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

DRAFT SPECIFIC SAFETY GUIDE XXX (DS485)

(Revision of NS-G-2.12)

IAEA

INTERNATIONAL ATOMIC ENERGY AGENCY

FOREWORD

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EDITORIAL NOTE

An appendix, when included, is considered to form an integral part of the standard and to have the same status as the main text. Annexes, footnotes and bibliographies, if included, are used to provide additional information or practical examples that might be helpful to the user.

The safety standards use the form 'shall' in making statements about requirements, responsibilities and obligations. Use of the form 'should' denotes recommendations of a desired option.

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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, commissioning and operation of nuclear power plants are established in Safety Requirements publications on Safety of Nuclear Power Plants: Design [1] and on Safety of Nuclear Power Plants: Commissioning and Operation [2]. The requirements on safety assessment are established in the General Safety Requirements: Safety Assessment for Facilities and Activities [3]. The General Safety Requirements publication on 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 means that ensuring the ageing effects will not prevent affected systems, structures and components (SSCs) from being able to accomplish required safety functions throughout the service life of the plant (including decommissioning), with account taken of changes that occur with time and use [1]. This requires addressing both physical ageing effects of SSCs, resulting in degradation of their performance characteristics, and non-physical ageing of SSCs, i.e. their becoming out of date in comparison with current knowledge, codes, standards and regulations, and technology.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 taken into account at all stages of a plant's life.

1.4. Effective ageing management of SSCs is a key element of the safe and reliable operation of nuclear power plants. In order to assist Member States, the IAEA has developed a comprehensive set of publications, e.g. Safety Report Series No. 82 "Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL) [5].

1.5. In addition, safety of nuclear power plants during long term operation (LTO) has become more important due to the steady increase in the number of Member States giving high priority to continuing the operation of nuclear power plants beyond the timeframe originally anticipated for their operation (LTO - see Section 2).

1.6. This Safety Guide supplements and provides recommendations on meeting the requirements set out in Refs [1, 2]. It identifies key elements of effective ageing management for nuclear power plants.

1.7. The Safety Guide may be used in preparing regulatory requirements, codes and standards, and in verifying effective ageing management in nuclear power plants.

1.8. This publication is a revision of a Safety Guide issued in 2009 as IAEA Safety Standards Series No. NS-G-2.12, Ageing Management for Nuclear Power Plants, and supersedes it. This revision takes into account developments in the international ageing lessons learned for nuclear power plants and expands the scope to include provisions for maintaining safety of nuclear power plants during long term operation. IAEA Safety Standards Series No. SSG-25, "Periodic Safety Review for Nuclear Power Plants" addresses also some aspect of physical ageing of SSCs and focuses more on non-physical ageing of SSCs, i.e. their becoming out of date in comparison with current knowledge, codes, standards and regulations, and technology.

OBJECTIVE

1.9. The objective of this Safety Guide is to provide recommendations for addressing the SSR-2/1 [1] Requirement 30: Qualification of items important to safety, Requirement 31: Ageing management and SSR-2/2 [2] Requirement 14: Ageing management and Requirement 16: Programme for long term operation.

1.10. The Safety Guide provides good international practices on establishing, implementing and improving ageing management and development ofa programme for safe LTO for nuclear power plants.

SCOPE

1.11. This Safety Guide deals with the establishment, implementation and improvement of ageing management and ageing related activities important for safe LTO of nuclear power plants (including decommissioning), taking account of the differing reactor designs worldwide.

1.12. The Safety Guide focuses on managing physical ageing of SSCs within the scope defined in Section 5 (in-scope SSCs). It also provides recommendations on safety aspects of managing technological obsolescence in Section 6 and recommendations on programme for safe LTO of nuclear power plants in Section 7.

1.13. Other aspects related to safe LTO such as obsolescence of knowledge and compliance with current codes, standards and regulations (see Table 1), as well as plant design, environmental impact of LTO, economic assessment and long term investment strategies are outside the scope of this Safety Guide. Economic assessment is covered in IAEA Nuclear Energy Series documents.

1.14. This Safety Guide is intended to provide recommendations on ageing management and development of a programme for LTO for nuclear power plants. This Safety Guide also includes facilities for spent fuel storage and radioactive waste management which are part of the plant. The Safety Guide also may be used as a basis for ageing management of separate facilities for spent fuel storage and radioactive waste management. In this context, the Safety Guide on storage of spent fuel [23] has to 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 LTO, which provide a common basis for the recommendations provided further on. Section 3 provides recommendations for ageing management of SSCs through all stages of the life of a nuclear power plant. Section 4 presents recommendations on plant documentation and programmes relevant to ageing management and safe LTO. Section 5 presents recommendations for managing the ageing effects during any operating period of an NPP life time. Section 6 presents recommendations on management of technological obsolescence in operational phase of nuclear power plant life time. Section 7 presents recommendations on ageing related activities important for safe LTO of nuclear power plant.

2. BASIC CONCEPTS

2.1. This section presents the basic concepts of ageing management, including their application to LTO, which provide a common basis for the recommendations given in this Safety Guide.

2.2. Physical ageing is a general process in which characteristics of a SSC gradually change with time or use. It occurs due to physical, chemical and/or biological processes (degradation mechanisms).

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

2.4. Physical ageing is referred to in this Safety Guide as ageing while non-physical ageing is referred in this Safety Guide as obsolescence.

2.5. Evaluation of the cumulative effects of both ageing and obsolescence on the safety of nuclear power plants is a continuous process and is required to be assessed in a Periodic Safety Review (PSR) or an equivalent systematic safety reassessment programme on a general level (see Section 4) [2].

AGEING MANAGEMENT

2.6. To maintain plant safety it is very important to detect the ageing effects on SSCs (i.e. net changes in characteristics) early to address associated reduction in safety margins and to take corrective actions before safety functions are impacted.

2.7. Ageing of SSCs increases 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 scope setting of structures and components (SCs) for ageing management, no credit is taken for redundancy or diversity among SSCs.

2.8. Ageing management covers all activities to appropriately prevent or control ageing effects within acceptable limits through the entire life cycle of the plant i.e. in design, fabrication/ construction, commissioning, operation including LTO, decommissioning including long term shutdown as described in Section 3.

2.9. Ageing management consists of design, operations and maintenance actions to prevent or control, within acceptable limits, the ageing of SSCs. It is an interdisciplinary activity that involves engineering, maintenance, surveillance, equipment qualification, in-service inspection, safety analysis and other relevant plant programmes. Reference [6] provides guidance on maintenance, surveillance and inspection practices.

2.10. Effective ageing management is in practice accomplished by coordinating existing plant programmes, and external programmes such as research and development, as well as implementing other specific actions as described below.

2.11. Effective ageing management throughout the service life of SSCs requires the use of a systematic approach to managing the ageing effects that provides a framework for coordinating all programmes and activities related to the understanding, control, monitoring and mitigation of ageing effects of the plant structure or component. This approach is illustrated in Figure 1, which is an adaptation of Deming's 'PLAN–DO–CHECK–ACT' cycle to the ageing management of SSCs [7].

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

- Design basis (including regulatory requirements, codes and standards);
- Safety functions and intended functions;

- Design and fabrication process (including the material, material properties, adverse residual effects from fabrication such as cold work or weld residual stresses, 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.

2.13. The PLAN activity in Figure 1 means coordinating, integrating and modifying existing programmes and activities that relate to managing the ageing of SSCs and developing new programmes, if necessary.

2.14. The DO activity in Figure 1 means minimizing (preventing and mitigating) expected degradation mechanisms (ageing effects) of SSCs by developing a specific operational procedure, water chemistry or other chemical/ environmental control programmes and other prevention/ mitigation actions.

2.15. The CHECK activity in Figure 1 means the timely detection and characterization of significant degradation mechanisms (ageing effects) through inspection and monitoring of a structure or component, and the assessment of observed ageing effects to determine the type and timing of any corrective actions required.

2.16. The ACT activity in Figure 1 means the timely correction of component ageing effects and introduction of further prevention/mitigation actions through appropriate maintenance and design modifications, including repair and replacement of a structure or component.

2.17. The closed loop of Figure 1 indicates the continuation and improvement of the ageing management, 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.

2.18. Ageing management programmes (AMPs) are developed consistent with using a structured approach, to ensure a consistent approach for defining and implementing ageing management, as described in Section 5.

2.19. Existing plant programmes, including those for maintenance, equipment qualification, in-service inspection, surveillance, and water chemistry are used, where appropriate, to manage ageing, or ageing effects/ degradation mechanisms as described in Section 4.

2.20. Where existing plant programmes are not sufficient, plant programmes have to be improved or new AMPs are developed and implemented as described in Section 5.

2.21. In practice, ageing effects and degradation mechanisms are studied and managed at the structure or component (SC) level (i.e. SC level ageing management). However, the AMPs for individual SCs may be integrated into an AMP at system and/or plant level.

2.22. Time limited ageing analyses (TLAAs) (also termed safety analyses that use time limited assumptions) are applied, in certain cases[1], to demonstrate that the analysed ageing effects will not adversely affect the ability of the SC to perform its intended function throughout an assumed period of operation, as described in Section 5.

2.23. TLAAs involve two types of parameters. The first parameter, a time-dependent parameter, is used to evaluate an analysis parameter, which is then compared to a regulatory limit or criterion to determine acceptability of the component for service. Examples of time-dependent parameters include component

[1] Examples where TLAA may be applied include reactor vessel neutron embrittlement, fatigue of mechanical components, and environmental qualification of electrical equipment and cables.

operating time, neutron fluence, or number of thermal cycles on a component. The second parameter, an analysis parameter associated with these time-dependent parameters could include fracture toughness of thermally aged cast austenitic stainless steel, neutron embrittlement of reactor pressure vessel materials, and fatigue cumulative usage factors, respectively.

2.24. The effectiveness of ageing management is periodically reviewed to maintain plant safety, and to ensure feedback and continuous improvement as described in Section 5.

