IAEA Safety Standards

for protecting people and the environment

Ageing Management for Nuclear Power Plants

Safety Guide

No. NS-G-2.12

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AGEING MANAGEMENT FOR
NUCLEAR POWER PLANTS

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AGEING MANAGEMENT FOR NUCLEAR POWER PLANTS

SAFETY GUIDE

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International Atomic Energy Agency
Wagramer Strasse 5
P.O. Box 100
1400 Vienna, Austria
fax: +43 1 2600 29302
tel.: +43 1 2600 22417
email: sales.publications@iaea.org
http://www.iaea.org/books

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FOREWORD

by Mohamed ElBaradei
Director General

The IAEA's Statute authorizes the Agency to establish safety standards to protect health and minimize danger to life and property — standards which the IAEA must use in its own operations, and which a State can apply by means of its regulatory provisions for nuclear and radiation safety. A comprehensive body of safety standards under regular review, together with the IAEA's assistance in their application, has become a key element in a global safety regime.

In the mid-1990s, a major overhaul of the IAEA's safety standards programme was initiated, with a revised oversight committee structure and a systematic approach to updating the entire corpus of standards. The new standards that have resulted are of a high calibre and reflect best practices in Member States. With the assistance of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its safety standards.

Safety standards are only effective, however, if they are properly applied in practice. The IAEA's safety services — which range in scope from engineering safety, operational safety, and radiation, transport and waste safety to regulatory matters and safety culture in organizations — assist Member States in applying the standards and appraise their effectiveness. These safety services enable valuable insights to be shared and I continue to urge all Member States to make use of them.

Regulating nuclear and radiation safety is a national responsibility, and many Member States have decided to adopt the IAEA's safety standards for use in their national regulations. For the contracting 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 designers, manufacturers and operators around the world to enhance nuclear and radiation safety in power generation, medicine, industry, agriculture, research and education.

The IAEA takes seriously the enduring challenge for users and regulators everywhere: that of ensuring a high level of safety in the use of nuclear materials and radiation sources around the world. Their continuing utilization for the benefit of humankind must be managed in a safe manner, and the IAEA safety standards are designed to facilitate the achievement of that goal.

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. The safety requirements use 'shall' statements together with statements of

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

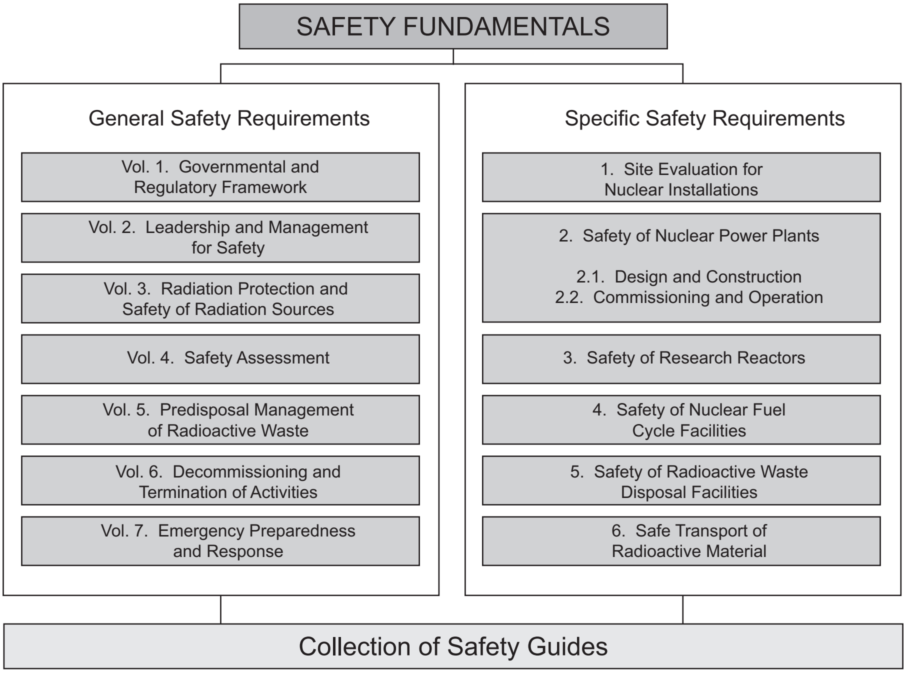

FIG. 1. The long term structure of the IAEA Safety Standards Series.

associated conditions to be met. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it 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 four safety standards committees, for nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on

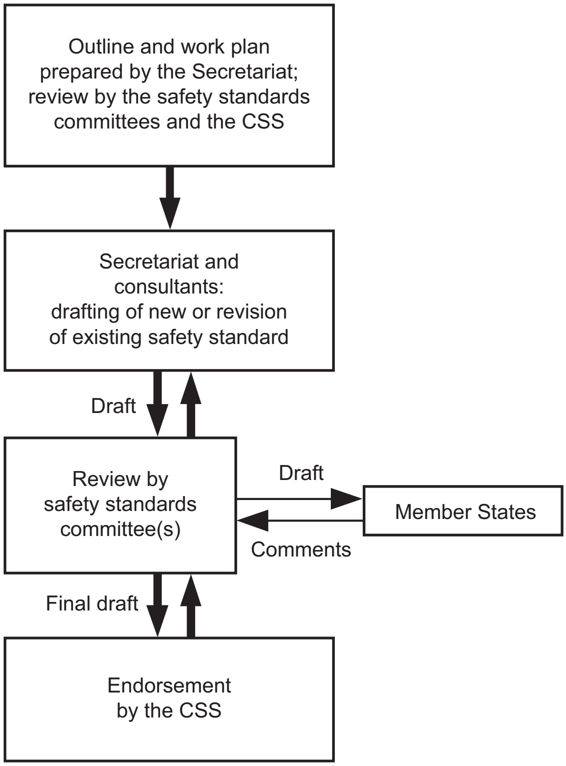

FIG. 2. The process for developing a new safety standard or revising an existing standard.

Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

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

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards. 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 for nuclear power plants. The requirements for the design and operation of nuclear power plants are established in the Safety Requirements publications on Safety of Nuclear Power Plants: Design [1] and on Safety of Nuclear Power Plants: Operation [2]. The Safety Requirements publication on Legal and Governmental Infrastructure for Nuclear, Radiation, Radioactive Waste and Transport Safety [3] addresses regulatory aspects in all stages of the lifetime of facilities or the duration of activities and for any subsequent period of institutional control until there is no significant residual radiation hazard.

1.2. Managing ageing for nuclear power plants means ensuring the availability of required safety functions throughout the service life of the plant, with account taken of changes that occur with time and use. This requires addressing both physical ageing of structures, systems and components (SSCs), resulting in degradation of their performance characteristics, and obsolescence of SSCs, i.e. their becoming out of date in comparison with current knowledge, standards and regulations, and technology.

1.3. A foundation for effective ageing management is that ageing is properly taken into account at each stage of a plant's lifetime, i.e. in design, construction, commissioning, operation (including long term operation[1] and extended shutdown) and decommissioning.

1.4. Effective management of ageing of SSCs is a key element of the safe and reliable operation of nuclear power plants. In order to assist Member States in managing ageing effectively, the IAEA has developed a comprehensive set of publications. Annex I provides brief descriptions and references for these publications as well as for guidance publications issued by other national and international organizations.

1.5. This Safety Guide supplements and provides recommendations on meeting the requirements set out in Refs [1, 2]. It identifies key elements of

[1] See para. 2.17.

effective ageing management for nuclear power plants, from the publications listed in Annex I and from Member States' experience.

OBJECTIVE

1.6. The objective of this Safety Guide is to provide recommendations for managing ageing of SSCs important to safety in nuclear power plants, including recommendations on key elements of effective ageing management.

1.7. The Safety Guide is intended for use by operators in establishing, implementing and improving systematic ageing management programmes for nuclear power plants. The Safety Guide may be used by regulators in preparing regulatory standards and guides, and in verifying that ageing in nuclear power plants is being effectively managed.

SCOPE

1.8. This Safety Guide deals with the establishment, implementation and improvement of ageing management programmes for SSCs important to safety in nuclear power plants.

1.9. The Safety Guide mainly focuses on managing the physical ageing of SSCs important to safety. It also provides recommendations on safety aspects of managing obsolescence and on the application of ageing management for long term operation. Issues relating to staff ageing and knowledge management are outside the scope of this Safety Guide.

