Plant renewals, modifications and upgrades, ageing
Background

In 1991, the General Conference (GC) in its resolution RES/552 requested the Director General to prepare ‘a comprehensive proposal for education and training in both radiation protection and in nuclear safety’ for consideration by the following GC in 1992. In 1992, the proposal was made by the Secretariat and after considering this proposal the General Conference requested the Director General to prepare a report on a possible programme of activities on education and training in radiological protection and nuclear safety in its resolution RES1584.

In response to this request and as a first step, the Secretariat prepared a Standard Syllabus for the Postgraduate Educational Course in Radiation Protection. Subsequently, planning of specialised training courses and workshops in different areas of Standard Syllabus were also made. A similar approach was taken to develop basic professional training in nuclear safety. In January 1997, Programme Performance Assessment System (PPAS) recommended the preparation of a standard syllabus for nuclear safety based on Agency Safely Standard Series Documents and any other internationally accepted practices. A draft Standard Syllabus for Basic Professional Training Course in Nuclear Safety (BPTC) was prepared by a group of consultants in November 1997 and the syllabus was finalised in July 1998 in the second consultants meeting.

The Basic Professional Training Course on Nuclear Safety was offered for the first time at the end of 1999, in English, in Saclay, France, in cooperation with Institut National des Sciences et Techniques Nucleaires/Commissariat a l'Energie Atomique (INSTN/CEA). In 2000, the course was offered in Spanish, in Brazil to Latin American countries and, in English, as a national training course in Romania, with six and four weeks duration, respectively. In 2001, the course was offered at Argonne National Laboratory in the USA for participants from Asian countries. In 2001 and 2002, the course was offered in Saclay, France for participants from Europe. Since then the BPTC has been used all over the world and part of it has been translated into various languages. In particular, it is held on a regular basis in Korea for the Asian region and in Argentina for the Latin American region.

In 2015 the Basic Professional Training Course on Nuclear Safety was updated to the current IAEA nuclear safety standards. The update includes a BPTC text book, BPTC e-book and 2 “train the trainers” packages, one package for a three month course and one package is for a one month course. The “train the trainers” packages include transparencies, questions and case studies to complement the BPTC.

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Editorial Note

The update and the review of the BPTC was completed with the collaboration of the ICJT Nuclear Training Centre, Jožef Stefan Institute, Slovenia and IAEA technical experts.
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1 INTRODUCTION

Learning objectives
After completing this chapter, the trainee will be able to:
1. Define the term plant renewals.
2. Describe the basic purpose of plant modifications.
3. Define the term plant upgrades.
4. Define and list different power uprates.
5. Explain the purpose of a periodic safety review (PSR).
6. Explain degradation mechanisms and ageing effects in nuclear power plants.
7. Define long term operation (LTO).

1.1 Definition of terms

Once a nuclear power plant is completed and approved for operation, its operation needs to comply with all applicable regulations and standards and other relevant safety requirements. Throughout its lifetime, the plant should be regularly inspected, tested and maintained, in accordance with approved procedures, to ensure that it continues to meet the design requirements and remains in compliance with the assumptions and results of the safety analysis.

Over its lifetime, a plant may undergo various changes on the basis of feedback of operational experience, the findings of periodic safety reviews, regulatory requirements, advances in knowledge and/or improvements in technology.

Reasons for modifications:

Economic reasons (e.g. for increased power or for the use of mixed oxide fuel).

To ensure recovery from an identified fault condition or a plant failure.

This Volume addresses several topics related to modifications to a nuclear power plant or research reactor that may take place during the life cycle of the installation. Modifications have many forms:
- Modifications to the physical configuration of the plant;
- The management and organization of the plant;
- The operating limits and conditions (OLCs) and operating procedures;
- The utilization of the facility in the case of research reactors.
Module XII: Plant renewals, modifications and upgrades, ageing

Generally, modifications must be subjected to the same rigorous safety assessment and regulatory review that was applied to the original installation. Regardless of the purpose or nature of a modification, it must be carefully evaluated to be sure that safety is not degraded and that cost-benefit criteria are satisfied. Modifications must be kept under strict control throughout the lifetime of the plant to ensure that configuration control is not lost at any time.

Modifications may be replacement or refurbishment of equipment items that have reached their end of life or no longer meet reliability standards.

In such cases, the term RENEWAL may be applied.

Modifications may also involve changes in structures, systems and components needed to mitigate ageing and other degradation mechanisms, as well as to take advantage of advances in technology and operating experience to upgrade the performance and safety of the installation.

In such cases, the term UPGRADES may be applied.

Increased demand for electricity and difficulties in gaining approval for new power plants has led many owners of nuclear power plants to apply for increases in the maximum power level at which the plant can operate, a process termed uprating.

Power uprates may cover a range from small uprates of a few percent to major uprates of 20% or more. Small uprates can be achieved without changes to the plant by using better analytical techniques for calibrating reactor power, measurements of feedwater flow and other reactor parameters.

Larger uprates can be achieved by changes to instrumentation set points, but without major plant modifications. Still larger uprates may be possible, but may require major plant modifications, such as improvements or replacement of the main turbine, or changes in fuel enrichment and fuel loading pattern.

Periodic Safety Reviews (PSRs) are considered to be an effective way to obtain an overall view of actual plant safety and the quality of the safety documentation, and to determine reasonable and practical modifications to ensure safety or improve safety to an appropriate high level.

On the basis of experience, the first PSR should be undertaken about ten years after the start of operation and subsequent PSRs every ten years until the end of operation. The duration of a PSR should not exceed three years. Within a period of ten years, there is a likelihood
of significant changes in safety standards, technology and underlying scientific knowledge and analytical techniques.

A PSR is part of the regulatory system in many states. It provides reassurance that there continues to be a valid licensing basis, with plant ageing, modifications to the plant and current national and international safety standards taken into account. Some states prefer alternative arrangements to PSRs, such as a systematic safety assessment programme dealing with specific safety issues, significant events and changes in safety standards and practices as they arise.

The objective of a PSR is to determine by means of a comprehensive assessment of an operational nuclear power plant the following:
- The extent to which the plant conforms to current national and international safety standards and practices;
- The extent to which the licensing basis remains valid;
- The adequacy of the arrangements that are in place to maintain plant safety until the next PSR or the end of the plant’s lifetime; and
- The safety improvements to be implemented to resolve identified safety issues.

Many systems, structures, and components (so-called SSCs) in industrial facilities, including nuclear power plants, are subject to ageing degradation.

For nuclear power plants, AGEING degradation is defined as ageing effects that could impair the ability of a structure, system or component to function within its acceptance criteria.

Ageing effects can be observed in a variety of changes in the physical properties of metals, concrete, and other materials in a power plant. These materials may undergo changes in their dimensions, ductility, fatigue capacity, mechanical or dielectric strength.

Ageing effects results from a variety of degradation mechanisms, and physical or chemical processes such as:
- Fatigue;
- Cracking;
- Embrittlement;
- Wear;
- Erosion;
- Corrosion and
- Oxidation.

These degradation mechanisms act on SSCs as a result of a challenging environment with high temperatures and pressures, radiation, reactive chemicals, and synergistic effects. Some operating practices such as power plant cycling (i.e., changing the power output)
and equipment testing can also create stress for plant SSCs.

There is a fairly limited set of degradation mechanisms, a large commonality in materials used, and fairly similar operating conditions. However, due to the diversity in plant designs, construction and materials used, operating conditions and histories, and maintenance practices, the specific effects of ageing, although similar, are unique for each plant. Even near-twin units at the same site can have substantial differences in the remaining lives of their major SSCs, based on subtle design or material differences and operating histories.

In recent decades, the number of IAEA Member States giving high priority to continuing the operation of nuclear power plants beyond the time frame originally anticipated for their lifetime (typically 30–40 years) has steadily increased. This is related both to economic conditions and to the age of nuclear power plants connected to the grid worldwide.

**Long Term Operation (LTO) of a nuclear power plant is defined as**
operation beyond an established time frame set forth by, for example, the licence term, design, standards, licence and/or regulations, which has been justified by safety assessment, with consideration given to life limiting processes and features of systems, structures and components (SSCs).

### 1.2 Questions

1. Define and list different modifications.
2. When can we use the term “Renewal”?
3. When can we use the term “Upgrade”?
4. What are the reasons for power uprates?
5. What is the difference between small and large uprates?
6. How do we define ageing effects and degradation mechanisms?
7. What is the main purpose of the periodic safety review (PSR)?
8. What is long term operation (LTO)?
2 IAEA SAFETY STANDARDS

Learning objectives
After completing this chapter, the trainee will be able to:
1. Recognize important safety standards for ageing management, modifications and power upgrades.

For this volume the following safety guides and safety requirements from IAEA Safety Standards Series are relevant:
- Safety guide NS-G-2.3; Modifications to Nuclear Power Plants,
- Specific Safety Requirements SSR-2/2; Safety of Nuclear Power Plants – Commissioning and Operation,
- Safety Guide SSG-25; Periodic Safety Review of Nuclear Power Plants,

Safety Guide NS-G-2.3 provides guidance and recommendations on controlling the activities related to modifications at NPPs designed to reduce risk, ensure that configuration control is maintained and ensure that the modified configuration satisfies licensing requirements. Guidance on changes in management is intended to ensure that such changes do not compromise the safety of the plant.

Recommendations are provided on:
- The roles and responsibilities of the operating organization, the regulatory body and other organizations, such as contractors;
- Modifications relating to the plant configuration, including categorization by safety significance, safety assessment, review and design considerations, modifications to OLCs, modifications to operating procedures and modifications to computer-based systems, and their implementation;
- Modifications to management systems, including organizational changes and their implementation, operation management and safety assessment tools and processes; and
- Quality assurance, training and management of documentation.

Specific Safety Requirements SSR-2/2 “Safety of Nuclear Power Plants: Commissioning and Operation” provides requirements for commissioning and operation related to the topic of this module such as:
- Requirement 10: Control of plant configuration;
- Requirement 11: Management of modifications;
- Requirement 12: Periodic safety review;
- Requirement 13: Equipment qualification;
- Requirement 14: Ageing management;
- Requirement 15: Records and reports; and
- Requirement 16: Programme for long term operation.

**Safety Guide SSG-25, Periodic Safety Review for Nuclear Power Plants** provides guidance and recommendations for periodic safety reviews of nuclear power plants, but could be applied with a suitable graded approach to research reactors and other nuclear installations. Routine reviews of NPP operations and special reviews following events of safety significance are the primary means of safety verification of operating installations. Some Member States have initiated a process termed the periodic safety review to assess the cumulative effects of plant ageing and plant modifications, considering operating experience, technical developments and siting considerations.

