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FINAL REPORT OF THE PROGRAMME ON SAFETY ASPECTS OF LONG TERM OPERATION OF WATER MODERATED REACTORS

RECOMMENDATIONS ON THE SCOPE AND CONTENT OF PROGRAMMES FOR SAFE LONG TERM OPERATION

JUNE 2007

INTERNATIONAL ATOMIC ENERGY AGENCY

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EXTRABUDGETARY PROGRAMME ON SAFETY ASPECTS OF LONG TERM OPERATION OF WATER MODERATED REACTORS
FINAL REPORT

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FOREWORD

During the last two decades, the number of IAEA Member States giving high priority to continuing the operation of nuclear power plants beyond the time frame originally anticipated is increasing. This is related to the age of nuclear power plants connected to the grid worldwide.

The IAEA started to develop guidance on the safety aspects of ageing management in the 1990's. Recognizing the development in a number of its Member States, the IAEA initiated this Extrabudgetary Programme on Safety Aspects of Long Term Operation of Water Moderated Reactors in 2003.

The objective of the Programme was to establish recommendations on the scope and content of activities to ensure safe long term operation of water moderated reactors. The term long term operation is used to accommodate various approaches in Member States and is defined as operation beyond an initial time frame set forth in design, standards, licence, and/or regulations, that is justified by safety assessment, considering life limiting processes and features for systems, structures and components.

The scope of the Programme included general long term operation framework, mechanical components and materials, electrical components and instrumentation and control, and structural components and structures. The scope of the Programme was limited to physical structures of the NPPs. Four Working Groups addressed the above indicated technical areas. The Programme Steering Committee provided coordination and guidance and served as a forum for the exchange of information.

The Programme implementation relied on voluntary in kind and financial contributions from the Czech Republic, Hungary, the Slovak Republic, Sweden, the United Kingdom and the USA as well as in kind contributions from Bulgaria, Finland, the Netherlands, the Russian Federation, Spain, the Ukraine, and the European Commission.

This report summarizes the main results, conclusions and recommendations of this Programme and provides in the Appendices I – IV detailed information developed by the four Working Groups, which is to a large extent based on the four Final Working Group Reports. Complete information on the Programme is available on http://www–ns.iaea.org/projects/salto/default.htm .

The contributions of all those involved in the Programme are greatly appreciated. In particular, the contributions in preparation of this report provided by A. Duchac, Directorate General, Joint Research Centre, European Commission, and T. Taylor, Pacific Northwest National Laboratory (PNNL), are acknowledged. The IAEA officers responsible for this report were R. Havel, E. Liszka, and L. Wang of the Division of Nuclear Installation Safety.

CONTENTS

SUMMARY

This report summarizes the major results of the Extrabudgetary Programme on Safety Aspects of Long Term Operation of Water Moderated Reactors (Programme). The objective of the Programme was to establish recommendations on the scope and content of activities to ensure safe long term operation of water moderated reactors. The Programme results should assist regulators and operators of water moderated reactors in ensuring that the required safety level of their plants is maintained during long term operation (LTO), should provide generic tools to support the identification of safety criteria and practices at the national level applicable to LTO, and should provide a forum in which MS can freely exchange information. The scope of the Programme was limited to technical aspects important to safety related physical structures. Further detailed results of the Programme are given in Appendices I–IV which contain Final Working Group Reports of Working Groups 1–4 [1–4].

The recommendations in this document may be used to justify LTO from perspectives of safety, to credit/upgrade existing plant programmes for managing ageing, and to identify new plant programmes for LTO, and to provide technical basis for regulatory approval.

BASIC PRINCIPLES

NPPs were mostly built to very conservative standards and, in many cases, have significant remaining safety margins. Current engineering technology is able to assess the remaining safety margins for physical structures of the NPP and indicate if safe LTO is technically feasible. During the initial period of operation, national/international practices required that NPPs be operated in a conservative manner compared to the design criteria. The combination of both aspects, conservative design, which is now better understood, and an operational regime that follows national/international practices, is an essential basis for continuing operation beyond the initial established timeframe. The approach to LTO is based upon the following principles:

- Current operational practices meet national regulations and international guidelines and are adequate to ensure safe operation of the NPP during the current period of operation.
- The existing regulatory process is adequate to maintain safe operation of the NPP and should be carried over the period of LTO provided the effects of ageing are managed.
- The current licensing basis (provides an acceptable level of safety and should be carried over the LTO in the same manner to the same extent, with the exception of any changes specific to LTO.
- NPP programmes may be credited for use in LTO provided that they meet the evaluation criteria that are provided in Section 3.2.

PRECONDITIONS

It is recommended that the following plant programmes and documentation, which were specifically selected by WG1, be considered preconditions for LTO, because these plant programmes and documentation impact all areas of plant operation identified in the scope of Working Groups 2, 3 and 4.

1. Existing plant programmes;
    - In-service inspection
    - Maintenance
    - Equipment qualification

- In-service testing
- Surveillance

2. Quality assurance, and configuration management;
3. Original time limited ageing analyses (TLAA) or residual life assessment;
4. Updated final safety analysis report (FSAR).

In order for the existing plant programmes above to be credited for LTO they should be reviewed against respective requirements set forth by the nine attributes described in Section 3.2 of this report.

LTO ENGINEERING PROCESS

It is recommended that the following engineering process should be used to ensure current licensing basis requirements be carried over and plant programmes be credited toward long term operation, probably with modification and addition for the latter.

1. Define the scope of structures and components (SCs) that will be evaluated for LTO using the scoping and screening process (Section 2.5). Useful example tables for SCs that would be included in LTO are provided in Appendices II – IV.
2. Review existing plant programmes and practices to ensure that they will remain effective and to identify modifications and/or new programmes in ensuring that SCs are able to perform their designated safety function for the period of LTO. Each existing plant programme to be used for LTO should be reviewed against the respective requirements set forth by the nine attributes described in Section 3.2 to determine its adequacy.
3. Review each SC within the scope of LTO to ensure that the effects of ageing are managed properly so that the SC is capable of performing its designated safety function. The review should include a technical explanation concerning management of ageing effects for each structure and component identified, so that their intended function(s) will be maintained consistent with the current licensing basis for the period of extended operation.
4. Existing plant specific TLAAs should be reviewed and revalidated with new assumed time of plant operation and in accordance with Section 3.3. The evaluation of each identified TLAA should justify that the safety function of the SC will remain within design safety margins during the period of LTO[1].
5. Identify and implement requirements for modification of existing plant programmes and development of new programmes.
6. Document the results of the engineering process and re-validation of the TLAAs in an update to the FSAR as appropriate.

MODIFICATION OF EXISTING PLANT PROGRAMMES

Any existing plant programme intended to be used to support long term operation and manage the ageing effects identified for LTO should be reviewed to determine whether they meet the respective requirements set forth by the nine attributes defined in Section 3.2. The outcome of the review should provide technical basis to clarify whether the ageing effects relevant to maintaining intended safety functions will be detected and characterized, or modifications and/or new programmes are necessary.

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[1] For example, for those specific structures and components that are near the end of the qualified life, a re-evaluation of the TLAA may be used to determine if an extension of qualified life for the period of LTO is valid.

Five existing plant programmes listed below are considered preconditions and likely candidates for ageing management programmes (with or without modifications) for LTO. They are specifically selected because these plant programmes impact all structures and components of NPPs. In addition to plant programmes listed below, Appendices II, III and IV provide a more detailed description of the candidate programmes within their focus area and provide recommendations for a number of additional plant programmes useful for LTO.

1. In-service inspection
2. Maintenance
3. Equipment qualification
4. In-service testing
5. Surveillance

REVIEW OF AGEING MANAGEMENT PROGRAMMES

The nine attributes of an effective ageing management programme are:

1. **A defined programme scope**
   The scope of the programme should include the specific structures and components subject to an ageing management review;
2. **Identification of preventive actions or parameters to be monitored or inspected**
   Actions to prevent or mitigate ageing degradation or parameters to be monitored or inspected for the intended function(s) of the particular structure or component should be identified;
3. **Detection of ageing degradation/effects**
   Detection of ageing effects should occur before there is a loss of the intended function(s) of a structure or component. This includes aspects such as method or technique (i.e., visual, volumetric, surface inspection), frequency, sample size, data collection and timing of new/one–time inspections to ensure timely detection of ageing effects;
4. **Monitoring and trending including frequency and methodologies**
   Monitoring and trending to provide predictability of the extent of degradation, and timely corrective or mitigative actions;
5. **Pre–established acceptance criteria**
   Acceptance criteria against which the need for corrective action will be evaluated, to ensure that the intended function(s) of a structure or component are maintained;
6. **Corrective actions if a component fail to meet the acceptance criteria**
   Corrective actions, including root cause determination and prevention of recurrences, should be timely;
7. **Confirmation that required actions have been taken**
   Confirmation process to ensure that preventive actions are adequate and that appropriate corrective actions have been completed and are effective;
8. **Administrative controls that document the programme's implementation and actions taken**
   Administrative controls to provide a formal review and approval process;
9. **Operating experience feedback**
   Operating experience of the ageing management programme, including past corrective actions resulting in programme enhancements or additional programmes, to provide objective evidence to support the conclusion that the effects of ageing will be managed adequately so that the intended function(s) of a structure or component will be maintained during the period of extended operation.

REVALIDATION OF TIME LIMITED AGEING ANALYSIS

Time limited ageing analysis (TLAA) or residual life assessment is an assessment of an identified ageing effect (time dependent degradation due to normal service conditions) and certain plant specific safety analyses that are based on an explicitly specified length of plant life (e.g. 30 years). For long term operation, once a TLAA is identified, an evaluation will be performed with the new assumed time of plant operation to demonstrate that the component will maintain its safety margin at the end of the extended plant life, and that at least one of the following criteria is applicable:

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

In some cases, depending on the safety relevance, a complete re–analysis of the ageing process might be needed and the time limits of safe operation should be set.

GENERAL RECOMMENDATIONS FOR LTO

1. Requirements for long term operation of existing nuclear power plants should be specified within their regulatory framework and a technical basis justifying the period of operation beyond design life of the facilities should be provided.
2. A set of preconditions containing plant specific programmes for LTO as defined in this report (see Section 2.6) should be implemented and appropriately documented.
3. The FSAR and its updates or other licensing documents should clearly and adequately describe the current licensing basis or the current design basis requirements for current plant operation. It is recommended that the implementation of plant activities for LTO should be properly documented in updating FSAR or other licensing documents that integrates the results of the LTO engineering process and constitutes the basis documents for LTO application and approval.
4. Existing NPP programmes may be credited with some modifications or enhancements upon evaluation/assessment for use in LTO. The evaluation criteria for existing NPP programmes are provided in Section 3.2. Ageing management programmes (AMPs) may be needed (or need to be modified) for those structures and components that were not in the scope for the current plant programme, but are in the scope for LTO for reasons such as operating experience, or PSA.

1. INTRODUCTION

1.1. BACKGROUND

During the last two decades, the number of IAEA Member States giving high priority to continuing the operation of nuclear power plants beyond the time frame originally anticipated (typically 30–40 years) is increasing. This is related to the age of nuclear power plants connected to the grid worldwide; out of a total of 442 reactors operating in the world, 81 have been in operation for more than 30 years, and 288 for more than 20 years (December 2006). A rather limited number of new plants are being put into operation.

The IAEA started to develop guidance on the safety aspects of ageing management in the 1990's. Recognizing the development in a number of its Member States, and the need for an internationally agreed upon, comprehensive guidance to assist regulators and operators in dealing with the unique challenges associated with the long term operation (LTO) issue, the IAEA initiated this Extrabudgetary Programme on Safety Aspects of Long Term Operation of Water Moderated Reactors (Programme) in 2003.

Decisions on LTO involve the consideration of a number of factors. While many of these decisions concern economic viability, all are grounded on the premise of maintaining plant safety. The International Conference on Topical Issues in Nuclear Installations Safety, Beijing, China, November 2004, identified the need to pursue the long term operation safety–related activities and recommended the IAEA to continue and further strengthen its effort in this particular area. At the International Conference on Operational Safety Performance in Nuclear Installations, Vienna, Austria, November 2005, it was observed that 80% of the reactors operating worldwide could be eligible for long term operation.

This report summarizes the main results, conclusions and recommendations of this Programme. Appendices I–IV contain the four Final Working Group Reports, which provide detailed Programme's results. Complete information on the Programme is available on http://www–ns.iaea.org/projects/salto .

1.2. OBJECTIVE

The objective of the Programme was to establish recommendations on the scope and content of activities to ensure safe long term operation of water moderated reactors.

The Programme results should assist regulators and operators of water moderated reactors in ensuring that the required safety level of their plants is maintained during long term operation, should provide generic tools to support the identification of safety criteria and practices at the national level applicable to LTO, and should provide a forum in which MS can freely exchange information.

The term "long term operation" is used to accommodate the various approaches in Member States and is defined as operation beyond an initial time frame set forth in design, standards, licence, and/or regulations, that is justified by safety assessment, considering life limiting processes and features for systems, structures and components.

1.3. SCOPE

A wide range of aspects have been identified that necessitate an assessment for LTO or, early shutdown of existing nuclear power plants. These aspects include:

- Technical aspects (including environmental impact, status of electrical grid, etc.)
- Deterministic and probabilistic safety analysis and hazard analysis
- Management and organisation of the plant
- Needs for plant upgrades based on new safety requirements
- Nuclear waste management
- Environmental, security, economic and social aspects.

The scope of this Programme was limited to safety aspects associated with the physical structures of nuclear power plants.

The Steering Committee agreed to use the IAEA Safety Guide on Periodic Safety Review of Nuclear Power Plants [5] as a reference to define the common terms associated with safe plant operation.

1.4. APPROACH

To achieve this objective, the Programme Steering Committee, composed of nominated senior experts from participating Member States, was established. The Steering Committee provided coordination and guidance and served as a forum for exchange of information. The Steering Committee at its first meeting recommended developing a workplan that would address the following areas:

- General LTO framework,
- Mechanical components and materials,
- Electrical components and I&C, and
- Structures and structural components.

The Programme activities addressed these areas through effort of 4 Working Groups. Working Group 1 dealt with the general aspects of long term operation and identified necessary preconditions and scoping criteria for Working Groups 2, 3, and 4. Working Groups 2, 3, and 4 evaluated information for those structures, systems and components that are within the scope of long term operation.

The Working Groups conducted their work in the following steps in line with [6-9]:

- Develop the ‘Country information report’ (CIR), summarizing the available detailed national requirements, practices and approaches for LTO, including a list of underlying references;
- Review and compare the information collected, identify common elements and differences;
- Identify generic challenges and open issues; and
- Develop a Final Working Group Report.

WG members conducted reviews of CIRs and prepared corresponding review reports that keep a record of reviewer’s findings and observations. The review reports were used as a basis to develop the four Final Working Group Reports [1–4], which contain detailed technical information and results achieved by the Working Groups. The four Final Working Group Reports were used as a basis to develop this Final Programme Report.

Almost 100 experts from 13 MS and the European Commission participated directly in the Programme activities during the period 2003-2006. The Working Group activities were guided by the Working Group leaders, assisted by the Working Group secretaries. To coordinate the work within Working Groups, four meetings of each Working Group were organized during the Programme. Most of the technical work was, however, conducted as 'homework assignments', involving a much larger number of experts. To coordinate the work among the Working Groups and to ensure consistency, Working Group leaders and secretaries met regularly, in addition to the Steering Committee meetings [10−31].

2. GENERAL FRAMEWORK FOR LONG TERM OPERATION

2.1. DEFINITION OF LTO

The following definition was agreed by MS participating in the Programme: “Long term operation (LTO) is operation beyond an established timeframe set forth e.g. by licence term, design limits, standards, and/or regulations etc., which has been justified by safety assessment considering life limiting processes and features for systems, structures and components (SSCs)”.

2.2. LAWS AND REGULATIONS RELEVANT TO LTO

The establishment of stable regulatory regime based on hierarchical legal system (laws, regulations, guides) has been a crucial precondition for the development of activities in the nuclear industry. The principal recommendations for the role of the government in this area are given in the IAEA Safety Standards, particularly in Safety Fundamentals and in the area of legal and governmental infrastructure.

The situation in Member States is generally consistent with the IAEA recommendations, although at varying degrees. Certain fundamental legal frameworks do exist, independent regulatory bodies have been established, and applicants/licensees are required to assume the primarily responsibilities for ensuring safety of their nuclear facilities.

With respect to long term operation, the laws and regulations in Member States range from a general decree to a very prescriptive law of technical requirements. Specifically, the general decree may not necessarily address any requirements for LTO, but simply states that safety should be maintained during plant operation.

Generally, for the initial licenses the design life was conservatively established by the principal designers in the Member States of origin taking into account the knowledge and the economical considerations at that time. Design life was defined in the time span of 30 to 40 years. The national regulatory bodies either explicitly define this time in the licenses or issued the operating licenses without a time specification.

Since the late eighties, some Member States initiated activities to assess qualified life of their NPPs by examining the important systems, structures and components (SSCs) at these plants, where qualified life is defined in the IAEA glossary as the period for which a system, structure or component has been demonstrated, through testing, analyses, or experience, to be capable of functioning within acceptance criteria for specific operating conditions while retaining ability to perform its safety functions during and after a design basis events.

In the early 1990s, the IAEA initiated activities focusing on physical ageing and ageing management of various types of SSCs and issued guidance in the form of TECDOCs, Safety Reports, Technical Reports Series, etc. (see Appendix V).

2.3. CURRENT DESIGN BASIS REQUIREMENTS AND PLANT PRACTICES

The following set of current design or licensing basis requirements and ongoing activities is significant for LTO:

- General design codes and standards
- Equipment qualification
- Maintenance practices

- In-service inspection, in-service testing, surveillance and monitoring
- Time limited ageing analysis
- Quality assurance and configuration management.

The current state of practice for each of the requirements and ongoing activities listed above is discussed briefly in the sections below. Recommendations specific to LTO are presented in Section 2.8.

2.3.1. General design codes and standards

Internationally recognized codes and standards were used in the original design of NPPs. Initially, former Soviet Union or US codes and standards were used as basis in all Member States, but later designs of NPPs had been increasingly influenced by European codes and standards.

Large efforts have been done and are continuously underway in Member States to maintain and enhance safety of existing NPPs to meet today's standards. In many Member States, significant safety upgrades were initiated following safety analyses and analyses of operating experience, as well as experience learned from incidents and accidents.

Documenting the design codes and standards used in the original design and upgrades, use of internationally recognised and accepted safety standards and methodology for assessing the status of an NPP is essential.

2.3.2. Equipment qualification

Equipment qualification (EQ) is a programme to generate testing or analytical evidence to ensure that a safety related equipment can perform its safety function under accident conditions (loss of coolant accident, high energy line break, post-loss of coolant accident, earthquakes) to meet system performance requirements for the design life of the equipment.

EQ has become part of regulatory requirements and in many Member States, the EQ programme has been established, implemented and maintained.

2.3.3. Maintenance

Maintenance is an integral part of activities performed by the operating organizations and includes preventive maintenance (regular, predictive) and corrective maintenance activities.

Depending on the prescriptive level of regulatory regime, the requirements for maintenance activities are laid down in laws, regulations, guidelines, industrial or equipment manufacturer requirements standards or other related documents. The method and scope of maintenance practices and the list of structures, systems and components (SSCs) which are subject to maintenance activities have been defined primarily based on the importance of the SSCs to safety and reliability of NPP operation, design documentation and domestic and international operating experience. The maintenance activities are part of long term (e.g., five years), medium term (annually), and short term planning.

The experience gained from some Member States illustrated a close relationship between maintenance activities and the long term operation of NPP. Maintenance activities may be performed by SSC manufacturers, plants or contractors qualified personnel in accordance with approved programmes and procedures.

Some Member States have been implementing risk informed approach in maintenance activities, while in other Member States this approach is at the stage of initial development. Use of operational experience and insights from risk analysis is important for the further development of preventive maintenance and for assessment and management of reliability of

SSCs during operation. Also, some Member States have implemented specific regulations on monitoring the effectiveness of maintenance that specifies performance and safety criteria.

2.3.4. ISI, IST, surveillance and monitoring

In-service inspection (ISI), in-service testing (IST), surveillance and monitoring are important tools for LTO. These programmes provide knowledge of SCs' status and a significant source of data for ageing management, and help plan plant operation and identify ageing mechanisms and characterize the effects of ageing management by determining size (dimension) and position of defects as well as wear, corrosion, changes of material properties, etc.

The results of these programmes provide a source of data for reassessment of SSC during the lifetime of an NPP.

2.3.5. Time limited ageing analysis

Time limited ageing analyses (TLAAs) are plant specific safety analyses that are based on an explicitly assumed time of plant operation. TLAAs are an essential part of the LTO evaluation. Examples of typical TLAAs in nuclear power plants include the following: RPV embrittlement, metal fatigue, thermal ageing and equipment qualification.

For the TLAA of long lived equipment the ageing effect of environmental stressors (temperature, radiation, humidity, etc.) on the validity of the equipment qualification shall be studied. If this study demonstrates that the qualified lifetime of the safety equipment cannot be extended by accepted TLAA techniques, such equipment shall be requalified or replaced at the expiry of their present qualification.

The scope of the TLAAs is different among Member States. In some Member States, TLAAs are regulatory precondition (requirements) for the long term operation. Some Member States performed comprehensive PTS analysis, fatigue analysis of major components as a part of TLAA and in other Member States; results of TLAA analysis should be documented in the FSAR update.

2.3.6. Quality assurance

The quality assurance (QA) requirements are stipulated in the legal framework (i.e. the legislation permitting development of commercial nuclear power and its implementing regulations). These quality assurance requirements are generally consistent with the recommendations of the IAEA [32]. These requirements cover all activities including siting, design, construction, operation, and decommissioning.

The operating and other organisations have been implementing international standards [33] or the national requirements [34]. For implementation of the QA procedures, plants have developed QA manual/handbooks which are approved by the plant manager. Existing QA programs have been fully integrated into the QA programs for LTO where applicable.

It is important to consider the design basis management and configuration management as part of the QA program. A NPP must be able to retrieve design, operating and safety information that is accurate and reflects the actual configuration.

It is the configuration management programme's goal to ensure that the infrastructure to make that happen is in place. Configuration management is an integrated programme to collect and manage the NPP configuration information from conceptual design throughout its operating lifetime, including changes made.

2.4. DESCRIPTION OF LTO PROCESS

The approach to LTO is based upon the following principles.

- Current operational practices meet national regulations and international guidelines and are adequate to ensure safe operation of the NPP during the current period of operation.
- The existing regulatory process is adequate to maintain safe operation of the NPP and should be carried over the period of LTO provided the effects of ageing are managed.
- The current licensing basis provides an acceptable level of safety and should be carried over the LTO in the same manner to the same extent, with the exception of any changes specific to LTO.
- NPP programmes may be credited for use in LTO provided that they have the nine attributes that are provided in Section 3.2.

The SSCs within the scope of LTO are those that perform the following functions:

- All SSCs important to safety that ensure the integrity of the reactor coolant pressure boundary.
- All SSCs important to safety that ensure the capability to shut down the reactor and maintain it in a safe shut down condition.
- All SSCs important to safety that ensure the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to the limits specified in the regulations of individual Member States.
- All SSCs not important to safety but whose failure could prevent satisfactory accomplishment of, or initiate challenges to, any of the safety functions defined above.

If not included through the description above, some MS may require that all SSCs that are credited in safety analysis to perform a function that mitigates the following events are also in the scope of LTO:

- Fires and floods
- Pressurized thermal shock
- Anticipated transient without scram (ATWS)
- Station blackout.

The following engineering evaluation ensures that the SSCs identified through the scoping and screening process outlined in Section 2.5 are able to perform their design safety function for the proposed LTO period. The engineering evaluation involves the following steps:

- Review existing plant programmes and practices to ensure that they will remain effective in ensuring that SCs are able to perform their safety function for the period of LTO. Each existing plant programme that is to be used for LTO should be reviewed against the respective requirements set forth by the nine attributes described in Section 3.2 to determine its adequacy.
- Review each SC within the scope of LTO to ensure that the effects of ageing are managed properly so that the SC is capable of performing its designated safety function. The review of each SC should include a technical explanation concerning management

of ageing effects, component failure data, material and performance degradation and obsolescence issue for each structure and component identified, so that their intended function(s) will be maintained consistent with the current licensing basis for the period of extended operation.

- Conduct of specific time limited ageing analyses (TLAAs) with new assumed time of plant operation and in accordance with Section 3.3. The evaluation of each identified TLAA should justify that the safety function of the SC will remain within design safety margins during the period of LTO.
- Identify and implement requirements for modification of existing plant programmes and development of new programmes.
- Document the results of the engineering process and re-validation of the TLAAs in an update to the FSAR as appropriate

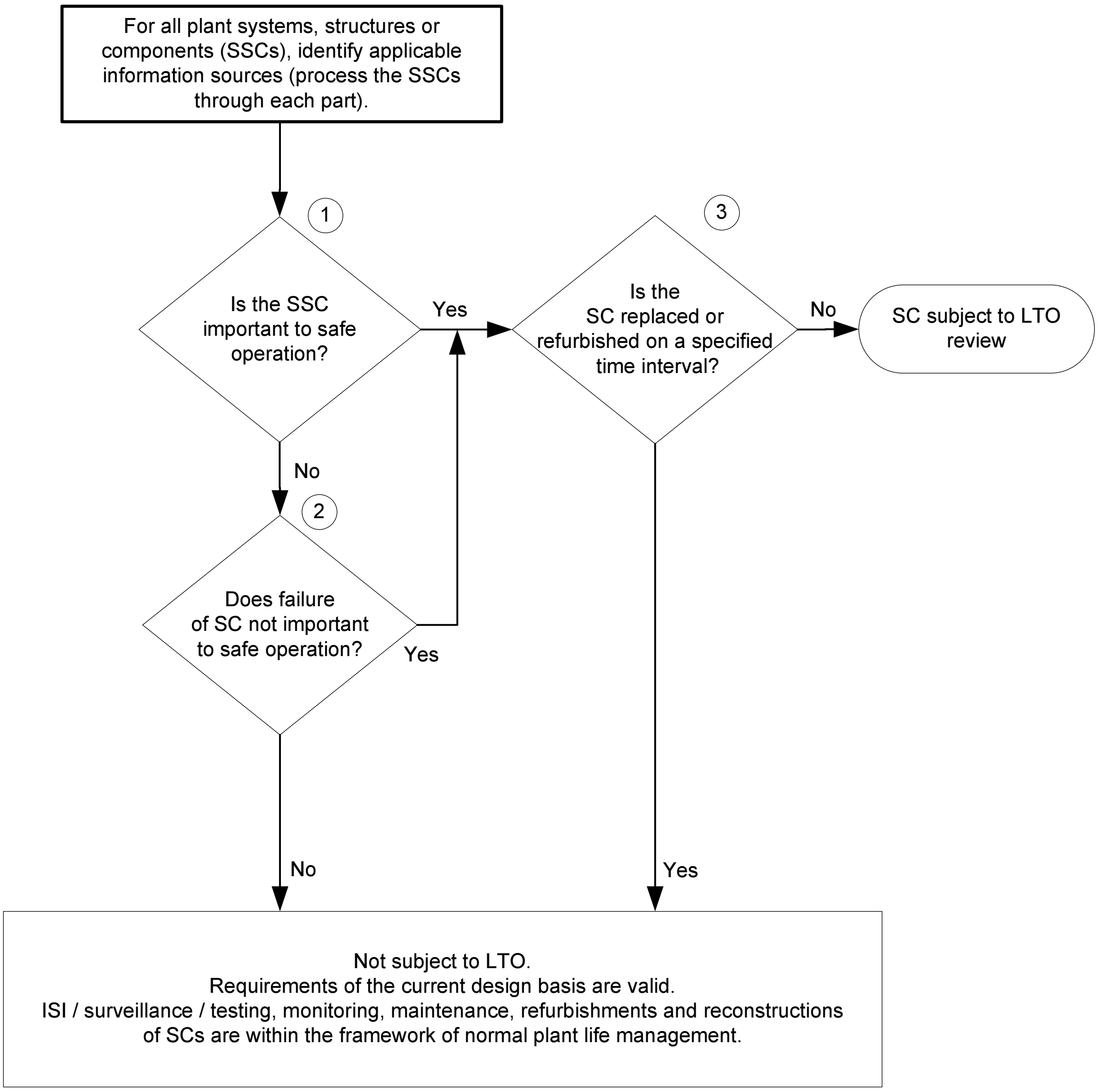
The general regulatory framework for LTO process has been based on license renewal (currently about 50 plants). Some countries are considering using another safety review process, such as PSR and in some countries these processes are combined. It is noted that if the PSR as currently defined in [5] is used as a regulatory basis for LTO, the PSR should include the following additional features which are described in this report:

- The broader focus of the LTO process including e.g. reviews of TLAAs;
- The systematic approach identifying SSCs within the scope of LTO;
- The engineering evaluation using defined acceptance criteria.