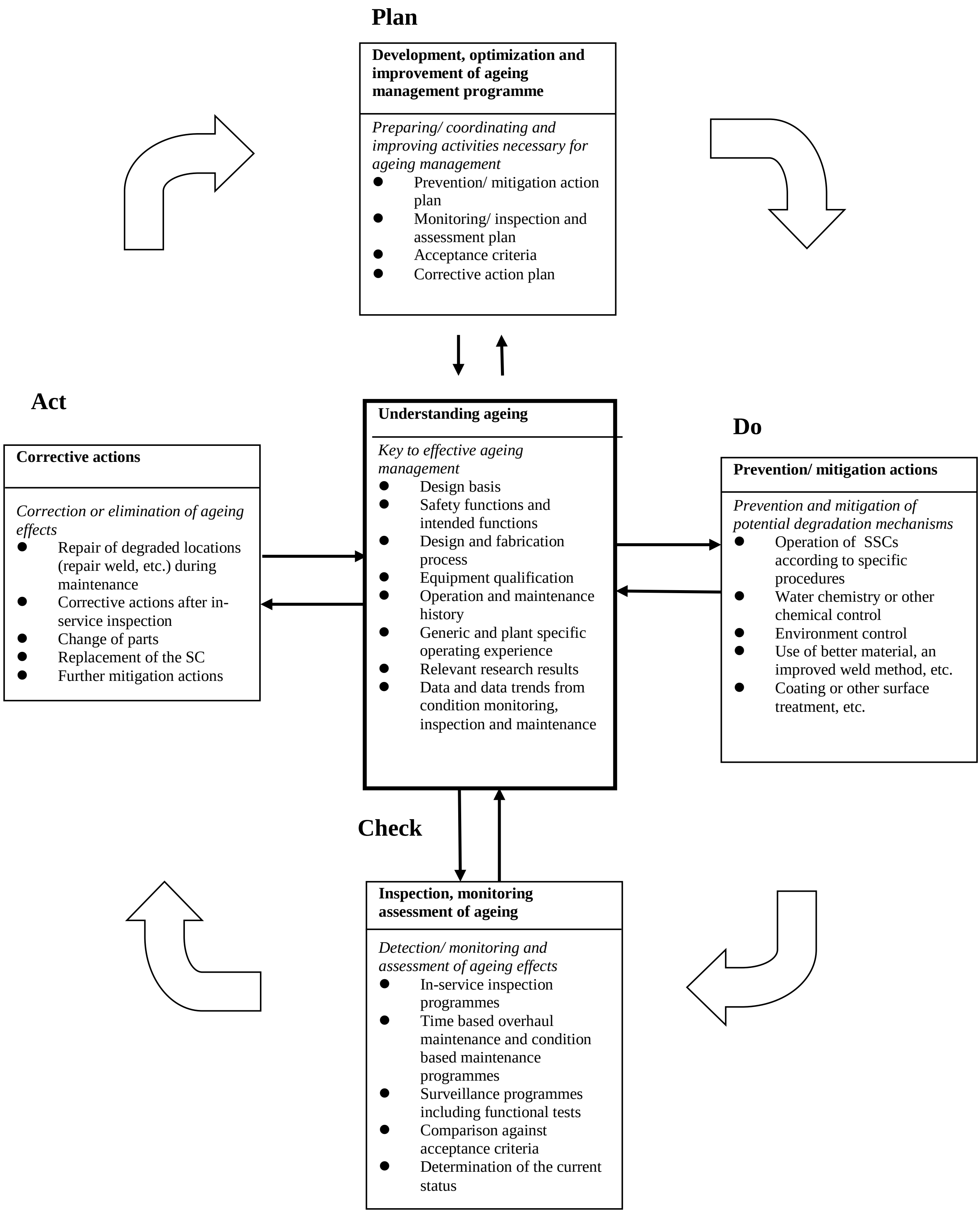


FIG.1. Systematic approach to ageing management

OBSOLESCENCE MANAGEMENT

2.25. 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.

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

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

2.28. Management of obsolescence of technology (also called "technological obsolescence") is discussed 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 Requirement 5 and 12 of [2] and Safety Factor 2 and 8 of [8], that deal with safety policy and the PSR. These aspects are not addressed in this Safety Guide.

TABLE 1. TYPES OF OBSOLESCENCE

Subject of obsolescence	Manifestation	Consequences	Management
Technology (Technological Obsolescence - See Section 6)	Lack of spare parts and technical support; Lack of suppliers Lack of industrial capabilities	Declining plant performance and safety owing 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, both hardware and software; Design weaknesses (e.g. in equipment qualification, separation, diversity or severe accident management capabilities)	Plant safety level below current regulations, codes and standards (e.g. weaknesses in defence in depth, or higher core damage frequency)	Systematic reassessment of plant against current regulations, codes and standards (e.g. periodic safety review) and appropriate upgrading, backfitting or modernization
Knowledge	Knowledge of current regulations, codes and standards and technology relevant to SSCs not updated	Opportunities to enhance plant safety missed	Continuous updating of knowledge and improvement of its application

PROGRAMME FOR LONG TERM OPERATION

2.30. LTO 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. LTO is to be justified by safety assessment and, depending on Member State, this may take place within a broader regulatory process such as licence renewal or a periodic safety review [8]. Among the various topics covered by the safety assessment, specific consideration is given to adequate management of the ageing processes that can affect the SSCs within the scope of the LTO review, and ensuring that these SSCs will retain functionality during the period of LTO.

2.31. The plant's programme for LTO is a set of activities, including evaluations, assessments, and testing aimed at justifying and demonstrating plant safety during the period of LTO. The programme for LTO is based on national regulatory requirements, considers international best practices, operating experience and research findings, and includes an implementation plan as discussed in Section 7.

2.32. If a decision is taken to pursue LTO, it is important to provide justification of the adequacy of ageing management for the LTO period, based on the results of PSRs [8] or the results of an adequate evaluation process (including scope setting, ageing management review (AMR), and TLAA revalidation as discussed in this Safety Guide), and overseen by the regulatory body.

3. AGEING MANAGEMENT THROUGHOUT THE PLANT LIFE

3.1. Ageing of in-scope SSCs (see Section 5) should be managed with foresight and anticipation through the entire life cycle of the plant i.e. in design, construction, commissioning, operation (including LTO and extended shutdown) and decommissioning. Managing ageing effects should be considered during all associated activities, such as, engineering, procurement, fabrication, transportation and installation.

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

3.3. Detailed requirements on use of operating experience and R&D results are provided in Requirement 6 of [1], Requirement 24 of [2] and [3]. Specifically for ageing management and LTO, the activities should focus on:

- Ensuring that all levels of the analysis are either performed, or specified and accepted, by adequately qualified experts within operating organisation, to ensure AM and LTO specific aspects are taken into account;
- Improvement of understanding of ageing effects for all in-scope SSCs by analyzing internal and external operational experience and R&D results;
- Application of lessons learned to update and improve the ageing management.

3.4. The operating organization should ensure that proactive strategies for ageing management are established, especially those for design, construction and commissioning stages, taking into account the latest knowledge on ageing effects and degradation mechanisms. Reference [9] provides more detailed information on proactive ageing management strategies for nuclear power plants.

3.5. Roles of all organizations that participate in ageing management of SSCs at different phases and activities should be properly defined.

3.6. The ageing management activities should be overseen by the regulatory body throughout the plant's life time.

DESIGN

3.7. At the plant design phase 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 introducing specific features, during the design phase to facilitate effective ageing management throughout the operation phase of the plant. Such measures should also be applied to modifications and to the replacement of equipment or components. Reference [1], Requirements 30 and 31 establish the design related requirements on ageing management of SSCs important to safety.

3.9. In the design phase, the following should be ensured:

- The operational states and accident conditions are taken into account in equipment qualification programmes;
- The in-service and accident environmental conditions are taken into account;
- All potential ageing effects/ degradation mechanisms for passive and active intended functions of SSCs are identified, evaluated and taken into account. Examples are provided in [5];
- Relevant experience (including experience from construction, commissioning, operation and decommissioning of nuclear power plants) and research results are reviewed and taken into account;
- Advanced materials with greater ageing resistant properties are used;
- Materials testing programmes for periodic monitoring of ageing effects during plant operation are implemented;
- On-line monitoring is implemented, particularly where this technology would provide forewarning of

degradation leading to failure of SSCs and where the consequences of failure could be important to safety;
- Relevant actions are taken to make inspections and maintenance possible for SSCs over a service life.

3.10. In the design and procurement documents for new facilities or SSCs, the operating organization should specify requirements to facilitate ageing management, including specification of information to be included in documentation from suppliers, engineering companies and manufacturers.

3.11. Ageing management should be addressed in the safety analysis report. Discussion of ageing management in the SAR should include the following topics [10]:

- The strategy for ageing management and prerequisites for its implementation;
- Identification of all in-scope 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 effects may occur that may affect the capability of components, equipment and systems to perform their intended function throughout the life of the plant;
- Ageing management for different types of in-scope SSCs (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 4) of the in-scope SSCs, 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, etc.);
- Appropriate consideration of the analysis of feedback of operating experience with respect to ageing.

3.12. The operating organization should establish a specific equipment qualification programme in order to meet the safety requirements of SSR 2/1 [1].

FABRICATION AND CONSTRUCTION

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

3.14. The operating organization should ensure that:

- Current knowledge about relevant potential ageing effects and degradation mechanisms as well as possible mitigation measures are taken into account in fabrication and construction of in-scope SSCs by manufacturers;
- All relevant reference (baseline) data are collected and documented (i.e. material chemistry information, material properties data, etc.);
- Sufficient surveillance specimens for specific ageing monitoring programmes (to cover possible LTO periods) are made available and installed in accordance with design specifications;
- It should be ensured that the EQ tests by the manufacturer are in compliance with applicable EQ programmes.

COMMISSIONING

3.15. 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.

3.16. The operating organization should verify that the environmental conditions are consistent with those considered in SSC design. 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 degradation mechanisms should be identified as early as possible, monitored if possible and tracked throughout plant operation.

3.17. The operating organization should collect baseline data and 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 as part of its inspection programme.

3.18. The operating organization should ensure that SSCs are not subjected to unnecessary stresses by the tests performed during commissioning, that are not accounted for in the design or could cause premature ageing. The operating organization should properly document and record the testing results during commissioning, in order to allow investigation of possible cases of subsequent premature ageing that may be caused by improper execution of some testing.

OPERATION

3.19. A systematic approach (see Figure 1 in Section 2) should be applied to manage ageing and obsolescence of SSCs, to ensure that required intended functions are maintained at all times during the operation phase of the plant life.

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

3.21. The operating organization should ensure that specific operational procedures, water chemistry or other chemical/ environmental control programmes and other prevention/ mitigation actions with respect to ageing are followed.

3.22. Specific parameters of concern should be monitored and recorded during facility 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.

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

3.24. The operating organization should ensure corrective actions are followed or taken to prevent/ mitigate or correct ageing effects of SCs through the appropriate maintenance, repair and replacement or modification of a SC, and / or appropriate changes to relevant plant operations, programmes and documentation.

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

3.26. The availability of spare parts or replacement parts and the shelf life of spare parts or consumables should be continuously monitored and controlled (see Section 6).

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

3.28. 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 ageing effects or failure caused by potential ageing effects and degradation mechanisms.

3.29. Evaluation of relevant operational experience and R&D programmes should be continuously performed to support better understanding of degradation mechanisms and their ageing effects and improvements to AMPs. If either a new ageing effect or degradation mechanism is discovered (e.g. through feedback of operating experience or R&D), the operating organization should perform an appropriate AMR and implement additional ageing management as necessary.

