AN INTRODUCTION TO A NEW IAEA SAFETY GUIDE: "AGEING MANAGEMENT FOR NUCLEAR POWER PLANTS"

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Abstract

This paper reports on a new IAEA Safety Guide entitled "Ageing Management for Nuclear Power Plants" which is currently in an advanced draft form, awaiting approval of publication. The new Safety Guide will be an umbrella document for a comprehensive set of guidance documents on ageing management which have been issued by the IAEA. The Safety Guide first presents basic concepts of ageing management as a common basis for the recommendations on: proactive management of ageing throughout the life cycle of a nuclear power plant (NPP); systematic approach to managing ageing in the operation of NPPs; managing obsolescence; and review of ageing management for long term operation (life extension). The Safety Guide is intended to assist operators in establishing, implementing and improving systematic ageing management programs in NPPs and may be used by regulators in preparing regulatory standards and guides, and in verifying that ageing in nuclear power plants is being effectively managed.

1. Introduction

Effective management of ageing of systems, structures and components (SSCs) is a key element of the safe and reliable operation of NPPs. In order to assist Member States in managing ageing effectively, the IAEA developed in 1990's a comprehensive set of guidance publications [1]. The new Safety Guide will be an umbrella document for these publications.

The IAEA's Statute authorizes the IAEA to establish safety standards to protect health and minimize danger to life and property — standards which the IAEA must use in its own operations, and which a State can apply to its nuclear and radiation related facilities and activities. In the mid-1990s, a major overhaul of the IAEA's safety standards programme was initiated, with a revised oversight committee structure and a systematic approach to updating the entire corpus of standards. The new standards that have resulted reflect best practices in Member States and have become a key element in a global safety regime for the beneficial uses of nuclear and radiation related technologies.

The IAEA Safety Standards Series covers nuclear safety, radiation safety, transport safety and waste safety, and also general safety (i.e. all these areas of safety). The publication categories in the series are Safety Fundamentals, Safety Requirements and Safety Guides. Safety Fundamentals present basic objectives, concepts and principles of safety and protection in the development and application of nuclear energy for peaceful purposes. Safety Requirements establish the requirements expressed as 'shall' statements that must be met to ensure safety. Safety Guides recommend actions, conditions or procedures expressed as 'should' statements for

meeting safety requirements. Information on the IAEA's safety standards programme is available at the IAEA Internet site http://www-ns.iaea.org/standards/ This paper reports on a new Safety Guide, "Ageing Management for Nuclear Power Plants" which is currently in an advanced draft form, awaiting approval of publication.

2. The development process of the new document

A uniform process for the preparation and review of all IAEA safety standards involves: preparing a work plan – a Document Preparation Plan (DPP); approval of the DPP by an advisory body responsible for an area of IAEA standards; approval of DPP by a Commission on Safety Standards (CSS) – a standing body of senior government officials with national responsibility for establishing safety standards; organizing expert group meetings to draft or revise documents; submitting draft documents to the relevant advisory committee for review; submitting draft documents to the IAEA's Member States for comment; obtaining endorsement by the Advisory Committee on Safety Standards and by CSS; obtaining the (internal) IAEA Publications Committee's approval to ensure compliance with the IAEA's editorial policy; submitting the standards to the Director General or, as appropriate, to the Board of Governors for approval.

The Nuclear Safety Standards Committee (NUSSC) oversees the preparation of safety standards in the areas of NPP operation, design and siting. It is composed of senior regulatory officials with technical expertise in nuclear safety.

The documents are drafted by the experts group under the oversight of IAEA technical officers. The Technical Officers organize the expert groups meetings, and are responsible for ensuring that the documents are prepared and reviewed expeditiously, and are technically sound. They are also responsible for circulating the document to Member States for Comment.