The reviews include an assessment of plant design and operation in the light of current safety standards and practices. The PSRs are complementary to routine and special reviews and do not replace them. Periodic safety reviews may reveal the need for plant modifications. Recommendations are provided on:

- The strategy for a PSR;
- Safety factors in a PSR;
- Roles and responsibilities in a PSR;
- The procedure for conducting a PSR;
- The basis for acceptability of continued plant operation and
- Post-review activities.

**Safety Guide NS-G-2.12** (Ageing Management for Nuclear Power Plants) provides recommendations for managing the ageing of SSCs important for safety in nuclear power plants, including recommendations on key elements of effective ageing management. The Safety Guide is intended for use by operators in establishing, implementing and improving systematic ageing management programmes for nuclear power plants. This Safety Guide may be used by regulators in preparing regulatory standards and guides, and in verifying that ageing in nuclear power plants is being effectively managed. This Safety Guide deals with the establishment, implementation and improvement of ageing management programmes for SSCs important to safety in nuclear power plants. The Safety Guide mainly focuses on managing the physical ageing of SSCs important to safety. It also provides recommendations on safety aspects of managing obsolescence and on the application of ageing management for long term operation. Issues relating to staff ageing and knowledge management are outside the scope of this Safety Guide.
3 AGEING MANAGEMENT

Learning objectives
After completing this chapter, the trainee will be able to:
1. Define the term ageing.
2. List the main ageing effects.
3. Explain the basic concepts of ageing management.
4. Explain the purpose of proactive ageing management.
5. List the most important tasks in ageing management in operation.
6. Explain the purpose of management of obsolescence.
7. Explain the aim of the IGALL programme.

Ageing is defined as a general process in which the characteristics of a structure, system or component gradually change with time or use.

It is common experience that over long periods of time, there is a gradual change in the properties of materials. These changes can affect the capability of engineered components, systems, or structures to perform their required function. Not all changes are deleterious, but it is commonly observed that ageing processes normally involve a gradual reduction in performance capability. All materials in a nuclear power plant can suffer from ageing and can partially or totally lose their designed function. Ageing is not only of concern for active components (for which the probability of malfunction increases with time) but also for passive ones, since the safety margin is being reduced towards the lowest allowable level.

The main degradation mechanisms and ageing effects of concern are:
- Changes in physical properties (e.g., electrical conductivity);
- Irradiation embrittlement;
- Thermal embrittlement;
- Creep;
- Fatigue;
- Corrosion (including erosion and cracking assisted by corrosion);
- Wear (e.g., fretting and cracking assisted by wear, such as fretting fatigue).

The term "ageing" thus represents the cumulative changes over time that may occur within a component or structure because of one or more of these factors. From this perspective, it is clear that this is a complex process that begins as soon as a component or structure is produced and continues throughout its service life. Ageing is certainly a significant factor in determining the limits of nuclear plant lifetime or life extensions. No nuclear plant, including those still under construction or being mothballed, should be considered immune from its effects.
The rate of ageing depends strongly on both the service conditions and the material sensitivity to those conditions. Therefore, consideration of ageing must start in the design phase by selecting appropriate materials and should be continued throughout their complete life cycle. Although nuclear plant ageing could have an impact on the efficiency of electric power generation, safety could also be affected – if degradation of key components or structures is not detected before loss of functional capability, and if timely corrective action is not taken. What must be understood is how the ageing process may change the likelihood of component failures (and therefore reduce safety margins), and how age degradation can cause such events to be initiated.

Concerns about ageing of equipment stem from the fact that failure can occur simultaneously (or effectively so) in redundant safety systems. Redundancy (coupled with diversity) is the principal means of guarding against the consequences of random failures of equipment and providing assurance that at least one complete chain of safety systems is functional at all times during plant operation. The required protection would not be provided if equipment ageing degrades the functional capability to the point where the increase in stress levels associated with a design basis event could cause simultaneous failure of redundant systems (or their failure within a critical interval of time).

### 3.1 Basic concepts of ageing management

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

**Physical ageing of SSCs may increase the probability of common cause failures, i.e. the simultaneous degradation of physical barriers and redundant components, which could result in the impairment of one or more levels of protection provided by the defence in depth concept.**

Effective ageing management is in practice accomplished by coordinating existing programmes, including maintenance, in-service inspection and surveillance, as well as operations, technical support programmes (including analysis of any degradation mechanisms) and external programmes such as research and development.

Understanding the ageing of a structure or component is the key to its effective ageing management. This understanding is derived from knowledge of:
3.2 Proactive ageing management

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

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

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

Other responsibilities of the operating organization are:
- **Design**: In the design and procurement documents for new facilities or SSCs, the operating organization should specify requirements to facilitate ageing management, including information to be included in documents received from suppliers and other contractors.
- **Fabrication and construction**: The operating organization should ensure that suppliers adequately address factors affecting ageing management and that sufficient information and data are provided to the operating organization.
- **Commissioning**: The operating organization should establish a systematic programme for measuring and recording baseline data relevant to ageing management for SSCs important to safety.
- **Operation**: A systematic approach to managing ageing should
be applied during plant operation.

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

### 3.3 Ageing management in operation

The most important tasks in ageing management in operation are:

- **Organizational arrangements:** the involvement and support of the operating organization and external organizations, experts from operations, maintenance, engineering, equipment qualification, design and research and development should be included;
- **Data collection and record keeping:** the system should be established early in the lifetime of the plant;
- **Scoping and screening of SSCs for the purposes of ageing management:** the focus should be on those SSCs that can have a negative impact on the safe operation of the plant and that are susceptible to ageing degradation;
- **Ageing management review:** the essential elements are understanding ageing (knowing examples of significant degradation mechanisms, materials and components), monitoring ageing and mitigation of ageing effects;
- **Condition assessment:** the actual condition of a structure, a component or a group of structures and components selected by the scoping and screening process should be determined on the basis of background information provided by the output of the ageing management review;
- **Development of ageing management programmes;**
- **Implementation of ageing management programmes;**
- **Improvement of ageing management programmes.**

The ageing management programme should identify effective and appropriate actions and practices for managing ageing that provide for timely detection and mitigation of ageing, its effects on the structure or component, and indicators of the effectiveness of the programme.

### 3.4 Management of obsolescence

Obsolescence of SSCs important to safety should be managed proactively throughout their service life.

The obsolescence management activities of the operating organization should be overseen by the regulatory body throughout the lifetime of the plant.
The operating organization should establish a programme for the management of obsolescence. This includes:

- Setting out the policy, objectives and organizational arrangements;
- Allocating appropriate resources (human and financial) and
- Monitoring the programme to ensure that it meets its objectives.

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

### 3.5 International general ageing lessons learned (IGALL) programme

Systematic ageing management provides for the availability of safety functions throughout the service life of the plant and decommissioning, taking into account changes that occur with time and use. This requires addressing both the physical ageing of systems, structures and components (SSCs), which result in the degradation of their performance characteristics, and the obsolescence of SSCs, i.e. as compared to the latest technology, standards and regulations.

Effective ageing management throughout the service life of an SSC requires the use of a systematic approach to managing ageing that provides a framework for coordinating all programmes and activities relating to the understanding, detection, monitoring, control and mitigation of ageing effects of plant components or structures. These activities include maintenance, in-service inspection, testing and surveillance, as well as operations, technical support programmes (including the analysis of any ageing effects and degradation mechanisms) and external programmes such as research and development.

Many IAEA Member States have already taken action to address the topic of ageing in their nuclear power plants. In 2009 the IAEA conducted a Technical Meeting where Member States recommended establishing an international platform for discussion between regulators and utilities regarding implementation of acceptable ageing management programmes (AMPs). The recommendations were to:

- Develop and maintain a document which can serve as a practical guide for implementing, maintaining and improving AMPs, made up of best practices and universal knowledge on proven AMPs for safety related SSCs;
- Establish a common basis for discussion between regulators and utilities with regard to implementation of acceptable AMPs.
In response, the IAEA initiated the ‘International General Ageing Lessons Learned’ Programme (IGALL).

The IGALL database is publicly available on IAEA web sites and contains information relevant for SSCs important to safety:

- A generic sample of ageing management review tables;
- A collection of proven ageing management programmes;
- A collection of typical time-limited ageing analyses.

This information is based on the approaches developed and implemented in various types of reactor designs in participating Member States and is periodically updated.

IGALL provides an internationally recognized basis for ageing management programmes, as well as a knowledge base for ageing management with respect to the design of new plants, design reviews, safety reviews (such as periodic safety reviews), etc., and serves as a guide for ageing management review and improvement.

The programme is being implemented in coordination with national and international partners on ageing management (the European Commission and the Nuclear Energy Agency of the Organization for Economic Co-operation and Development, etc.).

### 3.6 Questions

1. Why is ageing important for nuclear power plant safety?
2. What are the main ageing effects with an influencing long-term plant operation?
3. What are the basic ageing management concepts?
4. What are the responsibilities of the operating organization in providing proactive ageing management?
5. What are the most important tasks in ageing management in operation?
6. What should a programme for the management of obsolescence include?
7. What is the aim of the IGALL programme?
4 LONG TERM OPERATION

Learning objectives
After completing this chapter, the trainee will be able to:
1. Explain the basic principles of the approach to LTO.
2. List preconditions for LTO.
3. List the main steps in the review process.
4. List some examples of time limited ageing analysis.
5. Describe the aim of the SALTO peer review.
6. List the most important parts of the peer review preparation phase.

The nuclear power plants that are currently in operation were generally designed and built to conservative standards, and in many cases have significant remaining safety margins.

Current engineering technology is able to assess the remaining safety margins in the physical condition of SSCs in nuclear power plants and indicate whether safe Long Term Operation (LTO) is technically feasible.

In the initial period of operation, national or international regulations often required that nuclear power plants be operated in a conservative manner compared with their design criteria. The combination of conservative design and conservative operation that follows national and international practices is an essential basis for continuing operation beyond the initially established time frame.

Over the years operating experience has accumulated knowledge of physical ageing phenomena affecting SSCs (e.g. radiation embrittlement, stratification, nickel based alloy corrosion). Continuing research has also contributed to that goal. In cases where the useful life of individual components proved to be less than their intended design life, component replacements have taken place that allowed continued operation of the plant in accordance with safety principles and regulations. Plant surveillance, inspection and maintenance programmes, and consideration of feedback on operating experience, play an essential role in ensuring the safe operation of nuclear power plants in the current design period as well as in LTO.