STRUCTURE

1.10. Section 2 presents basic concepts of ageing management, which provide a common basis for the recommendations provided in Sections 3, 4, 5 and 6. Section 3 provides recommendations for the proactive management of the physical ageing of SSCs important to safety throughout the lifetime of a nuclear power plant. Section 4 presents recommendations on a systematic approach to managing ageing in the operation of nuclear power plants. Section 5 presents recommendations on managing obsolescence. Section 6 presents recommendations on the review of the management of ageing in support of long term operation. Section 7 highlights the technical areas of equipment qualification and periodic safety review that are deemed to be especially significant or closely related to ageing management. The annexes contain supplementary information.

2. BASIC CONCEPTS

2.1. This section presents the basic concepts of management of both ageing and obsolescence, including their application to long term operation, which provide a common basis for the recommendations provided in Sections 3, 4, 5 and 6.

2.2. Nuclear power plants experience two kinds of time dependent changes:

(i) Physical ageing of SSCs, which results in degradation, i.e. gradual deterioration in their physical characteristics;
(ii) Obsolescence of SSCs, i.e. their becoming out of date in comparison with current knowledge, standards and technology.

Evaluation of the cumulative effects of both physical ageing and obsolescence on the safety of nuclear power plants is a continuous process and is assessed in a periodic safety review or an equivalent systematic safety reassessment programme (see Section 7).

BASIC CONCEPTS OF MANAGING AGEING

2.3. To maintain plant safety it is very important to detect ageing effects[2] of SSCs, to address associated reductions in safety margins and to take corrective actions before loss of integrity or functional capability occurs.

[2] Ageing effects are net changes in the characteristics of an SSC that occur with time or use and which are due to ageing mechanisms. Ageing effects may be positive or negative. Examples of positive effects are increase in concrete strength from curing and reduced vibration from wear-in of rotating machinery. Examples of negative effects are reduction in diameter from wear of a rotating shaft, cracking, thinning or loss in material strength from fatigue or thermal ageing, and loss of dielectric strength or cracking of cable insulation.

2.4. Physical ageing (referred to in this Safety Guide as ageing) of SSCs may increase the probability of common cause failures, i.e. the simultaneous degradation of physical barriers and redundant components, which could result in the impairment of one or more levels of protection provided by the defence in depth concept. Therefore, in the screening of SSCs for ageing management, no account is taken of redundancy or diversity among SSCs [4].

2.5. Effective ageing management is in practice accomplished by coordinating existing programmes, including maintenance, in-service inspection and surveillance, as well as operations, technical support programmes (including analysis of any ageing mechanisms) and external programmes such as research and development. Reference [5] provides guidance on maintenance, surveillance and inspection practices.

2.6. Effective ageing management throughout the service life of an SSC requires the use of a systematic approach to managing ageing that provides a framework for coordinating all programmes and activities relating to the understanding, control, monitoring and mitigation of ageing effects of the plant component or structure. This approach is illustrated in Fig. 1, which is an adaptation of Deming's 'PLAN–DO–CHECK–ACT' cycle to the ageing management of an SSC [6].

2.7. Understanding the ageing of a structure or component, as illustrated in Fig. 1, is the key to its effective ageing management. This understanding is derived from knowledge of:

— The design basis (including applicable codes and standards);
— Safety functions;
— The design and fabrication (including the material, material properties, specific service conditions, manufacturing inspection/examination and testing);
— Equipment qualification (where applicable);
— Operation and maintenance history (including commissioning, repair, modification and surveillance);
— Generic and plant specific operating experience;
— Relevant research results;
— Data and data trends from condition monitoring, inspection and maintenance.

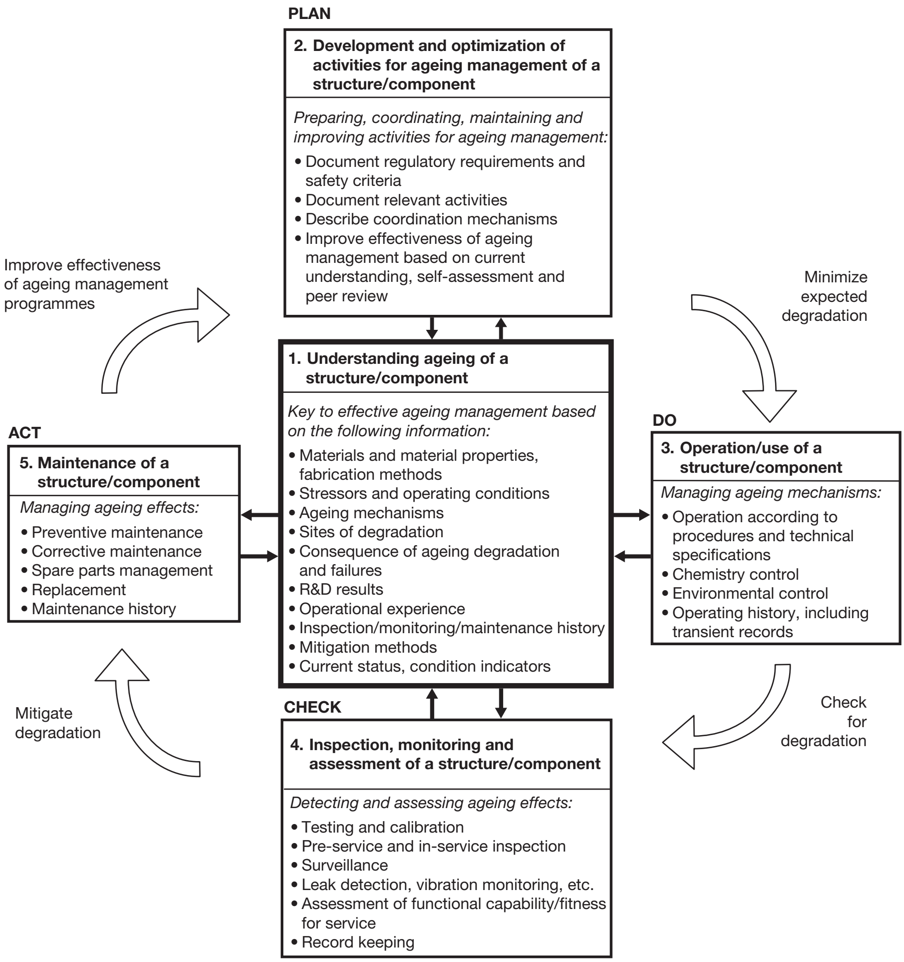

FIG. 1. Systematic approach to managing ageing of a structure or component.

2.8. The PLAN activity in Fig. 1 means coordinating, integrating and modifying existing programmes and activities that relate to managing the ageing of a structure or component and developing new programmes, if necessary.

2.9. The DO activity in Fig. 1 means minimizing expected degradation of a structure or component through its 'careful' operation or use[3] in accordance with operating procedures and technical specifications.

2.10. The CHECK activity in Fig. 1 means the timely detection and characterization of significant degradation through inspection and monitoring of a structure or component, and the assessment of observed degradation to determine the type and timing of any corrective actions required.

2.11. The ACT activity in Fig. 1 means the timely mitigation and correction of component degradation through appropriate maintenance and design modifications, including component repair and replacement of a structure or component.

2.12. The closed loop of Fig. 1 indicates the continuous improvement of the ageing management programme for a particular structure or component, on the basis of feedback of relevant operating experience and results from research and development, and results of self-assessment and peer reviews, to help ensure that emerging ageing issues will be addressed.

2.13. As shown in Fig. 1, ageing degradation is studied and managed at the structure or component level. However, if required by safety analysis, the ageing management programmes for individual structures and/or components may be integrated into an ageing management programme at the level of systems.

BASIC CONCEPTS OF MANAGING OBSOLESCENCE

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

2.15. There are several types of obsolescence, as shown in Table 1.

[3] Careful operation or use minimizes the rate of degradation of an SSC while maintaining the required levels of power production.