2.5. SCOPING AND SCREENING PROCESS

The scoping and screening processes are provided in Figs 1 and 2. The LTO evaluation process considers all plant SSCs, and identifies the applicable information sources. If an SSC is important to safety, its failure does impact safety function, and it is not replaced and refurbished within a specified time interval, then it is subject to a LTO review. If an SSC is important to safety, but it is replaced or refurbished within a specified time interval, then it is not subjected to LTO review. If an SSC is not important to safety but its failure could impact safety functions, then it is also subject to LTO review. Figure 1 depicts the scoping process starting with all plant systems, structures, and components. Figure 2 depicts the screening process to identify plant systems, structures, and components that are subject to LTO engineering evaluation.

The objective of the scoping and screening process is to ensure that all SSCs important to safety would be identified and subject to engineering evaluation as part of the LTO process. Appendices II - IV have example tables for SCs that would be included in LTO as a result of applying the scoping and screening process described here.



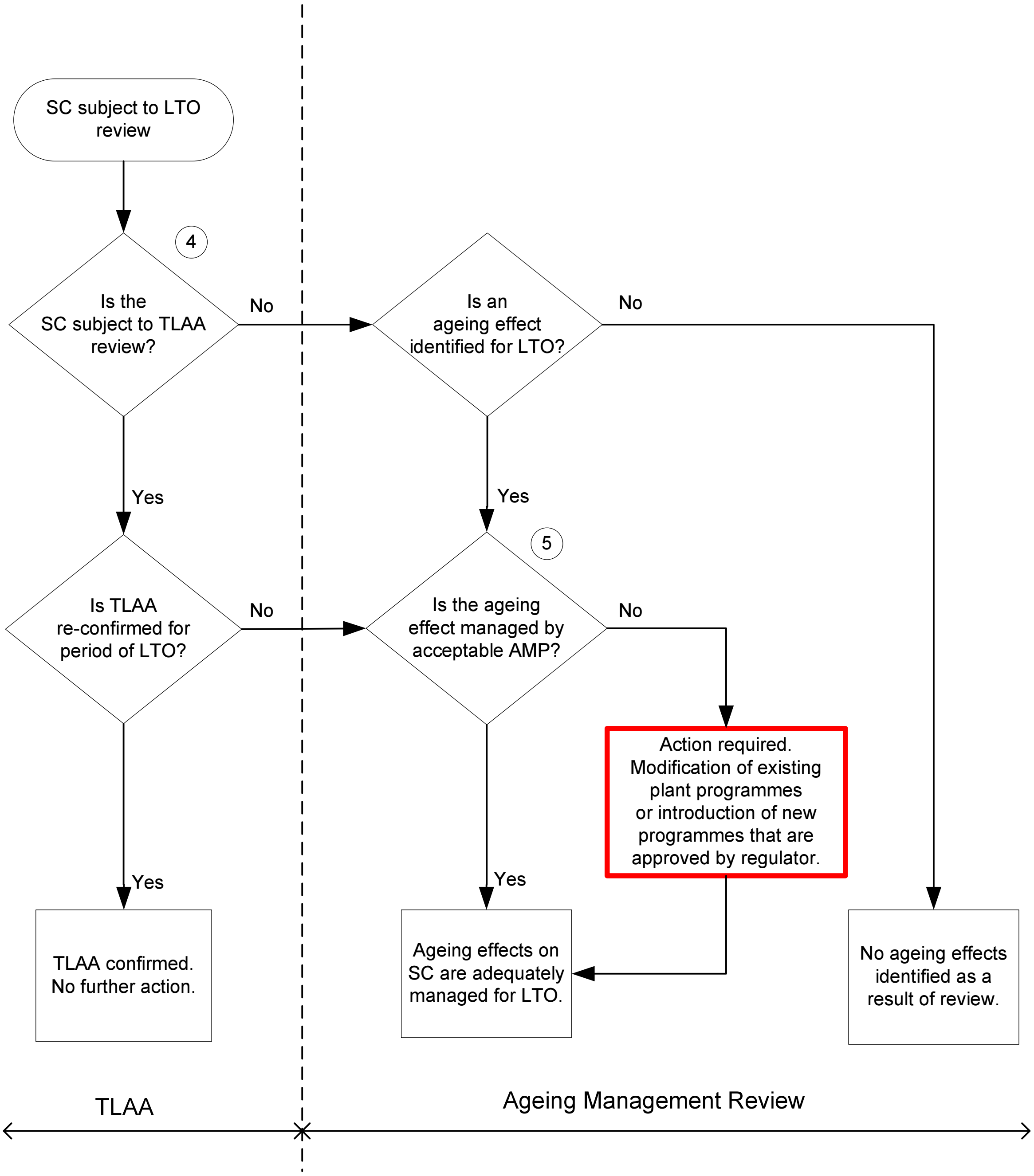
(1) Systems, structures and components important to safety that perform the following functions:

- ensure integrity of reactor coolant pressure boundary,
- ensure the capability to shut down the reactor and maintain it in a safe shutdown condition,
- ensure the capability to prevent or mitigate the consequences of accidents that could result in potential off site exposure.

(2) Structures and components not important to safety but whose failure may impact safety functions as defined in Item 1.

(3) Structures and components that are replaced or refurbished within a specified time period do not need to be included in an ageing management review or subjected to an ageing management programme.

FIG. 1. Scoping process for LTO.



(4) Time limited ageing analysis (see Section 3.3)
(5) Attributes of effective ageing management programmes (see Section 3.2)

FIG. 2. Screening Process for LTO.

2.6. PRECONDITIONS FOR LTO

All MS with successful LTO programmes completed preparatory activities or programmes prior to initiating an LTO programme. Based on the experience accumulated, the following basic steps are recommended:

- Technical assessment of LTO feasibility; including compliance with regulatory safety requirements;
- Economical assessment of LTO feasibility; including the cost of any safety upgrades necessary for LTO;
- Detailed plant programmes for LTO implementation.

The following plant programmes and documentation should be considered preconditions for LTO:

- Existing plant programmes;
    - In-service inspection
    - Maintenance
    - Equipment qualification
    - In-service testing
    - Surveillance
- Quality assurance, and configuration management;
- Original time limited ageing analyses (TLAA) or residual life assessment;
- Updated final safety analysis report (FSAR).

In order for the existing plant programmes above to be credited for LTO they should be reviewed against respective requirements set forth by the nine attributes described in Section 3.2 of this report.

2.7. UPDATE OF FINAL SAFETY ANALYSIS REPORT

In compliance with the national legislation, the Final Safety Analysis Report (FSAR) has to be submitted by the applicant to the regulatory body as a basis document for issuance of operating license of a NPP. This practice is very similar in all Member States. In many Member States the FSAR is updated annually.

This documentation is essential when performing the engineering evaluation for LTO in order to ensure that SSCs are able to function within the current licensing basis during the period of LTO.

Updating of the Final Safety Analysis Report, based on implementation of LTO engineering evaluation, should be conducted to integrate the results in plant programmes and safety analysis. The updated FSAR should reflect the overall plant safety with respect to long term operation and constitute the basis document for the operator in applying for, and the regulator in approving, the license for long term operation of the NPP.

2.8. RECOMMENDATIONS

Requirements for long term operation of existing nuclear power plants should be specified within their regulatory framework and a technical basis justifying the period of operation beyond design life of the plants should be provided.

The results of the review of the preconditions for LTO as defined in this report (see Section 2.6) should be implemented and appropriately documented.

The FSAR and its updates or other licensing documents should clearly and adequately describe the current licensing basis or the current design basis requirements for current plant operation. It is recommended that the implementation of plant activities for LTO be properly documented in updating FSAR or other licensing documents that integrate the results of the LTO engineering evaluation and constitute the basis documents for LTO license application and approval.

Existing NPP programmes may be credited with some modifications or enhancements upon evaluation/assessment for use in LTO. The requirements for existing NPP programmes are provided in Section 3.2. Ageing management programmes may be needed (or need to be modified) for those structures and components that were not in the scope for the current plant programmes, but are in the scope for LTO for reasons such as operating experience, or PSA.

3. PLANT ACTIVITIES FOR LTO

3.1. REVIEW AND MODIFICATION OF EXISTING PLANT PROGRAMMES

As stated in Section 2.6, the existing plant programmes described next are considered preconditions for LTO. The preconditions identified below were specifically selected by WG1 because these plant programmes impact all areas of plant operation identified in the scope of Working Groups 2, 3 and 4.

In addition to programmes described below, Appendices II-IV provide a more detailed description of the candidate programmes within their focus area and provide recommendations for a number of additional plant programmes useful for LTO (e.g. applied diagnostic systems including load monitoring, nondestructive material properties testing, chemical regimes monitoring, destructive tests and material research carried out during NPP operation).

Any existing plant programme intended to be used to support long term operation and manage the ageing effects identified for LTO should be reviewed to determine whether it meets the respective requirements set forth by the nine attributes defined in Section 3.2. The outcome of the review should provide the technical basis to clarify whether the ageing effects relevant to maintaining intended safety functions will be detected and characterized, or modifications and/or new programmes are necessary.

3.1.1. In-service inspection

The basic in-service inspection (ISI) methods are visual checks, destructive and non-destructive tests and continuous monitoring by permanently built-in systems. The range, periods, methods, evaluation, technology, etc. of ISI are mostly defined using deterministic methods; complementary risk informed (RI-ISI) approach which use contribution to core damage (risk), consequence of failure and an assessment of degradation to define the scope and periods of ISI (mainly piping) is increasingly adopted and developed.

The ISI programmes are usually tailor-made, taking into account the specific features of the plant design, material selection, and construction practices.

ISIs include inspections of structures and components set by national regulations and implemented through quality assurance documentation, equipment checks, diagnostic inspections and measurements etc. ISI of passive components and structures is a critical part of the operation and maintenance of nuclear power plants. ISI programmes provide part of the technical basis for ensuring that the structural integrity of systems, structures and components is adequate for operation.

The methodology, equipment and personnel, which are part of the ISI process, should be qualified according national standard, regulatory requirements, and IAEA recommendations. The qualification process should include requirements that provide a quantitative measure of effectiveness (e.g. UT detection capability and UT flaw characterization error) through blind trials on test block.

Operating organization should develop a review process for evaluating current ISI practices for effectiveness in detecting and characterizing the ageing mechanisms for each structure and component. The review process should provide a technical basis that justifies that the ageing phenomena will be adequately detected with the proposed inspection or monitoring activities.

Operating organizations should consider developing a living database that documents the effectiveness of ISI in detecting and characterizing degradation mechanisms. The database should provide technical references to support findings and conclusions.

If RI-ISI programmes are to be used during the period of LTO, consideration should be given to 1) developing comprehensive regulatory requirements for implementation of RI-ISI and 2) the effectiveness of RI-ISI should be evaluated as recommended under attribute 7 in Section 3.2, because RI-ISI programmes have limited operational experience.

The ISI result should be correctly documented so that a comparative analysis of the inspection results obtained during inspection can be done, especially when the inspections are performed in separate areas and at different periods of time.

3.1.2. Maintenance

Similar to in-service inspection, maintenance for active components include: testing activities for components set by national regulations and implemented through quality assurance documentation, equipment checks, diagnostic monitoring and measurements, repair, replacement etc. Testing of active components is a critical part of the operation and maintenance of nuclear power plants. The programmes to maintain the active components are typically country specific. The objective of the periodic maintenance activities is to ensure that active components are capable for performing its designed function.

Maintenance programmes for LTO should clearly identify the type of maintenance (preventive, predictive and corrective), the links with ageing management programmes, the frequency and tasks, the records, their evaluation and storage for optimization.

Operating organizations should evaluate current maintenance programmes for effectiveness in detecting and characterizing the ageing mechanisms for each structure and component. The evaluation should provide a technical basis to justify that the ageing phenomena will be adequately detected with the proposed inspection or monitoring activities. The attributes of such a programme should be made clear in terms of target performance goal, identification of the functional failure, feedback on operational experience.

Operating organizations should consider developing a systematic approach to the maintenance with respect to long term operation, addressing inadequacy of current programmes and technical development such as application of risk informed technology.

Operating organizations should consider developing a living database that documents the effectiveness of maintenance in detecting and characterizing degradation mechanisms. The database should provide technical references to support findings and conclusions.

Operating organizations should consider developing and maintaining databases (similar to RPV surveillance specimens) for I&C materials.

Operating organizations should consider applying destructive testing methods using specimens of electrical cables that were exposed actual environmental conditions during operation to monitor material degradation of during LTO.

The maintenance programme for the structures in the scope of the LTO based on standard preventive maintenance is not suitable to support an LTO programme. The maintenance programme should be focused to the monitoring of its effectiveness and therefore to be of the “condition based” type.

Initial values and maintenance results for mechanical, electrical, and physical/chemical properties of the cables should be properly documented.

3.1.3. Equipment qualification

Equipment qualification (EQ) establishes, through quality assurance processes and testing, that equipment within the scope of LTO is capable of performing an intended function during the period of LTO or that the equipment will be replaced / repaired in order that its intended function will not compromise safe operation during LTO. The EQ programmes are part of long term programmes and strategies.

Environmental and seismic qualification should be required for equipment important to safety and or equipment whose failure could jeopardize any safety function performance.

It should be demonstrated that equipment qualification remains valid over the expected period of LTO. The demonstration should support technical justification that the ageing effects on mechanical equipment will be managed effectively for LTO.

Equipment qualification status should be validated mainly through surveillance, maintenance, modifications and replacement control, environment and equipment condition monitoring and configuration management.

Environmental conditions should be assessed, taking into account natural phenomena, different accidents and also electromagnetic compatibility.

Equipment designed according to earlier standards should be requalified under a comprehensive programme that is focused to ensure that the equipment can perform its design function under current design basis accident conditions.

The operating organization should consider timely replacement of environmentally qualified mechanical and electrical equipment that is not qualified for the period of LTO, or have its qualification extended prior to reaching the ageing limits. A specific programme for replacement of environmentally qualified and non-environmentally qualified mechanical and electrical equipment should be developed.

Non-environmentally qualified mechanical and electrical equipment in the scope of LTO should be evaluated to determine if it can perform its function during the period of LTO.

Equipment reclassified as part of an LTO engineering evaluation should have an appropriate testing schedule or replacement programme including corrective measures to ensure the functionality during the period of LTO.

Qualification documentation should be stored in auditable form during the entire installed life of equipment including LTO.

Mechanical and electrical equipment in mild environment within the scope of LTO should be evaluated to determine if it can perform its function during the period of LTO.

3.1.4. In-service testing

Component in-service testing is a part of the normal operation or maintenance programme of operating power plants and serves to verify that the SSCs are capable of performing their design function. In addition to verifying the functional capability of equipment, these tests are often combined with a trending scheme to reveal potential problems, before the problems could lead to failure of the SSCs.

Start up functional tests are performed to check functionality of individual equipment as well as the entire system(s) following maintenance on the system or extended shutdown of the system. These tests involve calibration checks to ensure the accuracy of required metrological settings. Procedures should be detailed and well referenced ensuring that the uncertainty in the measurements is known and corresponds to the required accuracy of the measurement.

The power range tests are executed according to a schedule that is in compliance with the corresponding prescriptions of the operating limits and conditions (Technical Specifications).

A separate set of tests are generally conducted prior to unit shutdown to justify that the conditions of SSC required for the cool down of the reactor coolant system and its subsequent depressurization comply with the corresponding requirements.

In-service testing should be clearly tied with the operational requirements for the component. In general, component in-service tests are based on the operational limits and conditions specified and include:

- Acceptance criteria are established based on the safety analysis report and regulatory requirements;
- Check of the initial conditions prior to the tests;
- Start-up of the active equipment and monitoring of the basic parameters to be in the range of the allowable values;
- Check of the control and performance of the electrically and pneumatically driven valves, check of the full or partial stroke depending on the purpose and requirements of the performed tests;
- Check of correctness of any automated functions;
- Monitoring of the parameters during the tests.

The minimum requirements for component in-service tests should address the following topics 1) scope and scheduling, 2) acceptance criteria, and 3) criteria for monitoring and trending the results.

3.1.5. Surveillance and monitoring programmes

Surveillance and monitoring programmes monitor and trend the material properties or performance of structures and components important to safety. The results provide data that may be used to validate the forecasted material properties or component performance, based upon the available knowledge and well in advance of potential problems. Their scope (materials, type number of specimens or specific components), their pertinence (dosimeter sets, lead factors, and means for irradiation temperature control) as well as the completeness and the quality of the valuation of the results differ among Member States depending upon specific regulatory requirements.

Surveillance programmes using representative material samples addressing time limiting mechanisms should be extended or supplemented for LTO, if necessary.

Operating organizations should consider implementing controlled ageing programmes namely for electrical cables at their NPPs. Initial values and surveillance and monitoring results for mechanical, electrical, and physical/chemical properties of the cables should be properly documented. Periodic monitoring of the changes during the NPP lifetime is presumed, and the evaluation of their lifetime based on the experimental results and monitoring of the environment should be performed.

Operating organizations should consider conducting experiments on verifying the influence of the current effect of gamma radiation, increased temperature and electric load of the cables with the aim to create a relevant mathematical model.

3.2. AGEING MANAGEMENT PROGRAMMES FOR LTO

The importance of ageing management programmes is widely recognized. Ageing is the continuous time degradation of materials due to normal service conditions which include normal operation and transient conditions. The ageing management is combination of engineering, operations and maintenance actions to control ageing degradation and wear out of structures, systems or components remains within acceptable limits.

All structures and components resulting from the LTO scoping and screening process should be subject to an ageing management review which will identify the need for ageing management programmes. The ageing management review consists of the following steps:

Step 1 involves engineering assessment of the current status of structures and components within the scope of LTO and identifying potential ageing effects of degradation mechanisms. The engineering assessment requires an understanding of the operating environment and potential degradation that may affect structures and components and the effects of the degradation on the ability of the systems, structures and components to perform design functions. An adequate engineering assessment requires knowledge of the design basis (including applicable codes and regulatory requirements, design, and fabrication including material properties and specified service conditions), construction, operation and maintenance history (including commissioning, surveillance and any trend curves), the inspection results, the environment (inside and outside the structures and components) and the conditions including any transients and generic operating experience and research results.

Step 2 involves an evaluation process that achieves the following objectives:

- Review of existing plant programmes to determine that they meet the respective requirements set forth by the nine attributes defined next. This comparison should provide technical basis to clarify that the impact of the ageing effects will be detected and characterized. In the event that this evaluation identifies shortcomings the existing programmes should be modified accordingly. If existing plant programmes do not address identified ageing effects then new programmes should be developed and implemented. Section 3.1 provides detailed description of the most common existing operational programmes that may be evaluated for the use of LTO.
- Review of proposed ageing management programmes to ensure that intended functions will be maintained consistent with the current licensing basis for the proposed period of LTO.

Step 3 documents the technical justification demonstrating that the structures and components within the scope of LTO, identified in Step 1 will fulfil their safety related functions during the proposed period of LTO.

Further detailed technical information is provided in Appendices I-IV of this report.

EFFECTIVE AGEING MANAGEMENT PROGRAMME ATTRIBUTES

1. **A defined programme scope**
   The scope of the programme should include the specific structures and components subject to an ageing management review;
2. **Identification of preventive actions or parameters to be monitored or inspected**
   Actions to prevent or mitigate ageing degradation or parameters to be monitored or inspected for the intended function(s) of the particular structure or component should be identified;

3. **Detection of ageing degradation/effects**
   Detection of ageing effects should occur before there is a loss of the intended function(s) of a structure or component. This includes aspects such as method or technique (i.e., visual, volumetric, surface inspection), frequency, sample size, data collection and timing of new/one–time inspections to ensure timely detection of ageing effects;
4. **Monitoring and trending including frequency and methodologies**
   Monitoring and trending to provide predictability of the extent of degradation, and timely corrective or mitigative actions;
5. **Acceptance criteria**
   Acceptance criteria against which the need for corrective action will be evaluated, to ensure that the intended function(s) of a structure or component are maintained under all CLB conditions during the period of extended operation;
6. **Corrective actions if a component fail to meet the acceptance criteria**
   Corrective actions, including root cause determination and prevention of recurrences, should be timely;
7. **Confirmation that required actions have been taken**
   Confirmation process to ensure that preventive actions are adequate and that appropriate corrective actions have been completed and are effective;
8. **Administrative controls that document the programme's implementation and actions taken**
   Administrative controls to provide a formal review and approval process;
9. **Operating experience feedback**
   Operating experience of the ageing management programme, including past corrective actions resulting in programme enhancements or additional programmes, to provide objective evidence to support the conclusion that the effects of ageing will be managed adequately so that the intended function(s) of a structure or component will be maintained during the period of extended operation.

3.3. IDENTIFICATION AND REVALIDATION OF TIME LIMITED AGEING ANALYSIS

Time limited ageing analyses (TLAAs) are plant specific safety analyses that are based on an explicitly assumed time of plant operation or design life (for example, aspects of the reactor vessel design). Examples of TLAAs are those calculations and analyses used by the plant operator that:

- Involve systems, structures, and components within the scope of LTO;
- Consider the effects of ageing;
- Involve time limited assumptions defined by the current operation term;
- Are determined to be relevant by the plant operator in making a safety determinations as required by national regulations;
- Involve conclusions or provide the basis for conclusions related to the capability of the system, structure, or component to perform its intended function(s);
- Are contained or incorporated by reference in the current licensing basis.

For long term operation, once a TLAA is identified, an evaluation will be performed with the new assumed time of plant operation to demonstrate that the component will meet its design criteria at the end of the extended plant life, and that at least one of the following criteria is applicable:

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

In some cases, depending on the safety relevance, a complete reanalysis of the ageing process might be needed and the time limits of safe operation should be set.

Uncertainties in the material properties for SSCs in the scope of LTO constitute a major challenge for revalidation of TLAAs, even given the surveillance, monitoring and trending programme used in nuclear power plants.

Analytical techniques accounting for the impact of improved inspection methodology should be developed to justify analysis and plant programmes subsequently.

The following Sections describe a list of common TLAAs.

3.3.1. Reactor pressure vessel irradiation embrittlement

This group of time limited ageing analyses concerns the effect of irradiation embrittlement of the reactor vessel and how this degradation mechanism affects analyses that provide limits or address regulatory requirements.

3.3.2. Metal fatigue

This TLAA involves the thermal and mechanical fatigue analyses of plant mechanical components within the scope of LTO. Specific components have been designed and analyzed considering transient cycle assumptions identified in vendor specifications and the FSAR or design basis documentation. Typical component and analysis that are performed include:

- reactor vessel structural integrity
- reactor vessel internals structural integrity
- systems and components in the reactor coolant pressure boundary
- control rod drive mechanism structural integrity
- steam generator structural integrity
- pressurizer structural integrity
- reactor coolant pump structural integrity
- pressurizer surge line structural integrity
- piping structural integrity
- environmental effects on fatigue
- containment liner plate fatigue analysis
- BWR feedwater piping.

3.3.3. Fracture mechanics analysis

This TLAA involves the fracture mechanics analysis of plant passive components within the scope of LTO. Typical components that require fracture mechanics analysis include:

- leak-before-break analysis (depending upon design and regulatory requirements);
- component / piping indication analysis.

3.3.4. Thermal ageing

Examples of components that require thermal ageing analysis are components in the reactor coolant pressure boundary as well as other components subject to high temperature.

3.3.5. Loss of preload

This TLAA involves the analyzing the potential for loss of preload for passive components within the scope of LTO. Typical components that require loss of pre-load analysis are e.g. reactor vessel internal bolting, containment tendons, etc.

3.3.6. Loss of material

This TLAA involves the analyzing the potential for loss material and compromising function due to wear of passive or active components within the scope of LTO. Typical components that require analysis include:

- Steam generator tube wear
- Pipe wall thinning due to wear
- Bottom mounted instrumentation thimble tube wear
- Containment accident recirculation heat exchanger tube wear.

4. RESEARCH PROGRAMMES RELEVANT TO LTO AND OPERATING EXPERIENCES

Currently, most of the Member States do not have a process to collectively and systematically document and analyze research results and operating experiences. Available research results and operating experiences may have been collected and analysed by individual NPP, but were not shared with other Member States. A process needs to be in-place to gather the information, systematically analyzed by an organisation such that the information could be more useful as a whole for all Member States.

Available research results, operating experience but also maintenance and competence development, that are directly related to LTO should be shared and used by all Member States. Specifically, operating experience related to ageing of structures and components should be systematically documented and shared with other Member States. Research results should also be systematically analysed for its applicability to LTO and shared with other Member States.

The objectives of these projects should be:

- Identification of degradation mechanisms and their effects on long term functionality of safety related SSCs;
- Development of databases on ageing management assessment;
- Design of upgraded monitoring system to ensure accurate monitoring of all significant degradation effects;
- Analysis and trending of data for the evolution of SSCs degradation processes;
- Development of ageing management programs to minimize ageing degradation processes including the corrective measures of their effects.

Appendix I

GENERAL LONG TERM OPERATION FRAMEWORK

I.1. INTRODUCTION

This Appendix describes the results of Working Group 1 on General LTO Framework.

The objectives of WG 1 were to:

- Identify pre–conditions for LTO;
- Review regulatory approaches to LTO in participating Member States;
- Reach a consensus on approaches and safety criteria for LTO including their basis;
- Identify necessary information contained in design and safety basis documents to establish a baseline for LTO;
- Identify attributes of acceptable plant upgrading and ageing management programmes for LTO;
- Establish guidance on approaches to LTO; and to
- Discuss future challenges.

Sections I.2–6 of this Appendix address safety aspects of the general LTO framework, providing for each aspect the background, common elements and differences identified among the approaches used in the participating Member States, future challenges, and recommendations. Section I.7 of this Appendix provides a list of related regulatory documents for each participating Member State. The processes of scoping and screening are presented in Section 2.5 of the main report.

I.2. LAWS AND REGULATIONS RELEVANT TO LONG TERM OPERATION

I.2.1. Background

The establishment of a stable regulatory regime based on a hierarchical legal system (laws, regulations, guides) has been a crucial precondition for the development of activities in the nuclear sector in all Member States. The principal recommendations for the role of the government in this area are given in the IAEA recommendations, particularly in the Safety Fundamentals and in Safety Standards in the area of legal and governmental infrastructure.

The situation in Member States participating in the Programme is generally consistent with the IAEA recommendations, although to varying degrees. Certain fundamental legal frameworks do exist, independent regulatory bodies have been established, and applicants/licensees are required to assume the primary responsibilities for ensuring safety of their nuclear facilities.

This situation has been regularly confirmed by the review meetings of the contracting parties to the Convention on Nuclear Safety (1999, 2002, and 2005). All participating Member States of the Programme are contracting parties to the Convention and have submitted national reports for the reviews.

Support in the implementation of the IAEA Safety Standards has been provided by the Agency by means of safety services. Two of the services that are most important are: the International Regulatory Review Teams (IRRT), which is focused on the established regulatory regime and authority and the responsibility of national regulatory body; and the Operational Safety Review Team (OSART), which is focused on the activities and responsibilities of the operating organization regarding the safety of nuclear power plants (NPPs).

All Member States participating in the Programme have invited OSART missions to their NPPs during operations and the majority of the Member States have invited IRRT missions. The results of these missions are documented and available in the particular mission reports.

The definition of operation, in the IAEA Safety Glossary, is given as “all activities performed to achieve the purpose for which an authorized facility was constructed.” For NPPs, this includes maintenance, refuelling, in–service inspection, and other associated activities.