4.1 Principles and approach to long term operation

The approach to LTO is based upon the following principles:
- **Current operational practices** meet national regulations and follow international guidelines as applicable and are designed to ensure safe operation of the plant in the current design period.
- **The existing regulatory process** is appropriate to maintain safe
operation of the nuclear power plant for the current authorized period and focuses on the effects of ageing that need to be properly managed for the planned period of LTO.

- **The current licensing basis (CLB)** provides an acceptable level of safety for the current authorized period and is continued over the planned period of LTO in the same manner and to the same extent, with the exception of any changes specific to LTO.
- **Existing nuclear power plant programmes** may be licensed for use in LTO provided that they are consistent with the nine elements.

The decision of an operating organization to pursue LTO is based upon an evaluation that covers the following elements:

- Strategic elements such as the need for electric power and issues concerning supply diversity;
- Applicable regulatory requirements, including an assessment of the adoption of new requirements;
- A technical assessment of the physical condition of the nuclear power plant, including identification of enhancements or modifications to the physical facility if necessary, and of the impact of changes on nuclear power plant programmes and procedures necessary for continued safe operation;
- A technical assessment of the environmental impact of LTO;
- An economic assessment.

### 4.2 Preconditions for long term operation

The existing nuclear power plant programmes and documentation are essential in developing the foundation for successful LTO. The existence of all the following nuclear power plant programmes and documentation, which impact upon all SSCs of nuclear power plants and areas of safe plant operation, is considered a precondition for LTO:

- Plant programmes;
- A management system that addresses quality assurance and configuration management;
- Original time limited ageing analyses;
- Current safety analysis report or other licensing basis documents.

Each precondition needs to be properly documented in the current safety analysis reports or in other licensing basis documents and clearly and adequately describes the current licensing basis (CLB) or the current design basis requirements for plant operation.

Plant programmes are a planned series of events or a set of related long term measures or activities that are performed and conducted in a certain order or manner to achieve the purpose for which the plant was constructed. Plant programmes in the five areas listed below are
considered preconditions for LTO and are necessary to support the modifications for LTO associated with ageing management:

- Maintenance;
- Equipment qualification;
- In-service inspection (ISI);
- Surveillance and monitoring;
- Monitoring of chemical regimes.

**Maintenance programmes** are reviewed and evaluated for effectiveness in maintaining the intended function of each SSC within the scope of LTO. The review provides a technical basis that demonstrates whether the degradation mechanisms will be adequately managed by the proposed activities. Maintenance programmes for LTO clearly identify the links with ageing management programmes, including the frequency of maintenance activities and specific information on tasks and records and on their evaluation and storage. A systematic approach to maintenance addresses technical aspects such as development of acceptance criteria, reliability-centred maintenance, condition based maintenance and risk-informed methods.

**Equipment qualification** establishes that equipment, while being subject to environmental conditions, is capable of performing its intended safety functions, or that it will be replaced/repaird so that its intended safety functions will not be compromised during the planned period of LTO. Equipment qualification also demonstrates whether the environmental and seismic qualification of equipment will remain valid over the expected period of LTO.

**In-service inspection (ISI) programmes** are evaluated for effectiveness in detecting degradations of each SSC. The review process provides a technical basis that demonstrates whether the ageing phenomena will be adequately detected by the proposed inspection or monitoring activities.

**The surveillance programme** confirms the provisions for safe operation that were considered during the design phase, checked during construction and commissioning, and verified throughout operation. The programme will continue to supply data to be used for assessing the service life of SSCs for the planned period of LTO, for example through existing or additionally installed diagnostic systems. At the same time, the programme verifies that the safety margins are adequate and provides a high tolerance for anticipated operational occurrences, errors and malfunctions. Particular attention is paid to the following aspects:

- The integrity of the barriers between radioactive material and the environment (primary pressure boundary and containment);
- The availability of safety systems such as the protection system, the safety system actuation systems and the safety system
support features;
- The availability of items whose failure could adversely affect safety.

**Monitoring of chemical regimes** is important and may be used to minimize the harmful effects of chemicals, chemical impurities and corrosion on plant systems for LTO. The operating organization reviews its water chemistry programme to ensure that the programme is effective in maintaining the water quality required by the technical specifications.

### 4.3 Ageing management review for long term operation

To facilitate long term operation of a nuclear power plant, the operating organization should demonstrate, and the regulatory body should oversee, that the safety of the plant is acceptable when compared with current safety standards.

The review process should involve the following main steps:
- An appropriate scoping and screening method to ensure that structures and components important for safety will be evaluated for long term operation;
- Demonstration that the effects of ageing will continue to be identified and managed for each structure or component during the planned period of long term operation;
- Revalidation of time-limited ageing analyses, to demonstrate their continuing validity or that the ageing effects will be effectively managed, i.e. to demonstrate that the intended function of a structure or component will remain within the design safety margins throughout the planned period of long term operation.

Requirements for modifications of existing plant programmes and development of any new programmes should be identified and implemented. The results of the review of ageing management for structures and components for long term operation should be documented.

### 4.4 Time limited ageing analysis (TLAA)

An important part of the technical requirements in the licence renewal rule is to identify any structures and components that are subject to time-limited analysis. These are the calculations and analysis that:
- Involve SSCs within the scope of licence renewal;
- Consider the effects of ageing;
- Involve time-limited assumptions defined by the current operating term (for example 40 years);
- Were determined to be relevant by the licensee in making a safety determination;
- Involve conclusions or provide the basis for conclusions related to the capability of an SSC to perform its intended functions; and
- Are contained in or incorporated by reference in the licensing basis.

**Examples of time-limited ageing analysis:**
Fatigue analysis, environmental qualification of electrical equipment, embrittlement of reactor vessel, pressurized thermal shock, relaxation of pre-stressed tendons, and settlement of the foundations.

### 4.5 IAEA Safety Aspects of Long Term Operation (SALTO) Peer Review Service

The Safe Long Term Operation (SALTO) peer review is a comprehensive operational safety review service directly addressing strategy and the key elements for safe LTO of NPPs, which includes **Ageing Management Assessment Team (AMAT) objectives** and complements OSART reviews.

The SALTO peer review service is designed to assist NPP operators in adopting a proper approach to the LTO of their plants and in implementing complete and appropriate activities to ensure that plant safety will be maintained during the LTO period.

The SALTO peer review service can be tailored to focus on ageing management programmes (AMPs) and/or on other programmes related to LTO to support Member States in enhancing the safety of their NPPs. The SALTO peer review service can also support regulators in establishing or improving regulatory and licensing strategies for LTO of NPPs.

The SALTO peer review is based on Specific Safety Requirements for NPP operation SSR-2/2 and follows the IAEA Safety Report on Safe Long Term Operation of Nuclear Power Plants that addresses the following areas:
- LTO feasibility (feasibility studies, preconditions for LTO, plant programmes);
- Scoping and screening of systems, structures, and components (SSCs);
- Assessment and management of SSCs for ageing degradation for LTO;
- Time limited ageing analysis (TLAA, also termed safety analysis that uses time-limited assumptions);
- Documentation.
The SALTO peer review is conducted by a team of international experts with direct experience in the areas of the review. Judgements of performance are made on the basis of IAEA safety standards and other IAEA publications, and of the combined expertise of the international review team. The review is neither a regulatory inspection nor is it an audit against national codes and standards. The review is a technical exchange of experiences and practices at the working level aimed at strengthening the programmes, procedures and practices being followed.

The key objectives of the peer review are to provide:

- The host organization with an objective assessment of the status of preparedness for LTO with respect to international nuclear safety standards;
- The host organization with recommendations and suggestions for improvement in areas where performance falls short of international best practices;
- Key staff at the host organization with an opportunity to discuss their practices with experts who have experience with related practices in the same field;
- Member States with information regarding good practices identified in the course of the review;
- Reviewers and observers from Member States and IAEA staff with opportunities to broaden their experience and knowledge of their own field.

The SALTO peer review consists of the following elements:

- A workshop/seminar on IAEA safety standards and the SALTO review method;
- A pre-SALTO mission (more than one pre-SALTO mission can be performed for one plant, if required);
- The SALTO mission;
- The Follow-up SALTO mission.

The review addresses the following areas:

- A: Organization and functions, current licensing basis (CLB), configuration/ modification management;
- B: Scoping and screening and plant programmes relevant to LTO;
- C: Review of ageing management programmes and revalidation of time-limited ageing analyses for mechanical components;
- D: Review of ageing management programmes and revalidation of time-limited ageing analyses for electrical and I&C components;
- E: Review of ageing management programmes and revalidation of time-limited ageing analyses for civil structures;
- F: Human resources, competence and knowledge management for LTO (optional area).

Further areas related to LTO may be optionally covered if requested:
- Management, organization and administration, training and qualification, technical support, etc.

**Preparation of SALTO peer review**

Preparation is the key element of all phases of a peer review. The three most important parts of the preparation phase are:

- Preparation of logistics, mission scope and schedule with the host organization;
- Selecting a team of experts with appropriate experience;
- Preparation of an Advance Information Package by the host organization.

Preparation should begin not later than six months prior to the mission. This will enable all the experts to plan for specific activities and to conduct the necessary research and study prior to the mission. After a request for a SALTO mission has been received from a Member State, the IAEA designates a team leader. At the same time, the host organization nominates a contact person, the representative counterpart, with whom the team leader may correspond.

The team is composed of a team leader, who is an IAEA staff member, and up to six experts. A deputy team leader is assigned if necessary. A typical team composition includes a majority of external experts (usually senior experts from peer organizations) and one or two IAEA staff members (the team leader and the deputy team leader if applicable). No reviewer from the country to which the host organization belongs should be included in the team.

The SALTO mission report contains the following information:

- Executive summary;
- Introduction, describing the background for conducting the review, the scope and objectives of the review, and a description of the conduct of the review;
- Mission results containing general conclusions, detailed conclusions and good practices;
- Processing and presentation of issue sheets;
- Issue sheets that contain the issue description, facts and recommendations and suggestions.

### 4.6 Questions

1. What is the essential basis for continuing plant operation beyond the initially established time frame?
2. What principles are important in the approach to LTO?
3. What are the preconditions for LTO?
4. What calculations and analyses are important in the time-limited
5. List some examples of time-limited ageing analysis (TLAA).
6. What is the purpose of the SALTO peer review process?
7. What are the three most important parts of the peer review preparation phase?