TABLE 1. TYPES OF OBSOLESCENCE

SSCs out of date in comparison with current:	Manifestation	Consequences	Management
Knowledge	Knowledge of current standards, regulations and technology relevant to SSCs not updated	Opportunities to enhance plant safety missed; Reduced capability for long term operation	Continuous updating of knowledge and improvement of its application
Standards and regulations	Deviations from current regulations and standards, both hardware and software; Design weaknesses (e.g. in equipment qualification, separation, diversity or severe accident management capabilities)	Plant safety level below current standards and regulations (e.g. weaknesses in defence in depth, or higher core damage frequency); Reduced capability for long term operation	Systematic reassessment of plant against current standards (e.g. periodic safety review) and appropriate upgrading, backfitting or modernization
Technology	Lack of spare parts and/or technical support; Lack of suppliers and/or industrial capabilities	Declining plant performance and safety owing to increasing failure rates and decreasing reliability; Reduced capability for long term operation	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

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

APPLICATION OF AGEING MANAGEMENT TO LONG TERM OPERATION

2.17. Long term operation means operation beyond an established timeframe set forth by, for example, licence term, design, standards, licence and/or regulations, which has been justified by safety assessment, with consideration given to the life limiting processes and features of SSCs. If an operating organization decides to pursue long term operation, justification is supported by the results of periodic safety reviews, including review of management of ageing, and overseen by the regulatory body.

3. PROACTIVE STRATEGY FOR AGEING MANAGEMENT

3.1. Ageing management of SSCs important to safety should be implemented proactively (with foresight and anticipation) throughout the plant's lifetime, i.e. in design, fabrication and construction, commissioning, operation (including long term operation and extended shutdown) and decommissioning.

3.2. Regulatory requirements for ageing management should be established and updated and guidance should be developed to ensure that the operating organization of a nuclear power plant implements an effective ageing management programme.

3.3. The operating organization should be responsible for demonstrating that the relevant issues of ageing that are specific to the plant are clearly identified and documented in the safety analysis report throughout the plant's lifetime. Issues of ageing arising from other plants should be considered by the operating organization in evaluating the ageing management measures proposed by suppliers[4].

[4] In this Safety Guide, the term 'supplier' includes vendors, manufacturers and designers, as appropriate.

3.4. The ageing management activities of suppliers and the operating organization should be overseen by the regulatory body throughout the plant's lifetime.

DESIGN

3.5. The operating organization should be made responsible for demonstrating to the regulatory body that ageing issues of the plant concerned have been adequately addressed in the plant design for its entire lifetime. The operating organization should prepare a description of measures by which it is going to implement an effective ageing management programme throughout all stages of the lifetime of the plant.

3.6. In the design and procurement documents for new facilities or SSCs, the operating organization should specify requirements to facilitate ageing management, including information to be included in documents received from suppliers and other contractors.

3.7. Appropriate measures should be taken or design features should be introduced in the design stage to facilitate effective ageing management throughout the lifetime of the plant. Such measures should also be applied to the design of modifications or of replacements of equipment or components. Reference [1] establishes the following design related requirements on the management of ageing of SSCs important to safety:

> "Appropriate margins shall be provided in the design for all structures, systems and components important to safety so as to take into account relevant ageing and wear-out mechanisms and potential age related degradation, in order to ensure the capability of the structure, system or component to perform the necessary safety function throughout its design life. Ageing and wear-out effects in all normal operating conditions, testing, maintenance, maintenance outages, and plant states in a postulated initiating event and post-postulated initiating event shall also be taken into account. Provision shall also be made for monitoring, testing, sampling and inspection, to assess ageing mechanisms predicted at the design stage and to identify unanticipated behaviour or degradation that may occur in service" (Ref. [1], para. 5.47).

3.8. In the design:

- It should be ensured that the design basis conditions, including transient conditions and postulated initiating event conditions, are taken into account in equipment qualification programmes.
- All potential ageing mechanisms for passive and active SSCs should be identified, evaluated and taken into account. Potential ageing mechanisms that could affect the safety functions of the SSCs during their design life include thermal and radiation embrittlement, fatigue, corrosion, environment assisted cracking, creep and wear.
- Relevant experience (including experience from construction, commissioning, operation and decommissioning of nuclear power plants) and research results should be reviewed and taken into account.
- Consideration should be given to the use of advanced materials with greater ageing resistant properties.
- Consideration should be given to the need for materials testing programmes to monitor ageing degradation.
- Consideration should be given to the need to incorporate on-line monitoring, particularly where this technology would provide forewarning of degradation leading to failure of SSCs and where the consequences of failure could be significant to safety.
- Consideration should be given to plant layout and design of SSCs that facilitate inspection, maintenance and ease of access for inspection, testing, monitoring, maintenance, repair and replacement, and which will also minimize occupational exposure during these activities.

3.9. Ageing management should be included as a topic in the general design criteria and should be addressed in the safety analysis report. Ageing management should include the following topics [7]:

- The strategy for ageing management and prerequisites for its implementation;
- All safety significant SSCs of the plant that could be affected by ageing;
- Proposals for appropriate materials monitoring and sampling programmes in cases where it is found that ageing or other forms of degradation may occur that may affect the capability of components, equipment and systems to perform their safety function throughout the lifetime of the plant;
- Appropriate consideration of the analysis of feedback of operating experience with respect to ageing;

- Ageing management for different types of SSC important to safety (concrete structures, mechanical components and equipment, electrical and instrumentation and control equipment and cables, etc.) and measures to monitor their degradation;
- Design inputs for equipment qualification (see Section 7) of the SSCs important to safety, including required equipment, and equipment functions required to be qualified for normal operation service conditions and associated with postulated initiating events;
- General principles stating how the environment of an SSC is to be maintained within specified service conditions (location of ventilation, insulation of hot SSCs, radiation shielding, damping of vibrations, avoiding submerged conditions, selection of cable routes, need for stabilized voltage centres, etc.).

FABRICATION AND CONSTRUCTION

3.10. The operating organization should ensure that the suppliers adequately address factors affecting ageing management and that sufficient information and data are provided to the operating organization.

3.11. The operating organization should ensure that:

- Relevant information on the factors affecting ageing management is provided to SSC manufacturers and is properly taken into account in the fabrication and construction of SSCs;
- Current knowledge about relevant ageing mechanisms and effects and degradation and possible mitigation measures are taken into account in fabrication and construction of SSCs;
- Reference (baseline) data are collected and documented;
- Surveillance specimens for specific ageing monitoring programmes are made available and installed in accordance with design specifications.

COMMISSIONING

3.12. The operating organization should establish a systematic programme for measuring and recording baseline data relevant to ageing management for SSCs important to safety. This includes mapping the actual environmental conditions in each critical spot of the plant to ensure that they are in compliance with the design.

3.13. Special attention should be paid to identification of hot spots in terms of temperature and dose rate, and to measurement of vibration levels. All parameters that can influence ageing degradation should be identified as early as possible, should be controlled in commissioning if possible and should be tracked throughout the plant life.

3.14. The regulatory body, as part of its review and inspection programme, should ensure that the operating organization collects required baseline data and should confirm that critical service conditions (as used in equipment qualification) are in compliance with the design analyses.

OPERATION

3.15. A systematic approach to managing ageing (see para 2.6) should be applied during plant operation. Application of a systematic approach to managing ageing will assist the operating organization in establishing an appropriate programme for ageing management of each specific structure or component.

3.16. The following factors and lessons learned from successful ageing management programmes should be taken into account:

- Support and sponsorship of a systematic ageing management programme by the management of the operating organization;
- Early implementation of a systematic ageing management programme;
- A proactive approach based on adequate understanding and predictability of structure or component ageing, rather than a reactive approach responding to SSC failures;
- Careful use of SSCs to slow down the rate of ageing degradation;
- Adequate qualification and training of staff;
- Awareness and understanding of basic concepts of ageing management by all operations, maintenance and engineering staff;
- Staff motivation, training and sense of ownership;
- Availability and use of correct procedures, tools and materials, and of qualified and sufficient staff for a given job;
- Appropriate storage of spare parts and consumables susceptible to ageing, to minimize degradation while in storage and to control their shelf life properly;
- Use of multidisciplinary teams for dealing with complex ageing management issues;

- Effective internal communication (both ‘vertical’ and ‘horizontal’) and external communication;
- Feedback of operating experience (both generic and plant specific operating experience, including operating experience from non-nuclear industrial plants) to learn from relevant ageing related events;
- Use of databases on SSC reliability and maintenance histories;
- Use of adequate and qualified methods of non-destructive testing and ageing monitoring for early detection of flaws possibly resulting from intensive use of equipment.