For the preparation of the new safety guide on ageing management, the following approach was proposed by the IAEA Technical Officer and approved by NUSSC:

- The existing IAEA guidelines on ageing management to be used as a primary basis for the new Safety Guide.
- The Safety Guide to focus on managing physical/material ageing of SSCs important to safety.
- The Safety Guide to identify key elements of effective ageing management and provide references to the existing guidance documents for more detailed guidance.

The development process was complicated by several factors:

- Originally, it was proposed to draft the Safety Guide for both NPPs and research reactors. However, during the actual drafting of the Safety Guide this proposal was abandoned when it was recognized that such a Safety Guide would be complicated by numerous exceptions for research reactors and thus user unfriendly.

- Review of an early draft by a Technical Meeting and the need to disposition comments received.
- The need to coordinate drafting of the Safety Guide with a parallel Extra-budgetary Project on Safety Aspects of Long Term Operation (SALTO) of NPPs.
- Additional requests by NUSSC to address in the Safety Guide safety aspects of managing obsolescence and the application of ageing management to long term operation.

Several experts meeting were required to address these factors and prepare the current draft of the document. At the first stage of external review, by NUSSC, over 160 comments were reviewed from ten countries and one international organization with the majority being incorporated. At the second stage of review by Member States, about 70 comments were received in advance of the experts meeting that was convened to disposition the comments. The results are reflected in the current draft of the new safety guide which is now awaiting endorsement by NUSSC.

3. Highlights of the new document

The following presents a summary of the contents and highlights of the new safety guide.

Section 1 - Introduction

This section of the guide establishes its context and purpose. The overall objective of the guide is *"to provide a set of guidelines and recommendations for managing ageing of SSCs important to safety in nuclear power plants, including recommendations on key elements of effective ageing management and its implementation"*. The Safety Guide is intended primarily to assist NPP operators in establishing, implementing and improving systematic ageing management programmes in nuclear power plants; it may be also used by regulators in preparing regulatory standards and guides, and in verifying that ageing in nuclear power plants is being effectively managed.