5 MODIFICATIONS AND UPGRADES

Learning objectives

After completing this chapter, the trainee will be able to:
1. List and describe five reasons for carrying out modifications to nuclear power plants.
2. List the roles and responsibilities of the operating organization in the reactor modification process.
3. Explain the basis and reasons for power uprating.

5.1 Reasons for modifications

The IAEA Safety Guide NS-G-2.3 (Modifications to Nuclear Power Plants) lists five reasons for carrying out modifications to nuclear power plants:

- Maintaining or strengthening existing safety provisions and thus maintaining consistency with or improving on the current design,
- Recovering from plant faults;
- Improving the thermal performance or increasing the power rating of the plant;
- Increasing the maintainability of the plant, reducing the radiation exposure of personnel, or reducing the costs of plant maintenance;
- Extending the design life of the plant (currently called long term operation).

Maintaining or strengthening existing safety provisions

As a result of the PSR, modifications may be made to resolve any safety issues identified. Periodic safety reviews are discussed in more detail later in this Volume.

Modifications may also be made to reflect the results of a plant-specific probabilistic safety assessment (PSA). This analysis may uncover contributions to risk that have not been detected in the deterministic safety analysis, and reveal ways in which cost-effective plant modifications can provide significant risk reduction.

Modifications may also be made as a result of specific events. In the U.S.A., extensive modifications were made to the physical configuration of NPPs and to their management and regulation in response to the Three Mile Island accident of 1979. Also in the U.S.A., modifications of many LWRs were made to improve their
safety margins in Anticipated Transients without Scram (ATWS) events. In the 1990s, major modifications were made to many VVER and RBMK reactors to improve their safety.

**Recovering from plant faults**
Examples of modifications made for recovery from plant faults include steam generator replacements in many PWRs, head replacements in some PWRs, and many other modifications to correct design and operational problems.

**Improving the thermal performance or increasing the power rating of the plant**
Many modifications to existing plants have been made for this reason. Uprating has been pursued since the 1970s, but has been especially common since about 1990. World-wide, in the interval from 1990 to 2004 there was an increase in annual nuclear energy production from 1901 TWh to 2619 TWh, i.e. by 718 TWh. Clearly, power uprates have been an important factor in the contribution of nuclear power to electrical energy production.

**Increasing the maintainability of the plant, reducing the radiation exposure of personnel, or reducing the costs of plant maintenance**
Many advances have been made in such areas as risk-informed maintenance and in maintenance procedures designed to minimize exposure of personnel. Important advances have been made in plant outage planning and in execution of major maintenance tasks, such as refuelling and steam generator replacement.

**Long term operation (LTO)**
Extending the operating life of existing NPPs, currently called LTO in IAEA Safety Standards (SSR 2/2 Safety of NPPs: Commissioning and Operation, among others) has been a very important area in recent years. Preparation of an NPP for LTO primarily involves assessment of preconditions for LTO, an ageing management review of SSCs in the scope for LTO, a review of ageing management programmes and revalidation of time-limited ageing analysis (TLAAs).

The engineering assessment should take into account:
- The applicable design basis and regulatory requirements;
- Materials;
- Service conditions;
- Stressors;
- Critical locations;
- Degradation mechanisms;
- Ageing effects;
- Appropriate indicators;
- Quantitative or qualitative models of relevant ageing phenomena.
The result of the engineering assessment may lead to development of new or improvement of the existing ageing management programmes.

In some cases, components such as steam generators and the reactor vessel head have been replaced, but many passive, long-lived components are the original ones. Modifications may involve new monitoring programmes or augmented in-service inspections.

To facilitate long term operation of a nuclear power plant, the operating organization should demonstrate, and the regulatory body should oversee, that the safety of the plant is acceptable when compared with current safety standards and requirements.

### 5.2 Modifications to reactors

**Roles and responsibilities**

The operating organization should retain responsibility for the safety implications of the modification and for obtaining review and approval from the regulatory body as required. The different roles and responsibilities of the operating organization are shown in Figure 5.1.
Fig. 5.1: Roles and responsibilities of the operating organization.

The regulatory body (RB) should be involved in the modification process to the extent justified by the safety significance of the modification. As required by national regulations, the RB may review:

- Proposals for modification to SSCs and software important to safety;
- Proposals for modification to OLCs that affect the basis for the operating licence;
- Proposals for modification of procedures and other documents originally approved by the RB;
- Other proposals as deemed appropriate.

If required by national regulations, the RB should review and agree to changes in the operating organization’s structure, processes and management programmes that may have safety consequences. The RB also (if required) approves safety-related modifications and may issue a new or modified licence, signifying that the modification complies with regulatory requirements.

The RB should require that the operating organization has adequate arrangements to control the modification process, including categorization of the modifications.

The operating organization may contract engineering, assessment and execution of modifications to other organizations, but it remains the organization responsible for safety.

**Modifications relating to plant configuration**

A proposed modification should be categorized in accordance with its safety significance according to an established procedure agreed with the regulatory body. A possible categorization could be:

- **Category 1:** A modification that has a significant effect on the radiological risk or may involve alteration of the principles and conclusions on which the design and licensing of the plant were based. Such modifications may involve changes in the set of design basis accidents, alter the technical solutions adopted for meeting the safety goals, or lead to changes in operating rules. Such modifications require thorough analysis and possibly prior regulatory approval.

- **Category 2:** Changes in safety-related items, systems, operating approaches or procedures that usually require updating of the safety analysis report or other licensing documents, but have only a minor influence on safety and no significant alteration to the licensing principles.
- **Category 3**: Modifications that have no safety consequences, or involve items not important to safety, and have no potential for a significant increase in risk.

The principles for managing modifications are the same for all categories, but the categorization determines the depth and breadth of the safety review and regulatory control.

An initial safety assessment should be carried out before starting a modification to determine its safety significance and whether it is within the regulatory constraints for plant design and operation. Depending on the results of the initial safety assessment, a more comprehensive assessment may be needed, which should include an evaluation of the effect of the modification on radiological hazards throughout the life cycle of the modification, and demonstrate that the modified plant can be operated safely and in compliance with the system specifications and safety requirements. The comprehensive safety assessment should include both deterministic and probabilistic safety analysis, including use of a plant-specific probabilistic model if one is available and reliable.

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**The scope, safety implications and consequences of proposed modifications should undergo an independent assessment by personnel not immediately involved in their design or implementation.**

*These reviews should include independent validation and verification of software changes for major modifications.*

Modifications should minimize deviations from the characteristics and intent of the original design. Modifications relating to plant configuration should conform to the safety requirements for design; in particular, the capability of performing all safety functions shall not be degraded.

If changes to the operational limits and conditions are necessary, they should be considered to be modifications of Category 1 (or the equivalent). The OLCs should be reassessed and revised as necessary following any safety-related plant modification or change to the safety analysis report, and also on the basis of accumulated experience and technological developments. Particular care should be taken to ensure that the effects of any temporary changes to the OLCs are assessed and approved at the same level as a permanent modification.

Modifications to the operating procedures should be categorized in a manner similar to that used for other modifications and detailed safety assessments performed for changes in Categories 1 and 2 (or the equivalent). Modified operating procedures should be verified and validated before use, and operators should be trained in the revised procedures.
A structured change process under an effective configuration management system should be in place to govern both hardware and software changes. Strict configuration control should be maintained throughout the modification process for software. Only those items that have been through the entire change process should be installed. The modification process should include a comprehensive validation and verification process to establish the suitability of the changes. Possible common mode failure of redundant computer-based safety systems should be fully considered in the modification process.

Attention should be given to interrelationships between modifications.

When modifications are made to SSCs and process software, or when modifications are made to the OLCs, the relevant operating instructions and procedures should be changed accordingly.

**Modifications to management systems**

The operating organization should establish documented operations management programmes. Any modifications to these programmes should be reviewed by the operating organization for their consequences for safety and should be submitted to the regulatory body as appropriate.

The operating organization should seek improvements in the tools and data used in safety assessment of the plant, including such things as probabilistic safety assessment, risk-informed decision making and advanced maintenance and inspection techniques. Any modifications to the existing tools and processes should be reviewed for their safety implications and submitted to the regulatory body if required. Similarly, modifications to neutronic or thermal-hydraulic computer codes or methods for core calculations and accident analysis should be submitted to the regulatory body as appropriate.

**Temporary modifications**

Except when explicitly permitted by established procedures, the configuration of SSCs important to safety should not be altered without written orders or instructions from authorized persons. Such alterations should not violate the OLCs.

The number of temporary modifications should be kept to a minimum, and a time limit should be specified for removal or conversion into permanent modifications.

The procedure for obtaining approval for a temporary modification should be the same as that for a permanent modification, but the process for temporary modifications should allow for rapid review and assessment in case of urgency. However, urgent actions should not
reduce levels of safety nor bypass necessary regulatory approval. The principles for managing modifications are the same for all categories, but the categorization determines the depth and breadth of the safety review and regulatory control.

### 5.3 Modifications for power uprating

An uprating project normally requires a systematic review of the safety analysis, nuclear fuel and plant, structures, systems and components. Understanding the implications of the new power level on plant operation, plant design margins and licensing basis issues is critical to a successful programme. A good feasibility study can be an essential support to a successful project. From a programmatic point of view, well known project management practices, application of appropriate resources, communication among participating organizations and use of an integrated project schedule/software are important tools for project planning and execution.

From experience, the secondary plant structures, systems and components are more challenging considering that design information may be incomplete, or just not available. For older plants, what is considered necessary documentation for today's environment might not have been required in the past.

The whole power uprate project can also be considered as an opportunity to address equipment ageing and obsolescence issues, improve understanding of plant margins, incorporate plant efficiency improvements, create better interaction with licence renewal and improve knowledge of design and operations.

The greatest part of a power uprate project is composed of the engineering effort that provides an analysis demonstrating that all other SSCs are adequate for the proposed level of power uprate.

In summary, a power uprate, exclusive of the modification packages and planning of start-up testing, consists primarily of a large engineering effort. By its nature, this engineering effort must be carefully coordinated with other interested parties such as Operations, Maintenance, Training and Licensing.