3.17. The operating organization should identify and address the following potentially significant common weaknesses of ageing management:

- Insufficient understanding and predictability of ageing at the time of plant design and construction, which has been the underlying reason for significant ageing degradation of structures or components in many nuclear power plants;
- Premature ageing of structures or components in nuclear power plants (i.e. ageing degradation that occurs earlier than expected) caused by pre-service and service conditions that are more severe than, or different from, those assumed in design, or that are due to errors or omissions in design, fabrication, installation, commissioning, operation and maintenance, lack of coordination between these functions, or unforeseen ageing phenomena;
- Inappropriate use of reactive ageing management (i.e. repairing and replacing degraded components) as the primary means of managing ageing of structures or components;
- Lack of awareness of relevant industry operating experience and research results;
- Unexpected stress loading to structures or components in nuclear power plants by external events (e.g. earthquakes).

3.18. In the event of reactor power uprating, important modifications or equipment replacement, the operating organization should identify and justify possible associated changes in process conditions (e.g. flow pattern, velocity, vibration) that could cause accelerated or premature ageing and failure of some components.[5]

[5] Examples of significant ageing effects due to power uprating include radiation embrittlement of the reactor pressure vessel, flow accelerated corrosion and vibration of primary system piping.

3.19. If a new ageing mechanism is discovered (e.g. through feedback of operating experience or research), the operating organization should perform an appropriate review of the management of ageing.

3.20. For major SSCs that are essential to safe plant operation, the operating organization should consider preparing contingency plans or exceptional maintenance plans to deal with their potential degradation or failure caused by potential ageing mechanisms and effects.

3.21. The availability of spare parts or replacement parts and the shelf life of spare parts or consumables should be continually monitored and controlled.

3.22. Where spare parts or consumables could be vulnerable to ageing degradation due to their storage environment (e.g. high or low temperatures, moisture, chemical attack[6], dust accumulation), measures should be taken to ensure that they are stored in an appropriately controlled environment.

DECOMMISSIONING

3.23. Appropriate arrangements should be made to ensure that required equipment and SSCs (e.g. containment system, cooling equipment, lifting equipment and condition monitoring equipment) remain available and functional to facilitate decommissioning activities.

4. AGEING MANAGEMENT IN OPERATION

4.1. This section presents guidance and recommendations on a systematic approach to managing ageing in the operation of nuclear power plants. This approach consists of the following elements:

— Organizational arrangements;
— Data collection and record keeping;

[6] Chemical attack is the deterioration of structures or components as a result of contact with gases or solutions of chemicals.

— Screening of SSCs for the purposes of ageing management;
— Review of the management of ageing;
— Condition assessment;
— Development of ageing management programmes;
— Implementation of ageing management programmes;
— Improvement of ageing management programmes.

Each of the above elements is described in the following. Alternative approaches to those described in this Safety Guide would also be acceptable if it can be shown that they are effective in managing ageing degradation.

ORGANIZATIONAL ARRANGEMENTS

4.2. The comprehensive nature of ageing management requires the involvement and support of the operating organization and external organizations (e.g. technical support organizations, owners' groups and research, design and manufacturing organizations). Before an ageing management programme can be implemented, senior management of the operating organization should set out the policy and objectives of the ageing management programme and should allocate the necessary resources (human resources, financial resources, tools and equipment, and external resources).

4.3. An illustration of the organizational arrangements, including participating organizations and their roles and interfaces, is shown in Fig. 2.

4.4. Senior management should designate a coordinator for the ageing management programme with responsibilities as specified in Fig. 2. The coordinator should be a part of the operating organization, such as the operations, maintenance, engineering or quality management unit; a task force consisting of members of different units of the operating organization and external experts if necessary; or a dedicated ageing management programme unit.

4.5. The responsibilities of the coordinator should include:

— Coordination of relevant programmes;
— Systematic monitoring of relevant operating experience and of research and development results, and evaluation of their applicability to the nuclear power plant at hand;

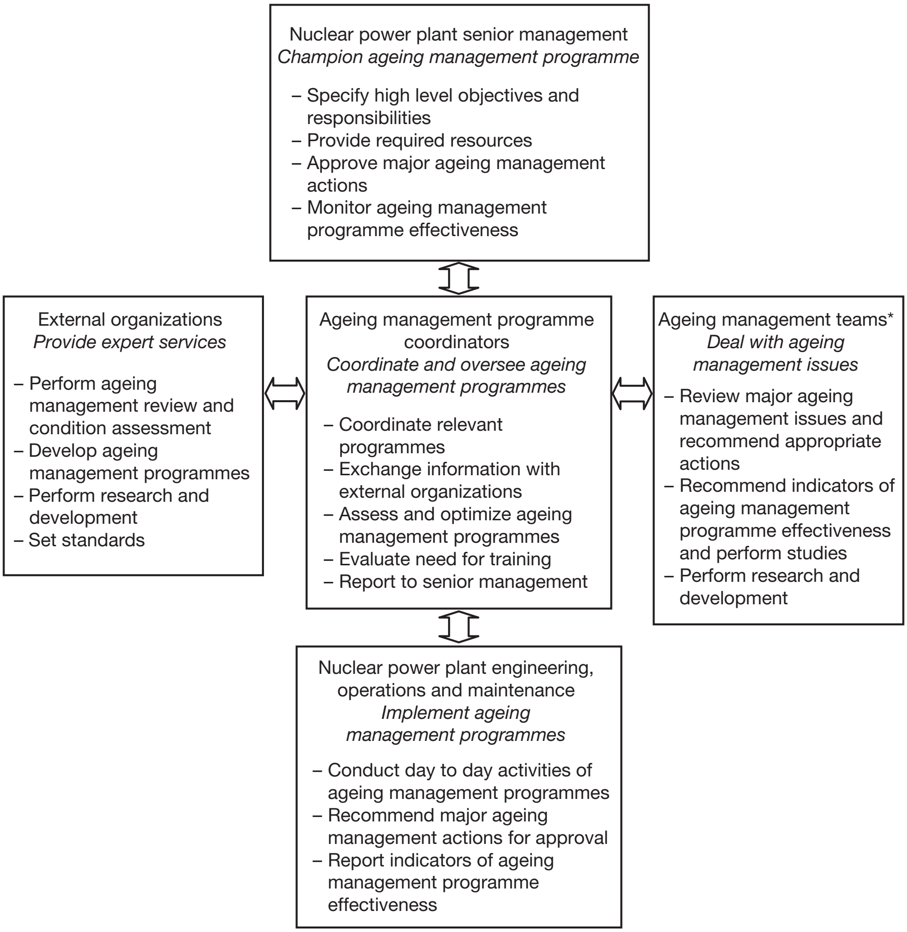

FIG. 2. Illustration of organizational ageing management arrangements.
** Includes representatives of nuclear power plant units and external technical support organizations.*

— Direction of interdisciplinary ageing management teams (ongoing or ad hoc ageing management teams) for managing complex ageing issues;
— Assessment and optimization of ageing management programmes;
— Dealing with external technical support organizations;
— Evaluation of further training needs;
— Performing periodic self-assessment;
— Improvement of activities relating to ageing management programmes.

4.6. Dealing with complex ageing issues may require an interdisciplinary approach. The participants of 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. In addition to the ageing management teams, external organizations may be requested to provide expert services on specific topics, e.g. condition assessments, research and standards development.

4.7. Different units of the operating organization of the nuclear power plant (e.g. operations, maintenance and engineering) should be responsible for the implementation of structure specific or component specific ageing management programmes and for reporting on the performance of structures and components. Such individual structure specific and component specific ageing management programmes are part of the overall ageing management programme for the plant and are integrated with it and with each other.

4.8. The operating organization should provide for training on the ageing of SSCs for staff involved in operations, maintenance and engineering, to enable them to make an informed and positive contribution to the management of ageing.

4.9. The operating organization should collect and evaluate relevant plant and industrial experience and should use it for improving the ageing management programme.

DATA COLLECTION AND RECORD KEEPING

4.10. The operating organization should establish a data collection and record keeping system that is defined by the ageing management programme and that supports it [8].

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

— Identification and evaluation of degradation, failures and malfunctions of components caused by ageing effects;

— Decisions on the type and timing of maintenance actions, including calibration, repair, refurbishment and replacement;
— Optimization of operating conditions and practices that reduce ageing degradation;
— Identification of new emerging ageing effects before they jeopardize plant safety, production reliability and service life.