As for LTO, the laws and regulations in different Member States range from a general decree to a very prescriptive law of technical requirements. Specifically, the general decree may not necessarily address any requirements for LTO, but simply states that safety should be maintained during plant operation. How to maintain safety is largely left to the licensees. Some participating Member States have licence terms for their operating NPPs. Validity of licensees varying from 5 years to 40 years depends on the Member State’s regulatory regime. Others do not have limitations in licence terms and their regulatory process is requiring continuous upgrade of plant operation when needed. Therefore, these Member States consider that their NPPs can continue operating without any additional safety measures for LTO.

Generally, for the initial licences, the design life was conservatively established by the principal designers in the Member State of origin, taking into account the knowledge and the economical considerations at that time. Design life was defined in the time span of 30 to 40 years. The national regulatory bodies either explicitly defined this time in the licences or issued the operating licences without a time specification (time unlimited operating life). By the IAEA’s definition, the design life is the period of time during which a facility or component is expected to perform its functions according to the technical specifications to which it was produced; whereas the operating life is the period during which an authorized facility is used for its intended purpose until decommissioning or closure.

Since the late eighties, some Member States have initiated activities to assess the qualified life of their NPPs by examining important structures, systems and components (SSCs) at these plants. Qualified life is defined in the IAEA Safety Glossary as the period for which an SSC has been demonstrated, through testing, analysis or experience, to be capable of functioning within acceptance criteria for specific operating conditions while retaining the ability to perform its safety functions during and after a design basis accident or earthquake.

In the early nineties, the IAEA initiated activities focusing on physical ageing and ageing management of various types of SSCs and issued recommendations in the form of TECDOCs, Safety Reports and Technical Reports.

LTO of the nuclear power plant facilities is a current topic in Member States. To make a timely decision on whether or not it is feasible and economical to pursue such a project, an international consensus approach to necessary safety decisions would be beneficial. This report contains the guidance for making these safety decisions and for establishing a process to guide safe LTO if so determined.

I.2.2. Common elements and differences

Originally, the term ‘long term operation’ was not defined in any Member State legislation. Since the responsibility for NPP safety is a national responsibility, the national regulatory regimes have differences. In principle, they can be divided into groups of the more prescriptive or less prescriptive regulatory regimes. The level of detail of the regulatory regime depends on various aspects such as the character of regulatory activities in the country, traditions in technical areas, size and standardization of the nuclear power programme, and the regulatory influence of the vendor country.

Both approaches have pros and cons. The more prescriptive approach describes the regulatory requirements in detail and prevents any ambiguity. However, its preparation and maintenance consumes a large amount of regulatory effort and could dilute the initiative of operators to seek their own solutions and the awareness of operators of their responsibilities for safety. The less prescriptive approach is flexible in its application and supports operations initiatives, but sometimes could create misunderstandings.

Also, different regulatory approaches have been developed in the area of regulation for LTO. Some Member States, during revisions or by amendment of General Legislation (Atomic Law, Atomic Energy Act, etc.), introduced a new licensing step – license of long term operation/licence renewal. Subsequently, the regulatory body issued a set of regulations and guides providing detailed requirements for this new licensing step. The approach of other Member States consists of postulating that adequate safety has to be maintained at any time during operation, taking into account the aspects of ageing. The information in this report is intended to be applicable to all Member State regulatory structures.

I.2.3. Future challenges

Any Member State that plans to pursue LTO will have to take necessary actions to ensure safe operation of its nuclear facilities. To achieve this goal, the Member State should develop its own regulatory framework that clearly establishes regulatory requirements for LTO or provides a technical basis for justifying an indefinite period of operation beyond the design life of the facilities. Whether an individual Member State has a short, long or indefinite licence term, a consistent and uniform definition of long term operation should be adopted. This would facilitate the exchange of relevant operating experience.

I.2.4. Recommendations

Member States interested in long term operation should stipulate requirements for the long term operation of existing nuclear power plants within their regulatory structures. In this report, the definition of long term operation is used as agreed and approved by the programme Steering Committee. Long term operation is defined as follows:

“Long term operation (LTO) is operation beyond an established timeframe set forth, e.g. by licence term, design limits, standards, and/or regulations etc., which has been justified by safety assessment considering life limiting processes and features for structures, systems and components (SSCs).”

Long term operation should be approved on the basis of activities that will maintain plant safety. The activities include meeting the preconditions as defined later in this report and providing acceptable ageing management programmes (AMPs).

I.3. CURRENT DESIGN BASIS REQUIREMENTS

I.3.1. General design codes and standards

I.3.1.1. Background

Internationally recognized codes and standards were used in the original design of NPPs. Initially, former Soviet Union or US codes and standards were used as a basis in all Member States, but later designs of NPPs had been increasingly influenced by European codes and standards.

I.3.1.2. Common elements and differences

Many NPPs were built to codes and standards that may not meet today's safety requirements. Large efforts have been made and are continuously underway in Member States to maintain and enhance the safety of existing NPPs to meet today's standards. In many Member States, significant safety upgrades were initiated following safety analyses and analyses of operating experience, as well as lessons learned from incidents and accidents.

I.3.1.3. Future challenges

Many Member States stressed that a clear and strict legal basis is necessary for safety upgrade programmes, particularly in a liberalized market and in a prescriptive regime. More effort is needed to make it happen.

Documenting the use of internationally recognized and accepted safety standards and methodology for assessing the status of an NPP is essential. Equally important, the design codes and standards used in the original design and upgrades should be documented for future reference.

I.3.1.4. Recommendations

The design codes and standards used should be clearly identified in the final safety analysis report (FSAR) or other licensing documents.

I.3.2. Periodic safety review

I.3.2.1. Background

In the past, many Member States participating in the Programme have performed extensive safety improvement programmes and have substantially changed and improved the original design basis requirements.

In addition to the continuous safety verification process, some Member States have seen great value in introducing and implementing periodic safety reviews and in many cases, the periodic safety review (PSR) is performed in periods of 10 years. PSRs provide an opportunity for a stand back look that is outside the normal regulatory processes. This review allows the safety integrity to be verified and confirmed, and also identifies areas for short term and long term safety improvements.

In 1994, the IAEA issued a Safety Guide on Periodic Safety Review of Nuclear Power Plants [5]; this was revised in 2003. This Safety Guide provides guidance on the systematic reassessment of the safety of NPPs at regular intervals to deal with concerns on the cumulative effects of ageing, modifications, operating experience and technical developments; the Safety Guide is focused on the operating lifetime of an operational facility.

The majority of the Member States accepted this approach implementing the PSRs at the recommended time interval of every ten years. The Programme Steering Committee recognized, however, that internationally agreed–upon comprehensive guidance is needed to assist regulators and operators in dealing with the unique challenges associated with LTO issues listed in the Safety Guide on PSR.

I.3.2.2. Common elements and differences

Various measures based on operational feedback and other inputs have been introduced and implemented since the plants started operation. Although deterministic safety criteria and analysis are the basis for licensing, probabilistic safety analysis (PSA) methodology is being used increasingly as a complementary basis in the modernization work.

Many Member States found that it is useful to consider different phases in the process of safety verification and upgrading by:

– Identifying the reference requirements and comparing the installation to them, i.e., to those of the initial licensing and to those that were decided during operation, to consider new developments and operational experience.

- Solving identified problems where conformity with reference requirements was not found, e.g., in materials issues and component integrity, separation and renewal of equipment, installation of new functions/systems.
- Safety reassessment against recent safety standards and definition of priorities for longer term improvements, e.g., the use of state–of–the–art deterministic and probabilistic methods, consideration of new safety concepts, comprehensive analysis and prioritization.
- Upgrading and safety improvement, e.g. building additional separated safety trains, introducing compensatory measures, implementing new instrumentation and control (I&C) systems and modifying control rooms, improving fire safety and resistance to other external events.

Some Member States agreed that in order to maintain and upgrade safety there is a need for licensees in all Member States to have processes in place to continuously verify the safety of nuclear installations in order to ensure that they operate in accordance with regulations. The processes should include technical, human, organizational and administrative factors. Strong drivers for such continuous safety programmes are, in addition to incidents and accidents, analyses of operational experience, systematic deterministic and probabilistic safety analyses, regulatory oversight, new internationally recognized safety standards, benchmarking and international peer review of licensee and regulatory practices, as well as research and development (R&D). Strong safety management, including systematic self–assessment of licensees, is needed to manage safety verification and improvement programmes. The importance of management systems for safety must not be underestimated. For these programmes to be effective, human and financial resources, as well as strong competences in leadership and safety, are needed.

It is essential to have systematic ageing management programmes to maintain safety during the entire period of operation. For these programmes, the licensees need to consider various types of ageing: physical ageing, technology ageing, requirement ageing, safety analysis and documentation ageing, and personnel and management ageing. The regulators need to pay significant attention to the effectiveness of licensee ageing management.

I.3.2.3. Future challenges

Member States agreed to the importance that NPPs built to earlier standards should:

- Fulfil all original regulatory requirements regarding design and operation;
- Fulfil additional requirements required by the regulator during operation;
- Be subjected to in–depth systematic safety assessment using modern analytical tools and considering operating experience and new knowledge, as well as recent standards of the IAEA; and
- Implement reasonable safety improvements that address findings from the assessments.

Safety upgrade programmes need to be based on a continuous licensing process for safety development, where PSRs may be an important driver. Many Member States agreed that, in the process of requiring safety upgrading of plants that were built to earlier standards, consideration needs to be taken to what is reasonable regarding costs versus safety. Some Member States stated that the safety concept of their modernization projects should be equivalent to state–of–the–art requirements.

I.3.2.4. Recommendations

The scope and extent of the continuous safety upgrading or verification process, such as the outcome of PSRs, should be clearly identified and described in the FSAR or other licensing documents.

For NPPs that have upgraded or plan to upgrade the power level, the following guidance should be followed:

For operators considering a power up rate, a review of operating experience and ageing management programmes should be performed prior to long term operation.

For operators who have permission for long term operation, a review should be conducted to ensure that ageing effects or ageing mechanisms considered as part of the long term operation review should continue to remain valid under the period of operation with power up rated.

I.3.3. Maintenance practices

I.3.3.1. Background

Maintenance practices are an integral part of activities performed by the operators of NPPs in all Member States participating in the Programme. Depending on the prescriptive level of the regulatory regime, the requirements for maintenance activities are laid down in laws, regulations, guidelines, requirements on industrial or equipment manufacturers, standards or other related documents. The method and scope of maintenance practices and the list of SSCs which are subject to maintenance activities have been defined primarily based on the importance of an SSC to the safety and reliability of NPP operation, on design documentation and on domestic and international operating experience. The maintenance activities are part of long term (e.g., five years), medium term (annual) and short term planning.

Maintenance programme activities are divided into preventive maintenance (regular, predictive) and corrective maintenance.

Maintenance activities may be performed by SSC manufactures, plant personnel or contractors. The country information reports (CIRs), which were prepared as a part of Working Group 1 activities, confirmed that, in all cases, maintenance activities are performed by qualified personnel in accordance with approved programmes and procedures. In addition, QA programmes were developed and implemented. Also, repairs and the use of spare parts have been subject to a similar regime as maintenance. Only a small number of participating Member States has been implementing a risk–informed approach in maintenance activities, while the rest of the Member States confirmed that this approach is at the stage of initial development. Use of operational experience and insights from risk analysis is important for the further development of preventive maintenance and for the assessment and management of reliability of SSCs during operation.

The experience gained from some Member States has confirmed the close relationship between maintenance activities and the long term operation of NPPs. Well–structured maintenance activities can be used to exclude active components from consideration of long term operation. They can also be used as acceptable ageing management programmes if they meet the definition set forth in Section I.4.4.

I.3.3.2. Common elements and differences

The CIRs confirmed that maintenance programmes exist in all participating Member States to ensure the safety, and in some cases, the reliability of plant operation. Maintenance activities are planned on the basis of different timescales (short term, medium term and long term). The general or detailed requirements for maintenance activities are given in binding documents either issued by a regulatory body, or described in manufacturer documents, industrial standards and plant procedures.

Stringent prescriptions for quality assurance of maintenance activities including qualified personnel exists in all participating Member States. The direct relevance of maintenance activities to long term operation of NPPs was not made clear in all CIRs, but some Member States give significant credit to their maintenance activities for long term operation.

Only a few Member States have applied the risk–informed approach to maintenance activities. For other Member States, this approach is still at the initial stage of development.

I.3.3.3. Future challenges

The challenges can be summarized into the following groups:

- optimization of maintenance activities on the basis of operating experience;
- implementing an approach to maintenance that sets goals and monitors efficiency; and
- implementing risk–informed tools to determine the scope and assess the risk of maintenance activities.

I.3.3.4. Recommendations

Analysis of the effectiveness of maintenance activities should be performed at NPPs and described in plant documents that are subject to regulatory oversight. An adequate maintenance programme should be identified as a pre–condition for long term operation.

I.3.4. Environmental qualification of electrical and mechanical equipment

I.3.4.1. Background

Environmental qualification (EQ) of equipment is a process to generate testing or analytical evidence to ensure that an item of safety related equipment can perform its safety function under accident conditions (loss of coolant accident, high energy line break, earthquakes, etc.) to meet system performance requirements for the design life of the equipment. The environmental qualification of the mechanical and electrical equipment of NPPs should be part of the design basis. CIRs confirmed that EQ has become part of regulatory requirements and, in many Member States, the EQ programme has been established and implemented.

On the basis of regulatory requirements, the utilities and NPPs prepared and implemented an EQ programme which consisted of:

- development and maintenance of a list of equipment to be qualified;
- type tests with ageing simulation based on postulated design basis events (the preferred method for EQ). Analysis and use of operating experience are alternative methods suitable mainly for mild environmental conditions and seismic qualification;
- providing evidence that equipment will perform intended safety function and will be maintained in auditable form during the entire installed life of the equipment;
- setting priority of environmental qualification on electric and I&C equipment that have to perform their safety functions during and following design basis events;
- replacement or refurbishment of equipment that is not qualified, or implementing corrective measures for ensuring performance of the required safety function; and
- preserving a valid EQ status mainly through surveillance, maintenance, modifications and replacement control, environment and equipment condition monitoring, configuration management and EQ personnel training.

A similar approach to EQ requirements and qualification practice has been implemented in many Member States. The EQ requirements apply to the electric equipment important to safety located in harsh environments. The following parameters are considered for environmental qualification: temperature, pressure, radiation, chemical effects, pre–ageing, submergency (if applicable), humidity, vibration and electromagnetic interference.

I.3.4.2. Common elements and differences

Environmental qualification has become part of regulatory requirements in Member States participating in the Programme and was or will be implemented by the NPPs. EQ is mainly based on US requirements and codes because of their early development and broad availability. A growing dependence is subsequently being developed and is centred on international standards (IEC, IEEE) and IAEA recommendations. Qualification practice is common for electric equipment in harsh environments associated with loss–of–coolant accident and high–energy line break in all participating Member States. A formal EQ programme is required (with the type test) as the preferred qualification method for simulation of ageing mechanisms following design basis accidents (DBAs).

The practices are different for qualification in a mild environment and for environmental qualification of mechanical equipment. Some Member States do not require formal EQ programmes for such cases. EQ is established on the basis of design practice, manufacturer preservations, in service testing, and appropriate QA control. The equipment that did not pass EQ was replaced. EQ documentation should be maintained in auditable form during the LTO. Performing of type tests are the preferred method for EQ. Analysis and operating experience are alternative methods mainly for mild environmental and seismic qualification.

I.3.4.3. Future challenges

EQ programmes have to be established and completed for current NPPs. For LTO, NPPs should be required to demonstrate that analyses remain valid, or the effects of ageing on the required (or demanding) function will be managed.

I.3.4.4. Recommendations

An adequate EQ programme should be a pre–condition for LTO.

I.3.5. Quality assurance practices

I.3.5.1. Background

For all Member States that participated in the Programme, the quality assurance requirements are stipulated in the legal framework (i.e. the Atomic Law and its implementing regulations.) These quality assurance requirements are generally consistent with those of the IAEA [32]. These requirements cover all activities including site approval, design, construction, operation, and decommissioning. They are prepared by operating organizations and are subjected to submission and approval by the regulatory body. Also, preparation for the QA programmes has been required also for activities important to safety (i.e. reconstruction and design changes etc.) According to the legal requirements, preparation of the QA programmes is obligatory for the design organization, manufacturers of SSCs important to safety, contractors, or supplier organizations whose activities may affect nuclear safety. The applicant has to submit the QA documentation to the regulatory body for review and approval for the main phases of the licensing process (siting, construction, operation) of an NPP.

The utilities and other organizations have been implementing international standards [33] or the national requirements [34]. For implementation of the QA procedures, operators have developed QA manual/handbooks which are approved by the plant manager. Also, the existing QA programmes have been fully integrated into the QA programmes for LTO.

The application and effectiveness of the quality assurance programme have been systematically and periodically reviewed by independent internal and external audits. The quality assurance function has been given a strong and independent position in the organization and has been directly subordinated to the top manager of the facility/organization. The QA programmes are developed at the utility and plant levels.

The QA regime has been applied to all activities affecting safety and reliability for selected SSCs which include designing, purchasing, fabricating, handling, shipping, storing, cleaning, erecting, installing, inspecting, testing, operating, maintaining, repairing, and refuelling.

It is important to consider the design basis management and configuration management as part of the QA program. A NPP must be able to retrieve design, operating and safety information that is accurate and reflects the actual configuration. It is the configuration management programme's goal to ensure that the infrastructure to make that happen is in place. Configuration management is an integrated programme to collect and manage the NPP configuration information from conceptual design throughout its operating lifetime, including changes made.

I.3.5.2. Common elements and differences

On the basis of CIRs, the QA programme has been developed and implemented as a part of the regulatory requirements in all participating Member States. The IAEA recommendations, international standards (ISO) and US codes and standards were used as the basis for the QA programmes.

I.3.5.3. Future challenges

QA programmes should be established and made up of all those planned and systematic actions necessary to provide adequate confidence that a SSC will perform satisfactorily in service, including quality control, design basis management, and configuration management.

QA programmes should comprise those quality assurance actions related to the physical characteristics of a material, structure, component, or system which provide a means to control and track the quality of the material, structure, component, or system to predetermined requirements.

I.3.5.4. Recommendations

An adequate QA programme, which addresses quality control, design basis management, configuration management and means to control and track the quality of the material, structure, component, or system to predetermined requirements, should be identified as a precondition for LTO.

I.3.6. Final safety analysis report and its update

I.3.6.1. Background

In compliance with the national legislation (Atomic Act, regulations), the FSAR has to be submitted by the applicant to the regulatory body as a basis document for the issuance of the operating licence of a NPP. This practice is very similar in all Member States participating in the Programme. The layout and content of the FSAR follows the USNRC Regulatory Guide [35] or is based on the requirements of national regulatory body. Some regulatory bodies have been following the USNRC Standard Review Plan [36] for review and assessment of submitted documentation.

In many Member States the FSAR is updated annually to include approved modifications, changes or reconstructions of the NPP. The conservative approach is applied in safety analyses in the FSAR (i.e. use of conservative models and parameters and initial conditions, application of single failure criteria). There is a tendency in some Member States to apply the best–estimate approach in safety analysis. A full update of the FSAR is performed in Member States with different time periods corresponding to the operating licence term or other regulatory activities/requirements.

In many Member States the probabilistic safety analysis (PSA) is not an official part of the licensing process. On the other hand, the PSA methodology is accepted as a complementary approach to safety evaluation and provides an in–depth insight of plant safety. For this reason, all NPPs have a plant–specific PSA level 1 and some have a plant–specific PSA level 2 completed or under development. The PSA level 1 covers, in the many cases, all operating states and internal risk (flood, fire) and external risk (earthquake) events.

Since the PSAs are regularly updated, the majority of the plants have at their disposal a living PSA (LPSA). These living PSAs are mostly used for evaluating modification or changes and as the basis for a risk–based or risk–informed approach. Risk monitors are available in some NPPs and are used to evaluate the effect of risk due to configuration changes during operation and during outages. In one Member State, the "In–Depth Safety Analysis Report" is prepared to include both deterministic and probabilistic safety analyses.

I.3.6.2. Common elements and differences

For all Member States the FSAR are prepared by the applicant and reviewed by the regulatory body. There is no significant difference between the requirements on the layout and content of FSAR. Many Member States have been implementing the USNRC practice (see [35, 36]) and some Member States have been using requirements issued by the national regulatory body. In many Member States, the FSAR is updated annually and in the framework the PSR has been officially updated every ten years. It is expected that differences exist in the conservatism and quality of safety analyses among the participating Member States and the analysed events.

I.3.6.3. Future challenges

It is essential to keep the FSAR up–to–date, especially if substantial modifications to plant facilities have been made or are under way. The FSAR should reflect the current plant configuration and the methodology, evaluation or analysis on which the configuration is based.

I.3.6.4. Recommendations

The FSAR and its update or other licensing documents should clearly and adequately describe the current licensing basis or the current design basis requirements for current plant operation. An updated FSAR or other licensing documents should be a pre–condition for LTO. If a PSA is performed and is used as a supporting justification, the evaluation should be submitted as supplementary licensing document.

I.3.7. In-service inspection programme

I.3.7.1. Background

Inspection programmes (instructions, plans, procedure) are, in essence, the first practical move to implement in–service inspection. Inspection programmes are developed in accordance with the standards and regulatory requirements and define the areas of inspection of equipment and pipelines for a particular unit of NPP as well as identifying the methodologies of inspection and norms for assessment of inspection quality along with the other significant aspects of in–service inspection.

The process (practice) for performing in–service inspections covers a broad spectrum of issues including scheduling and performing inspections, logistics for inspections (qualification of personnel and means of inspection, accessibility of equipment to be inspected), overview of inspection methods, and requirements for the necessary resources (human and material resources.)

Assessment of the quality and documentation of the inspection results is the final step and is an important stage within the process of in–service inspection of equipment and pipelines. Assessment of ‘permissibility’ or ‘inadmissibility’ concerning the defects detected during the inspection is key to identifying not only the reliability of some of the equipment elements and pipelines but also the safe operation of the entire NPP. Accurate documentation provides for a possibility of performing comparative analysis of the results obtained during the inspection, especially if the inspections are performed at different periods of time. Thus, this serves as a confirmation or to substantiate correctness of the assessment.

Identification of equipment and pipelines in the participating Member States for in-service inspection (ISI) is based upon the classification of NPP systems according to its safety significance. Such a classification is performed for a particular power unit of the NPP, in compliance with the requirements of national standards and regulatory requirements. Frequency, methods, and scopes of in–service inspection are regulated based on the classification of equipment and pipelines. Methods of inspection for components in country members of Working Group 1 are selected based on the classification of inspected objects and are put into categories. There are practically identical methods of inspection used at all NPPs.

ISI is important tool for LTO. It provides a significant source of data for ageing management and allows ageing mechanisms, the size (dimension) of defects and the position and growth rate of defects to be identified. The results of ISI may be used to assess the effectiveness of an ageing management programme.

The results of ISI provide a source of data for reassessment of SSCs during the lifetime of a NPP. Characteristics of ISI equipment include sensitivity for detecting a defect according its size and position in materials, identifying parameters for postulate defects. Determination of postulated defects is a key component for calculating the residual lifetime of an SSC.

The methodology, equipment and personal that are part of the ISI process, must be qualified according national standards, regulatory requirements, and IAEA recommendations. The ISI result must be correctly documented so that a comparative analysis of the inspection results obtained during inspection can be done, especially when the inspections are performed in separate areas and at a different period of time.

I.3.7.2. Common elements and differences

A review of the in–service inspection programme description in the CIRs revealed that there are many similarities between the programmes that perform in–service inspection of equipment and pipelines. They include the following key elements:

- Standards and regulatory requirements;
- Programmes (instructions, plans) of inspection;
- Process (practice) of performing inspection;
- Assessment of inspection results for quality; and
- Documentation.

Details of each of the key elements of in–service inspection programmes were also addressed in the CIRs. General principles and orders under which in–service inspection are being performed have been established on the basis of standards and regulatory requirements. This allows for classification of the inspected equipment according to its safety significance and for verification of inspection methods, scope and frequency according to the established qualification procedure.

I.3.7.3. Future challenges

ISI programmes need to be qualified (quantitative measure of effectiveness that supports the applicable assumptions) according to national standards, and regulatory requirements. ISI programmes, including requirements, methods, schedules, and procedures need to be clearly identified and followed.

I.3.7.4. Recommendations

An adequate ISI programme should be a pre–condition for LTO.

AMPs may be needed (or modified) for those structures and components that were not in the scope for the current ISI programme, but are in the scope for LTO for reasons such as operating experience, or PSA.

I.3.8. Time limited ageing analysis

I.3.8.1. Background

Time limited ageing analysis (TLAA) refers to calculations and analyses that involve SSCs within the scope of the licence for long term operation; that consider the effects of ageing; that involve time–limited assumptions defined by the current operating term, for example, 40 years; that were determined to be relevant by the applicant in making a safety determination; involve conclusions or provide the basis for conclusions related to the capability of an SSC to perform its functions are part of the current licensing basis or design basis.

TLAA or residual life assessment (RLA) is an assessment of an identified ageing effect (due to time–dependent degradation) of certain plant–specific safety analyses that are based on an explicitly specified length of plant life (e.g., 30 years). For long term operation, once a TLAA is identified, an evaluation will be performed to demonstrate that the component will meet its design criteria at the end of the plant life, and that at least one of the following criteria is applicable: the analysis remains valid for the period of long term operation, the analysis has been projected to the end of the period of long term operation, or the effects of ageing on the intended function(s) will be adequately managed for the period of long term operation.

CIRs confirmed that TLAAs or RLAs have been performed in a majority of NPPs. CIRs contained the description of a RLA of the reactor pressure vessel (RPV). The established ageing management programmes enable plants to detect, evaluate, and mitigate the ageing effects with identification of their location and to determine necessary corrective measures.

Besides the RPV, the analyses are applied to other important components of the primary circuit such as steam generators, main circulating pumps, pressurisers and piping. Monitoring of operating conditions (temperature, pressure, radiation, chemical regime) as well as data from non–destructive tests is used as input data for the evaluation. In some Member States, the thermal fatigue analysis due to thermal stratification has been required for components important to safety.

In other Member States, the performance of TLAAs on selected parts of the primary and secondary circuit is a regulatory requirement of precondition for long term operation.

The TLAAs are required for non–replaceable passive equipment which determine the operational life time of the unit. Besides the components of primary and secondary circuit, selected cabling and civil structures are also parts of the TLAA programmes. In some Member States, the items that are in scope of the TLAA are prescribed in detail, and there are requirements that:

- the analyses remain valid for the period of LTO;
- the analyses have been projected to the end of LTO;
- the effects of ageing on the intended functions will be adequately managed for the period of LTO including plant specific exceptions; and
- the FSAR will be supplemented by information on the programmes and activities intending to manage the effects of ageing for the period of LTO.

I.3.8.2. Common elements and differences

TLAAs or RLAs have been performed in all NPPs for RPVs and their scope have been extended to other major components of primary circuit, cabling and civil structures. The information serves as an input for monitoring of operating conditions, and also provides guidance for maintenance and verification of non– destructive testing (NDT) results and operating experience.

The scope of TLAAs is different among Member States. In several Member States, TLAAs are regulatory preconditions (requirements) for long term operation. Some Member States performed comprehensive fatigue analysis of major components as a part of TLAA; in other Member States, the FSAR update is based on the results of TLAAs.

I.3.8.3. Future challenges

Clear scoping and screening criteria have to be defined and applied to SSCs to identify those subject to TLAA. Missing TLAAs have to be performed. The TLAAs have to be updated in compliance with latest available state–of–the–art knowledge.

I.3.8.4. Recommendations

TLAA should be a pre-condition for long term operation.

I.4. CONSIDERATIONS GIVEN TO, OR ACTIVITIES PLANNED OR TAKEN FOR LONG TERM OPERATION

I.4.1 Background

The submitted CIRs indicated that, in all participating Member States, the long term operation of NPPs is envisaged and to some extent, preparatory activities have been undertaken. In the early nineties, this process was initiated by the utilities. Since that time, it has been necessary to make the strategic decision either to continue further operation of NPPs on the basis of modernization or to carry out decommissioning. In majority of the Member States, the utilities accepted, on the basis of existing information, the principal decision to extend the lifetimes of NPPs for 10–20 years and informed the national regulatory body of this decision. The programme for long term operation was established by the utilities and consists of the following main steps:

- technical assessment of LTO feasibility;
- economical assessment of LTO feasibility;
- detailed programme for LTO assurance.