### 5.4 Questions

1. What are the five most important reasons for carrying out modifications to nuclear power plants?
2. What should the engineering assessment take into account?
3. What are the roles and responsibilities of the operating organization?
4. How could we categorize different modifications?
5. What is the main reason for a power uprate project?
6 PERIODIC SAFETY REVIEW (PSR)

Learning objectives
After completing this chapter, the trainee will be able to:
1. Describe the purpose of a periodic safety review (PSR).
2. Explain important inputs from a PSR in assessing long term operation.
3. List different safety factors in a PSR.
4. Explain the role and responsibility of different organizations in the PSR process.
5. List and explain the steps in a PSR project.

Since the first generation of commercial nuclear power plants started operating in the 1950s, there have been substantial developments in safety standards and practices, and in technology, resulting in new scientific and technical knowledge, better analytical methods and lessons learned from operating experience. At the same time, for assessing the degree of plant conformity to those standards and practices, periodic safety reviews (PSR) are increasingly valuable.

Operational nuclear power plants in many states are subject to both routine and special safety reviews. It is a challenge to organize safety reviews that take into account improvements in safety standards and operating practices, modifications at the plant, the cumulative effects of plant ageing, feedback from operating experience, and possible developments in science and technology.

In many Member States worldwide, the PSR has been introduced as part of the regulatory system, and frequently runs on a 10-year cycle.

While every country through its regulatory body is free to choose its own safety review methodology, the minimum standards in the EU have to comply with the recommendations of the IAEA which are set out in the IAEA Specific Safety Guide SSG-25 Periodic Safety Review for Nuclear Power Plants.

6.1 Inputs from a PSR in assessing long term operation or licence renewal

A PSR can be used for various purposes:
- As a systematic safety assessment carried out at regular intervals;
- In support of the decision making process for licence renewal;
- In support of the decision making process for long term operation.
Where the PSR is to be used to support the decision making process prior to entering long term operation, any necessary safety improvements to ensure that the licensing basis remains valid during the period of LTO should be specifically identified. Such improvements might include refurbishment, the provision of additional SSCs and/or additional safety analysis and engineering justifications.

Where the PSR is to be used in decision making for long term operation or licence renewal, the review should pay particular attention to the following plant programmes and documentation, as these are of significant importance for LTO as described in Requirement 16 of SSR 2/2 Safety of NPPs, Commissioning and Operation:

- The scope of the review of safety factors should be adapted to determine the feasibility of LTO. For example, the scope of the safety factor relating to ageing should be expanded to include an evaluation of time-limited ageing analyses and an ageing management review.
- In the review, increased importance should be given to degradation mechanisms and ageing management programmes.
- If the PSR is to be used to justify LTO or licence renewal, the entire planned period of long term operation should be considered, and not just the ten years until the next PSR.

### 6.2 Review of strategy and general methodology

The scope of the PSR should include all safety aspects of a nuclear power plant and should be agreed with the regulatory body.

The review should cover all facilities and SSCs on the site covered by the operating licence (including, if applicable, waste management facilities, on-site simulators, etc.) and their operation, together with the operating organization and its staff.

When performing a PSR of a nuclear power plant with several units:

- Aspects such as radiation protection, emergency planning and radiological impact on the environment could be covered in reviews that are common to all units;
- Other aspects (for example, the actual condition of SSCs important to safety, ageing and safety performance) should be covered in reviews that are specific to each unit.

The conduct of a generic PSR of multiple standardized units can, by taking advantage of similarities in plant design and operating practice, decrease the resources or effort necessary for the PSR.
Before the review work is started, a number of prerequisites should be satisfied. The main prerequisite is an agreement between the operating organization and the regulatory body as to the scope and objectives of the PSR, including current national and international standards and codes to be used. This agreement is documented in the ‘basis document’ for the PSR, which should be developed by the operating organization and made subject to approval and/or confirmation by the regulatory body.

The PSR basis document is an essential instrument that governs the conduct of the PSR and the regulatory review of the PSR results. The basis document should identify the scope, major milestones (including cut-off dates beyond which changes to codes and standards and new information will not be considered), the methodology of the PSR, the safety factors to be reviewed, the structure of the documentation and the applicable national and international standards, codes and practices.

If there are no adequate national standards, reference should be made to international codes and standards (such as those of the IAEA, the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC)) or, where appropriate, to codes and standards of a recognized organization of a particular State (for example, the American Society of Mechanical Engineers (ASME), the Nuclear Safety Standards Commission (Kerntechnischer Ausschuss), or the Institute of Electrical and Electronics Engineers (IEEE)).

The practices of international organizations, such as the good practices collected by the World Association of Nuclear Operators (WANO) and the IAEA, as well as the information generated by owners’ groups, could also be relevant and should be taken into account.

The PSR basis document should provide or refer to a project plan that identifies all the activities to be performed during the review, together with associated timelines and responsibilities. The schedule should take into account that the review of safety factors is an iterative process and that the interface between safety factors also needs to be taken into account.

International experience suggests that a first PSR at an older nuclear power plant may reveal discrepancies between the design documentation and the actual configuration, or that information on the design basis of SSCs important to safety is incomplete.

Safety improvements should be implemented in accordance with the integrated implementation plan submitted to the regulatory body for agreement or approval. For a PSR of plants with multiple units, safety improvements may be implemented in a lead unit and lessons learned may then be used for the implementation of safety improvements in
the remainder of the units.
6.3 Safety factors in the PSR

The 14 PSR safety factors have been selected on the basis of States’ experience. These factors are divided into five subject areas, plus a global assessment to integrate the review of the individual safety factors (table 6.1).

| Plant | 1. Plant design  
| 2. Actual condition of SSCs  
| 3. Equipment qualification  
| 4. Ageing  |
| Safety analysis | 5. Deterministic safety analysis  
| 6. Probabilistic safety analysis  
| 7. Hazards analysis  |
| Performance and feedback of experience | 8. Safety performance  
| 9. Use of experience from other plants and research findings  |
| Management | 10. Organization and administration  
| 11. Procedures  
| 12. Human factors  
| 13. Emergency planning  |
| Environment | 14. Radiological impact on the environment |

Plant design

The objective of the review of the plant design is to assess the adequacy of the design and its documentation against current international standards and practices.

The review of the plant design should establish a comprehensive list of SSCs important to safety. These SSCs should have appropriate characteristics and should meet the requirements for plant safety and performance, including prevention and mitigation of events that could jeopardize safety. The review should assess the plant design against current safety standards and determine the safety significance (strengths or weaknesses) of any differences in relation to defence-in-depth.

Actual physical condition of the nuclear power plant

The objective of the review is to determine the actual physical condition of the nuclear power plant and whether it is adequate to meet design requirements. The review should also confirm that the condition of SSCs is adequately documented.

Knowledge of the actual physical condition of the structures, systems
and components of the nuclear power plant is of prime importance if an objective PSR is to be carried out. This knowledge should, as far as possible, be determined at an early stage of the PSR and should then be continually updated. The validity of existing records should be checked to ensure that they accurately reflect the condition of SSCs.

Having determined the condition of SSCs important to safety, each such SSC should be assessed against its design basis to confirm that ageing has not significantly undermined the design basis assumptions. Where consistency with the design basis cannot be fully demonstrated, alternative arrangements should be made to show that the SSC is fit for purpose, or corrective actions should be proposed.

**Equipment qualification**

The objective of the review is to determine whether equipment important to safety is qualified to perform its designated safety function throughout its installed service life.

Nuclear power plant equipment important to safety should be properly qualified to ensure its capability to perform its safety functions under postulated service conditions, including those arising from natural events and accidents (e.g. loss of coolant accidents, high energy line break and seismic or other vibration conditions). The equipment qualification requirements should be prescribed by relevant regulatory codes and guides and industrial standards.

The review of equipment qualification should determine:
- Whether assurance of the required equipment performance capability was initially provided and
- Whether equipment performance has been preserved by ongoing application of measures such as scheduled maintenance, testing and calibration.

**Ageing**

The objective of the review is to determine whether ageing in a nuclear power plant is being effectively managed so that required safety margins are maintained, and whether an effective ageing management programme is in place for future plant operation.

Ageing, the effects of ageing and monitoring is explained in Chapter 3.
Deterministic safety analysis

The objective of the review of deterministic safety analysis is to determine the extent to which the existing analysis remains valid considering actual plant design, the actual condition of SSCs and their predicted state at the end of the PSR interval, current deterministic methods, and current safety standards and knowledge. The review should also identify any weaknesses in the application of defence-in-depth.

A deterministic safety analysis should be conducted for each nuclear power plant to confirm the design basis for items important to safety and describe plant behaviour for postulated initiating events. The current state of the safety analysis should be reviewed for completeness, scope, methods and assumptions. The review should update the analysis as needed to ensure that it is based on the actual plant design, the current and predicted future state of SSCs and that it considers all postulated initiating events appropriate for the plant and its site.

Current analytical methods should be used. The review should determine whether the actual plant design is capable of meeting the prescribed regulatory limits for radiation doses and radioactive releases resulting from postulated accidents.

Probabilistic safety analysis

The objective of the review of the probabilistic safety analysis (PSA) is to determine the extent to which the existing plant-specific PSA remains valid considering changes in the design and operation of the plant, new technical information, current methods and new operational data.

The PSA should be reviewed to determine that it has been kept sufficiently up-to-date during the plant lifetime and that it reflects the current plant design, operation, methods, technical information and operational data. The results of the PSA should be compared with the probabilistic safety criteria or goals for system reliability, core damage and radioactive release frequency, etc. The accident management programme for beyond-design-basis accidents should be reviewed to determine whether the programme is adequate to prevent core damage or to mitigate the consequences.
Hazards analysis

The objective is to determine the adequacy of protection of the plant against internal and external hazards with consideration of the actual plant design, actual site characteristics, the actual and predicted future condition of SSCs, and current analytical methods, safety standards and knowledge.

The review should establish a list of relevant internal and external hazards that could affect plant safety, such as changes in plant design, climate, flood potential, and transport and industrial activities near the plant. It should be demonstrated, using current techniques and data, that the probability or consequences of the hazard are sufficiently low that no protective measures are needed, or that the measures provided are adequate. Any deficiencies should be identified.

Safety performance

The objective of the review is to determine the safety performance of the nuclear power plant and its trend from records of operating experience.

Safety performance is usually determined from assessments of operating experience, including safety related incidents, and records of safety system unavailability, radiation doses, and the generation of radioactive wastes and radioactive effluents. The operating organization should have a system for keeping a record of all incidents and evaluating their safety significance. In addition, records of plant operation, maintenance, testing, inspection, replacement and modifications should be regularly evaluated to identify any unsafe situations or trends. The results of these evaluations should be suitably summarized to give an overall assessment of safety performance during each year of plant operation. The safety performance indicators which have been developed by some states and by the World Association of Nuclear Operators (WANO) could be used for this purpose.