4.12. To facilitate obtaining the desired quality and quantity of ageing related data from plant operations, maintenance and engineering, representatives of the operations, maintenance and engineering units should be involved in the design of the record keeping system.

4.13. Examples of data that should be included in the data collection and record keeping system are shown in Annex II.

SCREENING SYSTEMS, STRUCTURES AND COMPONENTS

4.14. A nuclear power plant has a large number and variety of SSCs. The extent to which these SSCs are susceptible to ageing degradation also differs considerably. It is neither practicable nor necessary to evaluate and quantify the extent of ageing degradation in every individual SSC. A systematic approach should therefore be applied to focus resources on those SSCs that can have a negative impact on the safe operation of the plant and that are susceptible to ageing degradation [4, 6]. This should include SSCs that do not have safety functions but whose failure could prevent other SSCs from performing their intended safety functions.

4.15. A safety based approach, such as the one outlined in the following, should be applied to the screening of SSCs for review of the management of ageing:

— From a list of all systems and structures[7], those that are important to safety should be identified, on the basis of whether or not a component malfunction or failure could lead (directly or indirectly) to the loss or impairment of a safety function.

[7] Structures include both simple structures and complex structures that consist of structural elements.

- For each of the systems and structures important to safety, the structural elements[8] and components that are important to safety should be identified, i.e. those whose failure could lead (directly or indirectly) to the loss or impairment of a safety function.
- From the list of structural elements and components important to safety, those for which ageing degradation has the potential to cause component failure should be identified.
- To ensure that the ageing management review is resource effective, the list of identified structural elements and components important to safety that are susceptible to ageing degradation should be arranged into generic groups.

An outline of this screening process is illustrated in Fig. 3. The specific screening methodology used should be documented and justified.

4.16. The use of risk informed methods (probabilistic safety analyses and deterministic approaches) should be considered to prioritize the ageing management review of the selected components on the basis of their safety significance. For example, evaluation of structures and components whose failure would have a high impact on the core damage frequency should be given a high priority. In probabilistic safety assessments, consideration should be given to the possibility of common cause failures in the event that redundant structures or components undergo the same ageing degradation.

REVIEW OF THE MANAGEMENT OF AGEING

4.17. A review of the management of ageing for each structure, component or group of structures and components selected by the screening process should be performed in order to acquire information and knowledge about the following three essential elements:

(i) Understanding ageing;
(ii) Monitoring ageing;
(iii) Mitigation of ageing effects.

[8] Structural elements include both simple structures and elements of complex structures. The term 'structural element' is used only for this screening process for better understanding; in subsequent paragraphs structural elements are again referred to as 'structures'.

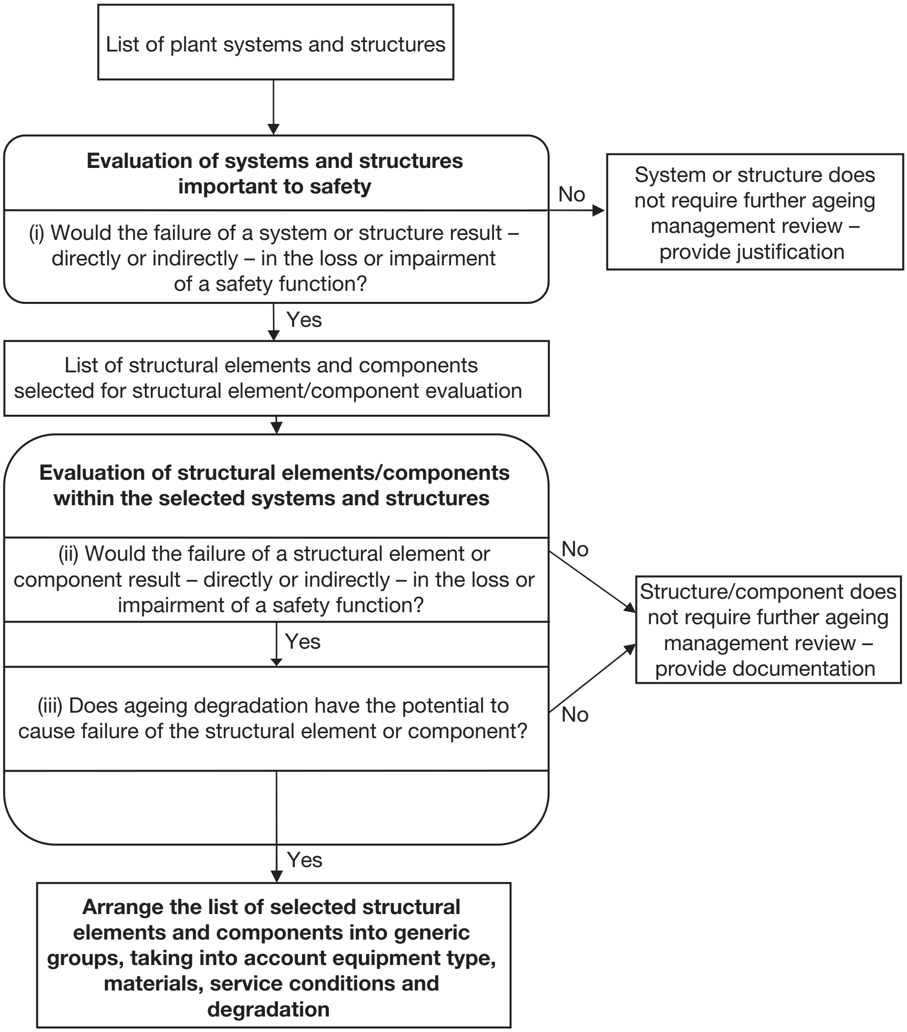

FIG. 3. Outline of the process for screening SSCs for ageing management. For the definition of structural elements, refer to footnotes 7 and 8.

4.18. Relevant applicable ageing management reviews (e.g. prepared by the owners' group, suppliers or support organizations) should be used to minimize duplication of effort, if available. Appropriate references should be made and an explanation of the use of these references should be provided.

4.19. A recommended methodology, which consists of the review and evaluation of relevant information and documentation of the findings, is illustrated in the flowchart shown in Fig. 4 and described further in paras 4.20–4.27 and in Ref. [4]. An ageing management review may not be necessary for some structures or components if the ageing mechanisms and effects affecting them are well understood and an effective ageing management programme is in place (i.e. it has the attributes of an effective ageing management programme as presented in Table 2).

Understanding ageing

4.20. Understanding ageing is the basis for the effective monitoring and mitigation of ageing effects. To understand the ageing degradation of a structure or component, its ageing mechanisms and effects should be identified and understood; post-service examination and testing of structures or components (including destructive testing) may substantially improve this understanding. Annex III provides examples of significant ageing degradation mechanisms and susceptible materials and components.

4.21. The review relating to the understanding of the ageing of structures and components should address materials, stressors[9] and the environment, ageing mechanisms of concern and sites of degradation, and available analytical models (i.e. based on theory) or empirical models (i.e. based on observation or experiment) for predicting future degradation. The results of the review relating to the understanding of ageing should be documented.

Monitoring ageing

4.22. Existing monitoring methods should be evaluated, with account taken of relevant operating experience and research results, to determine whether they are effective for timely detection of ageing degradation before failure of the structure or component occurs. Sampling checks of equipment should be applied to detect precursors of ageing degradation when applicable.

4.23. In the evaluation of existing monitoring methods to identify effective and practical monitoring methods and technology, the following should be addressed:

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[9] A stressor is an agent or stimulus stemming from pre-service and service conditions that can produce immediate or gradual ageing degradation of an SSC. Examples are heat, steam, chemicals and electrical cycling.