LONG TERM OPERATION

3.30. The operating organization should establish policy documents, dedicated organizational structures and action plans to perform LTO evaluations well in advance before the plant enters into LTO. The operating organization should identify evaluation subjects for LTO and assess the current physical status of relevant SSCs during the preparation phase for LTO (see Section 7).

3.31. The operating organization should justify that the physical status of SCs will be managed consistent with the current licensing basis[2] (CLB) for the LTO period. Concerning ageing management, the operating organization should review and validate the existing AMPs for all in-scope SCs that have an impact on the performance of systems important to safety. For these SCs the operating organization should identify all TLAAs and demonstrate that either all these analyses will remain valid for the LTO period, the SCs are replaced, or that further operation, maintenance or AMP actions are implemented.

3.32. Since LTO is operation beyond the originally established timeframe and LTO evaluations are based on assumptions, the operating organization should perform the following activities to validate or correct the ageing related assumptions so that plant safety during LTO is assured and further improved:

- Evaluation of internal/ external operational experience after entering LTO;
- Analysis of ageing effects trends;
- Review of AMPs and existing plant programmes for LTO;
- Incorporation of relevant R&D results;
- Evaluation of needs for new R&D programmes.

LONG TERM SHUT DOWN

3.33. Long term shut downs are plant shut downs lasting for a period exceeding generally more than one year, and exclude regular maintenance outages. During long term shut downs, 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.

3.34. The operating organization should review and, where necessary, revise the AMPs to ensure that relevant factors affecting ageing are taken into account for SSCs placed in lay-up or safe-storage states during long term shut downs.

3.35. Required provisions for ageing management should be defined in system lay-up specifications or preservation plans, including requirements for any condition assessments to be completed prior to the return to service of the plant following a long term shut down.

3.36. The provisions for ageing management, including scope of condition assessments, should be reassessed if the duration

[2] Current licensing basis (CLB) is the set of regulatory requirements applicable to a specific plant, a licensee's commitments for 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 license). The CLB also includes the plant specific design basis information as documented in SAR (which typically includes TLAAs), PSR report, and other plant documents.

of the shutdown is greatly extended beyond what was originally anticipated (for example, due to unforeseen issues or delays in the return to service).

DECOMMISSIONING

3.37. During the transition periods from reactor unit permanent shutdown to final decommissioning and, where required, to facilitate decommissioning, appropriate ageing management arrangements should be evaluated to ensure that required SSCs remain available and functional. This may require implementing relatively long term ageing management provisions for certain SSCs; for example, containment and spent fuel pool systems, fire protection systems, lifting equipment and monitoring equipment. Such provisions should be consistent with national regulations.

3.38. 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 the decommissioning phase (e.g. long-term integrity of SSCs to prevent its deterioration and ensure safe dismantling, handling, and transport of components before license termination; monitoring of SSCs to ensure containment integrity and ensure no significant radioactive releases during the long-term transition period before license termination; ensure integrity of subsurface infrastructure components; monitor potential spread of contamination from previous releases particularly radionuclide transport in groundwater cycle and conduct effective measure to minimize spread of contamination).

4. RELEVANT PLANT DOCUMENTATION AND PROGRAMMES

4.1 The following nuclear power plant programmes and documentation relevant to ageing management and, where relevant, LTO (plant programmes and documentation relevant to LTO are also called “preconditions for LTO”) should be in place at the plant:

- Safety analysis report and other CLB documents;
- Configuration/modification management programme including design basis documentation;
- Plant programmes relevant to ageing management;
- Plant programmes relevant to LTO;
- TLAAs according to Section 5.

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

SAFETY ANALYSIS REPORT AND OTHER CURRENT LICENSING BASIS DOCUMENTS

4.3 Ageing management policy and justification of LTO should be properly documented in the CLB, in particular in documents like the safety analysis report (SAR), PSR report or in other licensing basis documents.

4.4 The SAR [10] should be kept updated to reflect the results of the ageing management review.

4.5 The SAR should provide descriptions of activities to justify safe LTO to ensure that licensees maintain the information to reflect the current status of the plant and address new issues as they arise.

4.6 The PSR is a comprehensive assessment of the plant safety [2]. The content and the scope of the PSR should be consistent with [8]. <u>Among the 14 safety factors described in [8], some have a strong link with</u> ageing management. The operating organization should particularly consider:

- Adequacy of the design (Safety Factor 1) of the nuclear power plant and its documentation by assessment against the CLB and national and international standards, requirements and practices;
- Thoroughly documenting the actual condition of each SSC important to safety documenting thoroughly the 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 such safety

assessment;

- Whether qualification of equipment important to safety (Safety Factor 3) is being maintained through an adequate programme that includes maintenance, inspection and testing, and provides assurance that safety functions will be maintained at least until the next PSR.
- The effects of ageing on nuclear power plant safety, the effectiveness of AMPs and the need for improvements to AMPs, as well as the obsolescence of technology used in the nuclear power plant is part of such assessment (Safety Factor 4).

4.7 If national requirements do not require PSR, an alternative routine comprehensive safety assessment that meet the objectives of the PSR [8] and achieve the equivalent outcomes as those of the PSR should be performed.

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

CONFIGURATION/MODIFICATION MANAGEMENT PROGRAMME INCLUDING DESIGN BASIS DOCUMENTATION

4.9 As the plant preparation for safe LTO usually includes a number of important safety modifications and refurbishments, the plant should follow a configuration management/ modification management programme [1; 2; 11] to reflect the evolving status of the plant.

4.10 All modifications of SSCs, releases of process software, operational limits and conditions, set-points, instructions and procedures should be permanently recorded into accessible form. All safety-significant modifications should be part of SAR [11; 12].

4.11 For the purpose of a formal process to maintain design integrity, the plant should have an organizational entity (e.g. unit or staff person) who has an overall responsibility for the design process, approves design changes and is responsible for ensuring that the knowledge of design basis is maintained [12].

4.12 Management systems (quality assurance systems) should contain the processes and activities related to the configuration management and modification management programme.

4.13 The design basis information should be accessible to the plant.

4.14 The design basis should contain design basis requirements and supporting design information.

4.15 Design basis information should be a part of SAR or separate design basis documentation.

4.16 All changes to design basis should be included in SAR and separate design basis documentation [11; 12].

4.17 If design basis documentation is not complete or obsolete, an appropriate design basis reconstitution programme should be implemented.

PLANT PROGRAMMES

4.18 The existing plant programmes listed below should be considered essential to ageing management and LTO:

a) Maintenance;
b) Equipment qualification;
c) In-service inspection (ISI);
d) Surveillance;
e) Water chemistry;
f) Corrective actions.

4.19 Existing programmes which are credited for ageing management and LTO should be consistent with the nine attributes described in Section 5.

Maintenance

4.20 Maintenance programmes that are consistent with [6] should be available and properly implemented for ageing management and LTO evaluations of applicable in-scope SSCs.

4.21 Maintenance programmes should clearly identify the links with AMPs, including the frequency of maintenance activities, specific information on the tasks and records and on their evaluation and storage.

4.22 The plant maintenance programmes should be assessed to ensure that in-scope SSCs are capable of performing their intended functions at all times.

4.23 Results of assessment should be used to improve the existing maintenance programme. The documentation of the assessment should include all maintenance activities and provides technical references to support findings and conclusions.

Equipment qualification

4.24 An equipment qualification programme to achieve and maintain the qualified status of in-scope SSCs should be in place in order to meet Requirement 30 of [1] and Requirement 13 of [2].

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

4.26 The environmental qualification should demonstrate that the component is, at the end of its qualified life, capable of performing its intended function(s) under the full range of specified service conditions.

4.27 The environmental qualification should establish the equipment qualified life in order to ensure that ageing effects would not prevent satisfactory performance of the equipment for the approved operating period (possibly including LTO) if postulated accidents were to occur.

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

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

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

a. Equipment qualification master list;
b. Plant temperature and radiation monitoring results;
c. Equipment qualification evaluation report;
d. Equipment qualification test report;
e. Environmental qualification TLAA report (for LTO analysis), or other suitable equivalency.

4.31 The review of equipment qualification should include an assessment of the effectiveness Requirement 13 of [2] of the plant's equipment qualification programme. The review should also consider the ageing effects on equipment during service and of possible changes in environmental conditions during normal operation and predicted accident conditions since the programme was implemented.

4.32 Details of equipment qualification recommended practices, processes and methods are given in [13].

In- service inspection

4.33 ISI programmes that are consistent with [6] should be available and properly implemented for ageing management and LTO evaluations of applicable in-scope SSCs including consideration of baseline data.

4.34 The ISI procedures should be effective in detecting degradation within the scope of the ISI programmes to demonstrate whether the ageing effects will be adequately detected with the proposed inspection or monitoring technique.

4.35 ISI results should be documented such that a trending analysis can be carried out using the inspection results obtained from sequential inspections at the same location(s).

4.36 ISI results that indicate notable degradation (e.g. if the degradation is greater than expected or approaches the acceptance criteria) should be evaluated to ensure that the extent of condition for similar locations is appropriately determined.

4.37 A database should be developed and maintained that provides data to document the adequacy of non-destructive examination in detecting, characterizing and trending of the SCs degradation. The database should provide the technical bases to support the findings and conclusions necessary to support ageing management decisions.

Surveillance

4.38 The surveillance programmes including functional tests that are consistent with [6] should be available and properly implemented for ageing management and LTO evaluations of applicable in-scope SSCs.

4.39 The surveillance programmes should confirm the provisions for safe operation that were considered during the design phase, assessed during construction and commissioning, and verified throughout operation.

4.40 Surveillance programmes should continue to supply data by monitoring relevant parameters to be used for assessing the service life of SSCs for the planned period of LTO, for example through existing or additionally installed temperature, and pressure measurements, or additional diagnostic systems.

4.41 Surveillance programmes should verify that the safety margins for LTO are adequate and provide a high tolerance for anticipated operational occurrences, errors and malfunctions.

4.42 Particular attention should be paid to the following aspects:

- Integrity of the barriers between radioactive material and the environment (primary pressure boundary and containment);
- Availability of safety systems such as the reactor protection system, the safety system actuation systems and the safety system support features [14];
- Availability of items whose failure could adversely affect safety;
- Functional testing in accordance with Requirement 31 of [2] to ensure that the tested SSCs are capable of performing their design intended function(n).

4.43 Surveillance programmes using representative material samples (such as reactor pressure vessel material surveillance specimens, cable deposits, corrosion coupons etc.) should be reviewed and extended or supplemented for LTO, if necessary.