The radiation risk resulting from normal nuclear power plant operation and anticipated operational occurrences is also an important element of the plant safety performance. Relevant indicators include radiation dose data, which provide an indication of the risk posed to the plant personnel, and radioactive effluent data, which provide some indication of the environmental impact. Records of radiation doses and radioactive effluents should be reviewed to determine whether these are within prescribed limits, as low as reasonably achievable and adequately managed. In addition, data on the generation of radioactive wastes should be reviewed as such wastes contribute to the radiation risk.
Use of experience from other plants and research findings

The objective of the review is to determine whether there is adequate feedback of safety experience from other nuclear power plants and the findings of research.

Experience from other nuclear power plants, and sometimes from non-nuclear plants, together with research findings can reveal unknown safety weaknesses or help in the solution of existing problems. There are established arrangements for the dissemination of nuclear plant operational experience by the IAEA, the OECD Nuclear Energy Agency, WANO, the Institute of Nuclear Power Operations, and various plant owners’ groups.

Arrangements for dissemination of research findings are not as well established, owing partly to commercial considerations and the need to use the research findings in conjunction with operating experience. The operating organization should have arrangements for receiving and assessing feedback information as a part of its normal activities. A PSR should include a review of the adequacy of these arrangements and the timely implementation of assessment findings.

Organization and administration

The objective of the review is to determine whether the organization and administration are adequate for safe operation of the nuclear power plant.

The impact of organization and administration on nuclear power plant safety should be in every PSR. Together with human factors, they play a significant role in defining safety culture. The review should examine the organization and administration to ensure that these comply with accepted good practices and do not present an unacceptable contribution to risk. The aspects considered should include:

- Management;
- Succession planning;
- Configuration control;
- Technical and contractual support;
- Training;
- Quality assurance;
- Records and
- Compliance with regulatory and other statutory requirements.

The review should determine whether there is an adequate number of suitably qualified staff to carry out safety-related work. Because some of these aspects deal with the manner in which the operating organization conducts its affairs, it may be difficult for that organization to carry out an objective review and external specialists may be needed.
Procedures

The objective of the review is to determine whether nuclear power plant procedures for operation, maintenance, inspection, testing and modification are of an adequate standard.

Procedures should be comprehensive, validated, formally approved and subject to rigorous change control. In addition, they should be unambiguous and relevant to the actual plant, reflect current practice and take due consideration of human factor aspects. The review of this factor should cover:

- Operating procedures for normal and abnormal conditions (including design basis accidents and post-accident conditions);
- Procedures for management of beyond-design-basis accidents;
- Maintenance, test and inspection procedures;
- Work permit procedures;
- Control procedures for modifications of plant design, procedures and hardware, including updating of documentation;
- Radiation protection procedures, including those for on-site transfers of radioactive material.

Human factors

The objective of the review is to determine the status of the various human factors which may affect the safe operation of the nuclear power plant.

Human factors influence all aspects of safety of an operational nuclear power plant. They are a significant element of the plant safety culture. The review should examine the status of the human factors to determine if these comply with accepted good practices and do not present an unacceptable contribution to risk. The review should be wide ranging and include staffing, selection and training, personnel-related issues, the style of procedures and the human-machine interface. It should be carried out with the assistance of appropriately qualified specialists. Because of difficulties associated with carrying out an objective review of what is essentially its own human performance, the operating organization may decide that specific elements can only be carried out by external consultants. Detailed explanations of human performance are the subject of Volume 22.

Emergency planning

The objective of the review is to determine whether the owner/operator has adequate plans, staff, facilities and equipment for dealing with emergencies and whether the operating organization’s arrangements have been adequately co-ordinated with local and national arrangements and are regularly tested in exercises.
A PSR should include an overall review which checks that the emergency planning at the plant continues to be satisfactory. Emergency plans should be maintained in accordance with current safety analysis, accident mitigation studies and good practices. Emergency exercises should demonstrate and identify possible shortcomings in the competence of on-site and off-site staff, the required functional capability of equipment (including communications equipment) and the adequacy of planning. PSRs should check that account has been taken of changes at the plant site and in its use, organizational changes at the plant, changes in maintenance and storage of emergency equipment, and of industrial, commercial and residential developments around the site.

**Radiological impact on the environment**

The objective of the review is to determine whether the operating organization has an adequate programme for surveillance of the radiological impact of the nuclear power plant on the environment.

The operating organization should have an established and effective surveillance programme that provides radiological data on the surroundings of the plant site. Examples of such data are the concentration of radionuclides in air, water (river, sea and ground), soil, agricultural and marine products and animals. These data should be compared with the values measured before the nuclear power plant was put into operation. In the event of significant deviations, an explanation should be given taking into account relevant factors external to the nuclear power plant. A PSR should examine whether this programme is appropriate and sufficiently comprehensive in order to check all relevant environmental aspects. The radiological impact of the plant on the environment should not be significant compared to that due to naturally occurring sources of radiation.

**Global assessment**

The objective is to present an assessment of plant safety that takes into account all unresolved shortcomings, all corrective actions and/or safety improvements and plant strengths identified in the review of all PSR safety factors.

A global assessment report should be prepared that presents the significant PSR results, the integrated plan for corrective actions and/or safety improvements, and a ‘global risk’ judgement on the acceptability of continued plant operation with any remaining shortcomings. The global assessment should show to what extent the safety requirements and the defence-in-depth concept are fulfilled, in particular for the basic safety functions of reactivity control, fuel cooling and confinement of radioactive material.
6.4 Roles and responsibilities

The regulatory body has the responsibility for specifying or approving the requirements for a PSR, reviewing the conduct and conclusions of the review and the consequential corrective actions and/or safety improvements, and for taking appropriate licensing actions. It is also responsible for reporting the outcome of the PSR to the national government and the general public.

Detailed guidance and recommendations on the procedure for a PSR, including the activities of the operating organization and the regulatory body, are provided in Safety Guide SSG-25.

6.5 Review process and post-review activities

The basic procedure for implementing the PSR review consists of parallel activities by the operating organization and the regulatory body.

The activities of the operating organization can be divided into three steps (Fig. 6.1).

Fig. 6.1: Three steps in a PSR project.

The first step is the preparation for the PSR project. Since a PSR is a major task, an appropriate project management team should be established at the outset. This is necessary in order to achieve the
expected outcome within the agreed time-scale and budget. The PSR is typically performed by a number of review teams in parallel. A document should therefore be prepared to provide guidance on how to review the different safety factors so as to ensure a comprehensive, consistent and systematic approach. The results of the reviews should be recorded in a systematic and auditable manner. As the PSR process is a complex undertaking involving non-routine work by many of the staff of the operating organization, appropriate training of the reviewers would facilitate effective and efficient completion of the PSR.

The second step is the conduct of the PSR review. A single database of information to be used should be established to ensure consistency across all areas of the review. This should include not only historical data but also predictions of future operating regimes and service lifetime.

The third step is the preparation of a programme of corrective actions and/or safety improvements. Detailed proposals for the implementation of corrective actions and/or safety improvements should be prepared after receiving feedback from the regulatory body on the submitted reports. This should include the outcome of discussions with the regulatory body regarding the scope and adequacy of the outline proposals of corrective actions and/or safety improvements. In addition, the corrective actions and/or safety improvements should be prioritized.

Different approaches exist for the prioritization of corrective actions and/or safety improvements on the basis of deterministic analyses, PSA and engineering judgement.

The regulatory body’s activities are carried out throughout the PSR project. The regulatory overview of the PSR is a major responsibility that involves ongoing communication with the operating organization. To ensure that this is carried out efficiently and effectively, the regulatory body should designate a PSR project manager to coordinate all the regulatory body’s PSR activities and to be a focal point for communication with the operating organization.

Safety is enhanced by implementing the corrective actions and/or safety improvements. It is essential that the operating organization and the regulatory body maintain adequate arrangements for project management to ensure the timely completion of a committed plan of corrective actions and/or safety improvements.

### 6.6 Questions

1. What is the purpose of a PSR?
2. What are the most important inputs from a PSR in assessing long
term operation?
3. List the different safety factors in a PSR.
4. Who is responsible for conducting and approving a PSR?
5. What are the three steps in a PSR project?


7 CASE STUDIES

Learning objectives
After completing this chapter, the trainee will be able to:
1. Describe the Belgium experience in ageing management and long term operation.
2. Describe the Hungarian experience in ageing management and long term operation.

7.1 Ageing management (AM) and long term operation (LTO) in Belgium

National regulatory requirements for ageing management (AM) and LTO

In Belgium, the licences for operation of nuclear power plants granted by Royal Decree do not specify a fixed lifetime. The oldest plants, Doel 1&2 and Tihange 1, have been operational since 1975. The 2003 law regarding cessation of nuclear power limits the operation of nuclear power plants to 40 years.

However, in October 2009, the Belgian government declared that they intended to make it legally possible for Doel 1&2 and Tihange 1 to operate until 2025, which would mean a total lifetime of 50 years (this statement was confirmed by the Belgian government in June 2012, only for the Tihange 1 plant).

The Belgian Federal Agency for Nuclear Control (FANC) published in 2009 a strategic note regarding the requirements for long-term operation of Doel 1&2 and Tihange 1. The operator Electrabel GDF SUEZ started its LTO programme in order to respond to these requirements.

The LTO programme included the following areas of concern, identified in the FANC strategic note:
- Preconditions for long-term operation considering the IAEA guidelines;
- Ageing management;
- Design re-evaluation;
- Knowledge, competence and behaviour management.

The note also stated that the long-term operation of the plants should be evaluated within the framework of the fourth ten-yearly PSR, based upon IAEA NS-G-2.10. As such a licence renewal was not required for LTO, and the LTO approval will be integrated in the approval process of the 4th PSR.

In its strategic note, the Belgian Federal Agency for Nuclear Control explicitly stated that the AMP has to be in conformity with USNRC
10CFR54 and IAEA SRS 57.

**Management of physical ageing**

The following paragraph gives a high-level view of the Belgian IPA (Integrated Plant Assessment) process, including the following areas:

- Scoping and screening of SSCs for AM and LTO (passive and active components, long term and short term components);
- AMR and condition assessments of in scope SSCs;
- TLAA and AMP re-evaluation.