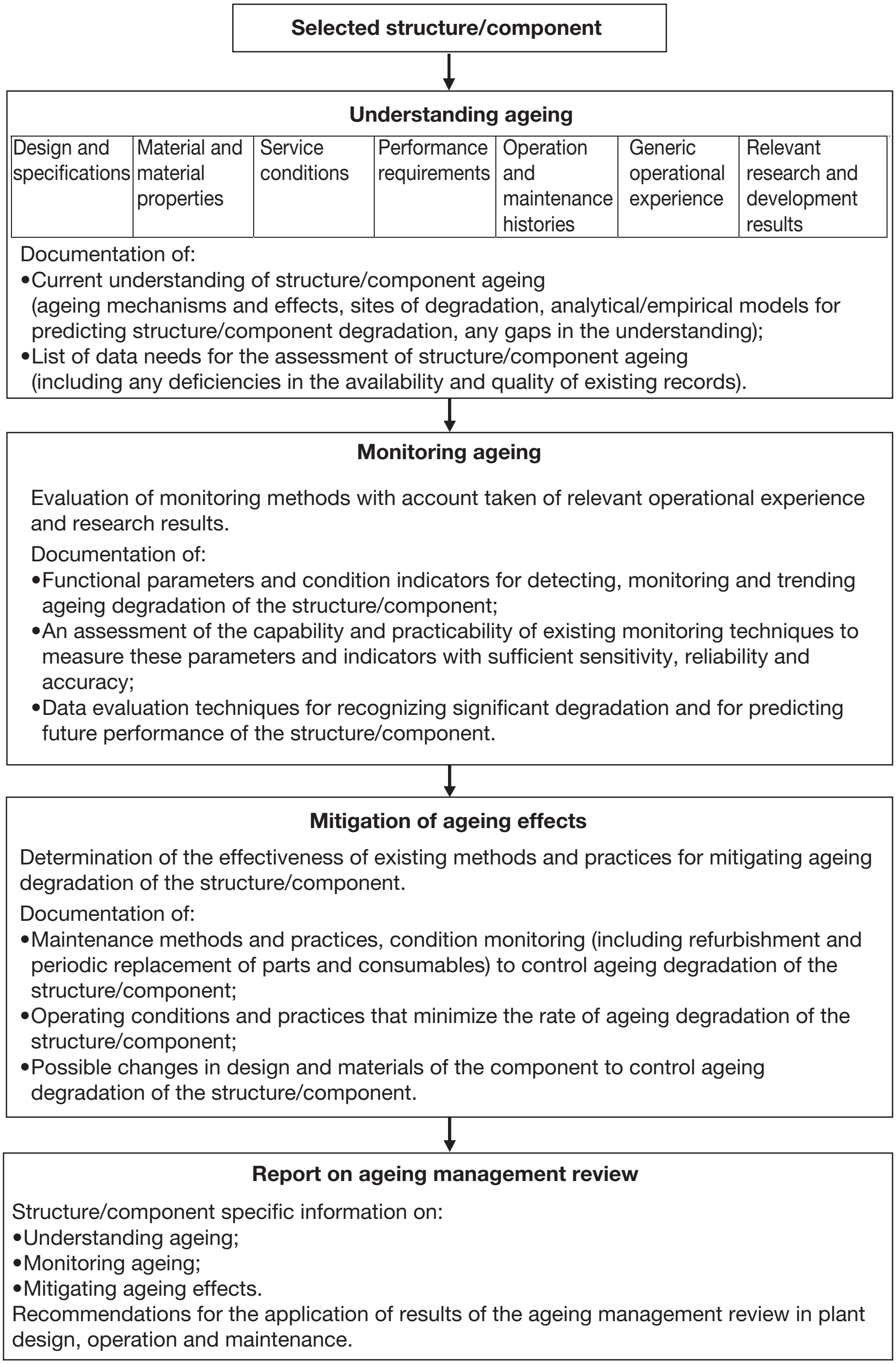

FIG. 4. Illustration of the review of the management of ageing.

— Functional parameters and condition indicators for detecting, monitoring and trending ageing degradation of the structure or component;
— An assessment of the capability and practicability of existing monitoring techniques to measure these parameters and indicators with sufficient sensitivity, reliability and accuracy;
— Data evaluation techniques for recognizing instances of significant degradation, failure rates and their tendencies, for predicting future integrity and functional capability of the structure or component.

The results of the review relating to the monitoring of ageing should be documented.

Mitigation of ageing effects

4.24. The effectiveness of existing methods and practices for mitigating ageing degradation of a structure or component should be determined, with account taken of relevant operating experience and research results.

4.25. Information obtained in this aspect of the review to identify effective and practical mitigation methods and technology should include:

— Maintenance methods and practices (including refurbishment and periodic replacement of parts and consumables) to control ageing degradation of the structure or component;
— Operating conditions and practices that minimize the rate of ageing degradation of the structure or component;
— Possible changes in design and materials of the component to control ageing degradation of the structure or component.

The results of the review relating to the mitigation of ageing effects should be documented.

Report on the ageing management review

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

4.27. The methodology used to carry out the review of ageing management should be documented and justified.

CONDITION ASSESSMENT

4.28. For the development of plans for effective ageing management, the actual condition of a structure, a component or a group of structures and components selected by the screening process should be determined on the basis of background information provided by the output of the ageing management review.

4.29. Assessment of the condition of the structure or component should be carried out on the basis of:

— The relevant report of the ageing management review;
— Operation and maintenance and engineering data, including acceptance criteria specific to the structure or component;
— Results from inspections and condition assessments, including results from updated inspections and assessments, if available and necessary.

4.30. Results of the condition assessment should be documented in an appropriate report and should provide information on:

— The current performance and condition of the structure or component, including assessment of any ageing related failures or indications of significant material degradation;
— Estimation of future performance, ageing degradation and service life, where feasible, of the structure or component.

DEVELOPMENT OF AGEING MANAGEMENT PROGRAMMES

4.31. A specific programme for the ageing management of each structure, component or group of structures and components selected by the screening process should be developed and documented. The ageing management programme should identify: (a) effective and appropriate actions and practices for managing ageing that provide for timely detection and mitigation of ageing effects in the structure or component; and (b) indicators of the effectiveness of the programme. Thus the effectiveness of current practices should be confirmed in light of applicable ageing evaluations and condition assessments, and/or improvements to current practices should be recommended, as appropriate.

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

— Material condition with respect to acceptance criteria.
— Trends of data relating to failure and degradation.
— Comparison of preventive and corrective maintenance efforts (e.g. in terms of person-years or cost).
— Number of recurrent failures and instances of degradation.
— Status of compliance with inspection programmes. Any existing nuclear power plant programmes that are considered for use in ageing management should also be evaluated against the attributes listed in Table 2. Programmes that do not have these attributes should be modified, as appropriate.

4.33. An engineering assessment may be used to develop each ageing management programme. The engineering assessment should take into account applicable design basis and regulatory requirements; information on the materials, service conditions, stressors, degradation sites, and ageing mechanisms and effects of the structure or component; and appropriate indicators and quantitative or qualitative models of relevant ageing phenomena. Every ageing management programme should have the generic attributes presented in Table 2.

4.34. A summary sheet for each ageing management programme may be produced. The summary sheet should provide an executive summary of the ageing management programme that highlights information useful for understanding and managing ageing, including materials, degradation sites, ageing stressors and environment, ageing mechanisms and effects, inspection and monitoring requirements and methods, mitigation methods, regulatory requirements and acceptance criteria.

IMPLEMENTATION OF AGEING MANAGEMENT PROGRAMMES

4.35. The operating organization should be made responsible for implementing ageing management programmes.

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 ageing mechanisms, susceptible sites): – Structure/component materials, service conditions, stressors, degradation sites, ageing mechanisms and effects – Structure/component condition indicators and acceptance criteria – Quantitative or qualitative predictive models of relevant ageing phenomena
2. Preventive actions to minimize and control ageing degradation	• Identification of preventive actions • Identification of parameters to be monitored or inspected • Service conditions (i.e. environmental conditions and operating conditions) to be maintained and operating practices aimed at slowing down potential degradation of the structure or component
3. Detection of ageing effects	• 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 to be collected to facilitate assessment of structure or component ageing • Assessment methods (including data analysis and trending)
5. Mitigating 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 action is evaluated
7. Corrective actions	• Corrective actions if a component fails to meet the acceptance criteria
8. Operating experience feedback and feedback of research and development 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

4.36. Implementation of major actions relating to ageing management should be subject to approval by the senior management of the operating organization, which should also resolve potential problems.

4.37. Implementation of ageing management programmes should include periodic reporting on the performance of structures and components and on the indicators for evaluation of the effectiveness of the ageing management programme.

4.38. 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.