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

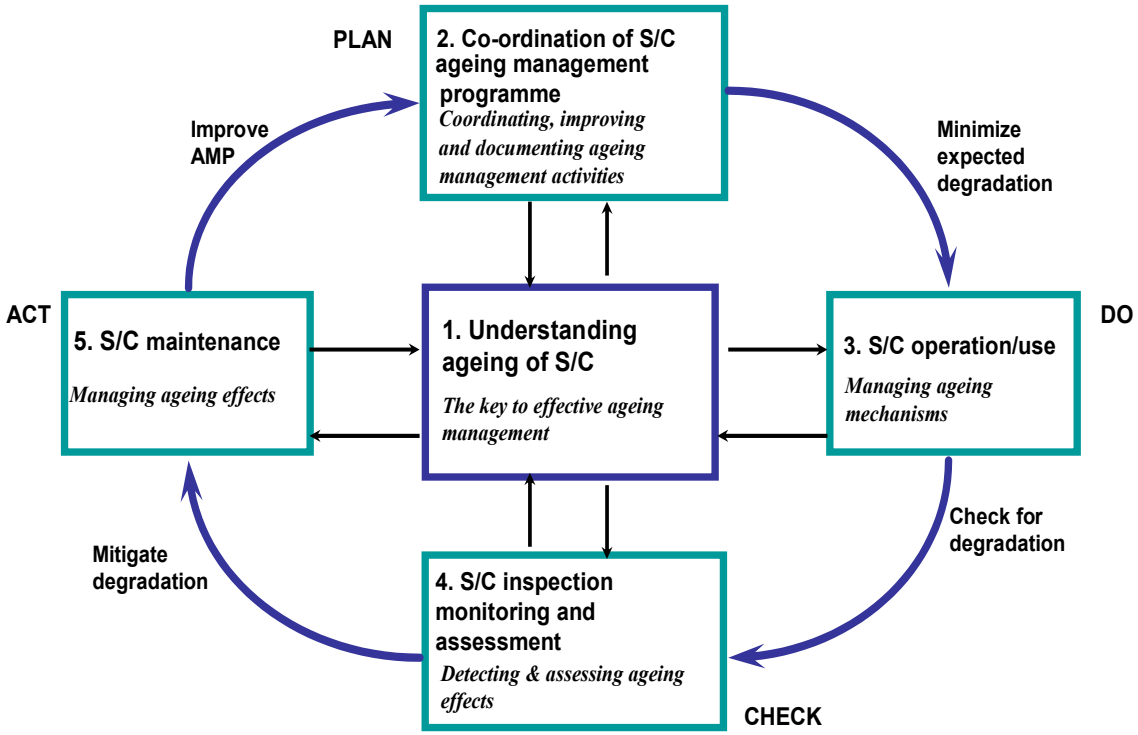
Section 2 - Basic concepts

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

Nuclear power plants experience two kinds of time dependent changes: *physical ageing* (further referred to as ageing) of SSCs, which results in degradation, i.e. gradual deterioration in their physical characteristics; and *obsolescence* of SSCs, i.e. their becoming out of date in comparison with current knowledge, standards and technology.

The key concept of effective ageing management is that of the *systematic ageing management process* [2] which is illustrated in Fig. 1. This is a simplified figure of that shown in the Safety Guide in order to highlight its main features:

- The process is applied to a specific structure or component (S/C)
- An S/C specific ageing management programme (AMP) is based on a current understanding/ predictability of its ageing
- AMP consists of and provides for co-ordination and communication between relevant plant and external programs and activities
- Careful operation/ use to minimize the rate of S/C degradation
- Inspection, monitoring and assessment of an S/C to provide for timely detection of degradation
- Maintenance to mitigate any S/C degradation
- Continuous improvement of S/C specific AMP



S/C - structure or component; AMP-ageing management programme

Fig.1 Systematic ageing management process

Nuclear power plant safety could be impaired if obsolescence of SSCs is not identified in advance and corrective action is not taken before associated declines occur in SSC reliability or availability. There are several *types of obsolescence* as shown in Table 1 below.

Table 1. Types of obsolescence

Type - SSCs out of date in comparison with current:	Manifestation	Consequences	Management
Knowledge	Knowledge of current standards, regulations and technology relevant to SSCs not updated	Opportunities to enhance plant safety missed Reduced ability for LTO	Continuous updating of knowledge and improvement of its application
Standards and regulations	Deviations from current regulations and standards, both hardware and software; design weaknesses (e.g. in equipment qualification, separation, diversity or severe accident management capabilities)	Plant safety level below current standards and regulations (e.g. weaknesses in defence in depth, or high core damage frequency) Reduced ability for LTO	Systematic reassessment of plant against current standards (e.g. periodic safety review) and appropriate upgrading, backfitting or modernization
Technology	Lack of spare parts and/or technical support Lack of suppliers and/or industrial capabilities	Declining plant performance and safety due to increasing failure rates and decreasing reliability Reduced ability for LTO	Systematic identification of useful service life and anticipated obsolescence of SSCs; provision of spare parts for planned service life; timely replacement Long term agreements with suppliers Development of equivalent SCs

Long term operation (LTO) is operation beyond an established timeframe set forth e.g. by license term, design, standards, license, and/or regulations etc., which has been justified by safety assessment, considering life limiting processes and features for SSCs. If an operating organization decides to pursue LTO, justification for LTO is supported by the results of a periodic safety review (PSR) and overseen by the regulatory body on the basis of the analysis which includes an in-depth review of the ageing management.

Section 3 - Proactive strategy for ageing management

Proactive ageing management strategy means implementing systematic ageing management throughout NPP life cycle with foresight and anticipation. Recommendations for the implementation of this strategy are presented in this section of the safety guide, including the following recommendations.