The overall process is represented in Figure 7.1.

Electrabel GDF SUEZ bases its LTO ageing approach on the US NRC integrated plant assessment (IPA) process.
Scoping is the first step for all SSCs. The LTO-ageing project covers safety-related and non-safety-related SSCs. SSCs that are within the LTO-ageing scope are defined according to 10CFR54.4. The scoping process consists of four different analyses:

- Three types of basic analysis, one for each of the three technical domains: mechanical, structural, EI&C safety related (criterion 1) and safety-impacting (criterion 2);
- One specific analysis, across the three basic domains, related to five specific functions: fire protection, environmental qualification (EQ), pressurized thermal shock (PTS), anticipated transients without scram (ATWS), station blackout (criterion 3).

Continual cross-checking between the technical domains and the scoping deliverables guarantees the overall coherence of the SSCs within the scope of LTO-ageing.

The subsequent process steps formed the ageing management evaluation (AME). The basic assessment process presented here was adapted for a number of situations: it was performed system-by-system (mechanical domain), commodity group by commodity group (EI&C domain), and structure type by structure type (structural domain).

The need for an AMP, a TLAA, or a plant-specific programme was identified in the ageing management review (AMR). As AMPs did not always exist, AMP development was progressively integrated into the ageing management evaluation (AME) for SSCs that are subject to LTO analysis. Up to now, IPA was mainly dedicated to passive components, whereas the LTO strategic note from FANC requests coverage of both active and passive components. Therefore, a specific approach for active components was added.

This specific AME was focused on the planned maintenance programmes and the evaluation of these programmes. The plant maintenance programmes applicable to active components identified as within the scope of LTO ageing were reviewed using the Reliability Centred Maintenance (RCM) approach in order to achieve the optimum reliability of the functions of the systems and components. The basics of RCM are as follows:

- Establishing the leading failure modes for each type of equipment;
- Criticality analysis and evaluation (gradation of the severity and frequency of the risk of failure) of the failure modes of active functional locations in scope;
- Identification of run-to-failure equipment;
- Check of preventive maintenance programmes and surveillance and inspection programmes regarding their capability to prevent critical functional failure;
- Improvement of task and frequency definition of periodic
Action plans were defined for implementation. These programmes are subject to a continuous improvement process (living programme).

The effectiveness of the living maintenance programme and AMPs is monitored through reports on the health of the systems concerned.

**Management of obsolescence**

Several types of obsolescence (knowledge, technology, standards and regulations) are addressed in the main LTO areas, as required in the FANC Strategic Note.

Additionally, a review of the management of obsolescence forms of the regular themes in PSRs.

*Obsolescence of knowledge:* Cultural changes, loss of knowledge and competence due to an ageing workforce (retirement) are specific parts of non-physical ageing processes.

Electrabel GDF Suez has performed and reported a self-assessment in order to ensure that these types of obsolescence are adequately managed and not jeopardizing the long term operating period. Action plans to complement them were prepared for use if necessary.

This area is connected with the following themes:
- Nuclear safety culture, as well as the behaviour and values that support it;
- Competence management, specifically the training and qualification of personnel;
- Knowledge management.

Personnel, organization and procedural subjects were taken into account in all of these three domains. In the analysis of the results, the most recent OSART audits were used, specifically in the domain of human behaviour, training and self-evaluation.

*Obsolescence of standards and regulations:* The area of LTO-design includes the systematic reassessment of plant against current standards (e.g. PSR) and appropriate upgrading, back-fitting or modernization. The objective is to develop measures of improvement that upgrade the design (see FANC strategic note), in order to reduce the residual risk as far as reasonably achievable (i.e. the probability of core damage and/or large scale radioactive releases).

The LTO-design activities comprise:
- A design review;
- Development of the improvement plan and the Agreed Design Upgrade (ADU);
- Implementation of the ADU, after approval and according to the
The following information sources were used during the design review:

- Regulation watch;
- WENRA reference levels;
- Benchmarks;
- PSR look-back;
- Operational experience feedback;
- Design basis documentation.

**Obsolescence of technology:** Some types of obsolescence are included in the scope of this area such as the unavailability of qualified spare parts for old equipment, disappearance of the original manufacturer or supplier for the plant maintenance programme.

Electrabel GDF Suez has performed and reported a self-assessment in order to ensure that the preconditions for LTO reached the IAEA expectations used as a reference for the evaluation. If needed, action plans to fulfil them were defined.

The management of these types of obsolescence was considered as preconditions for LTO and assessed as part of the plant programmes, especially for maintenance and equipment qualification.

**Review of Ageing management programmes (AMPs)**

During the screening/AMR analysis, a set of different AMPs applicable to the plant is defined. The implementation of these AMPs has to ensure that the intended functions of safety equipment are maintained in consistency with the current licensing basis (CLB) for the period of extended operation.

The AMPs contain the AM policies in a standardized, systematic and structured way and for different areas of concern (e.g. closed cycle cooling water, buried piping, boric acid corrosion, …) describe the actions to be taken (preventive, monitoring, corrective) in different domains (maintenance, in-service inspection and surveillance, operations, technical support). These are based on international programmes (NUREG1801), so as to ensure that the effects of ageing are adequately managed, and so that the acceptance criteria for safe operation are maintained and not exceeded.

For some specific ageing topics, for which NUREG 1801 does not give clear guidance, plant-specific AMPs were issued.

With reference to NUREG1801, new AMPs were developed in a standardized way, using the known specific attributes of passive components.

It is assumed that the ageing of active components is managed through
solid and proven maintenance programmes.

**Revalidation of TLAA for LTO**

The definition of TLAA as specified in 10 CFR part 54.3 was applied. The TLAA relating to LTO can be grouped into the following broad categories:

- Major nuclear steam supply systems (NSSS) components designed in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. The design specifications and stress reports for these components refer to a design life of the component for use in fatigue and wear analyses; they also describe neutron irradiation limitations for the expected plant life with regard to the material properties of the components;
- Major non-NSSS structural and safety-related components subject to the effects of ageing, fatigue, relaxation and degradation due to environmental conditions;
- Electrical equipment initially qualified for a specific time period.

The environmental qualification of electrical equipment is treated within the EI&C qualification approach.

In the first step, potential TLAA areas were identified and listed in two ways:

- By reviewing lists of previously identified TLAA and choosing those potentially applicable to Tihange 1 and Doel 1-2 for further evaluation. In particular the following information sources were consulted:
  - The list of the TLAA established by the WOG (Westinghouse Owners Group);
  - TLAA listed in NUREG-1800 and NUREG-1801;
  - TLAA listed as examples in NEI 95-10 (NEI);
  - TLAA performed in US NPP with similar design to the Tihange 1 and Doel 1&2 plants;
  - Engineering judgment of GDF Suez Tractebel Engineering, the responsible designer, and specialists;
- By searching the unit’s current licensing basis for calculations/analyses with a time element.

The necessity of reviewing these TLAA-subjects was examined and the final list of TLAA to be reviewed was validated by the Authorities.

In the second step, the necessary studies and analyses were made in order to update and revalidate the existing TLAA. For newly identified topics, a new TLAA was issued.

In some exceptional cases, where the TLAA approach was unable to justify continuous operation in the LTO time window, specific
programmes to manage the ageing mechanisms were established.

### 7.2 Ageing management and long term operation in Hungary

#### Basis of nuclear regulation
The national requirements for nuclear safety form a pyramid of legal documents; the first three levels are mandatory:
- The Atomic Energy Act (CXVI, 1996);
- Government Directives (118/2011 and 37/2012);
- Nuclear Safety Regulations (NSR) (as annexes to 118/2011);
- Hungarian Atomic Energy Authority (HAEA) Regulatory Guidelines;
- Internal documents of the HAEA and licensee.

#### Licensing process for LTO
A basic feature of the Hungarian nuclear safety regulations is that the licence for NPP operation is valid for a limited time, issued for the design lifetime of the plant. For the Paks NPP this is 30 years, although some structures and components have design lifetimes longer than this.

The Hungarian legislation for LTO was developed through adopting the relevant requirements and guidance of the IAEA and international best practice. The HAEA adopted some basic elements of U.S. NRC 10 CFR Part 54 for the regulation of licence renewal (LR). According to Volume 1 of the NSR, operation can be continued beyond the licenced term – i.e. the design lifetime – if the licensee obtains an operating licence for the term of the extension of operation.

In the Hungarian regulatory framework, control of compliance with the current licensing basis is maintained via:
- Final Safety Analysis Report (FSAR), and its annual update;
- PSR every ten years;
- Other regulatory tools, including maintenance effectiveness monitoring (MEM), inspections, review of AM activities etc.

The regulatory guidelines related to LTO in general are:
- NRC guideline 1.28 on the regulatory process of the licence renewal;
- NRC guideline 4.14 on preparation for long-term operation.

Licence renewal itself is a two-step process:
- Step one is the development of the LTO programme (on the basis of Guideline 4.14.). The LTO programme has to be submitted to the regulator at least four years before the design life is due to expire, but not earlier than 20 years before.
- The second step is the formal licence application (on the basis of Guideline 1.28). This has to be submitted one year before the
As in many other European countries, the PSR is an important element of Hungarian regulation, but it is not part of the Hungarian LTO licensing process. The PSR is a self-assessment and reporting obligation of the licensee. It is performed every 10 years primarily to assess the overall ageing of the plant SSCs on a time scale broader than the routine daily or even yearly checks. This broader time scale allows the reviewers better to take into account the development of science and technology in relation to safety and ageing. The PSR is considered the main method for identifying the need for any safety upgrade measures.

**Regulation of Ageing Management**

Activities related to AM are determined by the NSR and the accompanying regulatory guidelines. These requirements are in line with the international practice and guidelines (e.g. NUREG 1801). Regulatory Guidelines related to AM in general are:

- 1.26. Regulatory supervision of ageing management;
- 3.13. Ageing management issues in the design phase of a NPP;
- 4.12. Ageing management during the operation of a NPP.

The licensee has to ensure the required condition of the plant and the intended safety functions via plant programmes, i.e., maintenance, AMPs, programmes maintaining the qualified status of equipment, scheduled replacements and reconstructions.

The licensee has a certain freedom and flexibility in the application of these programmes. The licensee should continuously demonstrate the ability of SSCs to fulfil their required safety functions. The demonstration of fulfilment of safety functions may be achieved through safety analysis (e.g. TLAA), environmental qualification (EQ), AM or MEM, or by a combination of them.