The detailed programme consists of:

- safety upgrading of the NPP with the purpose of enhancing the safety of older units;
- life management of critical SSCs, from the LTO point of view, including their classification;
- Decisions on LTO by the operating organization should be made after sufficient operating experience has been accumulated.

In some Member States, application for LTO has to be submitted to the regulatory body 5 years prior to expiration of the current licence. In anticipation of the applications for long term operation, the regulatory bodies in some Member States issued new laws or updated existing laws, and revised regulations and guides which stipulate the requirements associated with the scope of activities and the documentation that needs to be submitted with the application. Several regulatory bodies expressed their point of view that the utility should take advantage of programmes existing at the NPP to the extent possible for LTO, but made reference to existing requirements or the establishment of new licensing requirements.

I.4.2. Common elements and differences

All participating Member States consider the extension of current design life time of 10 to 20 years. Two Member States issued the licence for long term operation. The process was initiated by the utilities that established the programme for long term operation. The programme consists of modernization programmes and ageing management programmes including TLAA assessment.

I.4.3. Future challenges

While planning for long term operation, certain issues of generic nature, such as boric acid corrosion of reactor vessel heads, environmental effects on fatigue evaluation, and cable degradation caused by moisture or submergence in water, may arise. These issues should be addressed for long term operation because of their importance to safety. The regulatory bodies should clearly identify these types of issues as emerging issues and the utilities should take into consideration these issues in their planning for long term operation. The approach to the resolution of these issues could be either generic or plant–specific and the timing of the resolution could be immediate or in the future, but resolution should be achieved prior to the start of long term operation.

I.4.4. Recommendations

Prior to long term operation, the following activities should be completed:

I.4.4.1. Scoping and screening evaluation

For all plant SSCs, identify the applicable information sources. If an SSC is safety related, its failure does impact safety function, and it is not replaced and refurbished within a specified time interval, then it is subject to a LTO review. However, if an SSC is safety related, but it is replaced or refurbished within a specified time interval, then it is not subjected to LTO. In addition, if an SSC is not related to safety but its failure could impact safety functions, then it is also subject to LTO. Section 2.5 of the main report, figures 1 and 2 provide a graphical representation of the scoping and screening processes. Figure 1 depicts the scoping process starting with all plant systems, structures, and components in a nuclear power plant. Figure 2 depicts the screening process to identify plant systems, structures, and components that are subject to LTO review.

I.4.4.2. Establishment of plant ageing management programme

An acceptable ageing management programme should contain the following attributes:

1. A defined programme scope – the scope of the programme should include the specific structures and components subject to an ageing management review (AMR);
2. Identification of preventive actions or parameters to be monitored or inspected –actions to prevent or mitigate ageing degradation or parameters to be monitored or inspected for the intended function(s) of the particular structure or component should be identified;

3. Detection of ageing degradation /effects – detection of ageing effects should occur before there is a loss of the intended function(s) of a structure or component. This includes aspects such as method or technique (i.e., visual, volumetric, surface inspection), frequency, sample size, data collection and timing of new/one–time inspections to ensure timely detection of ageing effects;
4. Monitoring and trending including frequency and methodologies – monitoring and trending to provide predictability of the extent of degradation, and timely corrective or mitigative actions;
5. Pre–established acceptance criteria – acceptance criteria against which the need for corrective action will be evaluated, to ensure that the intended function(s) of a structure or component are maintained under all current licensing basis (CLB) design conditions during the period of extended operation;
6. Corrective actions if a component fail to meet the acceptance criteria – corrective actions, including root cause determination and prevention of recurrences, should be timely;
7. Confirmation that required actions have been taken – confirmation process to ensure that preventive actions are adequate and that appropriate corrective actions have been completed and are effective,
8. Administrative controls that document the programme's implementation and actions taken – administrative controls to provide a formal review and approval process; and
9. Operating experience feedback – operating experience of the ageing management programme, including past corrective actions resulting in programme enhancements or additional programmes, to provide objective evidence to support the conclusion that the effects of ageing will be managed adequately so that the intended function(s) of a structure or component will be maintained during the period of extended operation.

I.4.4.3. Re–validation of the TLAAs

The options for TLAA evaluation are described in Appendix II. 6.

I.4.4.4. Considerations of open technical issues relating to LTO

Emerging issues are issues that arise during the review of an application that has generic applicability. A plant–specific or generic resolution should be achieved prior to LTO.

I.5. EXISTING PROGRAMMES THAT ARE DIRECTLY RELATED TO LONG TERM OPERATION

I.5.1. Background

The CIRs confirmed that all NPPs operated in participating Member States have existing programmes that are mostly oriented to evaluating the residual life of non–recoverable and non–replaceable items of the plant. They could be part of LTO programmes if they contained the necessary attributes for an acceptable ageing management programme. The operator, after evaluation, can identify those plant programmes that have the necessary attributes and do not require any modifications, and can require those programmes to be strengthened.

While in some Member States the programmes of modernization of the plant and its systems and components are not directly related to LTO, such a distinction does not exist in other Member States.

Some Member States consider it is important that all activities (AMP, FSAR updating, TLAAs, etc.) are integrated into one LTO project. This approach ensures that comprehensiveness and coordination of all activities are focused with respect to LTO.

Information on issues which may require additional development or studies of standards and methods was not provided in the majority of CIRs. The majority of the Member States apply PSRs after every ten years of operation.

I.5.2. Common elements and differences

In the NPPs of the Member States that participated in the SALTO programme, some plant–specific programmes were developed and implemented. These plant–specific programmes may not be acceptable as ageing management programmes. To be acceptable, a plant specific programme should contain the necessary attributes as described in Section I.4.4. The programmes that are described and evaluated in Chapters X and XI of the Generic Ageing Lessons–Learned (GALL) Report [37] meet those attributes. The scope of these programmes is focused primarily on non–replaceable structures and components in NPPs. In other cases, various programmes (modernization projects) that are not directly linked to LTO are performed at plants.

The majority of Member States have been implementing the PSR in line with the IAEA recommendations and have submitted plant–specific programmes as part of the required documentation for the PSR. While these activities are of great value toward improving and updating the plants' current operation, they need to be evaluated to determine if all the 9 necessary attributes of the AMP are met (see Section I.4.4 above). On the other hand, a few Member States chose to integrate all LTO related issues into a single complex project.

CIRs of some Member States also considered and discussed economical aspects of LTO. These can be the governing factor of decision making on the future of a particular NPP.

I.5.3. Future challenges

The majority of existing programmes need to be examined and determined whether they can be approved toward LTO as acceptable ageing management programme.

I.5.4. Recommendations

Existing plant programmes may be approved toward long term operation provided that they can meet the requirements of the programme (see Section I.4.4 and Section 3 of the main report).

I.6. AVAILABLE RESEARCH RESULTS AND OPERATING EXPERIENCES

I.6.1. Background

All operators of NPPs have been supporting the necessary research programmes and using operating experiences. These research projects are financed by various sources – ministries, utilities, and regulatory bodies. The organizational and financial arrangements vary depending on national conditions. Operators of NPPs have used extensively the information and services provided through the existing owner/user groups (Westinghouse – WOG, General Electric – GEOG, CANDU – COG, WWER – WWER operator club).

In some Member States, IAEA national technical cooperation (TC) projects related to LTO are underway. In smaller Member States, where financial resources and the number of highly qualified technical support organizations (TSOs) are limited, it is necessary to make optimal use of domestic resources.

In the participating Member States, where the regulatory body provides considerable support to the safe operation of NPPs, or through international research programmes coordinated by international organizations (IAEA, NEA/OECD, EU), the existing projects are oriented to the components of the primary circuit (RPV, piping, steam generators etc.,), and to cabling, I&C systems and selected civil structures.

The objectives of these projects are:

- the identification of degradation mechanisms and their effects on the long term functionality of safety related SSCs;
- the development of databases on life time assessment;
- the design of upgraded monitoring systems to ensure accurate monitoring of all significant degradation effects;
- the analysis and trending of data for the evolution of the SSC degradation processes;
- the development of ageing management programmes to minimize ageing degradation processes including the corrective measures of their effects.

I.6.2. Common elements and differences

Some Member States have been using the results of extensive and comprehensive programmes performed in the USA such as Nuclear Plant Aging Research (NPAR) programme, conducted by NRC, and ten NUMARC's Industry Reports supported by the US nuclear industry. Information resulting from the NPAR Program, contained in the Industry Reports, and from reported operating events related to ageing up to the year 2000, have been considered in the development of the NRC's Generic Aging Lessons–Learned (GALL) Report [37]. Regarding the use of operating experience, all Member States have been using the national operational experience feedback system. All Member States have been actively participating in international systems of the IAEA (Incident Reporting System – IRS) and WANO (Operational Experience Network).

I.6.3. Future challenges

Currently, most of the Member States do not have a process to collectively and systematically document and analyze research results and operating experiences. Available research results and operating experiences may have been collected and analysed by individual NPPs, but were not shared with other Member States. A process needs to be in place to gather the information that has been systematically analyzed by an organization such that the information could be more useful as a whole for all Member States.

I.6.4. Recommendations

Available research results and operating experience that are directly related to LTO should be shared and used by all Member States. Specifically, operating experience related to the ageing of structures and components should be systematically documented and shared with other Member States. Research results should also be systematically analysed for their applicability to LTO and should be shared with other Member States.

I.7. RELATED NATIONAL DOCUMENTS

Bulgaria

- Act on the Safe Use of Nuclear Energy (ASUNE), 2002
- Act on Environmental Protection, 2002
- Act on Energy 2003
- Regulation for Providing the Safety of Nuclear Power Plants, 2004
- Regulation for the procedure for issuing Licences and permits for safe use of Nuclear Energy, 2004
- Regulation for Safe Management of Radioactive Waste, 2004
- Bulgarian National Standards (BNS).
- Russian Regulations (OPB, PNAE–G etc.,)
- IAEA Safety Standards
- ISO Standards (EU standards)

Czech Republic

- Act. 18/1997 Coll. on Peaceful Utilization of Nuclear Energy and Ionizing Radiation
- SUJB Regulation – 195/1999 Coll. on Requirements on Nuclear Installations for Assurance of Nuclear Safety
- SUJB Regulation – 106/1998 Coll. on Providing Nuclear Safety and Radiation Protection of Nuclear Installations at Their Commissioning and Operation
- SUJB Regulation – 214/1997 Coll. on Quality Assurance in Activities Related to the Utilization of Nuclear Energy
- Instructions and Recommendations for Qualification of VVER 440/213 Nuclear Power Plants Equipment Important to Safety, SUJB, 1998
- Requirements on EQ Updates of Czech Nuclear Power Plants, 2003 (SUJB Internal Document – will be published)
- Inspection Manual on Feedback of Operational Events, 2003 (SUJB Internal Document)

Finland

- Nuclear Energy Act (990/1987) Government Resolution (395/1991) on the Safety of Nuclear Power Plants
- Regulatory Guides on nuclear safety (YVL)

YVL 1.3	Mechanical components and structures of nuclear facilities. Approach of testing and inspection organizations
YVL 1.4	Quality assurance of nuclear power plants
YVL 1.8	Repairs, modifications and preventive maintenance at nuclear facilities
YVL 1.9	Quality assurance during operation of nuclear power plants
YVL 1.11	Nuclear power plant operating experience feedback
YVL 2.1	Nuclear power plant systems, structures and components and the safety classification
YVL 2.2	Transient and accident analyses for justification of technical

solutions at nuclear power plants

- YVL 2.7 Ensuring a nuclear power plants safety functions in provision for failures
- YVL 3.5 Ensuring the firmness of pressure vessels of a NPP (in Finnish)
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- YVL 5.2 The structures materials and installations of technical components and cables needed in accidents

Hungary

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  - Volume 2: Quality assurance
  - Volume 3: Design
  - Volume 4: Operation
- Regulatory guidelines
- Licence Renewal
  - 1.28 Requirements for the scope of the lifetime extension licence application
  - 4.14 Conditions of operating licence renewal of nuclear installations
- Maintenance
  - 1.19 Inspection of the efficiency of the maintenance program of the nuclear power plant
  - 4.6 Nuclear power plant maintenance program and maintenance program and maintenance
- Ageing
  - Regulatory Inspection of the Ageing Management Program
  - Quality Assurance in the Ageing Management Program
  - Consideration of Ageing during Nuclear Power Plant Design
  - Management of Ageing During Operation of Nuclear Power Plants
- Equipment qualification
  - Regulatory control over equipment qualification and preservation of qualified status
  - Equipment qualification requirement during the design of nuclear power plants
  - Equipment qualification requirement for operating nuclear power plants

The Netherlands

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  - NVR 1.2. Safety Code for Nuclear Power Plant Operation (Adaptation of IAEA Code Safety Series 50–C–O rev.1)
  - NVR 1.3. Code for Quality Assurance for the Safety in Nuclear Power Plants and other Nuclear Installations (Adaptation of IAEA Code Safety Series 50 – C–Q)
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Russian Federation

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RB–028–04	Non–compliance analysis of nuclear power unit to the requirements of existing standards
RB–029–04	Composition and contents of materials on nuclear power unit residual life justification for its life extension
RB–030–04	Analysis of operation experience for nuclear power unit life extension

Slovakia

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  - BNS II.3.1/2000 Assessment of defect (flaw) acceptability detected within ISI of selected equipment (SSCs) of nuclear installations
  - BNS I.4.1/1999 Single failure criteria
  - BNS I.9.1/1999 Safety of nuclear installations during their decommissioning
  - BNS i.4.2/1996 PSA methodology utilization in the regulatory process
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- Safety Guides under development
  - BNS II.5.4/200x Qualification of NDE systems in nuclear industry. Requirements and guidelines

Sweden

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Ukraine

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Appendix II

MECHANICAL COMPONENTS AND MATERIALS

II.1. INTRODUCTION

This Appendix describes the outcome of Working Group 2 on Mechanical Components and Materials.

The objective of Working Group 2 was to develop a framework that supports the identification of safety criteria and practices for the area of mechanical components and material associated with LTO of water moderated reactors. Providing such a framework will assist regulators and operators of nuclear power plants (NPPs) in developing processes, procedures and engineering programmes that will ensure the required safety level of their plants is maintained during LTO.

The activities of Working Group 2 evaluated Member State processes and practices for the mechanical components and materials of systems, structures and components (SSCs) relevant to LTO whose function belonged in the following 4 categories:

1. All safety related SSC that ensure the integrity of the reactor coolant pressure boundary;
2. All safety related SSC that ensure the capability to shut down the reactor and maintain it in a safe shut down condition;
3. All safety related SSC that ensure the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure;
4. All non–safety related systems, structures, and components whose failure could prevent satisfactory accomplishment of, or initiate challenges to, any of the safety functions defined above.

There may also be certain other areas dedicated to a specific functional purpose that may be essential to safe operation of the plant, such as:

- fire protection,
- environmental qualification,
- pressurized thermal shock,
- anticipated transients without scram,
- severe accident management,
- station blackout.

Specifically for the mechanical components and materials area this includes the following items:

- piping
- pumps, both the active portion and the passive vessel
- valves, both the active portion and the passive vessel
- vessels
- vessel internals (of the RPV in particular)
- emergency diesels
- attachments, such as integrally welded supports, that may affect the integrity of a pressure boundary
- heat exchangers.

II.2. REQUIREMENTS

All Member States that are participating in the Programme have some type of provision for operation of nuclear power plants beyond their initial licence term (authorized period of operation). However, there are significant differences in the level of detail and technical criteria in codified requirements among Member States. As an example, some Member States require that an integrated plant assessment be performed as part of the justification for LTO. The process of performing an integrated plant assessment requires the identification of the structures, systems and components (SSCs) within the scope of LTO. Once specific SSCs have been identified, specific evaluation criteria must be addressed.

One Member State reported that the licensee elaborates a list of SSCs to be considered for LTO based on a specific NPP design. This list includes: (i) systems and components important to safety whose design life established in the design documentation is shorter than the unit's operational lifetime; and (ii) systems and components important to safety for which it is required to specify or determine the qualified life. Systems and components that fall in the LTO scope will undergo a comprehensive examination to determine their qualified life based on specific evaluation programmes developed for this purpose. This process should start in appropriate time before expiration of the qualified life in order to provide for appropriate time for regulatory assessment and decision making.

Another Member State reported that the NPP defines a selected set of SSCs in the scope of LTO as an important initial step in the development of the programme for implementation of LTO. The scope of SSCs whose performance is regularly monitored within the framework of the lifetime management programme is derived from the NPP scoping process, with account taken of the country's regulatory requirements.

Another Member State reported that a periodic safety review is required that must take place at least every 10 years. It must include verification that the plant fulfils all applicable safety requirements valid at the time but also the prerequisites that are valid in order to operate the plant in a safe manner up to the next periodic safety review. The latest developments in science and technology are included in this safety review. There are no specific SSCs selected for LTO. SSCs are classified into safety classes based on applicable technical reference documents and standards (domestic as well as international). Every ten years a full cycle of analysis is performed to determine the qualified life of the classified SSCs. Conclusions of analysis as well as the actions needed should be documented and submitted to regulatory body that will decide on the time for the next periodic safety review.

As can be seen from the preceding discussion, there is no identical approach in selecting SSCs to be considered for LTO. As a result, the scope of SSCs to be considered for LTO greatly varies from country to country. Nevertheless, there were common elements observed in the evaluation process of SSCs evaluated for LTO, such as:

- A violation of the necessary safety margins of the SSCs is not allowed during the period of extended operation.
- The operator of a nuclear power plant should have specific programmes that ensure that the required technical conditions of SSCs that are important to safety are maintained during the period of LTO.
- Any safety concerns revealed during actual operation of the plant should be resolved in the frame of the existing operational licence.
- Safety enhancements that could result from new requirements or experience feedback are implemented within the frame of periodic safety review or regulatory commitments.

- SSCs in the scope of LTO are the subject of a comprehensive examination for assessment/determination of their qualified life based on specific evaluation programmes that are developed for this purpose. This process starts in appropriate time before expiration of the qualified life.
- A reliability analysis belongs to one criteria for selection of SSCs for LTO.
- SSCs out of the LTO scope, but with design life shorter than NPP design life, are subject to replacement or refurbishment based on assessment of their residual design life.

One major potential safety issue that the members of Working Group 2 (in fact all working groups) recognized was the significant variation in technical criteria among Member States for determining SSCs that should be evaluated within the scope of LTO. Once this issue was recognized, all working groups collaborated in developing a recommended practice for scoping and screening SSCs for LTO. This recommended practice is discussed in detail in Section 2.5 of this report.

II.3. SCOPING OF SYSTEMS, STRUCTURES AND COMPONENTS

II.3.1. Background

A review of the information from the regulations of each participating Member State for LTO of materials and components shows that the details of the criteria for scoping and screening varied greatly among Member States. The differences in details for determining the SSCs subject to the engineering reviews and detailed fitness for service evaluations required by LTO resulted in significant technical differences and potential safety issues among Member States. Three examples of the differences in scoping criteria follow.

Example 1

The scoping criteria for one Member State included:

- Safety relevance
- Availability relevance
- Replacement ability
- Costs (price for the component, cost for repair or replacement as well as for prolonged or unscheduled outage)
- Accessibility (personnel dose, repair during operation possible or during outage)
- Availability of spare parts
- Operational performance
- Calculations and other methods, as specified in tasks of the specific work programme
- Analysis of information on spare parts (availability, prices).

Example 2

The scoping criteria for another Member State stated:

- A. Within the framework of internal legislation, the set of monitored SSCs in safety classes 1 and 2, divided into categories:
    - A.1. Components which could be replaced with difficulty;
    - A.2. Equipment and systems whose availability has to be ensured after the end of electricity generation in the NPP (thus category A.2 is derived from the requirements on decommissioning of the NPP).

- B. Selected SSCs in safety classes 1, 2, and 3, not included in (A) as yet, whose assessment will be required by the regulatory body within the framework of assessment of equipment readiness for LTO when renewing the licence beyond the limits of its design life.
- C. SSCs, not included in (A) and (B), which could cause considerable maintenance and investment costs if operated beyond the design life limits.

Example 3

The scoping criteria for a third Member State stated:

The intended functions of the following systems, structures, and components (SSCs) will be adequately maintained to ensure public safety:

- safety–related systems, structures, and components which are those relied upon to remain functional during and following design basis events to ensure the following functions:
  - The integrity of the reactor coolant pressure boundary;
  - The capability to shut down the reactor and maintain it in a safe shutdown condition; or
  - The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to those in excess of national standards.
- all non–safety–related systems, structures, and components whose failure could prevent satisfactory accomplishment of any of the safety functions identified in the preceding paragraph.
- all systems, structures, and components relied on in safety analyses or plant evaluations to perform a function that demonstrates compliance with the regulations for fire protection, environmental qualification, pressurized thermal shock, anticipated transients without scram, and station blackout.

II.3.2. Common elements and differences

After reviewing the scoping processes for Member States participating in the Programme, members of all working groups realized that a recommended ‘Scoping and Screening Process’ developed through collaboration of all Member States participating in the Programme would be necessary in order to meet the stated goal of the Programme. The collaboration from all working groups resulted in the process outlined in Section 2.5 of this report. Working Group 2 members then developed a set of SSCs for each major category listed below using the Scoping and Screening Process outlined in Section 2.5 of this report. The SSCs are presented in a table format in Section II.8 of this Appendix. It should be noted that the SSCs presented in the tables represent the best engineering judgment of the working group members. However, the SSCs have not been evaluated in a pilot study and should therefore be considered preliminary. The tables have been divided into the following categories which match the stated scope of work for Working Group 2.

- SCS that ensure integrity of reactor coolant pressure boundary
- SSCs that shut down the reactor and maintain it in a safe shutdown condition (including emergency systems)
- Non safety related SSCs whose failure impacts safety function
- SSCs to ensure offsite radioactive exposures are within national limits

II.3.3. Future challenges

Working Group 2 members believe that one of the major challenges for Member States considering LTO is implementing a scoping and screening process that provides a comprehensive list of SSCs to ensure that functions listed below are maintained with adequate safety margin.

- Ensuring the integrity of reactor coolant pressure boundary.
- Ensuring that the nuclear power plant can shut down and maintain a safe shutdown condition (including emergency systems and non–safety systems whose failure impacts).
- Ensuring there is no impact on safety function from the failure of non safety related SSCs.
- Ensuring offsite radioactive exposures are within national limits.

II.3.4. Recommendations

Working Group 2 members recommend that countries considering LTO adopt the scoping and screening process outlined in Section 2.5 of this report. Working Group 2 members also recommend that more detailed requirements and acceptance criteria should be developed to support the scoping and screening process. One way to develop more detailed guidance is to conduct a pilot study using the process on several power plant designs and documenting the results of the pilot study for use by Member States.

II.4. AGEING MANAGEMENT PROGRAMMES

II.4.1. Background

All Member States participating in the Programme have some form of ageing management programme (AMP). For LTO the programme includes all structures, systems and components relevant to safety and critical for safe operation beyond a fixed licence or design life. For most Member States participating in the Programme, an ageing management programme is part of the maintenance programme for plant units. In general the ageing management programmes have the following major phases.

Phase 1 involves carrying out an engineering assessment of the current status of SSCs within the scope of LTO and identifying potential ageing mechanisms or degradation mechanisms. The engineering assessment requires an understanding of the operating environment and potential degradation that may affect SSCs and the effects of the degradation on the ability of the SSCs to perform design functions. An adequate engineering assessment requires knowledge of the design basis (including applicable codes and regulatory requirements), the design and fabrication (including the material properties and specified service conditions), the operation and maintenance history (including commissioning, surveillance and any trend curves), the inspection results, the environment (inside and outside an SSC) and the conditions of operation, including any transients and generic operating experience and research results.

Phase 2 involves evaluating maintenance programmes and plant operational practices (including in–service inspection and in–service testing programmes) to ensure that the impact of the ageing mechanisms will be detected and characterized. A component specific comparison of the current maintenance practices against the detectable effects of ageing mechanisms relevant for the respective component must be done. This comparison should provide the technical basis to verify that ageing phenomena will actually be detected with the currently applied maintenance, inspection or monitoring activities. In some cases this evaluation will identify shortcomings. If shortcomings are identified it will be necessary for the plant owner to define additional measures (e.g. inspection activities) to account for all ageing mechanisms properly.

Phase 3 requires an evaluation to ensure that the safety margins of SSCs identified in phase 1 are adequate to ensure safe operation for the proposed period of LTO. A plan must be established based upon programmes identified in phase 2 that includes a technical justification that demonstrates adequate management of safety critical SSCs (e.g., the detection, characterization and mitigation of degradation prior to challenging the safety margins of SSCs).

Phase 4 defines the necessary preventive measures, additional inspections, repair and replacement work, and systems engineering activities, or any modification of operating modes which are required either individually or collectively to prevent accelerated degradation by the identified ageing and wear mechanisms and to ensure that the structures, systems and components can reach their design service life. This phase also develops a report that documents the technical justification that demonstrates that the SSCs within the scope of LTO (identified in phase 1) can fulfil their safety related functions during the proposed period of LTO.

II.4.1.1. Applicable ageing effects

The tables in Section II.8. of this Appendix provide an initial set of ageing effects for the SSCs within the scope of Working Group 2 activities. The ageing effects provided in the tables are based upon known ageing effects documented in technical literature and the judgment of the working group members.

II.4.1.2. Ageing mitigation measures

Ageing mitigation measures are specific actions performed by the plant owner to eliminate or significantly reduce one or more causes of degradation. Examples of ageing mitigation measures include but are not limited to the following:

- Control of water chemistry in the primary and secondary systems of reactors;
- Reduction or reversal of residual stresses in weldments (reduction in stresses, vibration, etc);
- Corrective maintenance including repair or replacement of components on a schedule that prevents failure;
- Installation of corrosion barriers.

Identification and early implementation of mitigation measures is critical to developing adequate ageing management programmes. The IAEA–TECDOCs [38–43] provide ageing mitigation guidance specific to many of the critical components in LTO.

II.4.2. Common elements and differences

A review of the information submitted by Member States of the Programme shows that some form of AMP has been implemented in all countries. The AMPs generally involve: (i) identification of degradation mechanism applicable to specific SSCs, (ii) learning the degradation process and its effect, and (iii) implementation of the appropriate mitigating measures at operating NPPs.

There are significant differences in the implementation of AMPs in Member States participating in the Programme. For example some Member States included active equipment, another focused on passive equipment (only such as components that perform their intended operation without moving parts, and without any variation in their shape or properties), while another considered components that are not replaced during the planned life cycle of the NPP (long–life components). The scope of the AMP is determined by the systems and components that impact on safety, known ageing mechanisms and possible effects, and the application of ageing management methods, according to the relevant Member State's regulatory reference documents.

All Member States reported that they have implemented specific ageing mitigation measures on the SSCs subject to LTO, such as monitoring of potential degradation through in–service inspection programmes, monitoring material characteristics, and evaluation of the results of periodic walkdowns regularly performed by the shift personnel. An example of a mitigation measure implemented at NPPs involves evaluation and subsequent change of operation parameters, implementation of specific design changes, change of component material, as well as replacement of equipment that has not passed qualification tests, or for which qualified life can no longer be demonstrated. However, very few Member States have performed an extensive review of in–service inspection practices vs. detection of degradation.

II.4.3. Identification of future challenges

The following challenges have been identified for AMPs. These challenges are very similar to those identified by Working Group 3 of the EBP SALTO Programme [3]:

- The need for harmonization of industrial standards and regulatory requirements applicable to AMP, for example the use of a master curve and calculations of neutron fluence to determine embrittlement and damage to vessel material should be standardized.
- Gaps in the knowledge that need to be covered in future research have been identified in EUR 19843, Safe Management of NPP ageing in European Union [44]. Topics specific to LTO are:
    - Life assessment technology and non–destructive evaluation (NDE) for physical properties altered by ageing;
    - Improved monitoring techniques;
    - Reproduction of phenomena on test specimens;
    - Repair and degradation mitigation technologies;
    - Development of a database (covering toughness, mechanical properties of aged materials, etc.);
- Gaps in the feedback of experience on making allowances for ageing at the design stage and monitoring ageing. The nuclear operator could then find itself torn between allowing operation to continue in degraded conditions and condoning outage for an extended period.