DESIGN

- Appropriate measures or design features should be introduced during the design stage to facilitate effective ageing management throughout the service life of the plant.
- Ageing management should be one of the topics to be included in the Safety Analysis Report.
- The operating organization should specify requirements for ageing management in the procurement documents for new facilities.

FABRICATION AND CONSTRUCTION

The NPP operating organization should ensure that:

- plant supplier adequately addresses factors impacting ageing management and that sufficient information and data are provided to SSC manufacturers
- fabrication of SSCs takes into account current ageing management knowledge
- baseline data are collected and documented
- surveillance specimens for specific AMPs are installed in accordance with design specifications.

COMMISSIONING

- The operating organization should demonstrate that issues relating to the ageing management are in compliance with the design, e.g. the ambient environment where the SSCs are located should be validated
- Baseline data should be collected and documented for major SSCs
- Parameters that can influence ageing degradation should be identified; e.g. hot spots in terms of temperature, dose rate, and vibration levels.

OPERATION (including long term operation and extended shutdown)

Lessons learned from successful ageing management programmes should be implemented, including:

- sponsorship of a systematic ageing management by NPP management
- early implementation of the systematic ageing management process to specific structures or components (S/Cs)
- proactive approach based on adequate understanding/ predictability of SSC ageing, rather than a reactive approach responding to SSC failures

- careful operation to minimize ageing degradation
- minimizing operating, maintenance and engineering errors that cause premature degradation
- multi-disciplinary teams for dealing with ageing management issues
- availability of spare parts or replacement parts and the shelf-life of spare parts or consumables should be continually monitored and controlled.

DECOMMISSIONING

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

Section 4 - Ageing management in operation

This section presents guidance on a systematic approach to ageing management which consists of the following elements that develop, implement and provide for continuous improvement of S/C-specific ageing management programs:

- Organizational arrangements
- Data collection and record keeping
- Screening of SSCs for ageing management
- Ageing management review
- Condition assessment
- Development of an ageing management programs
- Implementation of the ageing management programs
- Improvement of the ageing management programs.

Alternative approaches are acceptable if it can be shown that they are effective in managing ageing degradation.

ORGANIZATIONAL ARRANGEMENTS

The comprehensive nature of ageing management requires involvement and support of both plant operating organizations and external organizations (e.g. technical support organizations, owners groups, research, design, and manufacturing organizations). Before an AMP can be implemented appropriate organizational arrangements should be established.

Effective ageing management requires a component specific application of the systematic ageing management process (see Fig.1). It can be best accomplished under an umbrella-type ageing management programme that builds on and co-ordinates all relevant existing plant and external programmes and activities, such as operations, maintenance, technical support, and research and development. The operating organization senior management should set out the policy and objectives of the umbrella AMP, allocate necessary resources (human, financial, tools and equipment, and external), and monitor the program to ensure that it is meeting its objectives. For more guidance, see Ref. [2].

DATA COLLECTION AND RECORD KEEPING

A data collection and record keeping system should be established early in the life of an NPP in order to provide information for the following ageing management activities:

- Identification and evaluation of degradation, failures and malfunctions of components caused by ageing effects
- Decisions on the type and timing of maintenance actions
- Optimization of operating conditions and practices that reduce the rate of ageing degradation
- Identification of new emerging ageing effects before they jeopardize plant safety, production reliability and service life.

For more guidance, see Ref. [3].

SCREENING SYSTEMS, STRUCTURES AND COMPONENTS

A systematic approach should focus resources on those SSCs that can have a negative impact on the continued safe and reliable operation of the plant and which are susceptible to ageing degradation. Specific screening methodology used for this purpose should be documented and justified; a safety based screening process is recommended in the safety guide.

AGEING MANAGEMENT REVIEW

Ageing management reviews that provide information on the understanding, monitoring, and mitigation of ageing structures, components and groups of structures and components selected by the screening process should be available or performed. Existing ageing management reviews (e.g. generic reviews prepared by an owners group, plant supplier or technical support organizations) should be used to minimize duplication of effort.