The basic objective of AM is to maintain the safety of the passive SSCs with a safety function by managing ageing phenomena. For SSCs subject to ageing effects, this is realized by identification of degradation mechanisms, detection of ageing effects, evaluation and trend analysis, and introduction of preventive measures or retarding actions. When developing an AMP, IAEA NS-G-2.12 is taken into account, as well as the US Generic Ageing Lessons Learned (GALL) Report, with ten generic attributes for AMP reviews.

According to Guideline 1.26, AM should be implemented as minimum for:

- High priority mechanical components (e.g. reactor pressure vessel and internals, pressurizer, steam generators, etc.);
- Other mechanical components (e.g. feed-water lines, emergency core cooling system (ECCS) hydro-accumulators, high pressure ECCS pumps, sprinkler system pumps etc.).
- Building structures (e.g. reinforced concrete in the hermetic containment compartments, shafts, machine bases, metal support structures etc.);
- Cables and certain electrical components.

**Regulatory basis for Time Limited Ageing Analyses**

TLAAs are plant-specific safety analyses based on an explicitly assumed period of plant operation. They are an essential part of the LTO evaluation. The review and validation of TLAAs for an extended period of operation is a required element in the justification of licence renewal. According to Hungarian regulations, TLAAs are analyses which:

- Are necessary to maintain the safety of the installation, and/or to demonstrate the maintenance of function of SCs in accordance with the legal and regulatory requirements;
- Demonstrate for a given SC that its required safety functions and performance can be ensured (for a specific limited time) under stresses that could occur during normal operation, anticipated incidents and design basis accidents.

According to Guideline 1.28, the applicant for LTO has to demonstrate that:

- The analysis remains valid for the period of LTO;
- The analysis has been projected to the end of the period of LTO; or
- The effects of ageing on the intended function(s) will be adequately managed for the period of long-term operation.

Existing TLAAs need to be reviewed and revalidated in relation to the assumed new (extended) period of plant operation. The evaluation of each identified TLAA should demonstrate that the safety function of the SC will remain within design safety margins throughout the period of LTO.

**Methodology for scoping SSCs for LTO/LR**

According to the regulatory requirements, the scope of LTO/LR (licensing renewal) include Safety Class 1-3 components, and non-safety class components (“SC+”) whose failure may occur due to unmanaged ageing and which may jeopardize safety class components.

The first step in determining the LR scope is the system-level scoping process. The next step of component-level scoping is based on technological schemes, and tables for each mechanical technological system. The component lists are compared with the LR scope components in the technical database. The non-safety class components within the scope are verified by walk-down.

The basic method for determining which cables fall within the LR scope is the analysis of data from the cable database. This database
contains the main data, paths and connected equipment for cables. Cables are assigned to safety systems according to their designation and the connected equipment. The safety function of cables is determined through fire and electrical circuit analysis.

To determine the LR scope of buildings and structures, the base map of the plant showing all buildings is used, and a safety classification assigned to each building and structure as the basis for scoping.

**Selection of components to be managed by AM, EQ and MEM**

In accordance with regulatory requirements, the availability of SSCs to fulfil their safety function should be ensured and demonstrated for components within the LTO/LR scope. According to regulation, the licensee may choose the method of ensuring the intended safety function and the demonstration of performance. The basic rule is that the method selected depends on whether the SSC fulfils its intended safety function in active or passive way. Maintenance and MEM is only used for active components, while AM is used for passive ones. EQ can be applied to both active and passive components, and, in the case of a harsh environment, is an essential mean of demonstration.

**Types and contents of AMPs**

To comply with Guidelines 4.12, the Paks NPP should have an integrated AMP. Since the number of SSCs is very large and the ageing mechanisms are also numerous, the AMPs are structured to ensure the proper management of the activities.

In the case of mechanical components there are two types of programmes: degradation-type programmes and component-specific programmes.

In the case of civil structures practically the same concept is applied. However the basic programmes (called A-type programmes) are developed either for typical structural elements, members or degradation mechanisms. Ageing of complex civil structures that are composed of different structural elements are managed via frame programmes (called B-type programmes) built up from the basic programmes.

**AMPs for mechanical components:** The degradation type ageing management programmes (DTAMPs) define how to manage ageing caused by particular degradation mechanism. These programmes also comprise the fundamentals of the degradation mechanisms, the available scientific results related to that mechanism, and a summary of national and international experience.

DTAMPs are developed for 19 degradation mechanisms occurring in mechanical components, listed in Guidelines 1.26, e.g., for low-cycle fatigue, thermal ageing, radiation damage, stress corrosion, boric acid
corrosion, wear, radiation-assisted stress corrosion, swelling, erosion-corrosion, microbiological corrosion etc.

Component-specific ageing management programmes (CSAMPS) are developed for mechanical components (e.g. reactor pressure vessel, pressurizer, steam generator, main cooling pumps etc.) or commodity groups of mechanical components, cables and certain electrical components selected on the basis of Guideline 1.26. CSAMPS are based on DTAMPS and contain 10 attributes of AMPs.

Commodity groups are based on the approach (according to guideline 1.26.) that during the development of the AMPs, it is permissible to group components within the scope of an AM if it can be justified that the ageing of the components in the group is similar. The grouping is based on a given characteristic of the components (e.g. material, environment, operating parameters or construction). Passive mechanical components in the scope of the AM are grouped as heat exchangers, vessels, pipeline elements, appliances, pumps, valves, filters and special equipment.

**AMPs for civil structures:** The AM of civil structures at the Paks NPP is based on two types of AMP. Basic programmes (type “A”) are used for the typical structural elements and members structural components from which the complex buildings or structures of the plant are built, or for some general ageing processes such as settlement. These programmes are developed through the identification of structural elements, ageing mechanisms and locations (similar to DTAMPS for mechanical components).

AMPs of type “B” are used for the complex buildings and structures of the plant. These identify the ageing effects and mechanisms to be managed, and give lists and details of the proper application of type “A” AMPs to be used, while managing the ageing of the given building. The type “B” AMP also contains logistical information on how to perform the actions defined by the programmes, e.g., the accessibility of certain buildings (similar to CSAMPS for mechanical components).

**AMPs for cables:** Environmental qualification and/or AM is clearly an essential task regarding the safety functions of cables. The basic approach for justifying that cables are operable over the extended 20 years of operation is environmental qualification. In some cases environmental qualification is not possible for a group of cables, because of the cables’ allowable operational parameters. In these cases an AMP is implemented.

**AMPs for electrical components:** For some electrical-related equipment and structures AMPs are introduced for:

- The holding frame and casing of cabinets, relay panels and other E&IC boxes;
- Cable trays and supporters;
- Base structures of rotating machines;
- Fire barriers between the cable rooms;
- Phase buses and insulators of distribution cabinets (several programmes for different types);
- PVC insulated cables (also the target of EQ);
- Other types of cables (fibre optic, XLPE, etc.)

According to Hungarian regulations AMPs are developed to cover each of these components, following the 10 attributes of AMPs.

**Ageing management monitoring system**

The AM of high priority mechanical components requires handling data from many sources related to different aspects of design, operation, maintenance and inspection. The concept of the Data Acquisition and Analysis System for Ageing Management (DACAAM) is based on that of providing the most frequently used data from the AM activities to operational personnel in a structured form, and facilitating its retrieval for further processing and assessment.

The objectives of DACAAM application are derived from the basic requirement of the AMP to assess and evaluate data in order to justify LTO. These data need to be retained for the life of the plant. The DACAAM system has also been developed to provide easy-to-use data collection and record-keeping tools required by AM activities.

AMPs of commodity groups are supported by the plant technical database, based on an enterprise asset and work management system (Asset Suite).

**Review of AMPs for LTO:** The plant’s AMPs may be credited for use in LTO provided that they meet the evaluation criteria for the adequacy of plant programmes regarding LTO/LR. These programmes have to be reviewed and the adequacy of each has to be demonstrated, along with the adequacy of the whole system of programmes, its acceptability and completeness.

The review and qualification of the AMPs is made according to the standard ‘10 attributes’. The conclusions of the review are documented in the documentation for justification of the application for LR.

A preliminary review of AMPs was performed while developing the programme for LTO. Some existing programmes were qualified as adequate, and requirements for modifications or development of new programmes were identified. These modifications or new programmes were implemented during the programme for LTO. The full-scope and comprehensive AMP review is completed for the LR application, taking into account recent achievements and experiences.
Management of obsolescence: Conceptual (design) aspects of obsolescence are the subject of a PSR. The information or indicators for different aspects of obsolescence (ageing, difficulties in spare parts management) are collected from the experience gained while performing maintenance and MEM, or implementing other plant programmes.

The obsolescence issue is managed by scheduled replacement and reconstruction programmes.

Examples are the replacement of the reactor protection system, high-pressure preheaters, turbine condensation tubing, etc. An example of management of the preparation of scheduled reconstruction is the preparation of process control reconstruction. The need for reconstruction was identified via collection and analysis of operational and maintenance data. The preparatory work was performed and managed by a dedicated group of experts, who were overseen by the I & C Expert Board.

During the last twenty years the Paks NPP performed several safety enhancement projects that also involved replacement of obsolete systems and equipment.

Although the obsolescence issue is part of the scheduled replacement programme and related mainly to active replaceable systems and components, some aspects of obsolescence have already been accounted for in the AMPs. Procedures connected with AMPs are in place to provide for the availability of:

- Documentation to support SSC maintenance and replacement;
- Required technical support;
- Sufficient spare parts.

Revalidation of time-limited ageing analyses for LTO

The scope of TLAAs can be derived from the Guidelines related to LR: Guideline 1.28 on the licensing procedures for LTO, and Guideline 4.14 on the activities to be implemented by the operating organization to support LTO and LR. Guideline 4.14 provides the minimum scope for TLAAs.

The scope of the TLAAs is identified according to Guideline 4.14, i.e. taking into account the requirements of the CLB analyses needed for ageing processes that may limit the intended safety function, or that are relevant in determining safety.

According to the Guideline there are three possibilities for validation of the TLAAs:

- To extend the validity of the existing TLAAs;
- To replace the conservatism used in the original TLAA analysis by less conservative assumptions and methods for analysis. (This practically means performing a new analysis.)
To demonstrate that measures will be introduced during the extended service life that will control the ageing processes and assure the intended safety function.

In the LR application all TLAA analyses are revalidated for 30+20 years of operation with 10 years reserve.
8 REFERENCES


The views expressed in this document do not necessarily reflect the views of the European Commission.