4.44 Appropriate testing procedures and evaluation methods should be considered for defining the set of specimens to be included in the supplementary reactor pressure vessel material surveillance programme, if needed, at least for alternative assessments such as the master curve concept.

Water chemistry

4.45 A water chemistry programme is essential for the safe operation of a nuclear power plant and should be available [15]. The programme should ensure that degradation due to water chemistry stressors do not impact the ability of SSCs to perform their intended functions, in accordance with the assumptions and intent of the design. A chemistry programme should minimize the harmful effects of chemical impurities and corrosion on plant SSCs.

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

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

4.48 The water chemistry programme should also provide the necessary chemical and radiochemical assistance to ensure safe LTO, and integrity of SCs within the scope of ageing management and LTO.

Corrective actions

4.49 A corrective action programme should be implemented to ensure that conditions adverse to quality, such as age-related degradation, are identified and that corrective actions commensurate with the significance of the issue have been identified and implemented.

4.50 The corrective action programme should document occurrences of identified age-related degradation (conditions adverse to quality) and the methods used address the degradation, such as evaluation and acceptance, evaluation and monitoring, repair, or replacement, and consider this information as plant-specific operating experience.

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

4.52 The corrective action programme entries and the associated plant-specific operating experience should be routinely reviewed by the responsible ageing management programme owners. The review should determine whether ageing management programmes need to be enhanced to ensure that the 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 entries and the associated plant-specific operating experience, that the ageing management programme does not adequately manage the effects of ageing, a new ageing management programme should be developed or modifications to existing programmes should be identified and implemented, 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 in place to identify and allocate the necessary resources (human resources, financial resources, tools and equipment, and external resources). The organizational arrangements, such as organizational structure, plant policy, etc. should follow national requirements, and practices, as well as the IAEA Safety Standards [2; 16; 17; 18; 19].

5.2 A suitable organizational and functional arrangement should be established, such as e.g. shown in Figure 2, in which all necessary members of the plant organization and external organization are involved and support ageing management.

5.3 An authorized organizational entity (e.g. ageing management unit, manager or task force) should be designated with responsibilities for ageing management as specified in par 5.4 below. This ageing management entity should have close relationships with other plant organizations, such as the operations, maintenance, engineering and quality management units; and ageing management teams consisting of members of different units of the plant and external experts, if necessary.

5.4 The responsibilities of the ageing management entity should include:

- Development of the plant`s effective ageing management programme;
- Coordination of relevant existing and new plant programmes;
- Systematic monitoring of relevant operating experience and R&D results, and evaluation of their applicability to the nuclear power plant;
- Direction of interdisciplinary ageing management teams (permanent or ad hoc ageing management teams) for managing complex ageing issues;
- Assessment and optimization of AMPs;
- Dealing with external technical support organizations;
- Evaluation of further training needs;
- Performing periodic self-assessments; and
- Improvement of activities relating to AMPs.

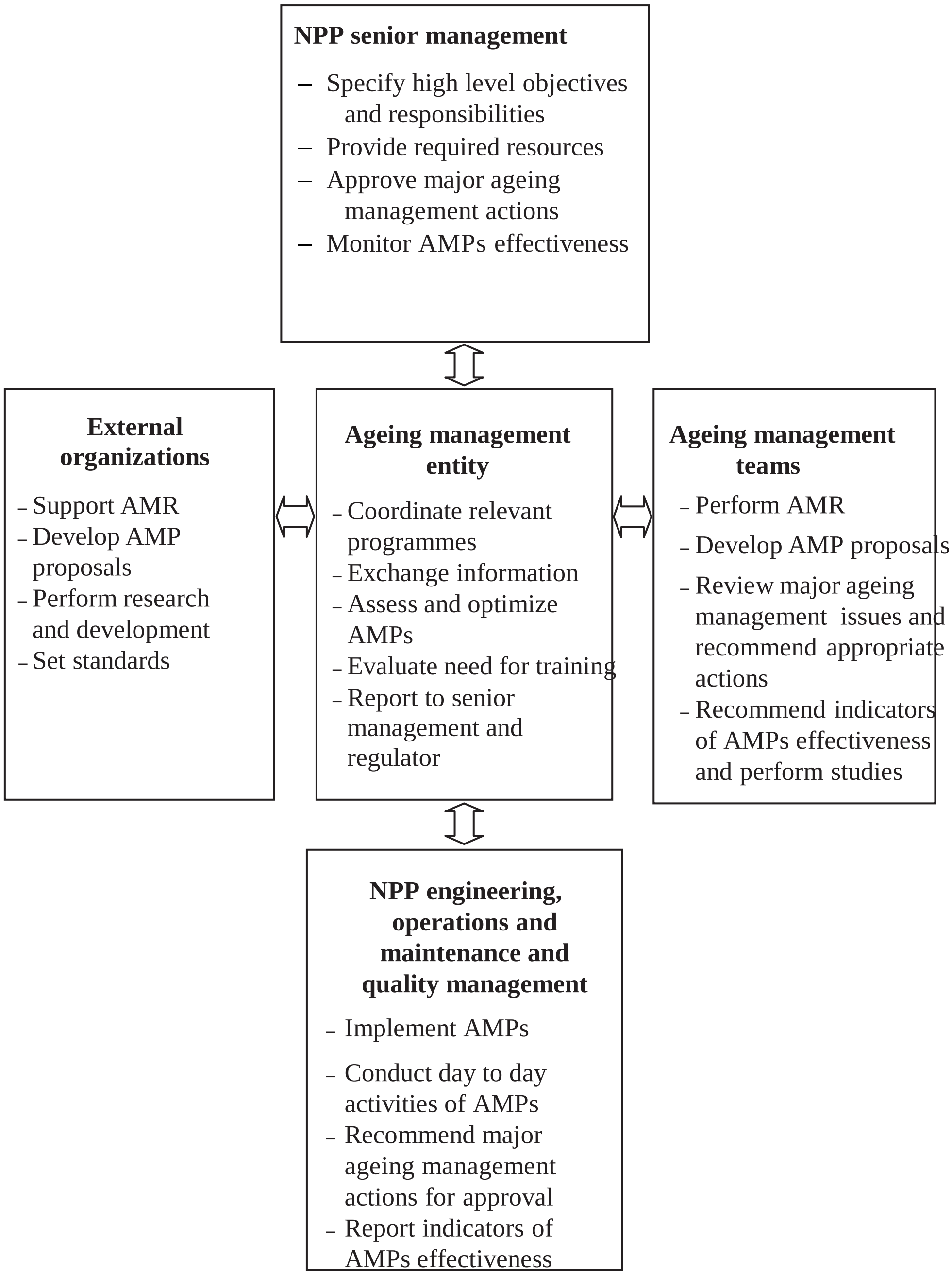


FIG. 2 Example of organizational ageing management arrangements

5.5 Management of complex ageing issues may require an interdisciplinary approach. The members of the ageing management teams (see Figure 2) should include experts from operations, maintenance, engineering, equipment qualification, design and R&D, 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 AMPs and for reporting on SSC performance should be defined and allocated within the plant organization (e.g. operations, maintenance and engineering).

5.7 Training on the ageing effects of SSCs should be provided for staff 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 for improving the AMPs.

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 shown in [20].

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

– Identification of fabrication, construction and environmental conditions that could adversely affect the ageing of SSCs;
– 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 avoid or minimize ageing effects;
– Identification of all ageing effects before they jeopardize plant safety, production reliability and service life.

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 maintance of the data collection and record keeping system.

5.12 The availability of design and supplier documentation should be recognized as essential in supporting effective ageing management.

SCOPE SETTING OF SYSTEMS, STRUCTURES AND COMPONENTS

Scope setting

5.13 A systematic scope setting (scoping) process to identify SCs subject to ageing management should be developed and implemented. This scope setting is also typically used for LTO evaluations.

5.14 A list or database of all SSCs at the nuclear power plant (such as a master list of SSCs) should be provided before implementing the scope setting process.

5.15 The following SSCs should be included in the scope:
- SSCs important to safety that are necessary to fulfil the fundamental safety functions [1]:
  (i) Control of reactivity;

(ii) Removal of heat from the reactor and from the fuel store; and
(iii) Confinement of radioactive material, shielding against radiation and control of planned radioactive releases, as well as limitation of accidental radioactive releases.

- Other SSCs whose failure may prevent SSCs important to safety from fulfilling their intended functions. Related examples of potential failures are:
  - Rotating machines` missile impact;
  - Lifting equipment failures;
  - Flooding;
  - High energy line break; and
  - Leaked liquids (e.g. from piping or other pressure boundary components).

- Other SSCs that are credited in safety analyses (deterministic and probabilistic) to perform the function of coping with certain types of events should be included in the scope, consistent with national regulatory requirements, e.g.:
  - SSCs needed to cope with internal events, e.g. internal fire and internal floods;
  - SSCs needed to cope with external hazards, e.g. extreme weather conditions, earthquake, tsunami, external flooding, tornado and external fire;
  - SSCs needed to cope with specific regulated events, e.g. pressurized thermal shock, anticipated transient without scram and station blackout; and
  - SSCs needed to cope with design extension conditions [1] or to mitigate the consequence of severe accidents.

5.16 SCs that satisfy both following conditions can be excluded from the scope:
- Subject to periodic replacement or scheduled refurbishment plan; and
- Not required by national regulatory requirements to be included in the scope.

5.17 Items that are subject to periodic replacement or scheduled refurbishment can be excluded from the scope, unless required by national regulatory requirements, as long as the replacement or refurbishment is based on a manufacture’s recommendation or other basis and not on an assessment of the condition of the item, which would be implementation of ageing management for the item.

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

5.19 In addition, plant walk-downs 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 a structure/ component (or its subcomponent) level, all SCs and their subcomponents within the scope for ageing management should be identified. If a group of components/ structures have similar functions, similar materials and are in similar environment, an SC commodity group may be defined for the group.

5.21 After the scope setting process, a clear distinction between SCs within the scope and those out of the scope should be provided. Typical scope setting process is illustrated in Figure 3.