Ageing management reviews should give clear recommendations for the application of results in plant operation, maintenance and design. For more guidance, see Ref. [4].

CONDITION ASSESSMENT

Using the results of the above ageing management reviews as a starting point, and relevant operation, maintenance and engineering data, condition assessments of specific structures, components and groups of structures and components of a nuclear power plant should be performed:

- to determine the current performance and condition of the S/C, including assessment of any age-related failures or indications of significant material degradation, and
- to estimate future performance, ageing degradation, and residual service life, where feasible, of the S/C.

This information is necessary for the development of effective S/C specific ageing management programs (AMPs).

DEVELOPMENT OF AMPs

An S/C specific AMP should be developed/ documented for major S/Cs and groups of S/Cs to identify (a) effective and appropriate ageing management actions and practices that provide for timely detection and mitigation of ageing effects in the S/C and (b) indicators of AMP effectiveness. This means confirming the effectiveness of current practices in light of applicable ageing management reviews and condition assessments and/or recommending improvements of current practices, as appropriate.

Examples of S/C-specific indicators of AMP effectiveness are: material condition with respect to acceptance criteria, service conditions with respect to prescribed limits, trends of failure/degradation data, comparison of preventive and corrective maintenance efforts (e.g. in terms of person-years or cost), inspection programme compliance, chemistry control index (chemistry parameters with respect to prescribed limits).

Ageing management programs should have the generic attributes presented in Table 2.

IMPLEMENTATION OF AMPs

Responsibility for implementing S/C specific AMPs lies with the NPP operating organization. AMP implementation should include periodic reporting on the S/C performance and the S/C - specific indicators of AMP effectiveness identified in the AMP.

IMPROVEMENT OF AMPs

NPP management should provide for performance review and continuous improvement of AMPs. Both the overall AMP of the operating organization (including policy, scope, organizational arrangements, resources) and S/C specific AMPs should be evaluated in light of current knowledge and adjusted, as appropriate. Current relevant knowledge consists of information on S/C operation, surveillance and maintenance histories, results of relevant research and development, and generic operating experience.

Consideration should be given to arranging for peer reviews of AMPs to obtain an independent assessment. And, results of the reviews and improvements should be submitted to the regulatory body.

Section 5 - Management of obsolescence

Obsolescence of SSCs important to safety should be managed proactively (i.e. with foresight and anticipation) throughout their service life. Thus, the operating organization should establish a program for the management of obsolescence - this includes setting out the policy, objectives and organizational arrangements, allocating appropriate resources, and monitoring the program to ensure that it meets its objectives.

The obsolescence management program should focus on the management of technological obsolescence to provide for the availability of complete and accurate documentation to support SSC maintenance and replacement; required technical support; and sufficient spare parts. In addition, the program should provide guidance on and monitor the management of obsolescence of standards and regulations (e.g. through periodic safety review).

Table 2. Generic attributes of an effective ageing management program

Attribute	Description
1. Scope of the AMP	Structures and components (including structural elements) subject to ageing management
2. Understanding/ predictability of S/C aging	Summary information on: - S/C materials, service conditions, stressors, degradation sites, aging mechanisms and effects; - S/C condition indicators and acceptance criteria; - quantitative or qualitative predictive models of relevant aging phenomena
3. Preventive actions to minimize and control ageing degradation	Service conditions (i.e. environmental and operating parameters) to be maintained and operating practices to be followed aimed at slowing down potential degradation of S/C
4. Monitoring and detection of ageing	- Effective technology (inspection, testing and monitoring methods) for detecting ageing effects before S/C failure - Condition indicators/ parameters monitored and collected to facilitate assessment of S/C ageing - Assessment methods (incl. data analysis and trending)
5. Mitigating ageing effects	Operations, maintenance, repair and replacement actions to mitigate detected ageing effects / degradation of S/C. This includes the application of appropriate acceptance criteria, and initiation of associated corrective actions.
6. Operating experience feedback	Mechanism that ensures timely feedback of operating experience and provides objective evidence that the operating experience is taken into account in the ageing management program.
7. Quality management	- Administrative controls for documenting AMP implementation and actions taken - Confirmation/verification process for ensuring that the above AMP actions are appropriate, completed timely, and are effective - Indicators of AMP effectiveness to facilitate its evaluation and improvement