II.4.4. Recommendations

Working Group 2 members recommend that Member States considering LTO or currently reviewing operating plants for LTO collaborate in developing a database of known degradation mechanisms for operating plants. This database would be an essential tool for plant operators and regulators when evaluating AMPs within the framework of LTO.

It is also recommended that Member States should have exchange of experiences in LTO application through technical exchange seminars and workshops that address specific gaps in knowledge related to LTO ageing management programmes. Examples of seminars are provided above in Section 4.3.

II.5. OPERATIONAL PROGRAMMES

II.5.1. In–service inspection practices for passive components

II.5.1.1. Background

In–service inspections (ISIs) include: inspections of base materials and welded joints non–destructive testing (NDT) inspections and non–material inspections set by quality assurance documentation, equipment checks, diagnostic inspections and measurements, etc. ISI of passive components is a critical part of the operation and maintenance of nuclear power plants for all Member States that participated in the Programme. ISI programmes of operating nuclear facilities in all Member States provide part of the technical basis for ensuring that the structural integrity of SSCs is adequate for operation. All ISI programmes are approved by the nuclear regulatory body.

II.5.1.2. Common elements and differences

After review of the Country Information Reports (CIRs), Working Group 2 members concluded that the following attributes were common to all Member States in–service inspection programmes.

1. All applied country–specific ISI programmes are based on common safety approaches.
2. Basic requirements for the ISIs are available in regulatory requirements that are country specific. The range, periods, methods, evaluation techniques, etc. of in–service inspections are generally defined using two different methods.
    - Deterministic methods for defining sample, periods, NDE methods and evaluation criteria are the most commonly used.
    - Within the last five to ten years, risk informed (RI–ISI) procedures and processes have been used to define ISI programmes. These procedures use the contribution to core damage (risk), the consequences of failure and an assessment of degradation to define the scope and periods of ISI. The RI procedures are applied mainly to piping. RI–ISI is broadly and successfully utilized by several Member States.
3. System qualification using NDT inspections is recognized as a crucial condition to ensure reliable results of ISI. In some Member States this process is more advanced, while in others it is currently under way.
4. The augmented ISI programmes covering erosion–corrosion damage mechanisms are highly developed and broadly and successfully applied at present.
5. Augmented ISI of steam generator tubing usually involves ISIs carried out by a combination of eddy current method, leakage tests, checking the formation of deposits and measurement of impurities.
6. Additional augmented inspections are performed when standard inspections provide unsatisfactory results or new damage phenomena occur that were initially not anticipated. Actual inspection methods vary depending on the actual problem.

II.5.1.3. Identification of future challenges

Working Group 2 members believe that one of the greatest challenges that face Member States and plant owners that are engaged in LTO or considering LTO is evaluating current plant maintenance practices (including ISI and in–service testing (IST)) for effectiveness in detecting and characterizing the ageing mechanisms for each component. The evaluation should provide the technical basis to verify that ageing phenomena will actually be detected with the currently applied maintenance, inspection or monitoring activities. In particular the

ISI programme should ensure that the inspection methods specified by the ISI programme are capable of detecting and characterizing the ageing effects for outside and inside the SSC under investigation. In case shortcomings are identified, it is necessary to define additional measures (e.g. inspection activities) to account for all ageing mechanisms properly. When used in reaching a technical justification for LTO, the relationship of ISI to the configuration management and design basis programme should be clearly identified.

A second challenge is developing qualification practices that provide an objective and quantitative measure of the effectiveness of NDE used to detect ageing mechanisms.

II.5.1.4. Recommendations

Working Group 2 members recommend the following actions for ISI when applied to LTO:

- ISI programmes should be a pre–condition for LTO;
- Plant owners should develop a review process for evaluating current plant maintenance practices (including ISI and IST) for effectiveness in detecting and characterizing the ageing mechanisms for each component. The review process should provide a technical basis for ensuring that the ageing phenomena will be adequately detected with the proposed maintenance, inspection or monitoring activities;
- Qualifications of NDE processes need to include requirements that provide a quantitative measure of NDE effectiveness through blind testing;
- A living database that documents experts' consensus on the effectiveness of NDE in detecting and characterizing degradation mechanisms should be set up on an international scale. The database should provide technical references to support expert opinion;
- The need for harmonization of advanced NDT inspections of reactor pressure vessel (RPV) shell and core region welds using methodologies of the IAEA and/or the European Network for Inspection and Qualification (ENIQ). Topical workshops may be an effective means to exchange information and experience and generate relevant guidelines;
- The effectiveness of RI–ISI, if used, should be further evaluated.

II.5.2. Maintenance codes or practices for active components

II.5.2.1. Background

All Member States have country–specific programmes to maintain the active components at their respective nuclear power plants. Each programme requires that nuclear power plants conduct periodic maintenance activities to ensure the active components are capable of performing their intended function.

II.5.2.2. Common elements and differences

The following common elements among Member States were determined after reviewing each CIR:

- Maintenance activities are based on national regulatory body regulations;
- Maintenance records are stored;
- A long term maintenance plan has been developed;
- Preventive maintenance is introduced;
- Maintenance records are evaluated;

- It is ensured that maintenance programmes and ageing management programmes are interrelated;
- The effectiveness of the maintenance activities is monitored;
- The frequency of maintenance is dependent on plant experience;
- The performance or condition of SSCs is monitored;
- There is risk–informed evaluation of maintenance.

The review of CIRs also showed that the specific requirements that specify the scope, specific period of maintenance activity and evaluation criteria vary among Member States.

II.5.2.3. Identification of future challenges

Working Group 2 members believe that one of the significant challenges facing Member States in the area of maintenance is the development of international standard practices or guidance for carrying out maintenance that will enable Member States to evaluate the effectiveness of maintenance practices.

II.5.2.4. Recommendations

The members of Working Group 2 provide the following recommendations in the area of maintenance.

- The process for developing maintenance programmes should be a pre–condition for LTO. This process should clearly address the types of maintenance (preventive, predictive and corrective), the links with ageing management programmes, the frequency and tasks, and the records, their evaluation and storage in view of optimization of the maintenance programmes;
- Maintenance activities should be based on national regulatory body legislation and should comply with international standards;
- Monitoring the effectiveness of the maintenance activities is recommended for addressing maintenance optimization.
- International cooperation should be encouraged to promote advanced methods and tools for predictive maintenance;
- International cooperation should encourage the development of a set of minimum risk based criteria for those Member States that use risk based maintenance.

II.5.3. Equipment qualification practices

II.5.3.1. Background

Equipment qualification (EQ) establishes, though quality assurance processes and testing, that equipment within the scope of LTO is capable of performing an intended function during the period of LTO or that the equipment will be replaced/repaired in order that its intended function will not compromise safe operation during LTO. All Member States participating in the Programme reported that equipment qualification programmes are part of their long term programmes and strategies.

II.5.3.2. Common elements and differences

Each of the EQ programmes has a requisite database that supports EQ maintenance programmes. Information provided by Member States established that Member States performed numerous qualification tests during the design, construction and commissioning phases and that the EQ tests could be performed at several facilities, including at an approved laboratory, at the manufacturer's, at relevant research institutes and even at the utility's premises. Qualification results were recorded in qualification reports established by the entity that was responsible for performing the tests. These reports contained an evaluation of the qualified equipment life, which varied depending on the location of the equipment.

The review of CIRs confirmed that the extension of qualified life for EQ equipment has been widely applied. There is also a possibility of extending design life of specific items of equipment by renewing some of their parts or by reassessing their life considering real environmental conditions (both internal and external) and projected design basis conditions. This approach allows for the replacement of only the equipment exposed to actual severe environmental conditions.

It was reported that environmental qualification of new equipment is also performed to determine its point of obsolescence; this is done when the NPP does not have the possibility to replace components with similar equipment before the qualified life of the component expires. Therefore when qualified equipment becomes obsolete, new equipment has to be found which is already qualified or which can be qualified. In this case the qualification process shall be well documented and shall fulfil requirements for necessary supervision. The qualification process may be extremely protracted depending on the required qualification level.

The differences among Member States concerning EQ programmes involved specific acceptance criteria.

II.5.3.3. Identification of future challenges

The greatest challenge that Member States identified in the area of equipment qualification is to establish a harmonized approach to EQ and define minimum acceptable standards for EQ.

II.5.3.4. Recommendations

Working Group 2 members recommend the following.

- Qualification programmes should be a pre–condition for LTO and should be based on national and international standards which cover the following points:
  - Environmental and seismic qualification should be required for equipment important to safety and for equipment not important to safety but whose failure could jeopardise any safety function performance.
  - Qualified equipment should be able to perform the required safety function under design–basis environmental and seismic conditions considering the ageing of the item of equipment through its intended lifetime.
- The programme of the equipment qualification process should be approved by the regulatory body.
- The equipment qualification status should be demonstrated by tests, analyses, operating experience or combinations of these.
- Qualification documentation should be stored in auditable form during the entire installed life of equipment.
- EQ status should be preserved mainly through surveillance, maintenance, modifications and replacement control, environment and equipment condition monitoring, configuration management and EQ personnel training.
- For LTO, it should be demonstrated that the EQ status will remain valid over the expected period of LTO; ageing effects on mechanical equipment should be simulated by specific pre–tests.

II.5.4. Component functional tests

II.5.4.1. Background

Functional tests are part of the normal operations or maintenance programme of operating power plants and serve to verify that the SSCs are capable of maintaining the functions they are designed for. Besides ensuring the functional availability, these tests are often combined with a trending scheme to reveal potential problems before the problems could lead to failure of the SSCs.

According to the review of the national reports, component functional tests are carried out in all Member States.

II.5.4.2. Common elements and differences

Among Member States that participated in the programme, the component functional tests were based on the operational limits and conditions specified by the supplier's and manufacturer's operational procedures and technical documentation. In many Member States the limits and conditions have been further developed based on national and international experience to enhance safety of the nuclear power plant.

The functional tests include:

- Establishment of acceptance criteria based on the safety analysis report and regulatory requirements;
- Check of the initial conditions prior to the tests;
- Start–up of the active equipment and monitoring of the basic parameters to ensure they are in the range of the allowable values;
- Check of the control and performance of the electrically and pneumatically driven valves, and check of the full or partial stroke depending on the purpose and requirements of the performed tests;
- Check of the correctness of any automated functions;
- Monitoring of the parameters during the tests.

Preventive activities are performed by the operational personnel at regular intervals. These activities include in–situ checks of the conditions of the equipment and systems and registration of values of the selected parameters in the shift log books, printouts and other records. These checks and their intervals are prescribed in accordance with the regulatory and technical requirements.

In addition to the general scheduled tests, special tests and experiments are carried out if required. Each test and experiment requires special procedures to be developed. All the tests performed are documented in the related reports, registered in the operational log books and kept in accordance with the document management rules for the corresponding documentation. Records of component functional tests are kept for trending purposes

The major difference noted among Member States for component functional tests is the schedule for testing, acceptance criteria and monitoring and trending criteria.

II.5.4.3. Identification of future elements

The greatest challenge that Member States identified in the area of component functional testing was establishing a harmonized approach to acceptance criteria, scheduling and monitoring and trending criteria.

II.5.4.4. Recommendations

It is recommended that a component functional testing programme should be considered a pre–condition for LTO.

The Member States should encourage development of minimum standards for component functional test would be that address:

- The scope and scheduling of component functional tests;
- Acceptance criteria for functional tests;
- Criteria for monitoring and trending the results of component functional tests.

Functional tests should be clearly tied with the operational requirements for the component. Working Group 2 recommends that the functional test results be documented and trended so that the safety margin defined by operational requirements is maintained during LTO.

II.5.5. Applied diagnostic systems (including load monitoring systems)

II.5.5.1. Background

Applied diagnostic systems are those systems in a nuclear power plant that aid the plant operator in determining the status of SSCs important to safety during all modes of plant operation. Examples of applied diagnostic and load monitoring systems include but are not limited to:

- Acoustic leak detection systems that support leak–before–break analysis;
- Systems to monitor confinement air cooler condensate;
- Moisture leak detection systems that help monitor the reactor coolant inventory;
- Systems to measure temperature changes related to stratification/thermal fluctuation;
- Systems to measure vibrations of rotating and electrical machines within the scope of LTO;
- Systems to analyse noise of RPV and reactor internals;
- Systems to measure temperatures, stress, fatigue cycles and displacement of components.

Load monitoring instrumentation and systems that measure displacements provide input into the diagnostic systems.

Applied diagnostic systems, if used properly, are essential in detecting the potential failure of machinery in time to permit corrective action before the safety margins are compromised.

II.5.5.2. Common elements and differences

All Member States reported that they have applied several different type of diagnostic and load monitoring instrumentation and systems at their NPPs. These systems are either built onto specific equipment (e.g. vibration monitors on the reactor coolant pump (RCP), turbine generators or diesel generators) or are portable devices.

There is however significant difference among Member States in the scope of equipment involved in testing (many CIRs included systems and components that are out of LTO scope). There are also significant differences in the methodology used in applied diagnostics; this have the potential to impact safe plant operation because incorrect conclusions may be reached concerning the cause or impending cause of failure.

II.5.5.3. Identification of future challenges

Working Group 2 members believe that the lack of accurate and minimum criteria when using diagnostic methodology is a significant potential safety issue that can result in incorrect conclusions regarding the degradation mechanisms and stressor sets that lead to component failure. Subsequent focusing of plant resources in pursuit of symptoms of the failure or on an incorrect failure cause impacts the safe operation of a nuclear power plant.

Working Group 2 members believe that one of the most significant challenges in the area of applied diagnostics will be incorporating technological advances in prognostic and diagnostic sciences into plants during LTO.

Among the issues that will need to be resolved are the economics of incorporating advanced diagnostic technology in existing operating plants, regulatory review acceptance of advanced diagnostic technology and harmonization of international standards for diagnostic systems.

II.5.5.4. Recommendations

It is recommended to Member States to develop minimum evaluation criteria for using diagnostic technology in support of LTO.

The applied diagnostic systems should be reviewed through the scoping and screening process, in the same manner as for SSCs, and that those applied diagnostic systems that are determined to be within the scope of LTO should be reviewed concerning their adequacy for LTO.

II.5.6. Surveillance programmes

II.5.6.1. Background

Based upon a review of the national reports, all Member States operate surveillance programmes that monitor and trend the material properties of the reactor pressure vessel during operation. The results provide data that may be used to validate the forecasted material properties, based upon the available knowledge and well in advance of the allowed operational period. Their scope (materials, type, number of specimens), their pertinence (dosimeter sets, lead factors, means for irradiation temperature control) as well as the completeness and the quality of the evaluation of the results differ between Member States.

Unplanned situations, such as annealing, and LTO need to be addressed by specific measures. Shortcomings, such as lack of representative material specimens, and possible compensations have also to be considered for any complementary surveillance programme.

RPVs that were not originally equipped with surveillance programmes need particular attention and efforts for ensuring the requested function.

The Member States did not report about surveillance programmes that use representative material samples to address other time limiting mechanisms.

II.5.6.2. Common elements and differences

The following main principles apply to the RPV surveillance programmes in all Member States:

1. The initial surveillance programmes are designed according to country specific regulations. Capsules including specimens of weld and base metals and the heat affected

zone (HAZ) are loaded into the RPV and, according to a predefined withdrawal plan, exposed to higher neutron fluxes than those typically found at the RPV inner surface. The initial surveillance programmes have similar objectives in each Member State, but the detailed layouts show differences in particular regarding the anticipation ('lead') factor.

2. The methodologies for assessing the embrittlement effects, including temperature, dosimetry and material toughness evaluations, are similar in each Member State, but continuous improvements are necessary to take advantage of technical developments that will compensate for shortcomings reduce uncertainties.
3. Spare material parts of representative materials (including broken specimens) are re–utilized to generate additional test results. These are then used to either complement the original results or supplement them by using advanced testing procedures and evaluation methods (e.g. master curves).
4. Changes in operational conditions (e.g. fuel type and/or management scheme) as well as in surveillance position characteristics (e.g. more refined assessments) may induce changes in the withdrawal plan.
5. Such supplementary surveillance programmes may also address additional research objectives such as providing materials for assessing open issues and/or exploring long term operation.

Some Member States have supplementary surveillance programmes that assess effects of corrective mitigation measures, such as annealing of the RPV. Host reactors, and materials that are tailored or comparable (e.g. from the same grade and origin), may be used for supplementary surveillance programmes, provided that all necessary justifications of the similarities of the irradiation conditions and the ability of the specimens to represent the material behaviour can be established with the required reliability.

Special investigation programmes have been implemented to support the operation of RPVs that were not originally equipped with surveillance programmes. Cut–outs have been used for mechanical tests at various stages (e.g. simulated initial conditions, annealed stage, re–embrittlement after acceleration) by using sub–size specimens. To some extent these techniques may be considered alternative surveillance programmes, but particular provisions should be considered to compensate for specific uncertainties due to the necessary use of successive correlations (size of specimens, ductile to brittle reference temperature, toughness).

II.5.6.3. Identification of future challenges

Working Group 2 members identified the following future challenges.

The basis for the design of a supplementary surveillance programme should consider all available specific data of the RPV, i.e. the initial state characteristics (subcomponents, geometry, chemical composition, manufacturing procedures, mechanical properties), the operational history (operational regimes, local power history of the external fuel elements, pressure tests, abnormal events, thermal annealing) the available surveillance programme results and the available representative materials. The preparation and implementation of an appropriate supplementary RPV surveillance programme has to be prepared and agreed with the safety authority well in advance. In addition, all relevant generic data and knowledge on embrittlement effects (or re–embrittlement effects, if relevant) and kinetics should be considered for predicting the expected material properties during LTO and designing the supplementary surveillance programme in detail. This includes reliable and accurate neutron dose evaluations. Advanced testing procedures and evaluation methods should be considered for defining the set of specimens to be included in the supplementary surveillance programme, at least for alternative assessments.

The development and execution of a generic investigation programme may assess tensile properties and toughness of the cladding during LTO in order to generate reference values to be used in integrity assessments.

II.5.6.4. Recommendations

Working Group 2 members recommend that:

- Early consideration of the subject is needed by NPP owners in order to prepare the relevant background, master and manage the operational aspects (e.g. fuel) and consider on time implementation of supplementary surveillance programmes;
- Supplementary RPV surveillance programmes should be a pre–condition for LTO; they should be based on national regulations and should consider international standards and guidelines. These programmes should consider reliable and accurate neutron dose evaluations as well as advanced testing procedures and evaluation methods;
- There is a need for internationally harmonised reactor dosimeter methodologies (analytical & experimental) applicable for the evaluation of RPV surveillance programme results. Topical workshops may be an effective means to exchange information and experience and generate relevant guidelines;
- It should be launched an international research project aiming to assess the uncertainties in reactor dosimeter evaluations and residual material toughness determination in order to consolidate the global reliability of the RPV surveillance data. This appears essential to guarantee appropriate safety margins for LTO.

Working Group 2 members also believe that existing surveillance programmes using representative material samples addressing other time limiting mechanisms should be extended or supplemented for LTO.

II.5.7. Non–destructive material properties testing

II.5.7.1. Background

The goal of the diagnostic activities performed to verify the basic mechanical properties of materials of the system components important for safety is to assess possible changes that may be due to the conditions of LTO. Mechanical material characteristics (yield strength Rp0.2 and tensile strength Rm) enter the basic calculating evaluations of the components important for safety whose operational safety and LTO depend, among other, also on the concrete values of these characteristics. Changes or degradation of material properties can occur as a result of factors such as the long term influence of the process medium, changes of operating parameters, and irradiation by the neutron flux and these changes can cause limitation or lowering of the safety of the critical components and thus limitations to LTO. The most common material property that is measured is hardness.

Measurement methods include the automated ball indentation testing (ABIT) method. This method is based on evaluation of a so called ‘indentation diagram’ (stress–deformation curve) acquired by a special device when pressing a ball indenter into the component material under clearly defined conditions. Magnetic methods for determination of material properties may be considered for material status investigation, but in–situ applications need extensive validation prior to using them for testing.

II.5.7.2. Common elements and differences

In the application of non–destructive material testing methods for nuclear power plants there are two basic philosophies. Eastern European plants have general requirements for the non–destructive measurement of hardness. On the other hand, other Member States do not specify requirements for non–destructive measurement of hardness, but rather rely on destructive metallurgical measurements for material properties.

II.5.7.3. Identification of future challenges

Working Group 2 members believe that the major challenges in the area of non–destructive measurement of material properties are as follows:

- Development of robust NDE technology to measure the following material conditions (the following list prioritizes the techniques in terms of potential for success)
  - Local stress in components
  - Local strain that could be used to monitor loss of pre–load
  - Void swelling
  - Embrittlement
  - Fatigue damage
- Development of harmonized criteria for regulatory acceptance of NDE material property measurements

II.5.7.4. Recommendations

Working Group 2 members recommend the following:

- Technical exchange meetings on NDE material property measurements;
- Agreement upon a benchmarking protocol for measuring the capability of NDE methods;
- Development of criteria that regulators may use in evaluating the acceptability of NDE material property measurements.

II.5.8. Destructive tests and material research carried out during NPP operation

II.5.8.1. Background

All Member States participating in the Programme conduct destructive tests to determine material properties for SSCs in the scope of LTO. The destructive testing methodology is based upon international standards such as ASTM standards, EN standards or GOST standards.

II.5.8.2. Common elements and differences

As stated above the common element among Member States is that all Member States perform destructive testing to monitor and measure material properties. The differences involve specific acceptance criteria and assumptions used when applying the results of destructive measurements to evaluations used in LTO.

II.5.8.3. Identification of future challenges

Working Group 2 members believe that the major challenge in the area of destructive measurements is developing a harmonized approach to acceptance criteria and application of destructive measurements to evaluations for LTO.

II.5.8.4. Recommendations

Working Group 2 members recommend that:

- International guidance be developed for application of destructive measurements in evaluations for LTO;
- An internationally agreed upon methodology for application of miniature specimens to determine material properties be evaluated;

- Databases be developed (similar to that of RPV surveillance specimens).

II.5.9. Chemical regimes monitoring

II.5.9.1. Background

The objective of monitoring chemistry is to mitigate damage caused by corrosion. The water chemistry programmes for Member States participating in the Programme rely on monitoring and control of water chemistry in both primary and secondary systems in SSCs within the scope of LTO.

II.5.9.2. Common elements and differences

Every Member State operating a nuclear power plant has specific requirements for monitoring water chemistry for primary and secondary systems. The difference in water chemistry programmes among Member States involves specific scheduling, analytic methods used to monitor chemistry (some programmes use automated equipment while others use wet chemical methods) and verification of the effectiveness of chemistry programmes.

II.5.9.3. Identification of future challenges

Working Group 2 members believe that the major challenge in water chemistry is verification of the effectiveness of water chemistry programmes. Several Member States require that plants that credit water chemistry as part of an AMP must verify the effectiveness of the water chemistry programme through additional inspections.

II.5.9.4. Recommendations

It is recommended that water chemistry programmes should be considered a precondition to LTO.

II.6. TIME LIMITED AGEING ANALYSIS

II.6.1. Background

Time limited ageing analyses (TLAAs) are plant–specific safety analyses that are based on an explicitly assumed time of plant operation or design life (for example, aspects of the reactor vessel design). Examples of TLAAs are those calculations and analyses used by the plant operator that:

- Involve systems, structures, and components within the scope of LTO;
- 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 plant operator in making a safety determination as required by national regulations;
- Involve conclusions or provide the basis for conclusions related to the capability of the system, structure, or component to perform its intended function(s);
- Are contained or incorporated by reference in the current licensing basis.

II.6.2. Common elements and differences

Among Member States participating in the Programme, the following is a list of common TLAAs:

Reactor vessel irradiation embrittlement

This group of time–limited ageing analyses concerns the effect of irradiation embrittlement on the belt–line regions (adjacent to the reactor core) of the reactor vessel and how this degradation mechanism affects analyses that provide limits or address regulatory requirements. The calculations discussed in this TLAA use predictions of the cumulative effects on the reactor vessels from irradiation embrittlement. The calculations are based on periodic assessment of the neutron fluence and resultant changes in the reactor vessel material fracture toughness. Further, it should include the effect of the warm pre–stressing (WPS) and role of the cladding, particularly for the pressurized thermal shock (PTS) analysis.

Metal fatigue

This TLAA involves the thermal and mechanical fatigue analyses of plant mechanical components within the scope of LTO. Specific components have been designed and analyzed considering transient cycle assumptions identified in vendor specifications and the FSAR or design basis documentation. Typical analyses that are performed include:

- Reactor vessel structural integrity
- Reactor vessel internals structural integrity
- Systems and components in the reactor coolant pressure boundary (RCPB)
- Control rod drive mechanism structural integrity
- Steam generator structural integrity
- Pressurizer structural integrity
- Reactor coolant pump structural integrity
- Pressurizer surge line structural integrity
- Piping structural integrity
- Environmental effects on fatigue
- Containment liner plate fatigue analysis (this is also discussed in the final report by Working Group 4 [4].

Fracture mechanics analysis

This TLAA involves the fracture mechanics analysis of plant passive components within the scope of LTO. Typical components that require fracture mechanics analysis include:

- Piping leak–before–break analysis (depending upon design and regulatory requirements)
- Component/piping indication analysis

Thermal ageing

Examples of components that require thermal ageing analysis include:

All components in the reactor coolant pressure boundary

Loss of preload (where appropriate, according to regulatory requirements)

This TLAA involves analysing the potential for loss of preload for passive components within the scope of LTO. A typical component that requires analysis of the loss of pre–load is the reactor vessel internal bolting.

Wear

This TLAA involves analysing the potential for loss of material and compromising function due to wear of passive or active components within the scope of LTO. Typical components that require analysis include:

- Bottom mounted instrumentation thimble tube wear
- Containment accident recirculation heat exchanger tube wear

The differences in TLAAs among Member States participating in the Programme were in the specific methodologies used to perform the analysis and acceptance criteria.

II.6.3. Identification of future challenges

Working Group 2 members identified the following challenges for TLAAs:

- Uncertainties in the material properties of SSCs in the scope of LTO, even given the surveillance, monitoring and trending programmes used in nuclear power plants;
- Developing analytic techniques that account for the impact of improved inspection methodology.

Working Group 2 members believe that the major challenge in the area of TLAAs involves developing minimum standards for methodology and acceptance criteria.

II.6.4. Recommendations

Working Group 2 members recommend the following actions to improve TLAAs:

- Sharing international experience on material properties for SSCs in the scope of LTO; this could be in the form of a database of material property measurements;
- Development of minimum standards specific applicable to LTO for TLAA:
- In order to improve the accuracy of TLAAs, research/development and codification of advanced analytic methods should continue;
- Workshops and training on developing TLAAs with respect to LTO should be carried out.