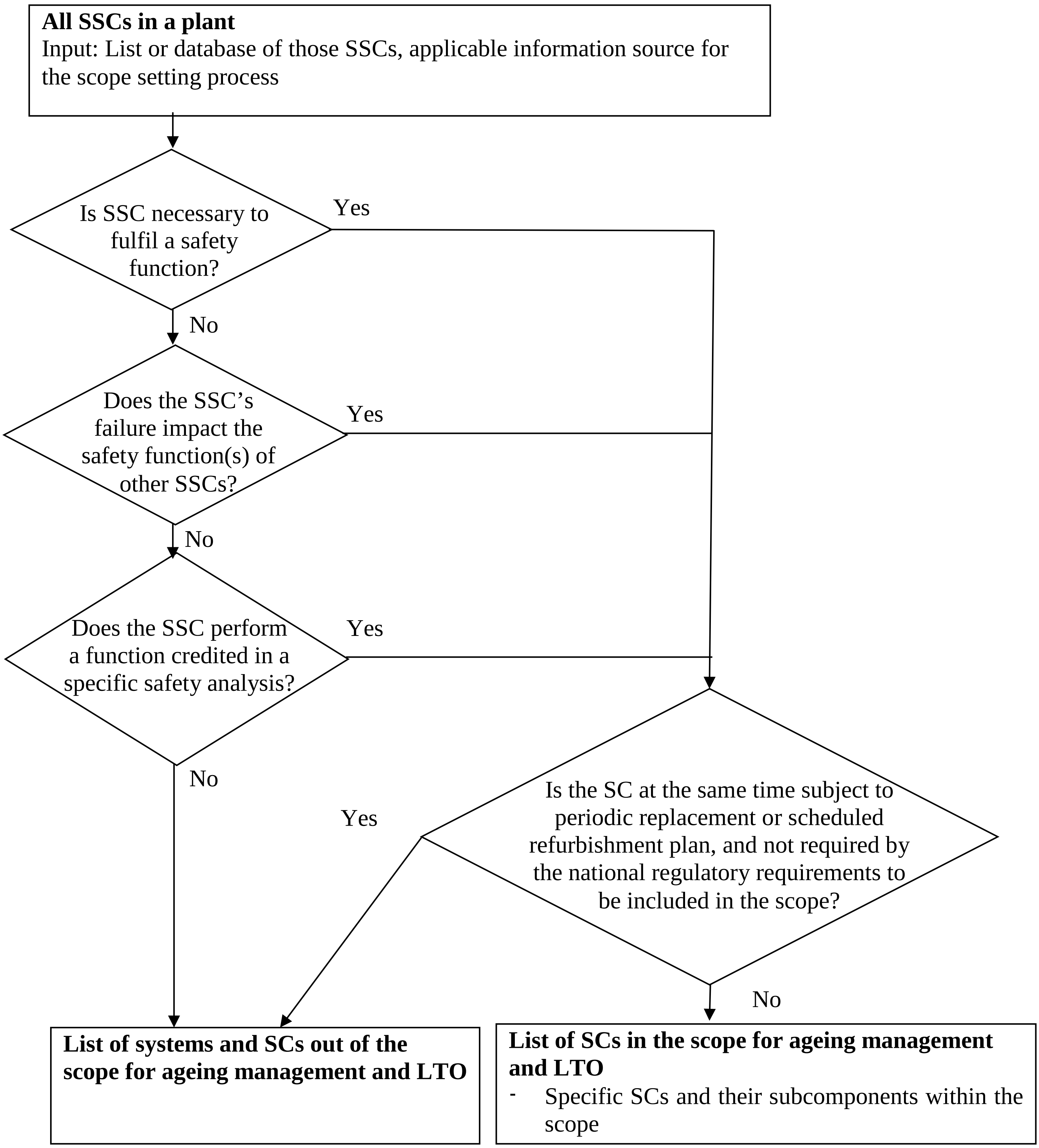


FIG. 3. Typical Scope Setting Process

5.22 The ageing management review (AMR) for in-scope SCs should be performed in order to ensure and demonstrate that ageing will be effectively managed.

5.23 The AMR should systematically assess ageing effects and their 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 SCs` ability to perform their intended function(s) identified in 5.15.

5.24 Relevant applicable ageing lessons learned [5] provides a good reference basis for the AMR but should not be used to replace a plant-specific AMR.

Process to identify programmes to manage ageing of in-scope SCs

5.25 A process to identify relevant ageing effects/ degradation mechanisms for each SC, and programmes to manage the identified degradation mechanisms should be in place as illustrated in Figure 4. This process should consider the following steps:

1. TLAAs associated with these SCs should be evaluated to determine continued validity for the intended period of operation. Results of the TLAA evaluation should be taken into account in AMR (see 5.63 to 5.67);
2. Identify all relevant ageing effects/ degradation mechanisms;
3. If ageing of SCs is managed by existing AMPs, the AMPs should be consistent with the nine attributes shown in Table 2;
4. If ageing of SCs is managed by other plant programmes, such as maintenance, these programmes should be consistent with the nine attributes shown in Table 2;
5. If ageing of SCs is not managed by any existing programme, a new programme should be established or existing programme(s) should be modified or improved, for example by extending the scope of the AMP, or a specific action (replacement of the SC or further analysis) should be taken.

5.26 The AMR should be performed for each in-scope SC or commodity group of SCs, and should consist of the following essential elements:

- Identification of ageing effects/ degradation mechanisms based on knowledge base for understanding ageing (design basis, materials, environments, stressors etc. - see Figure 1);
- Identification of appropriate programme for ageing management;
- AMR reporting to demonstrate that the ageing effects/ degradation mechanisms being managed.

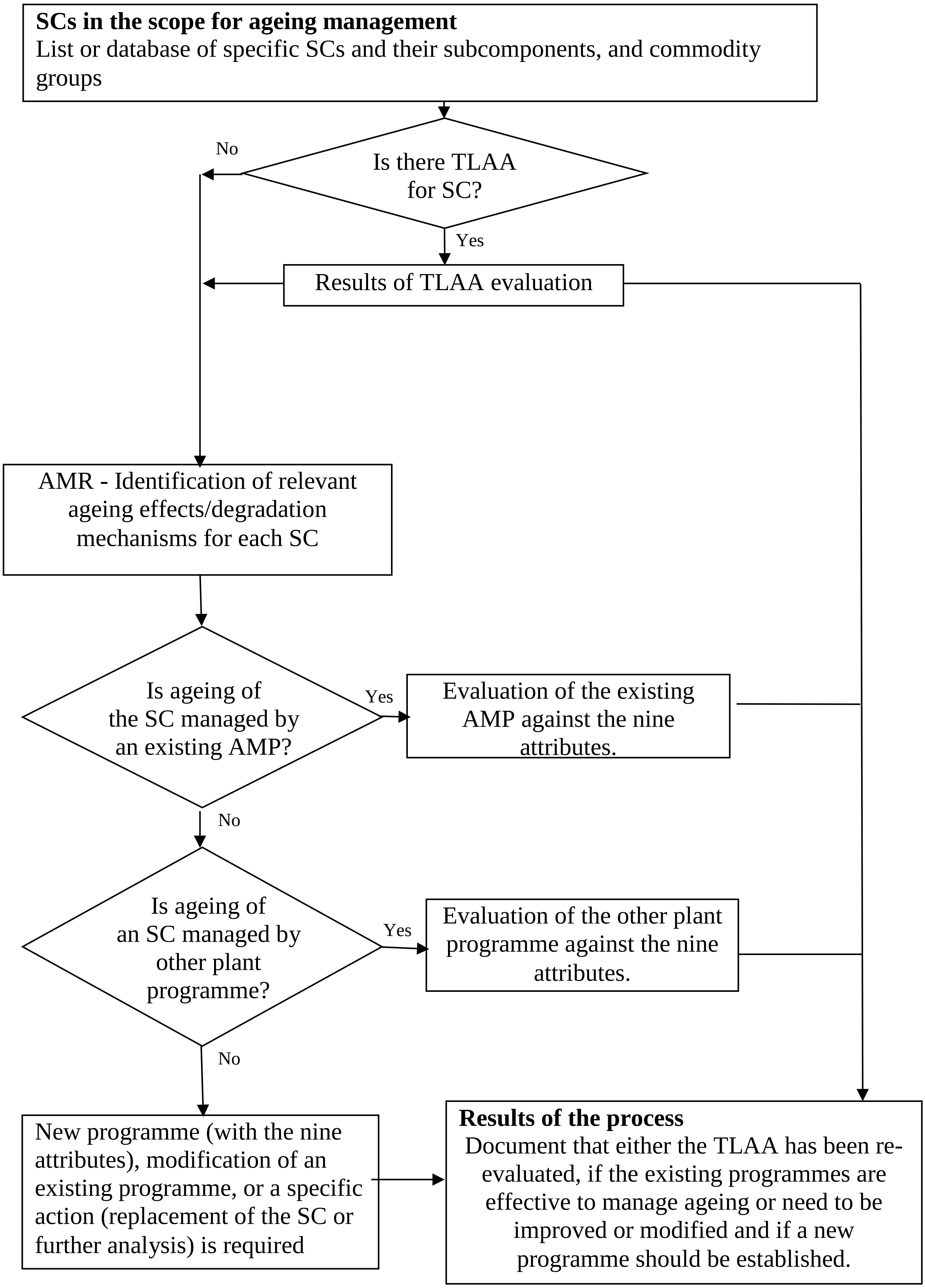


FIG. 4. Process to identify programmes to manage ageing of SCs

Identification of relevant ageing effects/ degradation mechanisms of SCs

5.27 All relevant ageing effects/ degradation mechanisms for each in-scope SC should be identified based on the understanding shown in 5.28 and 5.29.

5.28 A comprehensive understanding of SCs, their ageing effects/ degradation mechanisms and how these can affect the SSC's ability to perform its function(s) should be a prerequisite for a systematic ageing management process shown in Figure 1. This understanding should be based on:

- The design, including the SSC's intended function and applicable regulatory requirements, codes and standards, the design basis and design documents, including safety analyses;
- The fabrication, including material properties, manufacturing conditions that may affect ageing, and service conditions;
- The operation and maintenance history, including commissioning, operational transients and events, power uprating, modification and replacement;
- Stressors on the SCs (including loads on the SCs) and the environmental conditions inside and outside the SCs;
- Results of in-service inspections and surveillance;
- Operating experience, results of research and development, and any post-service examinations;
- Results from walk-downs, inspections and condition assessments, if available;
- Results of TLAA evaluation.

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

Identification of appropriate programme for ageing management

5.30 Appropriate methods to detect, monitor, prevent and mitigate the ageing effect/ degradation mechanisms of each SC should be identified.

5.31 Existing AMPs and other plant programmes should be evaluated for consistency with the nine attributes of Table 2 to determine if they are effective to detect, monitor, prevent or mitigate the ageing effects/ degradation mechanisms.

5.32 If existing AMPs 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.

Ageing management review reporting

5.33 Once the approach for managing the ageing effects/ 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 an AMR should be documented, including:

- A description and justification of the methods used to determine the SCs that are subject to an AMR;
- An identification and listing of SCs subject to an AMR and their intended function(s);
- The information sources used to accomplish the above, and any discussion needed to clarify their use.