Section 6 - Review of ageing management for long term operation (LTO)

This section presents recommendations on an in-depth review of ageing management in connection with the LTO of an NPP. The in-depth review of ageing management should ensure that plant programs and practices used to support the management of ageing effects during LTO

are reviewed and consistent with the generic attributes of an effective ageing management program given in Table 2 of this Safety Guide.

The review process involves the following main steps:

(1) An appropriate selection method and criteria to ensure that structures and components important to safety will be evaluated for LTO.

(2) Demonstration that the effects of ageing will continue to be identified and managed for each structure/component during the planned period of LTO.

(3) Revalidation of safety analyses with time limited assumptions[1] to demonstrate their validity or that the ageing effects will be effectively managed, i.e. to demonstrate that the intended function of a structure/component will remain within the design safety margins throughout the planned period of LTO.

Reference [5] provides more detailed guidance on the implementation of the above process.

Section 7 - Interfaces with other technical areas

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

EQUIPMENT QUALIFICATION

The equipment qualification program provides an example of effective means of managing ageing of plant components important to safety covered by this program. The scope of the equipment qualification program usually includes equipment that performs safety functions or contributes towards the execution of the safety functions, but it may vary between Member States. Ageing of specific equipment is managed either by using a concept of ‘qualified life’ or of ‘qualified condition’ established by equipment qualification.

Before the end of the equipment’s qualified life, the equipment should be replaced, life limiting components should be renewed or a new, longer qualified life should be established. The qualified condition of equipment established by equipment qualification is expressed in terms of a measurable condition indicator(s) for which it has been demonstrated that the equipment will meet qualified condition is maintained. For more guidance, see Ref. [6].

PERIODIC SAFETY REVIEW (PSR)

[1] Revalidation of safety analyses with time limited assumptions is an assessment of an identified ageing effect (time-dependent degradation due to normal service conditions) and certain plant-specific safety analyses that are based on an explicitly specified length of plant life. For example, fatigue calculation, pressurized thermal shock (PTS) analysis and equipment qualification of electrical and I&C cables are included in the analyses.

PSR provides reassurance that there continues to be a valid licensing basis, with cumulative effects of plant ageing (both physical ageing and obsolescence), modifications made to the plant and changes in international safety standards taken into consideration. In the frame of a PSR, the operating organization assesses the effects of ageing on nuclear power plant safety, the effectiveness of the ageing management program and the need for improvements to the ageing management program [7]. Possible outcomes of the ageing review are improvements to the scope, procedures and/or frequency of maintenance, surveillance and inspection, and modifications of operating conditions or design (including possible changes of the design basis of structures and components).

4. Conclusions

This paper reports on a new IAEA Safety Guide entitled "Ageing Management for Nuclear Power Plants" which is currently in an advanced draft form, awaiting approval of publication. The new Safety Guide will be an umbrella document for a comprehensive set of guidance documents on ageing management which have been issued by the IAEA. A number of challenges had to be addressed which required a substantial time and effort from the IAEA staff and an international group of experts in order to produce the current draft representing a synthesis of good ageing management practices and a required international concessus. The guidance of the new Safety Guide should help NPP operators in establishing, implementing and improving systematic ageing management programs which are essential for safe, reliable and profitable long term operation of nuclear power plants, and to regulators in verifying that ageing in nuclear power plants is being effectively managed.

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