AND APPROVAL

7.39. To ensure the safe long term operation of a nuclear power plant, the operating organization should demonstrate, and the regulatory body should oversee, that the safety of the nuclear power plant will be maintained throughout the period of long term operation in accordance with current safety standards and national regulatory requirements.

7.40. The demonstration of safety for long term operation should be provided to the regulatory body for review and approval at a level of detail, and in a manner, defined by national regulatory requirements. The justification should include trends of expected ageing effects during the period of long term operation based on past studies, such as studies undertaken in past periodic safety reviews, and, when appropriate, the plant modifications to be implemented to improve safety.

IMPLEMENTATION OF THE PROGRAMME FOR LONG TERM OPERATION

7.41. The programme for long term operation should be implemented by the operating organization in a manner consistent with the requirements of the national regulatory body and national regulations.

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