5.35 The methodology and results of the AMR should be documented, providing also information on:

- An identification of the ageing effects / degradation mechanisms requiring management;
- Understanding of ageing, monitoring of ageing and prevention/mitigation of ageing effects;
- An identification of the specific programmes or activities that will manage the ageing effects/ degradation mechanisms for each structure, component or commodity grouping listed, and necessity of development of new programmes;

- A description of how the programmes and activities will manage the ageing effects/ degradation mechanisms;
- The current performance and condition of the structure or component, including assessment of any indications of significant ageing effects;
- Estimation of future performance, ageing effects and service life, where feasible, of the structure or component;
- Recommendations for the application of results of the AMR in plant operation, maintenance and design.

5.36 If this documentation uses IGALL [5], then the demonstration should provide a justification that the generic industry reference is applicable to the plant 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/degradations mechanisms that require ageing management should be managed using existing AMPs 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 Figure 5.

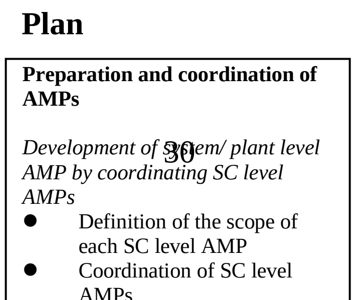
5.38 Each AMP should be consistent with the generic attributes of an effective AMP listed in Table 2.

5.39 Plant programmes and AMPs should include one or more of four types of activities:
- Prevention programmes preclude the ageing effect from occurring;
- Mitigation programmes attempt to slow the ageing effects;
- Condition monitoring programmes include actions to inspect and examine for the presence and extent of ageing effects, or provide surveillance using test samples or coupons intended to mimic the performance of the SC;
- Performance monitoring programmes test the ability of a structure or component to perform its intended functions.

5.40 If necessary, more than one type of AMP should be implemented to ensure that the ageing effects are adequately managed and that the intended function(s) of the SC is 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 SCs, the programme should describe and justify the methods used for selecting the samples to be inspected and the sample size, and demonstrate that the sampling is adequate to provide reasonable assurance that the ageing effects on the structure or component will not prevent the performance of its intended function throughout its life cycle. Plant specific PSA results may be used to determine the specific members of the population that will be inspected, given that the PSA is a living PSA.

5.42 Information and example summaries of SC specific or degradation mechanism specific AMPs provided in [5] can be used as a guidance.



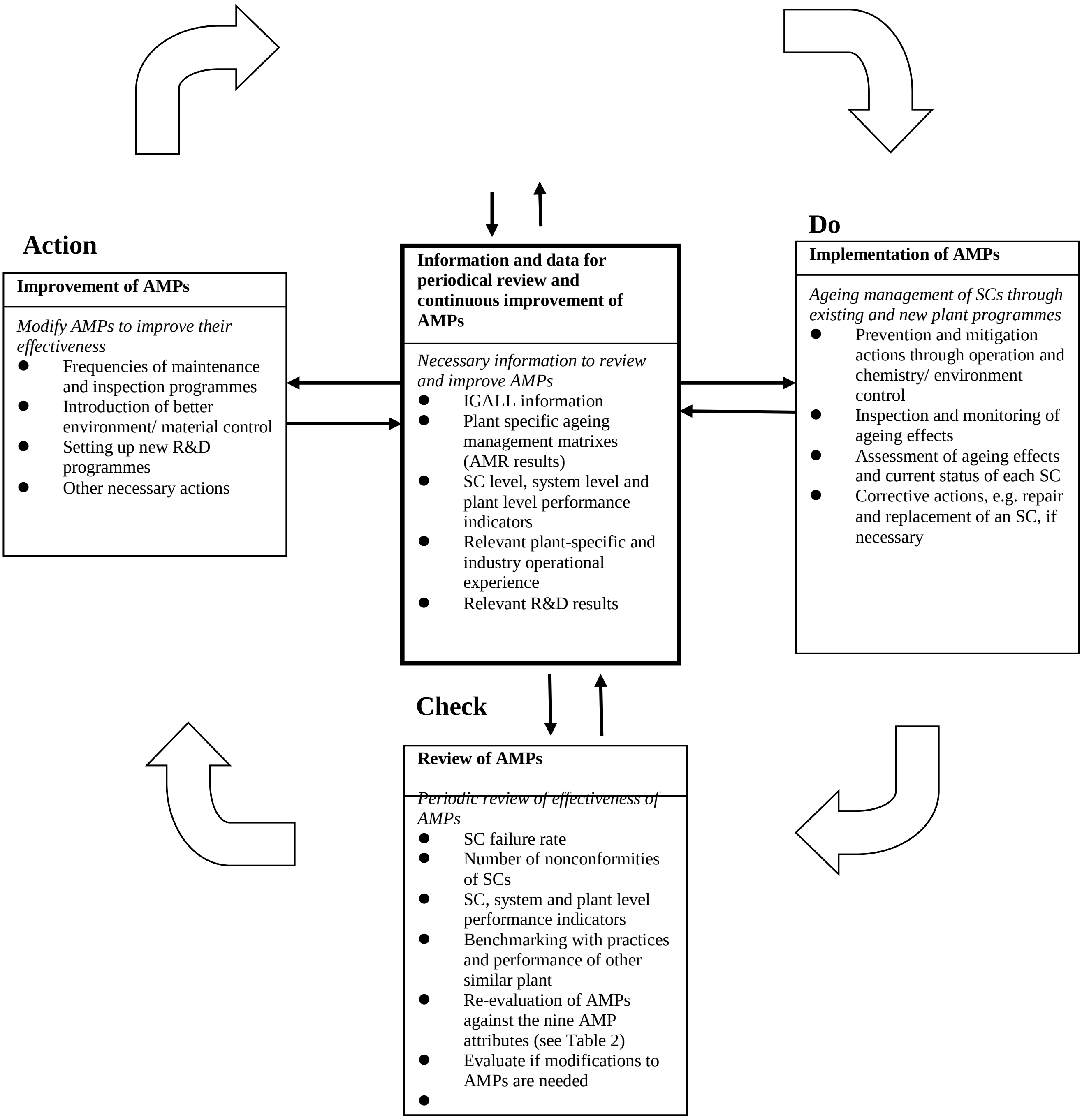


FIG. 5. Development, implementation, review and improvement of AMPs

Development of ageing management programmes

5.43 AMPs should be developed specific to ageing effects/ degradation mechanisms or specific to a structure or component. Existing plant programmes should be coordinated to cover the activities shown in 5.39. If necessary, a new programme which includes or supplements these activities should be developed. These existing/ newly developed programmes can be on a different level of detail (component, commodity group, system etc.) depending on their complexity and importance to safety.

5.44 Whether the AMP is SC specific or degradation mechanism specific, each AMP should identify specific actions relating to the prevention, detection, monitoring and mitigation of the ageing effects. Such specific actions may include plant programmes for maintenance, equipment qualification, in-service inspection, testing and surveillance, as well as controlling operational conditions.

5.45 The development of the AMPs should be based on the results of the AMR.

5.46 All newly developed programmes should comply with relevant national regulatory requirements, codes and standards and the ageing management policy of the plant (see 4.3) and should be consistent with the nine attributes of Table 2.

5.47 Appropriate acceptance criteria for inspection/ monitoring of ageing effects should be established for newly developed AMPs based on design basis/ requirements of the SC, relevant regulatory requirements and codes and standards so that a corrective action can be implemented sufficiently before loss of intended function(s) of the SC. Sufficient margin should be taken into account in these acceptance criteria.

5.48 Particular attention should be paid in developing AMPs to assure that the programme has provisions to detect, evaluate, mitigate or prevent ageing effects of anticipated degradation mechanisms, based on the findings from the AMR.

5.49 Information on the current status of in-scope SCs should be collected for subsequent review of effectiveness of the AMPs. Performance indicators representing the effectiveness of AMPs should be developed along with development of AMPs (see 5.55).

5.50 The SC specific or degradation mechanism specific AMPs provided in [5] should be considered as guidance for the development of AMPs.

TABLE 2. GENERIC ATTRIBUTES OF AN EFFECTIVE AMP

Attribute	Description
1. Scope of the AMP based on understanding ageing	• Structures (including structural elements) and components subject to ageing management • Understanding of ageing phenomena (significant degradation mechanisms, susceptible sites): – Structure/component materials, service conditions, stressors, degradation sites, degradation mechanisms and ageing 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 effects	• Identification of preventive actions • Determination of service conditions (i.e. environmental conditions and operating conditions) to be maintained and operating practices aimed at slowing down potential degradation of the SC
3. Detection of ageing effects	• Identification 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 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 SC
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 AMP
9. Quality management	• Administrative controls that document the implementation of the AMP and actions taken • Indicators to facilitate evaluation and improvement of the AMP • Confirmation (verification) process for ensuring that preventive actions are adequate and appropriate and that all corrective actions have been completed and are effective • Record keeping practices to be followed

Implementation of ageing management programmes

5.51 The AMPs should be implemented in a timely manner to assure fulfilment of intended functions of SCs.

5.52 Detailed implementation procedures that describe prevention/ mitigation actions, monitoring/ inspection and assessment actions, acceptance criteria and corrective actions should be established and shared among different units of the nuclear power plant (e.g. operations, maintenance and engineering) that are responsible for implementing AMPs.

5.53 As part of the implementation of the AMPs, 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 AMPs should be periodically evaluated in light of current knowledge and feedback from the programme and 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 world-wide industry operating experience.

5.55 To evaluate effectiveness of the AMPs, performance indicators should be developed and used by the operating organization. Examples of such indicators are:

- Material condition with respect to acceptance criteria;
- Trends of data relating to failure and degradation;
- Number of recurrent failures and instances of degradation;
- Status of compliance with inspection programmes;
- Number of newly discovered ageing effects/ degradation mechanisms;
- Number of newly developed AMPs.

5.56 Responsible units and other internal/ external organizations involved in ageing management should share data and information newly acquired through AMPs. Consideration should be given to connecting these data with the existing plant databases such as master equipment and component list. These organizations should periodically meet to review these data and information and to discuss if modification of an AMP or a new AMP is necessary.

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

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

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

5.60 An in-depth review of ageing management should be performed periodically, for example as part of PSR [8] or as part of the safety review for LTO (see Section 7), in order to assess the ageing effects on reactor facility safety and to evaluate the effectiveness of plant programmes and practices used to support ageing management throughout plant operation, including LTO if applicable.

5.61 The in-depth review should demonstrate that ageing effects will continue to be identified and effectively managed for each structure or component during the whole operation of the plant, including LTO if applicable. Requirements for modifications of existing plant programmes or development of any new programmes should be identified and implemented. 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.

5.62 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 degradation 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.