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

IMPROVEMENT OF AGEING MANAGEMENT PROGRAMMES

4.40. The operating organization management should provide for performance review and improvement of ageing management programmes, illustrated by the closed loop of the systematic approach to managing ageing (see Fig. 1 and para. 2.12).

4.41. The effectiveness of ageing management programmes should be periodically evaluated in light of current knowledge and should be updated and adjusted as appropriate. Current relevant knowledge would include information on the operation of the structure or component, surveillance and maintenance histories, information from the results of research and development, and generic operating experience.

4.42. Reviews, inspections and assessments should be periodically carried out to determine the effectiveness of ageing management programmes. Both the ageing management policy of the operating organization and its ageing management programmes should be assessed and improved by the operating organization.

4.43. The result of the reviews, inspection and assessment and improvement described in para. 4.42 should be submitted to the regulatory body for review and assessment.

4.44. 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 and to identify areas for improvement [9, 10].

4.45. 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 the understanding and predictability of ageing mechanisms and the causes of ageing, and associated monitoring and mitigation methods or practices. A strategic approach should be taken to promote relevant long term research and development programmes.

5. MANAGEMENT OF OBSOLESCENCE

5.1. Obsolescence of SSCs important to safety should be managed proactively (i.e. with foresight and anticipation) throughout their service life.

5.2. Obsolescence management activities of the operating organization should be overseen by the regulatory body throughout the lifetime of the plant.

5.3. The operating organization should establish a programme for the management of obsolescence. This includes setting out the policy, objectives and organizational arrangements, allocating appropriate resources (human and financial) and monitoring the programme to ensure that it meets its objectives.

5.4. The following organizational arrangements are recommended for the implementation of the obsolescence management programme:

— Responsibility for programme implementation should be clearly assigned within the operating organization of the nuclear power plant.
— The programme should be led by a dedicated professional with significant engineering, operations and maintenance experience.

— The programme activities should be implemented through a multifunctional organization with the part-time participation of persons from relevant units of the nuclear power plant, including engineering and technical support, maintenance and procurement.

5.5. The obsolescence management programme should focus on the management of technological obsolescence. In addition, the programme should provide guidance on, and monitor, the management of obsolescence of standards and regulations (e.g. through periodic safety review).

5.6. Procedures of the obsolescence management programme should be put in place to address:

— A systematic assessment of obsolescence;
— Dealing with any obsolescence issues identified;
— Continuous improvement of the programme.

5.7. Procedures for the management of technological obsolescence should be put in place to provide for the availability of:

— Complete and accurate documentation to support SSC maintenance and replacement;
— Required technical support;
— Sufficient spare parts.

6. REVIEW OF AGEING MANAGEMENT FOR LONG TERM OPERATION

6.1. To facilitate 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 is acceptable when compared with current safety standards[10]. This section presents recommendations on an in-depth

[10] This does not necessarily mean that all current safety standards have to be met, provided that assurance of safety can be demonstrated by other means.

review of ageing management in connection with the long term operation of a nuclear power plant.

6.2. The in-depth review of ageing management should ensure that plant programmes and practices that will be used to support the management of ageing effects during long term operation are reviewed and are consistent with the generic attributes of an effective ageing management programme such as that given in Table 2.

6.3. The review process should involve the following main steps:

- An appropriate screening method to ensure that structures and components important to safety will be evaluated for long term operation;
- Demonstration that the effects of ageing will continue to be identified and managed for each structure or component during the planned period of long term operation;
- Revalidation of safety analyses that were developed using time limited assumptions[11], to demonstrate their continuing validity or that the ageing effects will be effectively managed, i.e. to demonstrate that the intended function of a structure or component will remain within the design safety margins throughout the planned period of long term operation.

6.4. Requirements for modifications of existing plant programmes and development of any new programmes should be identified and implemented.

6.5. The results of the review of ageing management for structures and components for long term operation should be documented.

6.6. Reference [11] provides more detailed information on the implementation of the process described in para. 6.3.

[11] Revalidation of safety analyses with time limited assumptions is an assessment of an identified ageing effect (time dependent degradation due to normal service conditions) and certain plant specific safety analyses that were developed on the basis of an explicitly specified length of plant life. Safety analyses with time limited assumptions would include fatigue calculations, pressurized thermal shock analysis and equipment qualification of electrical and instrumentation and control cables.

7. INTERFACES WITH OTHER TECHNICAL AREAS

7.1. This section highlights two technical areas that are deemed to be especially significant or closely related to ageing management: equipment qualification and periodic safety review. Plant programmes and activities that are an integral part of the ageing management programme (e.g. maintenance, inspection, monitoring, surveillance, chemistry and feedback of operating experience) have been addressed in the previous sections.

EQUIPMENT QUALIFICATION

7.2. The equipment qualification programme of a nuclear power plant provides an example of an effective means of managing ageing of the plant components important to safety covered by this programme. The scope of the equipment qualification programme usually includes equipment that performs safety functions or contributes to the performance of safety functions, but it may vary between States [4].

7.3. A demonstration of the functionality of any safety related item of equipment that performs safety functions under harsh environmental conditions is important for the equipment qualification programme. Service conditions following a postulated initiating event are significantly different from normal operational conditions, and little confidence in the continued functionality of an item of equipment can be derived from performance during normal operation, pre-operational tests and periodic surveillance tests.

7.4. The ageing of individual items of equipment is managed by using a concept either of 'qualified life' or of 'qualified condition'[12] established by equipment qualification.

7.5. It is important to demonstrate that ageing issues have been correctly taken into account for the whole planned lifetime of the plant, by ensuring that:

— Qualification tests take into account potential ageing effects, in light of international knowledge and practice;

[12] See para. 7.7.

— Environmental conditions at the site are monitored to detect any changes from assumed values;
— Procedures for modifying qualified lifetimes are provided, especially in the case of changes from assumed values or of increasing failure frequency of some item of equipment;
— Procedures for adapting ageing tests and their duration of validity are provided.

7.6. The qualified life established by equipment qualification is the period of time of normal operation for which ageing degradation would not prevent satisfactory performance of the equipment if a postulated initiating event were to occur. Before the end of the equipment's qualified life, equipment replacement is carried out, life limiting components are renewed or a new, longer qualified life is established.

7.7. The qualified condition of equipment established by equipment qualification is expressed in terms of one or more measurable condition indicators for which it has been demonstrated that the equipment will meet its performance requirements.

7.8. Further information on implementation and review of equipment qualification is provided in other IAEA publications [12, 13].

PERIODIC SAFETY REVIEW

7.9. Periodic safety review is used in many States. It is an instrument for reviewing the safety of plant operation throughout its service life and for addressing requests by the operating organization for authorization to continue plant operation beyond an established licensed term or a period established by safety evaluation. According to Ref. [12], the periodic safety review process is valid for nuclear power plants throughout their service life and provides reassurance that there continues to be a valid licensing basis, with cumulative effects of plant ageing (both physical ageing and obsolescence), modifications made to the plant and changes in international safety standards taken into consideration.

7.10. In the frame of the periodic safety review [12], the operating organization assesses the effects of ageing on nuclear power plant safety, the effectiveness of the ageing management programme and the need for improvements to the ageing management programme.

7.11. The objective of the review of management of ageing in a periodic safety review is “to determine whether ageing in a nuclear power plant is being effectively managed so that required safety functions are maintained, and whether an effective ageing management programme is in place for future plant operation” (Ref. [12], para. 4.21). The review of management of ageing within a periodic safety review therefore aims to establish whether:

- For each SSC important to safety, all significant ageing mechanisms have been identified;
- There is a thorough understanding of the relevant ageing mechanisms and their effects;
- The ageing behaviour of SSCs over the period of operation to date is consistent with predictions;
- There are adequate margins in respect of ageing to ensure safe operation for at least the period until the next periodic safety review is due for completion;
- There is an effective ageing management programme (addressing operations, chemistry, maintenance, surveillance and inspection) in place for future plant operation.

Possible outcomes of the review of management of ageing within the periodic safety review are improvements to the scope, procedures and/or frequency of maintenance, surveillance and inspection, and modifications of operating conditions or design (including possible changes of the design basis of structures and components).

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Annex I

EXISTING PUBLICATIONS ON AGEING MANAGEMENT

I–1. IAEA publications provide guidance and information on ageing management programmes, component specific guidance and guidance on ageing management review.