II.7. RELATED NATIONAL DOCUMENTS

Bulgaria

- Safe Use of Nuclear Energy Act
- Ordinance for the order of issuing licenses and permits for safe using of the nuclear power – Prom. SG. 41 – 18 May 2004
- Final Report of IAEA Safety Review Mission to Kozloduy NPP units 3, 4 – June 2002
- Second Report of the Republic of Bulgaria on the fulfilment of the obligations on the Convention on Nuclear Safety – Sofia, October 2001
- INFORMATION PACKAGE – Bulgarian Activities regarding the Observations and Recommendations of the “Report on Nuclear Safety in the Context of Enlargement” (doc. 9181/01 ATO 36 ELARG 118) and “Peer Review Status Report” (doc. 9601/02 ATO 68 ELARG 197)
- Comprehensive Evaluation of the Safety Status of KNPP 3&4 – Final Report ENCO–FR–(02)–09/8–4, July 2002 ENCONET Consulting
- Evaluation of Rest Lifetime of Kozloduy NPP Unit 3&4 – Final Report 08/04/2002
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Czech Republic

- Law No. 18/1997 Coll., on Peaceful Utilization of Nuclear Energy and Ionizing Radiation
- SONS Regulation No. 309/2005 Coll., Assurance of Technical Safety of Selected Equipment
- SONS Regulation No. 214/97 Coll. on Quality Assurance during Activities Connected with Utilization of Nuclear Energy and Activities Leading to Irradiation and on Establishing of Criteria for Inclusion and Dividing of Selected Equipment into Safety Classes
- SONS Regulation No. 195/1999 Coll., on Requirements on Nuclear Facilities for Ensuring of Nuclear Safety, Radiation Protection, and Emergency Preparedness
- SONS Regulation No. 106/1998 Coll.
- Law No. 50/1976 Coll. – Building Act
- Law No. 505/1990 Coll – Metrology Act
- Law No. 174/1968 Coll., ČÚBP
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- ČÚBP Regulation No. 20/1979 Coll. for Restricted Electrical Equipment
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- ČSKAE (Czechoslovak Atomic Energy Commission), Regulations for Inspections of Welded Joints and Weld Claddings for NPP, PK 1514–72, June 1976
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- Assessment of Strength of Equipment and Piping of VVER Type Nuclear Power Plants, Section III, normative technical documentation, A.S.I., 1996
- ČSN (Czech State Standard) 341090 – Electrotechnical ČSN Regulations. Regulations for Temporary Electrical Equipment
- 50–C–O Nuclear Power Plant Safety – Operation, Commissioning and Decommissioning of a Nuclear Power Plant
- NS–G–2.6 Maintenance, Monitoring, and In–service Inspections in Nuclear Power Plants
- 50–C/SG–Q5 Assessment
- 50–C/SG–Q13 Quality Assurance in Operation
- Nuclear Facilities Safety – Guidelines and Recommendations for Qualification of Equipment Important for Safety of VVER 440/213 Type Nuclear Power Plants, SONS, Prague, 12/1998
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Hungary

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- Nuclear Safety Regulations, Volume 1–4 (Issued as appendices of 89/2005 KORM. Governmental Decree)
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Finland

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II.8. COMPONENT SUMMARY TABLES FOR LONG TERM OPERATION

The following set of Tables provide examples of SSCs that may result when the Scoping and Screening Process from Section 2.5 is applied to a nuclear power plant with respect to mechanical components and materials. It is intended that *each of the SSCs determined to be within the scope of LTO* be evaluated and that the evaluation provide sufficient technical justification to demonstrate that plant operational processes and procedures are adequate to ensure that ageing effects are properly managed and that an SSC can perform its intended function during the period of LTO.

The column titled “Practice for Inspection or Testing” provides a brief description of the current practice for inspection and testing of the indicated “Component Grouping”. In some cases, where no general description of current practice was available, this column indicates a recommended practice.

Table II.1. SSCs THAT ENSURE INTEGRITY OF REACTOR COOLANT PRESSURE BOUNDARY

Component Grouping	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Vessels					
Reactor Pressure Vessel	Carbon Steel with Stainless Steel Cladding	Chemically treated borated water 270° C up to 340°C (644°F) ; Two phase steam in accident condition to 856°C; Fission products environment barrier;	Cumulative fatigue damage/ Fatigue	Conservative Analysis provides technical justification for that Fatigue will not be a problem during the period of extended operation Fatigue is a time–limited ageing analysis (TLAA) to be evaluated for the period of extended operation, and, for Class 1 components, environmental effects on fatigue are to be addressed. One Member State: Performs off–line fatigue calculation according real operation condition as well as the extrapolation of damage factor D. One Member State: Stress and fatigue analysis of the components and specific areas for the whole spectrum of normal operational conditions (NOC), abnormal operational conditions (AOO) and accident conditions (AS) most favourable based on actual recorded transient data.	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws

Component Grouping	Materials	Environment or Stressors	Degradation Mechanism/Ageing Effect	Safety Strategy	Practice for Inspection or Testing
			Loss of Fracture Toughness due to Embrittlement and Neutron Flux	Conservative Analysis (including analysis for pressurized thermal shock) provides technical justification that Embrittlement will not be a problem during the period of extended operation Possible annealing of the RPV core region weld to recover radiation embrittlement Vessel Material surveillance program	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
			Loss of material/ Boric acid corrosion of external surfaces	Non-destructive examination of External surfaces	All Member States have some type of programme for visual examination of exterior surfaces.
			Loss of material/ Wear	Non-destructive examination to detect, quantify and trend damage	In–service inspection of reactor pressure vessel to ensure adequate component material during operation
			Flow Induced Vibration	Non-destructive examination to detect, quantify and trend damage	In–service inspection of reactor pressure vessel to ensure no flaw initiation
			Crack initiation and growth/ Primary water stress corrosion cracking	Non-destructive examination to detect, quantify and trend damage	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws “Water Chemistry,” Control

Component Grouping	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
			Wear of Moving Components	Maintenance and periodic component functional tests	Maintenance and In–service Inspection practices
Pressurizer Shell/heads	Carbon Steel with stainless steel cladding	Chemically treated borated water or saturated steam 270–343°C (554–650°F)	Cumulative fatigue damage/ Fatigue	Conservative Analysis provides technical justification for that Fatigue will not be a problem during the period of extended operation (This fatigue analysis is a TLAA)	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
			Loss of material/ Boric acid corrosion of external surfaces	Non-destructive testing to detect, monitor and trend damage	All Member States have some type of programme for visual examination of exterior surfaces.
			Crack initiation and growth/ Stress corrosion cracking, cyclic loading	Control Water Chemistry and Non-destructive Testing to detect, monitor and trend damage	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws Water Chemistry Control
Steam Generators					
Pressure boundary and structural	Carbon steel, low–alloy steel	Up to 300°C (572°F) steam	Cumulative fatigue damage/ Fatigue	Conservative Analysis provides technical justification for that Fatigue will not be a problem during the period of extended operation One Member State: Strength calculation of the SG feed water nozzle metal	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
			Loss of material/ General, pitting, and crevice corrosion	Control Water Chemistry and Non-destructive Testing to detect, monitor and trend damage	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws. Water Chemistry Control.

Component Grouping	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
			Wall thinning/ Flow–accelerated corrosion	Control environmental conditions of temperature and chemistry – Also include Non-destructive Testing to detect, monitor and trend damage by measuring wall thickness	Erosion Corrosion Programme and/or Flow Accelerated Corrosion Program
			Loss of section thickness/ Erosion	Non-destructive Testing to detect, monitor and trend damage by measuring wall thickness	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
			Loss of material/ Boric acid corrosion of external surfaces	Non-destructive Testing to detect, monitor and trend damage	All Member States have some type of programme to inspect the exterior surface of components subject to corrosion
Tube bundle Tubes and sleeves	Alloy 600 Austenitic stainless steel	Chemically treated borated water up to 340°C 644°F) and 15.5 MPa, secondary system water	Crack initiation and growth/ Primary water stress corrosion Cracking; Outer diameter stress corrosion Cracking and Loss of section thickness/Fretting; Pitting, Stress corrosion cracking on the outer surface	Control Water Chemistry and Non-destructive Testing to detect, monitor and trend damage	All Member States use a combination of non–destructive inspection methodology to ensure the integrity of Steam Generator Tubing Water Chemistry Control
			Sludge or Fouling leading to loss of heat transfer	Control Water Chemistry and Non-destructive Testing to detect, monitor and trend damage	There are a variety of methods to mitigate sludge or fouling such as water lancing, etc. Water Chemistry Control
Piping and Fittings					

Component Grouping	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Piping	Stainless Steel; carbon steel with Stainless Steel clad and Carbon Steel	288°C (550°F) reactor coolant water or steam	Crack initiation and growth/ Stress corrosion cracking, intergranular Stress corrosion cracking, thermal and mechanical loading	Control Water Chemistry and Non-destructive Testing to detect, monitor and trend damage RI ISI is being applied recently by several Member States	Water Chemistry Control In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
			Cumulative fatigue damage/ Fatigue	Conservative Analysis provides technical justification for that Fatigue will not be a problem during the period of extended operation	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
			Wall thinning/ Flow–accelerated corrosion	Control environmental conditions of temperature and chemistry – Also include Non-destructive Testing to detect, monitor and trend damage by measuring wall thickness	All Member States have some type of erosion corrosion program
	Cast Stainless Steel		Loss of fracture toughness/ Thermal ageing embrittlement	Conservative Analysis provides technical justification for that Fatigue thermal ageing? will not be a problem during the period of extended operation	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
Primary nozzles and safe ends	Carbon steel with stainless steel cladding, safe ends: stainless Steel (NiCrFe buttering, And stainless steel or NiCrFe weld)	Chemically treated borated water up to 340°C (644°F)	Crack initiation and growth/ Stress corrosion cracking, primary water stress corrosion cracking Fatigue?	Control water chemistry and Non-destructive Testing to detect, monitor and trend damage	In–Service Inspection for Class 1 components Water Chemistry Control

Component Grouping	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Pumps					
Pump Casings	Cast austenitic stainless steel, stainless Steel, carbon steel	288°C (550°F) reactor coolant water or steam	Cumulative fatigue damage/ Fatigue	Conservative Analysis provides technical justification for that Fatigue will not be a problem during the period of extended operation One Member State: Stress and fatigue analysis of the inlet and outlet nozzles and the welds of the pump body/ Main Coolant Pumps/	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
			Crack initiation and growth/ Stress corrosion cracking, intergranular stress corrosion cracking	Control water chemistry and Non-destructive Testing to detect, monitor and trend damage	Water Chemistry Control In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
			Cavitation	Operational procedures to avoid cavitation Non-destructive testing to detect, monitor and trend damage	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
			Loss of fracture toughness/ Thermal ageing embrittlement	Conservative Analysis provides technical justification for that Fatigue Thermal ageing? will not be a problem during the period of extended operation and Non-destructive Testing to detect, monitor and trend damage	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
Valves					

Component Grouping	Materials	Environment or Stressors	Degradation Mechanism/Ageing Effect	Safety Strategy	Practice for Inspection or Testing
Valve Bodies	Carbon steel, cast austenitic stainless steel, stainless steel	288°C (550°F) reactor coolant water or steam	Cumulative fatigue damage/ Fatigue Low cycle fatigue	Conservative Analysis provides technical justification for that Fatigue will not be a problem during the period of extended operation One Member State: **Main Isolation Valves** – Low cycle fatigue analysis of the main flange connection	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
			Loss of fracture toughness/ Thermal ageing embrittlement	Conservative Analysis provides technical justification for that Fatigue Thermal ageing? will not be a problem during the period of extended operation and Non-destructive Testing to detect, monitor and trend damage	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
			Wall thinning/ Flow–accelerated Corrosion, Corrosion, Wear	Control environmental conditions of temperature and chemistry – Also include Non-destructive Testing to detect, monitor and trend damage by measuring wall thickness	Country specific Erosion Corrosion Programme and/or Flow Accelerated Corrosion Program
Bolting	Flange: stainless steel; bolting: High strength low–alloy Steel; carbon steel	Air with metal temperature up to 288°C (550°F) also boric acid spray on external side of components	Loss of material/ Wear	Non-destructive Testing to detect, monitor and trend damage	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws

Component Grouping	Materials	Environment or Stressors	Degradation Mechanism/Ageing Effect	Safety Strategy	Practice for Inspection or Testing
			Loss of preload/ Stress relaxation	Non-destructive Testing to detect, monitor and trend damage	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
			Cumulative fatigue damage/ Fatigue	Conservative Analysis provides technical justification for that Fatigue will not be a problem during the period of extended operation and Non-destructive Testing to detect, monitor and trend damage	In–Service Inspection for Components of the reactor coolant pressure boundary to detect service induced flaws
Hangers and Piping Supports	Stainless steel and Carbon Steel	Air with metal temperature up to 288°C (550°F)	Loss of material/ Wear Structural Distress	Non-destructive Testing to detect, monitor and trend damage	In–Service Inspection for is generally a visual examination to detect evidence of structural distress

Table II.2. SSCs THAT SHUT DOWN THE REACTOR AND MAINTAIN IT IN A SAFE SHUTDOWN CONDITION
(Including Emergency Systems)

Component Group	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Vessels					
Core Flood Tank	Stainless Steel	Chemically Treated borated water At temperature < 93°C 200°F)	Crack initiation and growth/ Stress corrosion cracking	Control Water Chemistry Non-destructive examination to detect, quantify and trend damage	Water Chemistry Control In–service Inspection according to national regulations
Refuelling Water Storage Tank	Stainless Steel	Chemically Treated borated water At temperature < 93°C 200°F)	Crack initiation and growth/ Stress corrosion cracking	Control Water Chemistry Non-destructive examination to detect, quantify and trend damage	Water Chemistry Control In–service Inspection according to national regulations
Reactor Vessel Control Rod Drive	Type 403 and 316 stainless steel; type 304 stainless steel or cast austenitic stainless steel CF–8; SA 508 class 2 with alloy 82/182 cladding	Chemically treated borated water up to 340°C (644°F) For VVER potential Acid Environment Check Water Chemistry	Crack initiation and growth/ Primary water stress corrosion cracking	Control Water Chemistry Non-destructive examination to detect, quantify and trend damage For VVER Check Water Chemistry – generally Primary coolant is at pH of 6	Water Chemistry Control In–service Inspection according to national regulations
Reactor Vessel Internals	Stainless steel	Chemically treated borated water Up 270 to 340 644°F)	Crack initiation and growth/ Stress corrosion cracking, irradiation assisted Stress corrosion cracking	Control Water Chemistry and Non-destructive Testing to detect, monitor and trend damage	Water Chemistry Control In–service Inspection according to national regulations
			Changes in dimensions/ Void Swelling	This programme has not been fully developed – The components of the programme will include all a attributes of an	An ageing management programme has not yet been approved . The applicant is to provide a plant–

Component Group	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
				acceptable Ageing Management Program	specific AMP or participate in industry programmes to investigate ageing effects and determine appropriate AMP. Otherwise, the applicant is to provide the basis for concluding that void swelling is not an issue for the component.
			Cumulative fatigue damage	Conservative Analysis provides technical justification for that Fatigue will not be a problem during the period of extended operation	In–service Inspection according to national regulations
			High cycle fatigue		
			Loss of ductility due to irradiation		
		vibration stresses		One Member State: Determination of the actual vibration stresses by developing a calculation model for the RPV internals and using the results of measurements with the vibration monitoring system	
			Loss of preload/ Stress relaxation	Monitor and trend neutron flux Non-destructive testing to detect, monitor and trend damage	In–service Inspection according to national regulations Acoustic “Loose Part Monitoring,” or “Neutron Noise Monitoring”
			Loss of fracture toughness/ Thermal ageing and neutron Irradiation embrittlement,	The programme has not been fully developed – programme will contain Conservative Analysis provides	In–service Inspection according to national regulations

Component Group	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
			void swelling	technical justification for that Fatigue Thermal ageing/embrittlement will not be a problem during the period of extended operation; Programme ill include all a attributes of an acceptable Ageing Management Program	
			Loss of material/ Wear	Non-destructive Testing to detect, monitor and trend damage	In–service Inspection according to national regulations
Condensate Storage Tank	Stainless Steel	Chemically Treated borated water At temperature < 93°C 200°F)	Crack initiation and growth/ Stress corrosion cracking	Control Water Chemistry Non-destructive examination to detect, quantify and trend damage	Water Chemistry Control In–service Inspection according to national regulations
Piping, fittings and miscellaneous items					
Piping and fittings such as Temperature elements/indicators Strainers	Stainless steel	Chemically Treated borated water At temperature < 93°C 200°F)	Crack initiation and growth/ Stress corrosion cracking	Control Water Chemistry Non-destructive examination to detect, quantify and trend damage	Water Chemistry Control In–service Inspection according to national regulations
Containment spray system Eductors	Stainless steel	Chemically treated borated water at Temperature < 93°C (200°F)	Crack initiation and growth/ Stress corrosion cracking	Control Water Chemistry	Water Chemistry Control In–service Inspection according to national regulations
Headers and spray nozzles	Carbon steel	Air	Loss of material/ General corrosion	Augment Erosion Corrosion Program	Water Chemistry Control In–service Inspection according to national regulations

Component Group	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Hangers and Piping Supports	Stainless steel and Carbon Steel	Air with metal temperature up to 288°C 550°F)	Loss of material/ Wear Structural Distress	Non-destructive examination to detect, quantify and trend damage	In–service Inspection according to national regulations
Heat Exchangers					
Heat exchanger Tubing Shell Case/cover	Carbon steel, stainless steel	Chemically treated borated water on one side and open cycle Cooling water (raw water) on the other side	Loss of material/ General and microbiologically Influenced corrosion and bio fouling	Control Water Chemistry Non-destructive examination to detect, quantify and trend damage	Water Chemistry Control In–service Inspection according to national regulations
Pumps					
Pump Bowl/casing Internal Surface	Stainless Steel; Carbon Steel	Chemically treated borated water at Temperature < 93°C (200°F)	Crack initiation and growth/Stress corrosion cracking Loss of material/ Erosion	Control Water Chemistry Non-destructive examination to detect, quantify and trend damage	Water Chemistry Control In–service Inspection according to national regulations
Bowl/casing External Surface	Casing: carbon steel with stainless steel cladding	Air, leaking chemically Treated borated water	Loss of material/Boric acid corrosion	Non-destructive examination of External surfaces	All Member States have a programme to inspection the external surfaces of components, generally through system walk down
			Cumulative fatigue damage/Fatigue	Conservative Analysis provides technical justification for that Fatigue will not be a problem during the period of extended operation	In–service Inspection according to national regulations
			Loss of fracture toughness/Thermal ageing embrittlement	Conservative Analysis provides technical justification for that Fatigue Thermal ageing will not be a problem during the period of extended operation and Non-destructive testing to detect monitor and trend damage	In–service Inspection according to national regulations

Component Group	Materials	Environment or Stressors	Degradation Mechanism/Ageing Effect	Safety Strategy	Practice for Inspection or Testing
Valves					
Valves Body and bonnet	Stainless steel	Chemically treated borated water at Temperature < 93°C (200°F)	Crack initiation and growth/Stress corrosion cracking	Control Water Chemistry Non-destructive examination to detect, quantify and trend damage	Water Chemistry Control In–service Inspection according to national regulations
	Carbon steel, stainless steel	Inside surface: treated or raw water, liquid waste; outside surface: ambient air	Loss of material/ General and microbiologically Influenced corrosion and bio fouling	Augmented Erosion Corrosion Program Non–destructive examination for wall thickness	A plant–specific ageing management programme to detect erosion/corrosion and evidence of microbiologically influenced corrosion.
			Cumulative fatigue damage/Fatigue	Conservative Analysis provides technical justification for that Fatigue will not be a problem during the period of extended operation	In–service Inspection according to national regulations
			Loss of fracture toughness/Thermal ageing embrittlement	Conservative Analysis provides technical justification for that Fatigue will not be a problem during the period of extended operation and Non-destructive testing to detect, monitor and trend damage	In–service Inspection according to national regulations
Bolting					
Bolting at Flanges	Carbon steel, low–alloy steel	Air, leaking chemically Treated borated water	Loss of material/ Boric acid corrosion	Non-destructive examination to detect, quantify and trend damage	In–service Inspection according to national regulations
Bolting at Pumps	Carbon steel, low–alloy steel	Air, leaking chemically Treated borated water	Loss of material/ Boric acid corrosion	Non-destructive examination of External surfaces	All Member States have some programme to inspect the exterior surfaces of components

Component Group	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Bolting at Valves	Carbon steel, low–alloy steel	Air, leaking chemically Treated borated water	Loss of material/ Boric acid corrosion	Non-destructive examination of External surfaces	In–service Inspection according to national regulations

Table II.3. NON SAFETY SSCs WHOSE FAILURE IMPACTS SAFETY FUNCTION
(Typical Systems include Fire Protection, Station Blackout, etc.)

Component Group	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Vessels					
Liquid Radiation Waste Tank	Carbon Steel Stainless steel	Borated Water	Loss of Material due to corrosion	Non–destructive examination	In–service inspection according to national standards
Underground Tanks for Fuel Oil External Surface Internal Surface	Carbon steel	Fuel oil, water (as contaminant) or Outdoor ambient conditions	Loss of material/ General, pitting, crevice, microbiologically influenced corrosion and bio fouling	Maintain fuel oil chemistry	"Fuel Oil Chemistry" AMP is to be augmented by verifying the effectiveness of fuel oil chemistry control. A one time inspection of the tank is recommended to verify the effectiveness of the chemistry/maintenance programme
Piping, fittings and miscellaneous items					
Piping and fittings	Carbon steel (for fresh water only) aluminumbronze, brass, copper–nickel, stainless steel	Raw water	Loss of material/ General, galvanic, pitting, crevice, microbiologically influenced corrosion and Bio fouling, selective leaching	Water chemistry Measurement and trending of wall thickness	In–service inspection according to national standards this may include a pressure test
		Saturated air	Loss of material/ General and pitting corrosion	Water chemistry Measurement and trending of wall thickness	"Compressed Air Monitoring" programme – inspection according to nation requirements
Underground piping and fittings (external surface, with or without organic coating or wrapping)	Carbon steel Cast iron	Soil	Loss of material/ General, pitting, crevice, and microbiologically influenced Corrosion; Selective leaching	Water chemistry Measurement and trending of wall thickness	Country specific inspection programmes to monitor corrosion of affected components
Hangers and Piping Supports	Stainless steel and Carbon Steel	Air with metal temperature up to 288°C (550°F)	Loss of material/ Wear Structural Distress	Periodic inspection and testing	In–Service Inspection according to national requirements

Component Group	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Heat Exchangers					
Heat exchanger Tubing Shell Case/cover	Carbon steel, stainless steel	Chemically treated borated water on one side and open cycle Cooling water (raw water) on the other side	Loss of material/ General and microbiologically Influenced corrosion and bio fouling	Periodic inspection and testing including pressure testing	Water chemistry control In–service inspection according to national standards
Pumps					
Pump Bowl/casing Internal Surface	Stainless Steel; Carbon Steel	Chemically treated borated water at Temperature < 93°C (200°F) Cooling water (raw water)	Crack initiation and growth/Stress corrosion cracking Loss of material/ Erosion	Periodic inspection and testing including pressure testing	Water chemistry control In–service inspection according to national standards Country specific erosion corrosion program
Bowl/casing External Surface	Casing: carbon steel with stainless steel cladding	Air, leaking chemically Treated borated water	Loss of material/Boric acid corrosion	Visual Inspection of exterior surfaces	All Member States have some type of programme to inspection the exterior surfaces of components
			Cumulative fatigue damage/Fatigue	Fatigue is a time–limited ageing analysis (TLAA) to be evaluated for the period extended operation.	In–service inspection according to national standards
			Loss of fracture toughness/Thermal ageing embrittlement	Loss of fracture toughness is evaluated for the period of extended operation	In–service inspection according to national standards

Component Group	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Valves					
Valves Body and bonnet	Carbon steel, stainless steel	Inside surface: treated or raw water, liquid waste; outside surface: ambient air	Loss of material/ General and microbiologically Influenced corrosion and bio fouling	Water chemistry and plant specific programme to monitor valves for loss of material	Water chemistry control In–service inspection according to national standards
Bolting					
Bolting at Flanges	Carbon steel, low–alloy steel	Air, leaking chemically Treated borated water Outdoor/Indoor Ambient conditions	Loss of material/ Boric acid corrosion	Water chemistry Measurement and trending of wall thickness	Country specific erosion corrosion program All Member States have some type of programme to inspect the exterior surfaces of components
Bolting at Pumps	Carbon steel, low–alloy steel	Air, leaking chemically Treated borated water Outdoor/Indoor Ambient conditions	Loss of material/ Boric acid corrosion	Visual Inspection of exterior surface	All Member States have some type of programme to inspect the exterior surfaces of components
Bolting at Valves	Carbon steel, low–alloy steel	Air, leaking chemically Treated borated water Outdoor/Indoor Ambient conditions	Loss of material/ Boric acid corrosion	Visual Inspection of exterior surface	All Member States have some type of programme to inspect the exterior surfaces of components

Table II.4. SSCs TO ENSURE OFFSITE RADIOACTIVE EXPOSURES ARE WITHIN NATIONAL LIMITS

Component Group	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Vessels					
Ion exchanger (demineralizer) Shell Nozzles	Carbon steel with elastomer lining	Chemically treated borated water Air, leaking chemically treated borated water (External Surface)	Loss of material/ Pitting and crevice corrosion (only for carbon steel after lining degradation) Loss of material/ Boric acid corrosion	Control Water Chemistry Non-destructive examination to detect, quantify and trend damage Periodic functional and pressure testing	Water Chemistry Control augmented by an acceptable verification programme. All Member States have some type of programme to inspect the exterior of components
Piping, fittings and miscellaneous items					
Auxiliary and Radwaste Area Ventilation System	Carbon steel	Hot or cold treated water	Loss of material/ General, pitting, crevice corrosion	Non-destructive examination to detect, quantify and trend damage	In–service inspection of components according to country national standards
	Carbon steel, low–alloy steel	Air, leaking chemically Treated borated water	Loss of material/ Boric acid corrosion	Non-destructive examination to detect, quantify and trend damage	In–service inspection of components according to country national standards
Ducts					
Duct fittings, access doors and closure bolts Equipment frames and housing	Carbon steel (galvanized painted) bolts: plated carbon steel	Warm, moist air	Loss of material/ General, pitting, crevice corrosion, And microbiologically Influenced corrosion (for duct drip–pan] and piping for moisture drainage)	Non-destructive examination to detect, quantify and trend damage	Plant Specific Programme to be evaluated
Flexible collars between ducts and fans Seals in dampers and doors	Elastomer (Neoprene)	Warm, moist air	Hardening and loss of strength/ Elastomer degradation	Non-destructive examination to detect, quantify and trend damage	Plant Specific Programme to be evaluated

Component Group	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Filters					
Housing and supports	Carbon Steel	Warm, moist Air or Air, leaking chemically treated borated water	Loss of material/ General, pitting, crevice corrosion, And microbiologically Influenced corrosion (for duct drip–pan] and piping for moisture drainage)	Non-destructive examination to detect, quantify and trend damage	Plant Specific Programme to be evaluated All Member States have some type of programme to inspect the exterior surface of components
Elastomer seals	Elastomer (Neoprene)	Warm, moist air	Hardening and loss of strength/ Elastomer degradation	Non-destructive examination to detect, quantify and trend damage	Plant Specific Programme to be evaluated
Spent Fuel Pool	Carbon steel with elastomer lining	Chemically treated borated water	Loss of material/ Pitting and crevice corrosion (only for carbon steel after lining degradation)	Control Water Chemistry Non-destructive examination to detect, quantify and trend damage	Water Chemistry Control augmented by verifying the effectiveness of water chemistry control.
Air Handler Heating/Cooling					
	Copper/nickel	Warm, moist air	Loss of material/ Pitting and crevice corrosion	Non-destructive examination to detect, quantify and trend damage	Plant Specific Program
Heat Exchangers					
Heat exchanger (serviced by closed–cycle cooling water system) Shell and access Cover Channel head and access cover (external surface)	Carbon steel, low alloy steel	Air, leaking chemically Treated borated water	Loss of material/Boric acid corrosion	Non-destructive examination to detect, quantify and trend damage	In–service inspection of components according to country national standards

Component Group	**Materials**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Pumps					
	Carbon steel, low alloy steel	Air, leaking chemically Treated borated water	Loss of material/Boric acid corrosion	Non-destructive examination to detect, quantify and trend damage	In–service inspection of components according to country national standards
Valves					
Spent Fuel Pool	Carbon steel with elastomer lining	Chemically treated borated water	Loss of material/ Pitting and crevice corrosion (only for carbon steel after lining degradation)	Control Water Chemistry Non-destructive examination to detect, quantify and trend damage	Water Chemistry Control. augmented by verifying the effectiveness of water chemistry control.
	Carbon steel with stainless Steel cladding	Chemically treated borated water	Crack initiation and growth/Stress corrosion cracking	Control Water Chemistry Non-destructive examination to detect, quantify and trend damage	Water Chemistry Control
Bolting					
Closure Bolting	Carbon steel, low–alloy steel	Air, leaking chemically Treated borated water	Loss of material/ Boric acid corrosion	Non-destructive examination to detect, quantify and trend damage	NDE of Subject Components

Appendix III

ELECTRICAL, AND INSTRUMENTATION AND CONTROL COMPONENTS

III.1. INTRODUCTION

This Appendix provides in detail the results of Working Group 3 on Electrical, and Instrumentation & Control Components [3].