TIME LIMITED AGEING ANALYSES

5.63 TLAAs should meet all six of the following criteria [5]:

1. *Involve systems, structures, and components within the scope for ageing management*. Scope setting is described in Figure 3.
2. *Consider ageing effects*. The ageing effects include, but are not limited to: loss of material, change in dimension, change in material properties, a loss of toughness, loss of pre-stress, settlement, cracking, and loss of dielectric properties.
3. *Involve time limited assumptions defined by the current operating term*. The defined operating term should be explicit in the analysis. Simply asserting that a component is designed for a service life or plant life is not sufficient. The assertion is supported by calculations or other analyses that explicitly include a time limit or a time-based assumption.
4. *Were determined to be relevant by the plant in making a safety determination as required by national regulations*. Relevancy is a determination that the plant makes based on 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 a plant's safety determination and, in the absence of the analyses, the plant might have reached a different safety conclusion.
5. *Involve conclusions or provide the basis for conclusions related to the capability of the SSC to perform its intended function(s)*.
6. *Are contained or incorporated by reference in the CLB*. The CLB includes the technical specifications as well as design basis information, or plant commitments documented in the plant-specific documents contained or incorporated by reference in the CLB including, but not limited to: the SAR, regulatory safety evaluation reports, the fire protection plan/hazards analyses, correspondence to and from the regulator, the quality assurance plan, and topical reports included as references in the SAR. If a code of record is in the SAR for a particular group of SCs, reference material includes all calculations called for by that code of record, for those SCs.

5.64 Safety analyses that meet all criteria except of criterion 6 (above) and have been newly developed in Member States to demonstrate preparedness for the intended period of operation, should be also considered TLAAs. Further examples of TLAAs for different reactor technologies are provided in [5].

5.65 TLAAs 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 value of neutron fluence should then be used to evaluate certain analysis parameters, such as the adjusted nil-ductility temperature or fracture toughness.

5.66 The validity of TLAAs over intended period of operation should be assessed through demonstrating satisfaction against one of the following criteria [5]:

i. *The analysis remains valid for the intended period of operation.* The time-dependent parameter value for the intended operating period does not exceed the time-dependent parameter value used in the existing analysis;
ii. *The analysis has been projected to the end of the intended period of operation.* The value of the analysis

parameter value is changed based on the time-dependent parameter projected for the intended operating period and the value of the analysis parameter continues to meet the regulatory limit or criterion;

iii. *The ageing effects on the intended function(s) of the SC will be adequately managed for the intended period of operation.* The value of the analysis parameter will be managed (using an AMP) to assure that the ageing effects are adequately managed and that the value of the analysis parameter will continue to meet the regulatory limit or criterion during the intended period of operation.

5.67 If the TLAA cannot be found acceptable using (i), (ii), or (iii), then corrective actions should be implemented. Depending on the specific analysis, corrective actions could include:

- Refinement of the analysis to remove excess conservatism;
- Implementation of further actions in operation, maintenance or AMP; or
- Modification, repair or replacement of the SC.

DOCUMENTATION OF AGEING MANAGEMENT

5.68 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 the IAEA Safety Standards [2]. The documentation should be developed and retained in an auditable and retrievable form.

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

- Description of plant programmes and documentation relevant to ageing management;
- List of commitments or plans for improvement or development of plant programmes and documentation relevant to ageing management.

5.70 The documentation should include a FSAR update reflecting the assumptions, activities and results of the plant programme for ageing management.

5.71 The assumptions, activities, evaluations, assessments, and results of the plant programme for ageing management should be also reflected in the PSR report, if applicable.

5.72 If the PSR is to be used to justify LTO or licence renewal, the safety assessment performed as defined in [8] should consider 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 resolved before associated declines occur in reliability and availability.

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

6.3 The technological obsolescence programme should ensure participation of the engineering, maintenance, operations, work planning, 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 in a level of detail defined by national regulatory requirements.

6.5 The technological obsolescence programme should be consistent with the nine attributes (Table 2), as applicable.

6.6 A technological obsolescence programme should include three basic steps illustrated in Figure 6:

1. The operating organization should identify the installed SSCs important to safety that are technologically obsolete;
2. The identified equipment should be prioritized based upon the safety and criticality of the obsolete equipment (impact to the plant); and
3. The operating organization should effectively develop and implement replacement solutions in a timely manner. Technological obsolescence solution methods are illustrated in Figure 7 and described in IGALL Technological Obsolescence Programme [5].

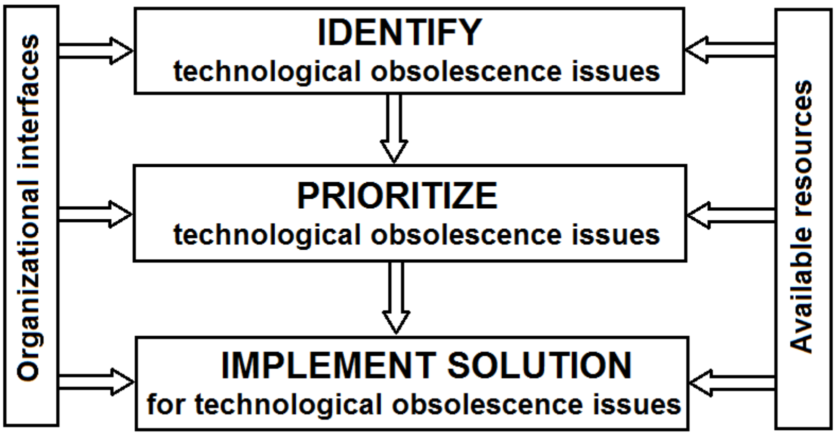


FIG. 6. Basic steps of the generic proactive obsolescence process

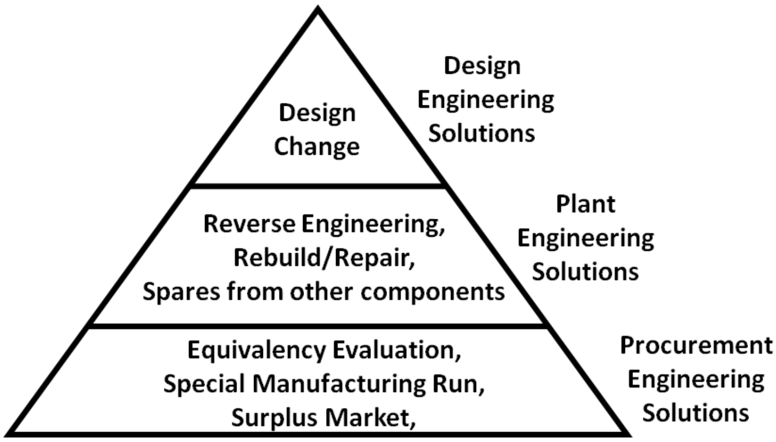


FIG. 7. Technological obsolescence solution methods

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

– Collect SC data usually from plant asset management systems (equipment databases with manufacturer and part information);
– Determine if the manufacturer(s) still supports (provides) replacement equipment and spare parts.

6.8 For the prioritization adequate criteria should be used such as: safety relevance, plant demand, quantity in stock, component classifications, failure history, SCs reliability, work order information, stock history; uncertainty (spare parts with insufficient data).

6.9 Training should be conducted on obsolescence to educate staff involved to understand the process.

6.10 The operating organization should exchange information and participate in the industry collaboration to utilize industry tools to identify and resolve common technological obsolescence.

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

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

7. PROGRAMME FOR LONG TERM OPERATION

7.1 The IAEA Safety Standards [2] in Requirement 16 provides requirements on programme for LTO. Detailed information on programme for LTO is provided in [21].

7.2 The national regulatory framework should specify requirements for LTO.

ORGANIZATIONAL ARRANGEMENTS

7.3 The operating organization should adopt a comprehensive project structure or similar organizational arrangement for preparation and implementation of the programme for LTO, considering arrangement for management of physical ageing as described in Section 5. The organizational arrangement for management of physical ageing, including technological obsolescence, should be properly implemented and should be one of the prerequisites for NPP decision to pursue LTO.

7.4 In addition to the existing obligations assossiated with ageing management, the operating organization should clearly define the additional responsibilities and authorities for LTO preparation and implementation, after considering all the regulatory requirements relevant to LTO. The operating organization should ensure that appropriate resources are available to accomplish the assigned responsibilities and accountabilities regarding LTO preparations and implementation.

PRINCIPLES AND APPROACH TO LONG TERM OPERATION

7.5 Major steps of programme for LTO, in particular for ageing management of SSCs necessary to assure safe LTO [21], are illustrated in Figure 8.

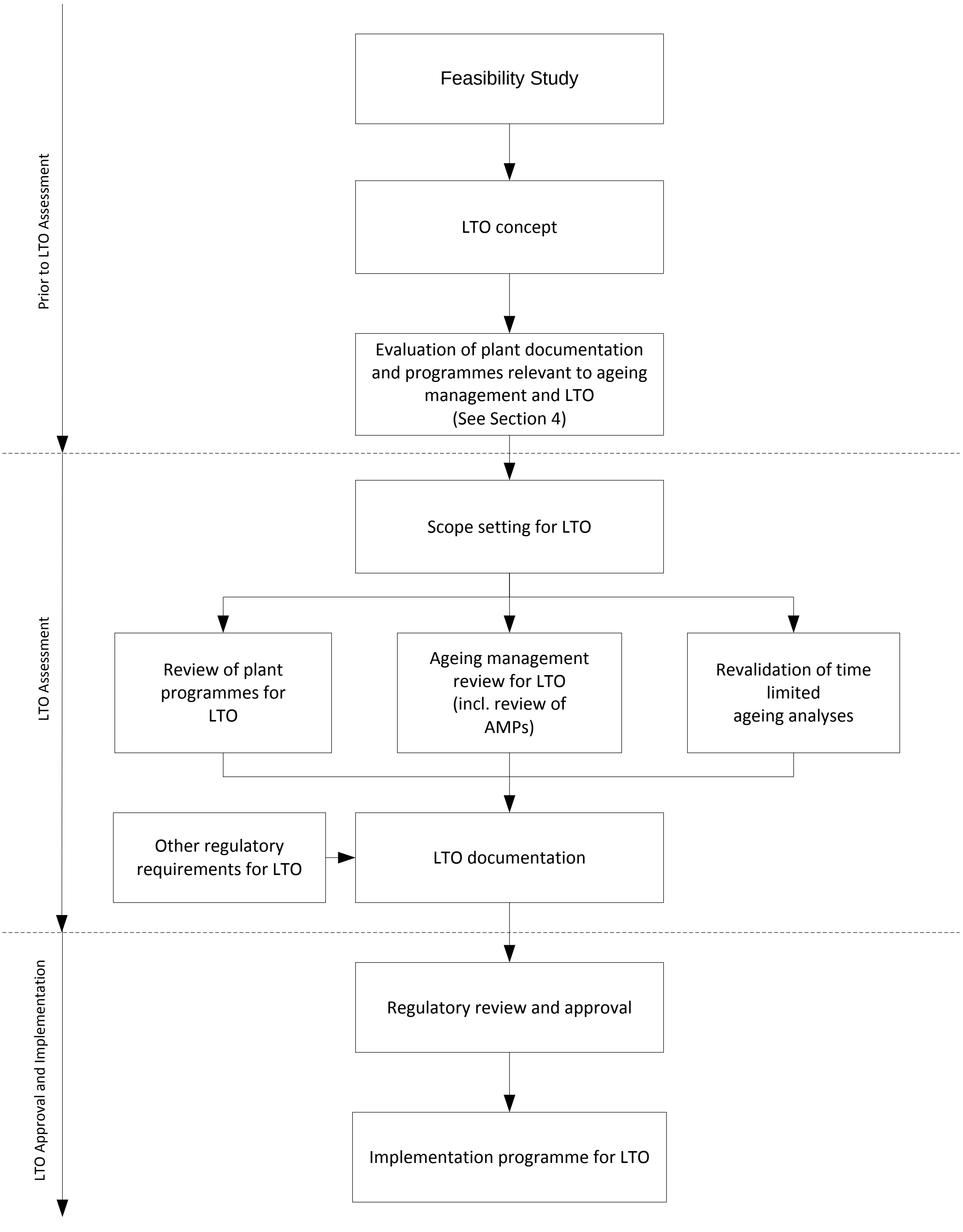


FIG. 8. Overview of major steps of programme for LTO

7.6 The decision of an operating organization to pursue LTO is typically based upon an evaluation (a feasibility study) [21] that addresses:

- Strategic elements such as the need for electric power and issues concerning supply diversity;
- Compliance with currents codes, standards, and regulations;
- Latest relevant international standards and guidance documents;

- A technical assessment of the physical condition of the plant;
- Evaluation of past operational experience of the plant related to ageing, obsolescence and other safety issues;
- Spent fuel storage for LTO;
- Radioactive waste management for LTO;
- An assessment of the environmental impact of LTO as required by national regulations;
- An economic assessment.

7.7 A plant policy in the area of LTO should exist and should cover LTO principles and concept. When LTO is connected to a regulatory process such as licence renewal or PSR, this policy should take account of it.

7.8 The LTO programme should be based upon the following principles:

a) Operational practices should meet national regulations and follow international guidelines as applicable and should be adequate to ensure safe operation of the plant;
b) The regulatory process should be adequate to maintain safe operation of the nuclear power plant and should focus on ageing effects that need to be properly managed for the planned period of LTO;
c) The CLB should provide an acceptable level of safety [22] and should be carried over to the intended period of LTO in the same manner and to the same extent, with the exception of any changes specific to LTO.

7.9 LTO concept should address basic goals and objectives, milestones, activities, organizational roles and responsibilities, interactions with other major projects, interaction with external organizations.

7.10 The plant staff should be familiar with and should understand LTO principles and concept.

7.11 AMR and TLAA evaluation should have been completed previously in accordance with Section 5. If this has not been previously completed, then it should be completed for LTO.

7.12 Technological obsolescence should have been addressed previously in accordance with Section 6. If this has not been previously completed, then it should be completed for LTO.

7.13 The LTO assessment should demonstrate that the ageing effects will be adequately managed so that the intended functions can be maintained consistent with the plant's CLB for the planned period of LTO.

7.14 The approach to an LTO assessment is outlined in Fig. 8. An overview of major steps of programme for LTO should involve the following main steps:

a) Demonstration that the ageing effects will continue to be identified and managed for each SC in the scope of LTO for the planned period of LTO (including the feedback of operating experience and R&D findings); and
b) Review of TLAAs to ensure that the analyses continue to meet the criteria specified in 5.66.

DEVELOPMENT OF PROGRAMME FOR LONG TERM OPERATION

7.15 Ageing management for the LTO period should use the same approach described in Section 5, accounting for the differences that will occur with the LTO period, e.g., longer operating times, higher neutron fluences. In addition, changes that occur before the LTO period should be considered, including changes in regulatory requirements, codes and standards, knowledge, and operating experience.

7.16 TLAAs should be re-evaluated for the LTO period and demonstrated to meet the criteria of 5.66.

7.17 The programme for LTO should include the following activities, evaluations, assessments, and results:

a) The scope setting method, results obtained (SCs in scope and out of scope of LTO), and supporting technical justifications as outlined in Section 5;
b) Demonstration that the programmes credited for LTO support the conclusion that the intended functions of SSCs and the required safety margins will be maintained. This demonstration addresses the following topics:
   (i) A description of the intended functions of the SCs;

(ii) Identification of applicable ageing effects and degradation mechanisms based on materials, environment, operating experience, etc.;

(iii) Identification and description of operational programmes and AMPs that manage the identified ageing effects;

(iv) Demonstration that these operational programmes and AMPs (including new programmes) are effective.

c) Demonstration that the review performed for the SSCs within the scope of LTO is consistent with the process outlined in Section 5 and a technical justification is provided that:

(i) Demonstrates that the ageing effects will be adequately managed for each SC in such a way that the intended function(s) of the SC will be maintained throughout the planned period of LTO in a manner that is consistent with the CLB;

(ii) Ensures that operating experience and research findings are adequately reflected in assessing ageing effects of SCs in scope of LTO and will continue to be taken into account during the entire LTO period.

d) Demonstration that the TLAAs have been revalidated and that the evaluation includes:

(i) Identification of TLAAs in accordance with the definition specified in 5.63;

(ii) Revalidation of each identified TLAA in accordance with the revalidation requirements specified in 7.27 to demonstrate that the intended function(s) of the SC will be maintained throughout the planned period of LTO in a manner that is consistent with the CLB;

e) The implementation programme for LTO identifying the corrective actions and/or safety improvements required for safe LTO, respective schedule and plant commitments.

SCOPE SETTING OF SYSTEMS, STRUCTURES AND COMPONENTS FOR LTO

7.18 Scope setting for LTO should follow the same approach identified in Section 5, accounting for differences in regulatory requirements, and codes and standards.

7.19 Process to identify programmes to manage ageing of in-scope SCs as identified in Section 5 should be used.

7.20 Ageing management review for LTO, review of plant programmes for LTO and revalidation of time limited ageing analyses should be performed as described in following paragraphs of this Section.

AGEING MANAGEMENT REVIEW FOR LTO

7.21 The AMR for LTO should follow the same approach identified in Section 5, accounting for differences in regulatory requirements, codes and standards, knowledge and operating experience for the LTO period.

7.22 The AMR for LTO should focus on the following issues:

– If any new ageing effect/ degradation mechanism is anticipated during the LTO period;
– If significance, degradation rate or susceptible sites of degradation mechanism is expected to change during the LTO period;
– If current relevant operational experience and research findings have been incorporated into AMPs.

7.23 If the operating organization has not performed any AMR, the results of a LTO AMR should serve to identify or develop effective AMPs in order to detect and mitigate those effects before the integrity and functional capability of the SSCs are compromised.

7.24 The AMR should provide a clear demonstration that the ageing effects will continue to be identified and managed for each SC in scope of LTO for the planned period of LTO.

REVIEW OF PLANT PROGRAMMES FOR LTO

7.25 Based on the results of the AMR for LTO, the existing plant programmes used for ageing management and existing AMPs should be reviewed to ensure that they will remain effective to manage the effects identified for the planned period of LTO. This review should identify programme modifications and/or new programmes necessary to ensure that the SCs are able to perform their designated intended function(s) for the planned period of LTO.

7.26 Any existing and new plant programme for LTO should be reviewed to determine whether they are consistent with the nine attributes described in Table 2. In addition, the plant documentation and programmes identified in Section 4 should be also reviewed with respect to the planned LTO period.

REVALIDATION OF TIME LIMITED AGEING ANALYSES

7.27 TLAAs should be reviewed to determine continued acceptability of the analyzed SC for the LTO period, consistent with 5.66. In this case, the time-dependent parameter is determined from a re-evaluation or analysis of plant operating history, which is projected to the end of the LTO period, to define a value of the parameter that applies to, or bounds the expected value of the parameter at the end of the LTO period. The value of the time-dependent parameter applicable to the LTO period is used to re-evaluate the TLAA.

LTO DOCUMENTATION

7.28 The assumptions, activities, evaluations, assessments, and results of the plant programme for LTO should be documented 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 technical basis for approval of LTO.

7.29 The documentation should provide detailed information on each element outlined in 7.17, and other information required by national regulatory requirements.

7.30 The documentation should also include the following to demonstrate that ageing effects will be managed during the LTO period:

- Description of plant programmes and documentation relevant to ageing management during LTO;
- List of commitments for improvement or development of plant programmes and documentation relevant to ageing management during LTO, and implementation of new AMPs.

7.31 The methodology used to carry out the AMR for LTO should be documented and justified.

7.32 All information and conclusions with regard to the scope of an AMR for LTO should be documented, including:

- An identification and listing of SSCs subject to an AMR and their intended functions;
- A description and justification of the methods used to determine the SCs that are subject to an AMR;
- The information sources used to accomplish the above, and any discussion needed to clarify their use.

7.33 The results of the AMR for LTO should be documented in an appropriate report. The report should address the understanding of ageing, monitoring of ageing and prevention/mitigation of ageing effects. In addition, recommendations should be provided for the application of results of the AMR in plant operation, maintenance and design.

7.34 Documenting the demonstration that ageing effects will be adequately managed during LTO should include:

- An identification of the ageing effects/ degradation mechanisms requiring management;
- An identification of the specific programmes or activities that will manage the ageing effects/ degradation mechanisms for each structure, component or commodity grouping listed;
- A description of how the programmes and activities will manage the ageing effects/ degradation mechanisms.

7.35 The documentation should include an update of the FSAR reflecting the assumptions, activities and results of the plant programme for LTO. The FSAR update should also include documentation of the revalidation of the TLAAs for the LTO period.

7.36 The assumptions, activities, evaluations, assessments, and results of the plant programme for LTO should be also reflected in the PSR report, if applicable.

7.37 If the PSR is used as a licensing tool, the safety assessment performed for safety factors 2, 3, 4, and 5 as defined in [8] should consider the whole intended LTO period.

REGULATORY REVIEW AND APPROVAL

7.38 To ensure safe LTO 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 LTO period against the current safety standards, consistent with national regulatory requirements.

7.39 The demonstration for LTO should be provided to the regulatory body for review and approval in a level of detail defined by national regulatory requirements. The justification should include trends of expected ageing effects during the LTO period based on past studies, such as those under past PSRs.

IMPLEMENTATION PROGRAMME FOR LTO

7.40 The LTO programme should be implemented in a manner consistent with the approval of the national regulatory body and national regulations.

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