I–2. The following reports relating to ageing management programmes have been developed using the experience of Member States:

— Data Collection and Record Keeping for the Management of Nuclear Power Plant Ageing [I–1] provides information on the necessary baseline, operating and maintenance data and a system for data collection and record keeping;
— Methodology for the Management of Ageing of Nuclear Power Plant Components Important to Safety [I–2] provides guidance on screening (selecting) SSCs to make effective use of limited resources and on performing ageing management studies to identify or develop effective ageing management actions for the selected components;
— Implementation and Review of Nuclear Power Plant Ageing Management Programmes [I–3] provides information on the systematic approach to managing ageing and an organizational model for its implementation.
— Equipment Qualification in Operational Nuclear Power Plants: Upgrading, Preserving and Reviewing [I–4] documents current methods and practices relating to upgrading and preserving equipment qualification in operational nuclear power plants and reviewing the effectiveness of the plant equipment qualification programme;
— Proactive Management of Ageing for Nuclear Power Plants [I–5] provides information on recognizing common weaknesses in ageing management for nuclear power plants, applying the systematic approach to managing ageing and strengthening the role of proactive ageing management.

I–3. The component specific guidance for major nuclear power plant components important to safety includes information on component description and design basis, potential ageing mechanisms and their significance, operating guidelines to control age related degradation, inspection and monitoring requirements and technologies, and methods of assessment and maintenance. Guidance on Assessment and Management of Ageing of Major

Nuclear Power Plant Components Important to Safety has been issued for the following components: steam generators, concrete containment buildings, CANDU pressure tubes, pressurized water reactor (PWR) pressure vessels, PWR vessel internals, metal components of boiling water reactor (BWR) containment, in-containment instrumentation and control cables, CANDU reactor assemblies, PWR primary piping, BWR pressure vessels, BWR pressure vessel internals, revision of PWR pressure vessels and revision of PWR vessel internals, e.g. Ref. [I–6].

I–4. Reference [I–7] provides guidance for ageing management assessment teams and for utility self-assessments, which aim to provide advice and assistance to utilities or individual nuclear power plants to strengthen and enhance the effectiveness of their ageing management programmes.

I–5. The IAEA also provides technical guidance on specific types of ageing degradation, such as radiation embrittlement of reactor pressure vessels, and on life management for nuclear power plants, e.g. Ref. [I–8].

I–6. In addition to the above IAEA publications on ageing management, significant information on ageing management for nuclear power plants has been developed since the mid-1980s by individual Member States and by other international organizations such as the OECD Nuclear Energy Agency and the European Commission, e.g. Refs [I–9–I–11].

I–7. Common ageing terminology [I–12, I–13] facilitates communication and mutual understanding among nuclear professionals when dealing with ageing management issues.

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Annex II

EXAMPLES OF CONTENTS OF DATA COLLECTION AND RECORD KEEPING SYSTEMS

II–1. The data required for the ageing management programme of a nuclear power plant are typically divided into the following three categories:

(i) Baseline information, consisting of data on the design of the plant and/or of the SSC and conditions at the beginning of the service life of a component or structure;
(ii) Data on the operating history of the plant, covering service conditions at the level of SSCs (including transient data), and data on the testing of availability and failure of components and structures;
(iii) Data on the maintenance history, including data on the monitoring of the condition of and maintenance of components and structures.

II–2. Examples of relevant data are:

— Records of environmental qualification tests, including test specifications and results;
— Records of fabrication and construction, including fabrication and inspection specifications, results of inspections and deviations;
— Results of pre-service inspections, including inspection specifications and results, as well as findings that exceed reporting levels;
— Results of commissioning tests, including testing specifications and results of tests, as well as mappings of environmental conditions during commissioning;
— Results of water chemistry investigations and any variations therein;
— Results of in-service inspections, including inspection specifications and results, as well as findings that exceed reporting levels;
— Results of periodic functional testing and related findings;
— Findings of monitoring from control room and plant tours;
— Findings of preventive maintenance;
— Findings of corrective maintenance;
— Data on ageing related failures or significant degradation of SSCs, including results of root cause analyses.

II–3. Data from an effective ageing management programme contribute to effective plant configuration management, and vice versa. Ideally, the database containing the data relating to SSCs as listed in para. II–2 is part of an integrated database that provides a coherent source of data for operation, configuration management, maintenance and engineering functions.

Annex III

EXAMPLES OF SIGNIFICANT AGEING MECHANISMS AND SUSCEPTIBLE MATERIALS AND COMPONENTS

III–1. Table III–1 provides some examples of ageing mechanisms for mechanical components, electrical components and equipment, and civil structures. Ageing degradation of a specific structure or component is identified on the basis of its material and environmental and other conditions through the process for review of ageing management described in Section 4.

TABLE III–1. SIGNIFICANT AGEING MECHANISMS AND SUSCEPTIBLE MATERIALS AND COMPONENTS

Ageing mechanism	Susceptible regions, materials and components
Mechanical components	
Radiation embrittlement	Reactor pressure vessel beltline region, reactor pressure vessel internals
General corrosion, pitting and wastage (low and high temperatures)	Crevices and hideout regions, low and no flow components, safety injection systems, service water systems
Stress corrosion cracking on internal surfaces (low and high temperatures)	Weld vicinity in components (off-normal chemistry conditions)
Stress corrosion cracking on external surfaces (chloride related, low and high temperatures)	Components located near leaking valves and in coastal plants (e.g. insulation)
Crevice corrosion (low and high temperatures)	Stagnant regions, weld vicinity, sleeved regions, welds with backing rings
Microbial influenced corrosion (low temperatures)	Service water, heat exchangers, equipment where pressure tests are performed, equipment that is out of service, anchor bolts, diesel generators
Corrosion fatigue (low and high temperatures)	Thermal mixing regions, especially carbon and alloy steels
Fatigue (low and high temperatures)	Rotating equipment supports and piping attached to large components

TABLE III–1. SIGNIFICANT AGEING MECHANISMS AND SUSCEPTIBLE MATERIALS AND COMPONENTS (cont.)

Ageing mechanism	Susceptible regions, materials and components
Weld related cracking (lack of fusion, hot ductility, ferrite depletion, crevice formation, high or low temperatures)	Similar metal welds, wrought materials to castings, low ferrite filler joints, seam welds
Dilution zone cracking (high or low temperatures)	Dissimilar metal welds, vessel cladding interfaces, nozzle to safe ends, valves or pumps to pipes (carbon steel to stainless steel)
Low temperature sensitization (high temperatures)	Stainless steel components, cast components
Mechanical wear, fretting (low and high temperatures)	Rotating equipment
Binding and wear	Components within pumps and valves
Electrical and instrumentation and control components	
Insulation embrittlement and degradation	Cables, motor windings, transformers
Partial discharges	Transformers, inductors, medium and high voltage equipment
Oxidation	Relay and breaker contacts, lubricants, insulation materials associated with electrical components
Appearance of monocrystals	Whiskers, dendrites
Metallic diffusion	Alloys and welds in electronic devices
Civil structures	
Ageing of concrete due to aggressive chemical attack and corrosion of embedded steel	Concrete elements: walls, dome, basemat, ring girder, buttresses, containment (as applicable)
Cracks and distortion due to increased stress levels from settlements	All concrete elements
Loss of prestress due to relaxation, shrinkage, creep and elevated temperature	Prestressed containment tendons
Loss of material (scaling, cracking and spalling) due to freeze–thaw processes	Concrete elements: walls, dome, basemat, ring girder, buttresses, containment (as applicable)

CONTRIBUTORS TO DRAFTING AND REVIEW

Banks, P.	British Energy, United Kingdom
Deschildre, O.	DGSNR, France
Duhac, A.	European Commission Joint Research Centre
Faidy, C.	EDF, France
Gettings, A.	British Energy, United Kingdom
Inagaki, T.	International Atomic Energy Agency
Kang, Ki-Sig	International Atomic Energy Agency
Katona, T.	Paks Nuclear Power Plant, Hungary
Kearney, M.	International Atomic Energy Agency
Koutaniemi, P.	STUK, Finland
Kupca, L.	International Atomic Energy Agency
Pachner, J.	Pachner Associates, Canada
Taylor, T.	Pacific Northwest National Laboratory, United States of America
Thoma, K.	Beznau Nuclear Power Plant, Switzerland

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