The objectives of WG 3 were to:

- Identify the necessary requirements, approaches and laws (if applicable) associated with ageing and ageing management of E I&C essential to safe LTO in the Member States;
- Identify operators' approaches, processes, practices (experiences) associated with ageing and ageing management of E I&C essential to safe LTO in the Member States (including existing operators/plant programmes, procedures, quality assurance plan or programmes, ageing management programmes, technical specifications, verified databases of E I&C operational experience etc., related to E I&C LTO);
- Identify available research activities (results and existing programmes) that are directly related to E I&C LTO;
- Establish guidance on approaches to LTO;
- Discuss future challenges; and to
- Provide recommendations.

The scope of Working Group 3 activities included the SSCs that fall into the following three categories:

- All safety–related SSCs that are important to the fundamental safety functions:
  - the control of the reactivity;
  - the removal of heat from the fuel, and
  - the confinement of radioactive materials and control of operational discharges, as well as limitation of accidental releases.
- All non–safety–related systems, structures, and components whose failure could prevent satisfactory accomplishment of, or initiate challenges to, any of the safety functions defined above.
- Other areas dedicated to a specific functional purpose that may be essential to safe operation of the plant, such as:
  - fire protection;
  - environmental qualification;
  - pressurized thermal shock;
  - anticipated transients without scram;
  - severe accident management, and
  - station blackout.

Sections III.2–III.6 of this report address different aspects of long term operation for electrical components and I&C, providing for each aspect the background, common elements and differences identified among the approaches used in the participating Member States, future challenges, and recommendations.

III.2. REQUIREMENTS

Most Member States stated that they have laws generally applicable to LTO but there are no specific laws for LTO of nuclear power plant (NPP) E I&C components and commodity groups. This is mainly because E I&C components provide primarily for supporting functions to the SSCs that are considered in an application for licence renewal. Evaluation of the E I&C components is normally performed together with the main system(s) they belong to. Summary discussions in the text below covering this topic therefore involve a general approach that most of the contracting parties have applied in selecting SSCs for LTO and do not focus explicitly on E I&C components.

Applicable laws and regulations have been presented in Appendix I. and are therefore not repeated in this section. It is, however, useful to look at some examples of the similarities and differences identified relative to specific E I&C issues.

The US regulatory system is based on the Code of Federal Regulations, a codification of legally binding rules. Title 10 on Energy contains federal laws regarding all aspects of nuclear regulation from the organization and powers of the Nuclear Regulatory Commission (NRC), to the licensing of nuclear material, NPP design requirements, and specific operational and maintenance requirements on individual SSCs including requirements for LTO. For example, detailed requirements on environmental qualification of electrical equipment important to safety for NPPs are provided in 10 Code of Federal Regulations 50.49, Environmental Qualification of Electric Equipment important to safety for Nuclear Power Plant [45].

By comparison, the Russian legal system for the nuclear energy sector is based on a more general set of Federal Rules and Standards that contain rules and provisions that are also applicable to the design, operation and maintenance of NPPs. Detailed requirements on SSCs for LTO (in particular for E I&C equipment) are laid down in regulatory documents issued by RosAtom.

As a third example, the Swedish legal system in the Act on Nuclear Activities contains provisions regarding a periodic safety review (PSR) of the power plants. Requirements for the PSR are laid down by the Statens kärnkraftinspektion or SKI (Swedish Nuclear Power Inspectorate) regulations that require a PSR to take place at least every ten years and include amongst other items the ageing of E I&C SSCs.

Although the IAEA safety standards establish an essential basis for safety, the incorporation of more detailed requirements in accordance with national practice is seen as necessary. Moreover, there will generally be special aspects that need to be assessed by experts on a case by case basis.

III.3. SCOPING OF SYSTEMS, STRUCTURES AND COMPONENTS

An overall process for understanding and performing a LTO scoping process was developed by a joint assembly of all four working groups and is provided in Section 2.5 of this report.

III.3.1. Background and methodology

Normally the power plant’s electrical department is responsible for performing scoping evaluations on the plant's electrical and instrumentation and control (E I&C) systems for their applicability to licence renewal requirements. These systems are identified at specific voltage levels or within functional performance related systems (e.g., radiation monitoring, engineered safety feature (ESF) actuation, reactor protection, etc.) for electrical power or instrumentation and control, respectively.

The scoping process evaluations (Section 2.5.) include an initial review of the system and component information to determine completeness of the system component list. Since some electrical components are contained in generic systems (e.g., metering and relaying) these components needed to be identified and transferred into their specific electrical systems.

During the scoping process, an evaluation boundary is established for each electrical and I&C system or commodity group (a grouping of like functioning components such as a power cables) in order to identify the functions associated with the system or commodity being evaluated. Each system, with which the system being evaluated interfaces, is defined and the interfacing equipment is identified at the component level. For power cables to equipment (e.g., motors, valves, etc.), the system interfaces are assumed to be placed and situated at the protective device (breaker or fuse) and the cable associated with the equipment. For interfaces between systems at different voltage levels, the interconnecting transformers are the interface and they are included in the system as identified in the system drawings. This is necessary in order to ensure that the appropriate scoping criteria and all system–level functions are identified. For commodities, the types of components that define the commodity are determined to identify their appropriate scoping criteria and system–level functions.

The boundaries for the in–scope systems are defined to accurately determine the components that would need screening. Information regarding the systems and commodities is identified from review of the final safety assessment report (FSAR), the technical specifications, commitments–in–effect that are contained in docketed licensing correspondence, plant databases and documents, procedures, drawings, specifications, codes/standards, and system walkdowns. Collectively, this documentation forms an envelope of operation referred to in the US as the current licensing basis (CLB).

The scoping identifies which E I&C components are in–scope for licence renewal or PSR. The screening process evaluates these in–scope E I&C components to determine which ones are long–lived and passive, and therefore subject to an ageing management review (see Section 2.5.).

All in–scope E I&C components are evaluated to determine if they perform their intended function without moving parts or change in configuration or properties. The determination of active or passive status for each structure and component is recorded in the database.

A large number of operating NPPs are currently reaching the end of their original design life. A number of different methods are currently being used to assess the residual life of specific items of E I&C equipment that have an impact on safety, with the aim of allowing for life extension of the specific item of E I&C equipment or the whole NPP in general. For E I&C equipment that has reached its qualified life design limits or that cannot be extended for other reasons (financial, etc), refurbishment or replacement of specific components is carried out. Replacement is sometimes limited because some of the E I&C equipment cannot be easily replaced or the associated costs of replacement would be too high. It is therefore important to select a list of E I&C equipment that require reanalysis so that a demonstration of qualified life for life extension can be achieved to ensure continued NPP safety.

A flow chart depicting the scoping process that was agreed to in the framework of the Programme is provided in section 2.5 of this report. It provides general guidance to identify the minimum list of SSCs subject of LTO.

For illustration, E I&C component summary tables for LTO (including degradation mechanisms and current practice) are provided in this Appendix, Section III.8. These summary tables contain E I&C equipment that was included in LTO as a result of the scoping process described in Section 2.5.

Many active E I&C components are inside the environmental qualification envelope; they have an in–service inspection (ISI) programme, and are regularly tested. They can and will be refurbished or replaced, if needed, or they can be qualified for LTO. In most instances it is more effective to replace active components than to perform expensive time limiting ageing analyses (TLAAs) for them.

The situation is somewhat different for mechanical components. Replacing pumps and valves can be much more expensive and it makes economic sense to include essential elements of programmes that would test, monitor and evaluate active components.

III.3.2. Common elements and differences

Most Member States reported that they do not have codified rules or procedures that would explicitly provide for criteria on how to select appropriate E I&C equipment for LTO.

It was observed that in general, owing to many country's legal requirements, a similar scoping process as described above could be included as a means of selection of E I&C equipment for LTO in submittals from licensees (e.g. licence renewal or PSR).

Some Member States already have implemented an integrated plant assessment (IPA), part of which is identification of the E I&C equipment within the scope of analysis. This is supported by given evaluation criteria. The scoping process defines the entire plant in terms of major E I&C equipment and identifies their system–level functions. All of these systems and components are then evaluated against the scoping criteria to determine whether they perform or support an intended function for responding to a design basis event, or perform or support specific regulatory requirements. Even if only a portion of a system or structure meets the scoping criteria of applicable regulatory requirements, the E I&C equipment is identified as in–scope for LTO. A screening process evaluates the in–scope components for their relevance to LTO evaluation. The result of the screening process is a list of E I&C components that would be subject to an ageing management review.

One Member State reported that the licensee elaborates a list of E I&C equipment to be considered for LTO based on a specific NPP design. This list includes (i) systems and components important to safety whose design life, as established in the design documentation, is shorter than the unit's operational lifetime; and (ii) systems and components important to safety which are required to have their qualified life specified.

Another Member State reported that the NPP defines a selected set of E I&C equipment to be within the scope of LTO as an important initial step in the development of the programme for the implementation of LTO. The scope of the E I&C equipment within the framework of the lifetime management programme is derived from the NPP scoping process considering relevant regulatory requirements of the country. The performance of components within the lifetime management scope is regularly monitored as part of the conditions for future operation.

One Member State reported that a periodic safety review is required that must take place at least every 10 years from the beginning of operation. It must include verification that the plant fulfils all applicable safety requirements valid at the time of the review, but also that the prerequisites for the next periodic safety review are valid as well. This is to ensure that the plant can be operated in a safe manner until the subsequent review. In this is included the latest developments in science and technology. SSCs (EI&C) are not specifically selected for LTO, but are classified into safety classes based on applicable technical reference documents and standards (domestic as well as international). Every ten years a full cycle of analysis is performed to determine the qualified life of the safety classified SSCs. Conclusions of the analysis are specified, as are the actions and documentation to be submitted to regulatory body prior to the next periodic safety review.

III.3.3. Future challenges

As can be seen from above discussion, there are widely varying approaches to selecting E I&C equipment to be considered for LTO. As a result, the scope of E I&C equipment to be considered for LTO varies greatly from country to country. Working Group 3 identified the following challenges:

- A violation of the required safety margins of the E I&C equipment is not allowed by postponing of equipment replacement when it has passed the expiration of qualified life;
- A licensee shall commence and perform continuously any activity for preserving the required technical conditions of E I&C equipment important to safety within its designed life;
- Any safety concerns revealed during actual operation of the plant should be resolved in the frame of the existing operational licence;
- Safety enhancements that could result from new requirements or experience feedback are implemented within the frame of licence renewal or PSR;
- E I&C equipment in the scope of LTO is subject to a comprehensive examination for assessment/determination of its qualified life based on specific evaluation programmes that are developed for this purpose. This process starts at an appropriate time before expiration of the qualified life;
- A reliability analysis forms one criterion for safe operation of E I&C equipment for the duration of LTO period.

III.3.4. Recommendations

Working Group 3 members recommend the following:

- Member States adopting LTO should use the scoping process that was agreed to in the framework of this Programme to identify E I&C systems and components for LTO evaluations.

III.4. AGEING MANAGEMENT PROGRAMMES

III.4.1. Background

Ageing management process normally consists of three key elements: (i) selecting SSCs in which ageing should be controlled; (ii) understanding the mechanisms and rates of degradation in these SSCs; and (iii) managing degradation through effective inspection, surveillance, condition monitoring, trending, record keeping, maintenance, refurbishment, replacement, and adjustments that consider the operating environment and service conditions.

The most common ageing effect for passive electrical components is electrical failure due to thermal/thermo–oxidative degradation of organic material. Material ‘thermal life’ can be evaluated using methodology for electrical cables and connections [46]. In many cases, conservative assumptions are used to simplify the analysis. Thermal life is not used to determine the scope of components in the cable condition monitoring programme. The programme includes all in–scope electrical cables and connections within specified plant spaces, and adequately addresses ageing effects due to thermal conditions.

Electrical failure due to radiolysis and radiation induced oxidation is considered a significant ageing effect only for those passive electrical components installed in containment close to the main steam lines in boiling water reactors (BWRs). For these components, the moderate damage thresholds for the materials are to be reviewed against expected and measured radiation environments. The cable condition monitoring programme includes all in–scope electrical cables and connections within specified plant spaces, and must adequately address ageing effects due to radiation.

Moisture induced electrical failure for in–scope passive electrical components is considered to be a third significant ageing effect. Medium–voltage cables are known to experience water–treeing type degradation in a wet, electrically energized environment: underground cable duct banks typically form such an environment. There are in–scope medium–voltage cables in underground duct banks. Industry and plant operating experience also supports moisture as a significant stressor for electrical connectors. The cable condition monitoring programme must include all in–scope electrical cables and connections within specified plant spaces, and adequately address ageing effects due to moisture.

Applicable ageing effects

Most countries reported on their research activities in the area of ageing. The main aim of research activities is the evaluation of NPP systems in relation to ageing management programmes. However, the scope of the E I&C systems and components to be considered for ageing management oriented research differs markedly among countries.

Research programmes were carried out in some countries that aimed at development of the scope of equipment to be included in ageing management programmes (AMPs), equipment specific programmes, procedures and criteria and finally the legislation related to AMPs and LTO in accordance with regulatory guidance on ageing management of nuclear power plants.

The IAEA conducted a coordinated research programme (CRP) on the management of ageing in–containment I&C cables [47]. The general objective of the CRP was to identify the dominant ageing mechanisms and to develop an effective strategy for managing ageing effects caused by these mechanisms. The specific objectives were (i) to validate predictive cable ageing models accounting for synergistic effects that take place when radiation and thermal ageing occur over the long time period associated with real plant environments, and (ii) to provide practical guidelines and procedures for assessing and managing the ageing of I&C cables in real plant environments. The scope of the CRP was limited to those materials and cables types considered to be of widest interest. The programme was therefore limited to low voltage (< 1 kV) I&C cables based on cross linked polyethylene (XLPE), ethylene propylene based materials (EPR/EPDM) and ethylene vinyl acetate (EVA). Because of their similarity in materials and construction, low voltage power cables were also included in the programme.

The US Nuclear Plant Aging Research (NPAR) programme, conducted under the auspices of the NRC Office of Nuclear Regulatory Research, and other related ageing management programmes developed a broad range of technical information on managing ageing. The ageing management process central to these efforts consists of three key elements as stated in the first paragraph. The NPAR report, [48], concisely reviews and integrates information developed under NPAR and other ageing management studies and other available information related to understanding and managing age–related degradation and provides specific references to more comprehensive information on the same subjects.

Ageing mitigation measures

The effects of ageing on E I&C equipment are detected through different mechanisms in NPP operation (preventive and corrective maintenance, inspections, monitoring, E I&C equipment performance monitoring). The mechanism that has given rise to the degradation of the behaviour or characteristics of E I&C equipment material can be determined through the subsequent analysis of these effects. The election of an efficient method for mitigating ageing in E I&C equipment material depends on an accurate determination and evaluation of the degradation mechanism and the underlying stressor that caused the ageing. These mitigation methods can be grouped into three main categories:

- change of the E I&C equipment design;
- change/recovery of material characteristics; and
- changes of operating parameters (resulting in material environmental changes)

For those structures and components in US plants that are subject to ageing management review, the licence renewal rule requires demonstration that the effects of ageing will be adequately managed so that the intended function(s) will be maintained consistent with the current licensing basis (CLB) for the period of extended operation.

III.4.2. Common elements and differences

Review of the Country Information Reports (CIRs) submitted concluded that ageing management programmes (AMPs) have been implemented in all countries. The AMPs generally involve:

- identification of degradation mechanism applicable to E I&C equipment;
- learning the degradation process and its effect; and
- implementation of the appropriate mitigating measures at their operating NPPs.

There have been considerable differences identified in the scope of E I&C equipment that was included in AMPs among the different countries. For example some countries included active equipment, while others focused on passive equipment only, such as components that perform their intended operation without moving parts, without any variation in their shape or properties, or that are not replaced during the planned life cycle of the NPP (long–life components). The scope of the ageing management programme must be determined by the systems and components that impact on the safety, known ageing mechanisms and their possible effects, and application of ageing management methods, according to relevant country's regulatory reference documents.

All countries reported that they have implemented specific ageing mitigation measures on E I&C equipment such as monitoring of mechanical and electrical characteristics, qualification under representative conditions, visual inspection by thermo vision (infrared) instrumentation and evaluation of the results of periodic walkdowns regularly performed by the shift personnel. An example of a mitigation measure implemented at NPPs involves evaluation and subsequent change of operation parameters, implementation of specific design changes, change of component material, as well as replacement of equipment that has not passed qualification tests, or for which qualified life could no longer be demonstrated.

Another approach [49] discusses the issue of the extent to which the regulatory staff should review existing programmes relied on for licence renewal. To accomplish this, they must determine whether an applicant has demonstrated reasonable assurance that such programmes will be effective in managing the effects of ageing on the functionality of structures and components in the period of extended operation. The approach provides a description of different options for crediting existing programmes and recommends one option believed to improve the efficiency of the licence renewal process. The regulatory staff focuses on areas where existing programmes should be augmented for licence renewal. A generic ageing lessons learned (GALL) report [37]was developed to document the staff's evaluation of generic existing information and programmes. The GALL report is intended to document the staff's basis for determining which existing programmes are adequate without modification and which existing programmes should be augmented for licence renewal. The GALL report is intended to be referenced in the standard review plan for licence renewal (SRP–LR) as a basis for determining the adequacy of existing programmes.

The European Union approach to ageing management [44] involves ageing or 'service–life' management programmes. Their status in different EU countries is nevertheless different:

In France and Belgium, ageing management is the responsibility of the utility, which must operate safely taking also into account the economic aspects in order to reduce the operation costs. From a licensing point of view, the utility shall be able to demonstrate at any time the safety of its plants;

In Spain, the licence requires that each year plant owners prepare and submit to the regulatory authority an annual report including a lifetime management programme, its status as well as activities performed within this programme. As a result, plant operators generally follow UNESA methodology;

In the UK, formal consent is needed to restart the plant after shutdown due to maintenance or refuelling, providing the opportunity to ensure, within a 2 to 3 years interval, that the plant is adequately safe for a further period of operation. Generic issues are particularly considered.

III.4.3. Future challenges

The following challenges have been identified:

- Harmonization of industrial standards and regulatory requirements applicable for ageing management programmes could be a possible approach to further improve implementation of ageing management programmes (for example, standards for electrical cables and connections in Member State nuclear power plants).
- Gaps in the knowledge that need to be covered in future research, as they have been identified in report, Safe Management of NPP ageing in European Union [44] such as:
  - Life assessment technology and non–destructive examination (NDE) for physical properties altered by ageing;
  - Improved monitoring techniques;
  - Repair and degradation mitigation technologies;
  - Availability of an aged materials database (covering toughness, mechanical properties of aged materials, etc.);
- Gaps in the feedback of experience on making allowances for ageing at the design stage and monitoring ageing. The nuclear operator could then find itself torn between allowing operation to continue in degraded conditions and condoning outage for an extended period.

III.4.4. Recommendations

Working Group 3 members recommend the following:

- Member states considering LTO should adopt ageing management programmes for E I&C that are based upon best practice standards and that contain very explicit testing methodology and acceptance criteria.
- Member states considering LTO should develop minimum criteria for ageing management programmes for electrical cables and connections that are not subject to the environmental qualification requirements and are exposed to adverse localized environments caused by heat, radiation, or moisture. The criteria should provide reasonable assurance that the intended functions will be maintained in a manner that is

consistent with the current licensing basis (CLB) through the period of extended operation.

- Technical exchanges through different international networks should be encouraged so that Member State considering LTO may share information on degradation mechanisms and mitigation techniques for electrical cables and connections.

III.5. OPERATIONAL PROGRAMMES

It is essential to know the qualified life of equipment or its components to determine the date of replacement. It is therefore important to understand the elemental construction of a 'typical' nuclear plant electrical system. The operational ageing management of E I&C components that fall into the environmental qualification (EQ) category is well defined. Consideration should also be given to those categories of active and passive components that are outside the EQ envelope.

For E I&C equipment and components that are within the EQ envelope, the EQ criteria should require best practice methods that demonstrate the equipment is capable of functioning correctly with sufficient safety margin even in the case of a design basis accident during the period of LTO. Generally, verification of the qualified life of EQ and non EQ equipment can be accomplished by (i) surveillance/periodic testing, (ii) ageing analysis and prediction, and (iii) appropriate maintenance programmes, component repair/ replacement or operational environment improvements.

System summary tables for LTO (including degradation mechanisms and current practice) are provided in this Appendix, Chapter III.8. These tables contain examples of E I&C equipment considered for LTO.

III.5.1. Maintenance standards or practices for active components

III.5.1.1. Background

The EQ programmes deal with thermal, radiation and fatigue ageing of components, as applicable, through the use of ageing evaluations based on appropriate qualification methods. It is generally required that EQ components not qualified for the current licence term are to be refurbished, replaced, or have their qualification extended by acceptable analysis prior to reaching the ageing limits established in the evaluation.

The EQ programme covers certain equipment types including solenoid operated valves, electric motors, electrical penetration assemblies, heat shrink tubing, wire and cable, electrical connectors, resistance temperature detectors, and high range radiation monitors. The EQ programme ensures that these EQ components are maintained within the bounds of their qualification bases.

The majority of active E I&C components are monitored using equipment calibration testing or preventive maintenance checks (component functional testing or degradation specific testing). These periodic tests are required in the operating limits and conditions (OLCs) that each plant must follow in order to retain its operating licence. Electrical component maintenance for active components is governed by the plant technical specifications. Refurbishment or replacement is required when defective E I&C components are identified through calibration testing or by surveillances required by LTO regulation.

The EQ programme guidance does not require monitoring and trending of the condition of components or of performance parameters of in–service components to manage the effects of ageing. EQ programme actions that could be viewed as monitoring include tracking how long qualified components have been installed. Monitoring or inspection of certain environmental conditions or component parameters may be used to ensure that a component is within the bounds of its qualification bases, or as a means to modify the qualified life.

For EQ equipment, the operating limits and conditions provide calibration and test frequencies. EQ programme actions that could be viewed as preventive actions include (i) establishing the component service condition tolerance and ageing limits (e.g., qualified life or condition limit), and (ii) where applicable, requiring specific installation, inspection, monitoring or periodic maintenance actions to maintain component ageing effects within the bounds of the qualification bases.

III.5.1.2. Common elements and differences

It was observed from the CIRs that a standard maintenance approach has been applied for a majority of E I&C equipment including that considered in LTO. Active E I&C equipment and its component parts have a normal design life that is generally shorter than the NPP design life. They reach their end of life much faster than long lived passive equipment such as cables, connectors, penetrations, terminal boxes, etc. Availability of spare parts for a specific brand is also a limiting factor to long term maintenance. Owing to that fact, some countries reported that the active I&C equipment and/or its components are subject to regular replacement at most NPPs.

In some countries, there are regulatory requirements available to allow reassessment of the design life for active E I&C equipment with the aim of extending it beyond its original design life. This approach is generally applied as a temporary solution before scheduling large scale replacement/refurbishment projects at the NPP.

Some countries implement the EQ programme because it is required by country regulatory requirements for the applicable E I&C components important to safety. Those requirements also define the scope of components to be included, require the preparation and maintenance of a list of in–scope components, and require the preparation and maintenance of a qualification file that includes component performance specifications, electrical characteristics and the environmental conditions to which the components could be subjected.

III.5.1.3. Future challenges

Working Group 3 members identified the following challenge:

Minimum criteria for replacement of EQ and non EQ E I&C equipment need to be developed. While the majority of the EQ programme requirements of Member States are quite similar, maintaining an accurate inventory of EQ equipment and replacing it according to its expiration schedule presents both a logistical and a financial burden to the utilities. For this reason, it is necessary for the regulator to be exceptionally vigilant in ensuring compliance with replacement schedules of EQ gear.

III.5.1.4. Recommendations

Working Group 3 members recommend the following:

- that Member States adopting LTO should develop minimum criteria for replacement EQ and non EQ E I&C equipment;
- that Member States adopting LTO should consider replacement of EQ E I&C equipment that is not qualified for the period of LTO, or should have its qualification extended prior to reaching the ageing limits established in the evaluation;
- that Member States should consider evaluating non EQ E I&C equipment that its used on safety related systems to determine if that equipment should be re–classified and qualified as EQ equipment. Any equipment that is reclassified should have an

appropriate testing schedule or replacement programme that includes corrective measures that must be implemented to ensure functionality during the period of LTO.

III.5.2. Equipment qualification practices

III.5.2.1. Background

All countries reported that qualification of E I&C equipment is implemented through EQ programmes. These have been implemented at most NPPs along with the requisite database that supports preventive EQ maintenance programmes. This approach helps facilitate the replacement of E I&C equipment and component at the time best suited to minimize the economic impact.

The CIRs indicate that countries perform numerous qualification tests along with qualification methods in an approved laboratory, at the manufacturer's, at relevant research institutes and even at the utility's premises. Qualification results are recorded in qualification reports established by the entity that was responsible for performing the tests. These reports contain an evaluation of the qualified equipment life, which may vary depending on the location (and hence the environment) of the equipment.

The review of CIRs confirmed that the extension of qualified life for EQ equipment has been widely applied. There is also a possibility of extending the design life of E I&C equipment by renewing some of its parts or by reassessing its life considering realistic environmental and projected DBA conditions. This approach allows for the replacement of only the equipment exposed to actual severe environmental conditions.

It was reported that environmental qualification of new equipment is also performed to determine its time of obsolescence; this is done when the NPP does not have the possibility of replacing components with like equipment before the qualified life of the component expires. Therefore when qualified equipment becomes obsolete, new equipment has to be found which is already qualified or which can be qualified. It is also possible to find equipment which has been qualified by others. In this case the qualification process shall be well documented and shall fulfil requirements for necessary supervision. The qualification process may be extremely protracted depending on the required qualification level.

III.5.2.2. Common elements and differences

Most countries identified electrical cables and connectors amongst other E I&C equipment as the most limiting factors for LTO. For many older units, electrical cables for equipment and motors including the safety related equipment and motors were insulated with PVC, without qualification, a real knowledge of environmental conditions, or projected lifetime. There is, therefore, a risk that a non–qualified cable may not be able to correctly operate under accident conditions. Currently, it is estimated that the direct cost of unit re–cabling could be equivalent to 2.5% of the NPP unit price and that the duration of such an operation could be nearly 1.5 years (see ref. [44], EUR19843). Therefore special attention is given to replacement of PVC or other unqualified cables with new qualified ones, or at least to running re–qualification programmes including ageing prediction.

III.5.2.3. Future challenges

Working Group 3 members identified the following challenge:

An internationally agreed upon set of minimum criteria for prequalification of EQ and non EQ E I&C equipment that were built according to earlier standards needs to be developed.

For the equipment at the plant that was designed according to earlier standards, comprehensive re–qualification programmes should be implemented that are aimed at obtaining missing information on whether the equipment can perform as expected under design accident conditions. In addition if the information is not available from other sources, re–qualification programmes should cover accelerated thermal, moisture and radiation ageing, to obtain information on equipment ageing perdition.

III.5.2.4. Recommendations

Working Group 3 members recommend the following:

- Member States that adopt LTO should verify and further develop qualification results on safety related E I&C equipment located in the containment. The qualification results should specify that the equipment has been qualified to perform under design basis accident environmental conditions.
- Member States that adopt LTO should regularly update the plant specific list that contains EQ cables and connectors on safety related equipment as well as non EQ cables and connectors having an impact on performance of safety related systems.
- Member States that adopt LTO should consider timely implementation of corrective measures with regard to the design shortcomings of electrical penetrations to ensure the proper functioning of electrical containment cable penetrations. New materials evaluations and further testing could be a reasonable approach to this critical item.

III.5.3. Component functional tests

III.5.3.1. Background

Functional tests are carried out periodically to determine whether the technological E I&C material is in a condition capable of accomplishing the functions for which it was designed. Besides justifying the current functional availability, these tests are used to reveal potential performance deviations before these deviations could lead to inadequate functionality of the E I&C equipment in the interval before the next scheduled test.

Based on requirements of the relevant technical specifications, maintenance documents and recommendation of the manufacturers, functional testing of the E I&C system and components is regularly performed in the frame of maintenance activities. In response to industrial requirements and regulations, the NPPs have developed detailed procedures to conduct functional tests to satisfy applicable industrial and regulatory requirements.

A start up functional test is performed to check the functionality of individual equipment as well as the entire system(s) following maintenance or extended shutdown of the system. These tests involve calibration checks to ensure the accuracy of required metrological settings. Procedures are detailed and well referenced ensuring that the uncertainty in the measurements is known and corresponds to the required accuracy of the measurement.

The power range tests are executed according to a schedule that is in compliance with the corresponding prescriptions of the operating limits and conditions (technical specifications).

A separate set of tests is generally conducted prior to unit shutdown to justify that the conditions of SSCs required for the cool down of the reactor coolant system and its subsequent depressurization comply with the corresponding requirements.

III.5.3.2. Common elements and differences

All countries reported that they have implemented functional tests for E I&C systems and components at their NPPs. The scope of the E I&C components as well as the frequency of functional testing that is performed is maintained within the relevant country's technical reference documents and regulatory requirements.

There have been differences identified among countries in the scope of equipment included in testing (many CIRs included systems and components that are outside the definition of LTO scope given in this document) as well as in methods used for testing (testing cycle, testing procedure, etc.).

III.5.3.3. Future challenges

Working Group 3 members identified the following challenge:

Members States that adopt LTO should develop minimum criteria for determining E I&C equipment that will be subject to functional testing as well as minimum requirements for scheduling, testing methods, procedures and testing devices. The scoping methodology provided in Appendix I is recommended as a consensus technique developed by all working groups.

III.5.3.4. Recommendations

Working Group 3 members recommend the following:

Member States adopting LTO should facilitate development of minimum criteria for determining E I&C equipment that will be subject to functional testing. The criteria should include minimum requirements for scheduling, testing methods, procedures and testing devices. The scoping methodology provided in Section 2.5. is recommended as a consensus technique developed by all working groups.

III.5.4. Applied diagnostic systems (including load monitoring systems)

III.5.4.1. Background

Applied diagnostic systems are those systems in a nuclear power plant that aid the plant operator in determining the status of safety related SSCs (including the environment) during all modes of plant operation. Examples of applied diagnostic and load monitoring systems that use E I&C components include, but are not limited to:

- acoustic leak detection systems that support leak–before–break analysis;
- confinement air cooler condensate monitoring systems;
- moisture leak detection systems that help monitor reactor coolant inventory;
- stratification/thermal fluctuation related temperatures measurement;
- measurement of vibrations of rotating and electrical machines within the scope of LTO;
- noise analyses of RPV and reactor internals;
- measurement of temperatures, stress, fatigue cycles and displacement of components;
- load monitoring instrumentation and systems that measure displacements and thermal fatigue and provide input into the diagnostic systems.

Applied diagnostic systems, if used properly, are essential in detecting the potential failure of machinery in time to permit corrective action before the safety margins are compromised and as such it is essential that their related E I&C components are properly maintained for the period of LTO.

Current electrical diagnostic and prognostic practice applied in a number of Member States focuses on a set of measurement tools including:

- infrared;
- vibration;

- ultrasound;
- current signature analysis;
- insulation partial discharge;
- insulation high potential testing (Megger testing).

These tools give indications that can be interpreted as an assessment of the machinery condition and state of environmental stress. Correlations have been developed to link condition and stressor levels to project the useful residual life of an in–service component. The basic function of E I&C is to ensure that sensors are energized and that information flows appropriately.

III.5.4.2. Common elements and differences

All countries reported that they have applied different diagnostic systems at their NPPs. These diagnostic systems are either built based on specific equipment (vibration monitors on the reactor coolant pump (RCP), turbine generators or diesel generators) or are portable devices.

There are however significant differences among countries regarding the scope of equipment involved in testing (many CIRs included systems and components that are out of LTO according to the scope of this report).

III.5.4.3. Future challenges

Working Group 3 members identified two major challenges for applied diagnostic systems. The first challenge involves developing and adopting technology to reduce the dependence of systems on electrical cables. As an example, fiber optics or wireless technology may replace cables where appropriate.

The second challenge is related to the first and deals with efficient regulatory acceptance of new technology. While most regulators encourage the development and use of diagnostic and prognostic technologies, many have been slow to accept the touted accuracy as acceptable proof of system or component health. Laboratory developments are therefore difficult to implement in operating nuclear plants.

III.5.4.4. Recommendations

Working Group 3 members recommend the following:

Member States that adopt LTO should ensure that diagnostic and prognostic systems are widely used to detect actual component conditions with possibility to predict possible component degradation under given operational conditions. Diagnostic methods and their accuracy should be subject of regulatory body approval before implementing them in operating nuclear plants.

Function of applied diagnostic systems is important and must be maintained during the period of LTO.

III.5.5. Surveillance specimen programmes

III.5.5.1. Background

Due to the research performed to quantify the damage due to temperature and radiation effects in cables, individual plants do not always perform cable or E I&C component sample testing. As part of the equipment qualification programme, monitoring of the stressor levels is frequently performed to maintain a record of the environment that is necessary for re–qualification or extended life (LTO) of E I&C materials and components.

III.5.5.2. Common elements and differences

Some countries have carried out research programmes to quantify the damage due to temperature and radiation effects in cables, while individual plants do not normally perform cable or E I&C component sample testing. As part of the equipment qualification programme, monitoring of the stressor levels (temperature and radiation levels) are frequently performed to maintain a record of the environment that is necessary for re–qualification or extended life (LTO) of E I&C materials and components.

Most countries reported on their controlled ageing programme for electrical cables. Initial values of mechanical, electrical, and physical/chemical properties of the cables are stored in a database. Periodic monitoring of the changes during the NPP lifetime is presumed, and the evaluation of their residual lifetime is based on visual inspections, the experimental results and monitoring of the environment. In ‘hot spot’ locations, micro–samples of the cable jackets are extracted for the verification of the condition of cables. During the replacements of operational cables, assessments of their as–found condition are carried out, and the results are used for refining the predicted lifetimes. Experiments are made, verifying the influence of the current effect of gamma radiation, increased temperature and electric load of the cables with the aim to create a relevant mathematical model.

One country reported on conducting a surveillance specimen programme for electrical cables. A cable specimen is stored in the containment to simulate accumulated thermal and radiation ageing. Tests are then performed on the samples as described in relevant technical reference documentations.

Another country reported that, in addition to cables, valve component material is sometimes tested.

III.5.5.3. Future challenges

Working Group 3 members identified the following challenges:

- There should be timely implementation of action items derived from the qualification test results, namely surveillance and condition monitoring activities on installed electrical cables, especially in PVC cables in areas affected by high radiation and/or design bases accident.
- Applications of qualification results should be further developed on safety related electrical equipment located in the containment, and this should be qualified to given accident environmental conditions.

III.5.5.4. Recommendations

Working Group 3 members recommend the following:

- Member States that adopt LTO should implement controlled ageing programmes for electrical cables at their NPPs. Initial values of mechanical, electrical, and physical/chemical properties of the cables should be stored in an appropriate database. Periodic monitoring of the changes during the NPP lifetime is presumed, and evaluation of the lifetime of the cables should be performed, based on the experimental results and monitoring of the environment.
- Member States that adopt LTO should conduct experiments on verifying the influence of the current effect of gamma radiation, increased temperature and electric load of the cables with the aim to create a relevant mathematical model.

III.5.6. Non–destructive material properties testing

III.5.6.1. Background

In order to ensure proper operation of E I&C equipment, there are some specific electrical parameters measured through non–destructive testing of samples. For LTO, the most important property of electrical equipment such as electrical cables and high voltage bus bars is their dielectric strength. This property cannot be determined from equipment that is in service, and so instead non–destructive tests are carried out on de–energized systems to gain information on the present condition of the insulation of electrical equipment considered important to the scope of LTO.

There are a number of methods used for monitoring the condition of electrical cables, such as electrical, mechanical or chemical tests. The electrical tests include the Megger test for electrical resistivity, and measurement of direct current and alternate current resistance. The mechanical tests involve measurement of insulation elasticity or cable external coating discoloration in order to identify the transition of the material to drying, brittle fracture or cracking–disposed states. The chemical tests involve taking samples of cable insulation and cable coating for chemical analysis in laboratory conditions.

In general the E I&C equipment testing is performed according to the plant technical specifications and involves calibration testing and trending of the resulting data.

An acceptable cable condition monitoring programme requires:

- visual inspection of a representative sample of accessible electrical cables and connections in adverse localized environments at least once every 10 years for evidence of jacket surface degradation;
- testing of nuclear instrumentation circuits once at least every 10 years to detect a significant reduction in cable insulation resistance; and
- testing of a representative sample once every 10 years of in–scope, medium–voltage cables not designed for submergence but subject to prolonged exposure to significant moisture and significant voltage, to detect deterioration of insulation.

Some countries reported on the methods they use to verify the degree of cable ageing, such as:

- local mechanical compression of the cable coating by a special compressing tool;
- sampling of small amount (some milligrams) of cable insulation or coating to study material composition and structure, applying physical and chemical methods such as differential scanning calorimetry, thermogravimetry or IR – Fourier analysis;
- stretching to breakage of cable samples taken out from service;
- the ‘return voltage’ method for power cables with paper–oil insulation (this method is also applicable for evaluating the ageing of control cables with various types of insulation).

III.5.6.2. Common elements and differences

Non–destructive tests of the material properties of electrical cables are the common element among countries to verify material conditions of electrical cables as well as the degree of cable ageing. These non–destructive tests are based on the fact that operating conditions generate physical and chemical processes, which modify the molecular structure of the material. It leads to modification of dielectric parameters, like the insulation resistance, which can be measured. Specific indicators of the material conditions of electrical cables are measured or calculated, such as insulation resistance, polarization index and loss factor.

III.5.6.3. Future challenges

Working Group 3 did not identify any challenges on this subject.

III.5.6.4. Recommendations

Working Group 3 members recommend that Member States that adopt LTO should use non destructive testing methods to monitor degradation of materials during LTO.

III.5.7. Destructive material properties testing

III.5.7.1. Background

Destructive tests are widely applied to samples of electrical cables. These tests apply the elongation to break method for monitoring cable insulation performance. As the cable ages, its insulation material becomes more rigid, and therefore the elongation to break value decreases. Samples are taken from the insulation materials applied in different parts of the cable (insulation of elementary wires, covers, etc.). In case of low cross–section cables, or insulation of elementary wires, the wire is removed from the insulation, and the insulation is then subject to testing. In case of high cross–section cable parts, standard test samples are cut from the insulation materials. The samples are tested in a tensile stress machine. The elongation is measured from the initial state until the insulation material breaks.

Samples of electrical cables that were taken out of service are often used for measurement of ductility and tensile strength of insulating and jacket materials and determination of mass density.

Using the method of differential scanning, calorimetric values of oxidation/induction time/temperature are measured and the thermal resistance of non–metallic materials is evaluated.

High voltage destructive tests are performed on samples of electrical cables in order to verify that electrical properties of insulation are not degraded.

III.5.7.2. Common elements and differences

Most countries reported that they have implemented destructive testing methods to verify the material conditions of electrical cables.

Some countries use periodic destructive tests for the surveillance of cable specimens. The most conventional ageing indicators are elongation at break and tensile strength parameters. Because surveillance cable specimen programmes have been implemented only relatively recently, only limited data is currently available, but more data is required to accurately determine significant trends or limit situations.

In some countries, the destructive testing of E I&C materials is not required in conjunction with the LTO programme.

III.5.7.3. Future challenges

Working Group 3 did not identify any challenges on this subject.

III.5.7.4. Recommendations

Working Group 3 members recommend that Member States that adopt LTO should use destructive testing methods using specimens of electrical cables that were exposed to actual environmental conditions during operation to monitor material degradation of during LTO.

III.6. TIME LIMITED AGEING ANALYSIS

III.6.1. Background

Time–limited ageing analyses (TLAAs) are plant–specific safety analyses that are based on an explicitly assumed time of plant operation. Therefore, TLAAs are an essential part of the LTO evaluation. Examples of typical TLAAs in nuclear power plants include the following: RPV embrittlement, metal fatigue, thermal ageing and equipment qualification that is specific to E I&C equipment.

TLAA is performed on certain plant–specific safety equipment whose safety assurance is based on explicitly assumed environmental conditions and a resulting plant life. Two areas of plant technical assessment are required to support the application for changes in the CLB. The first area of technical review is the integrated plant assessment (IPA). The IPA is designed to describe and justify methods used to identify SSCs subject to an ageing management review (AMR). The second area of technical review required is the identification and evaluation of plant–specific TLAAs and exemptions.

For the TLAA of long lifetime equipment, the ageing effect of environmental stressors (temperature, radiation, humidity, etc.) on the validity of the equipment qualification is studied. If this study demonstrates that the qualified lifetime of the safety equipment cannot be extended by accepted TLAA techniques, such equipment is re–qualified or replaced at the expiry of its present qualification.

Generally, TLAAs are defined as calculations and analyses (including EQ) that meet the following criteria:

- involve systems, structures, and components within the scope of licence renewal or PSR;
- consider the effects of ageing;
- involve time–limited assumptions defined by the current operating term (for example, 40 years);
- are determined to be relevant by the applicant in making a safety determination;
- involve conclusions, or provide the basis for conclusions, related to the capability of the system, structure, and component to perform its intended function(s);
- are contained or incorporated by reference in the current licensing basis.

Calculations that meet the preceding criteria are identified by searching the current licensing basis, which includes the updated final safety analysis report, design–basis documents, previous licence renewal applications, technical specifications, as well as other relevant standards.

III.6.2. Common elements and differences

TLAAs have been developed and implemented at US NPPs as a part of licence renewal requirements. The LTO applicant must evaluate calculations for each specific plant against the six criteria specified to identify the TLAAs.

The use of TLAA in Europe differs from country to country; analyses similar to TLAAs have been implemented in some European countries (Hungary, for example) as part of their licence renewal process. Other countries have not adopted TLAA processes.

III.6.3. Future challenges

Working Group 3 members identified the following challenge:

Development of minimum criteria for the acceptance of TLAA.

III.6.4. Recommendations

Working Group 3 recommends that Member States that adopt LTO should implement TLAA as a good example of an analytical process to be followed by LTO applicants in order to demonstrate qualified life of E I&C equipment for LTO. TLAA should be appropriately considered in an updated FSAR.

III.7. RELATED NATIONAL DOCUMENTS

Czech Republic

- Law No. 50/1976 Coll., Building Act
- Law No. 18/1997 Coll., about the peaceful exploitation of nuclear energy and ionizing radiation
- SÚJB Decree no. 214/97 Coll. about the quality assurance in activities related with the exploitation of nuclear energy, and activities leading to irradiation, and about determination of criteria for classification and division of selected equipment into safety classes
- SÚJB Decree no. 195/1999 Coll. about requirements for nuclear facilities for assurance of nuclear safety, radiation protection, and emergency preparedness
- Safety of nuclear facilities – Guides and recommendations for the qualification of equipment important for the safety of nuclear power plants of the VVER 440/213 type, SUJB, Praha, 12/1998
- Equipment qualification in operational nuclear power plants: Upgrading, preserving and reviewing, IAEA Safety Report Series No.3, 1998
- ČSN IEC 60780: 2001 (35 6609) Nuclear power plants – Electrical equipment of a safety system – Capability verification
- ČSN IEC 980:1993 (IEC 60980:1989) recommended procedures for seismic verification of electric equipment for nuclear power plants safety systems
- IEEE Std –323–1983 Standard for qualifying class 1 E equipment for nuclear power generating stations
- IEEE Std 344–1987 IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations
- ASME QME–1–1994 Qualification of Active Mechanical Equipment Used in Nuclear Power Plants
- PP066 “ECC complex assessment”
- PP038 “Project base”
- ME042 “Assessment of the ECC impact on the project”
- Directive SM 021 “Projects administration”
- Procedure 041 “Equipment qualification”
- Methodology ME 060 “Specification of qualification requirements for ordering new equipment”
- Methodology ME 061 “Maintenance of equipment qualification”
- Methodology ME 083 “Selection of equipment for qualification”
- Methodology ME 084 “Creation of qualification documentation”
- PP 053 “Lifetime Management”

Hungary

- "Summary of the question of LTO of Paks NPP", Institute for Electric Power Research (VEIKI Rt.) – Research Institute for Atomic Energy (AEKI), 1998. October.
- "Aging management of NPP equipment – Cables", VEIKI Rt., 1998. November.

- "Feasibility study on LTO of Paks NPP", VEIKI Rt., 2000. October.
- "Summary of procedures that are necessary for licensing LTO of Paks NPP, based on the evaluation of the practice used by USNRC. Part 1. Working Plan", VEIKI Rt., 2001. April.
- "Summary of procedures that are necessary for licensing LTO of Paks NPP, based on the evaluation of the practice used by USNRC. Part 2. Guide on methodology", VEIKI Rt., 2001. June.
- "Guideline plans for LTO of Paks NPP", VEIKI Rt., 2001. October.
- "Project for LTO of Paks NPP. Part 3/1. Summary of project work", VEIKI Rt., 2002. July.
- "Project for LTO of Paks NPP. Appendix for Part 3/1. Description of main tasks", VEIKI Rt., 2002. July.
- "Project for LTO of Paks NPP. Part 3/3. Methodology of action necessary for environmental qualification of E,I&C", VEIKI Rt., 2003. April.
- Updated FSAR of Paks NPP.
- Other internal documents of Paks NPP

Russian Federation

- Recommendations on contents of the report on in–depth safety assessment of NPP power units with reactors of WWER and RBMK type in operation (RB G –12–42–97).
- Temporary provision for annual reports on operational safety current status evaluation for NPP power units with WWER–type reactors.
- Provision for issuance Gosatomnadzor’s annual permissions on first generation NPP units operation (RD–04–25–97).
- Standard provision for life management of NPP power unit elements (RD EO 0096–98).
- Standard programme for comprehensive examination of a NPP power unit aimed at operational lifetime extension.
- General requirements to lifetime extension of a NPP power unit (NP–017–2000).
- Reliability in the engineering. Basic concepts, terms and definition. GOST 27.002–89.
- Reliability of nuclear plants and their equipment. GOST 26291–84.
- Provision for annual reports on assessment of NPP unit operational safety performance” (RD EO–0143–99).
- Gosatomnadzor regulation № 6 of 17.09.97.
- Requirements to justification of option of assigned operational lifetime extension for atomic energy utilization facilities (NP–024–2000).
- Requirements to control systems important for NPP safety (NP–026–01).
- Standard engineering requirements to methods of evaluation of technical conditions and residual life of NPP power unit elements (RD EO 0141–99).
- Methodical guidance on evaluation of technical conditions and residual life for cable service of protection control and instrumentation systems at nuclear power plants (RD EO–0146–99).
- Scope and standards of electric equipment testing (RD 34.35–51.300–97).
- Provision for life management of power unit elements (RD EO 0281–01).

- Requirements to composition of document package and contents of the documents justifying safety of a NPP unit during additional operational period (RD 04–31–2001).
- Standard procedure for NPP industrial buildings and civil structures maintenance (RD 30–0007–93).
- Methods of evaluation of technical conditions and residual life of valves of engineering systems of NPP power unit (RD EO–0190–00).
- General provisions for organization of Rosenergoatom’s industrial information system on operational experience of nuclear plants (RD EO 0152–99).
- Methods of evaluation of technical conditions and residual life for the ABP–1500 uninterrupted power supply unit (RD EO–0438–02).
- Methodical guidance on evaluation of technical conditions and residual life of 6–kV induction electromotors (RD EO– 0342–01).
- Methodical guidance on evaluation of technical conditions and residual life of 0.4–kV induction electromotors (RD EO– 0343–01).
- Methodical guidance on evaluation of technical conditions and extension of service life of power transformers (RD EO–0410–02).
- Provisions for evaluation of technical conditions and ageing management of NPP cables (RD EO–0322–02).
- Methodical guidance on evaluation of technical conditions and extension of service life for NPP relay devices (RD EO–0321–02).
- Management of life cycle and ageing at nuclear power plants: improved I&C maintenance (IAEA–TECDOC–1402).

Slovak Republic

- No 541 Coll. “Act on Peaceful use of nuclear energy (”Atomic Act”) and on amendment and alterations of several acts”
- Regulation No. 49/2006 Coll. on periodic assessment of nuclear safety.
- Regulation No. 50/2006 Coll. on details of the requirements for nuclear safety of nuclear installations during sitting, design, construction, commissioning, operation, decommissioning and closure of repositories as well as on criteria for the categorization of classified equipment into safety classes.
- Regulation No. 56/2006 Coll. on the requirements on documentation of quality systems of the authorization holders as well as details on quality requirements for nuclear facilities, details on quality requirements of classified equipment and on the scope of their approval.
- Regulation No. 58/2006 Coll. on details of the scope, content and manner of maintaining of documentation of nuclear facilities needed for the individual decisions.
- BNS I.9.2/2001, Ageing management of nuclear power plants, Requirements“
- VTP project no. 1500, “Evaluation of selected systems of NPP”
- VTP project no. 1300, “Ageing management and lifetime optimization of NPPs with VVER–440 units”
- Power plant guide of OP–11–005, „Procedure for the expert inspection and test of electrical equipment“.
- SE/MNA 029.03.004 – (NPP guide under preparation)
- STN 35 1090.

- STN 35 1086.
- STN 35 0010.
- Project PHARE 2.06/95
- Study of PSA for the unit no.1 of Mochovce NPP for nominal power level (1997 – 2000)
- PSA study of the 1st level for NPP Mochovce unit 1 for the operation at low power levels and during the shutdown condition (2001 – 2002)
- Implementation of Risk–Monitor at the unit no. 1 of Mochovce NPP (2003)
- Living PSA (2004 – 2006)
- Low power and shutdown PSA for WWER440/V213
- Optimization of the limiting conditions of operation for the unit 1 of the J. Bohunice V1 NPP and unit 3 of the J. Bohunice V2 NPP
- IAEA–EBP–WWER–03 „Safety issues and their ranking for WWER–440 model 213 nuclear power plants“.
- Programmes of ageing management of selected electrical and I&C equipment – methodologies, V01–0430VS.2004.1
- Final report of qualification of electrical equipment and components of JE V–2 Bohunice, KABO/DOC/055MA/044
- Final report of qualification of I&C equipment of JE V–2 Bohunice, KABO/DOC/043LU/045

Sweden

- SKIFS 2004:1 Regulations concerning safety in certain nuclear installations
- SKIFS 2000:2 Regulations concerning mechanical components in certain nuclear installations
- SKIFS 2004:2 Regulations concerning the design and construction of nuclear power plants
- TBE–package included Technical Requirements for Electrical Equipment

Ukraine

- The law of Ukraine about use of nuclear energy and radiation safety 35/95–WR
- The resolution of CM about approval of the Complex working programme on prolongation of operational term (LTO) of working NPP power units 263–r from 29.04.04
- The typical programme of NPP power unit elements aging management PM–D. 0.08.222 – 04
- Regulation about organizational structure on NPP power units operational term management PL–S.0.03.044–01
- The general provisions of safety maintenance at removal of NPP and RR from operation NP 306.20.2/1.004–98
- The general provisions of NPP safety maintenance NP 306.1.02/1.034–00
- General Requirements on Extension of NPP Unit Lifetime Beyond Designed Period Based on Periodic Safety Review, NP 306.2.099–2004

- Requirements on Modifications of Nuclear Installations and Procedure of Their Safety Assessment, NP 306.2.106–2005
- Nuclear and radiation safety requirements to information and managing systems, important for safety of nuclear power plants NP 306.5.02/3.035–2000
- Organization of maintenance service and repair of systems and equipment of nuclear power plants KND 95.1.08.01.55
- The programme of work on qualification of Ukrainian NPP equipment 02.09.841.03.00
- Reliability of NPP and equipment. Prolongation of lifetime of means of control and management, included in systems, important for safety. General requirements to the order and contents of work ND 306.711–96
- The requirements to the order and contents of work for prolongation of operational term of information and managing systems, important for NPP safety. NP 306.5.02/2.068–2003
- Regulation about the order of prolongation of service life/resource of SIS equipment. PL–D.0.08.126–04
- Management of production delivery. An evaluation of the suppliers STP 0.06.026–2003
- Qualification of NPP equipment and technical devices NPP. The standard of enterprise. STP 0.08.050–2004
- Requirements to the system of quality. The basic regulations. STP 0.06.011–2001
- The programme of cable production aging management PM–Ò.0.08.121–04
- Reliability of technique. Methods of an estimation of reliability parameters on experimental data. DSTU 3004 C 95
- Technical operation of power stations and networks. Rules. GKD 34.20.507–2003
- Regulation about the order of collection, accounting, storage and exchange of data on reliability of NPP equipment and systems PL–D.0.08.168–03
- Technique of statistic reliability analysis of NPP SSC important for safety MT–T.0.0.8.118–03
- Maintenance service of relay protection devices, anti–accident automatics, electro automatic, remote control and signal system of power stations and substations GKD 34.35.604.96
- The decision on optimization of maintenance service system and fixture repair system and organization of work on their extractable parts lifetime prolongation TR–S.0.03.031.02
- Rules of arrangement and safe operation of NPP equipment and pipelines PNA E–G–7–008.89
- Control system of transferring machine – UKMP, PM–T.0.03.082–02
- Set of equipment AKNP–3, PM–T.0.08.092–04
- Programme of inspection of technical condition of typical NPP equipment. Prolongation of operational term. Measuring thermoradiation resistive cable not supporting burning PETIng, PM–T.0.03.094–02

USA

- NUREG–1800, Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants, U.S. Nuclear Regulatory Commission, July 2001.

- CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants"
- NUREG–1801, Generic Aging Lessons Learned (GALL) Report, U.S. Nuclear Regulatory Commission, July 2001.
- ANSI N18.7–1976, "Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants"
- ACI 201.1R–68, "Guide for Making a Condition Survey of Concrete in Service" (copyright 1968; reaffirmed 1979)
- SAND 96–0344, "Aging Management Guideline for Commercial Nuclear Power Plants – Electrical Cable and Terminations," Sandia National Laboratories for the U. S. Department of Energy, September 1996.
- EPRI TR–109619, "Guideline for the Management of Adverse Localized Equipment environments."
- EPRI TR–103834–P1–2, "Effects of Moisture on the Life of Power Plant Cables"
- Letter of 28 June 2002 from Ashok Thadani of NRC Office of Nuclear Regulatory Research to Samuel Collins, Director Office of Nuclear Reactor Regulation, Subject: Technical Assessment of Generic Safety Issue (GSI) 168, "Environmental Qualification of low–voltage instrumentation and control (I&C) cables".
- Point Beach Nuclear Plant and R. E. Ginna, Nuclear Power Plant Applications for Renewed Operating Licenses
- JARRELL, D. B., SISK, D. R., BOND, L. J. "Prognostics and condition–based maintenance: a new approach to precursive metrics", Nuclear Technology Journal, Volume 145 · Number 3 · (March 2004) · Pages 275–286.

EU

- EUR 19843, Safe Management of NPP ageing in European Union, May 2001.

III.8. COMPONENT SUMMARY TABLES FOR LONG TERM OPERATION

The following set of tables provides examples of E I&C components that may result when the scoping and screening process, Section 2.5, is applied to a nuclear power plant. It is intended that each of the E I&C components determined to be within the scope of LTO be evaluated and that the evaluation provide sufficient technical justification to demonstrate that plant operational processes and procedures are adequate to ensure that ageing effects are properly managed and that the E I&C component can perform its intended function during the period of LTO.

The column titled "Practice for Inspection or Testing" provides a brief description of the current practice for inspection and testing of the indicated "Component Grouping". In some cases, where no general description of current practice was available, this column indicates a recommended practice.

Table III.1. E I&C COMPONENTS THAT ENSURE INTEGRITY OF REACTOR COOLANT PRESSURE BOUNDARY
(Including degradation mechanisms and current practice)

Component Grouping	**Material**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Loops inside containment					
Loop instrumentation (PWR only) (pressure, delta p, flow, temperature)	Sensing element materials, copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity, vibrations, internal sensor element wear	Loss of accuracy, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Environmental Qualification Measure thermal and hydraulic parameters within required limits to maintain design basis	Calibration, repair by replacement
Control and signal cables, connectors, cable trays and junction boxes	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity	Loss of accuracy, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Measure electrical and physical parameters (BWR) Power and reactivity control (PWR)	Insulation resistance, ageing management programme, visual inspection, accelerated ageing testing
Reactor Coolant Pump					
Motor	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity	loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Measure electrical and physical parameters	Insulation resistance, partial discharge, ageing management programme
Power cables and connectors	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity, vibration	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Measure electrical and physical parameters (BWR) Power and reactivity control (PWR)	Insulation resistance, partial discharge, ageing management programme, visual inspection, accelerated ageing testing
Control and signal cables, connectors cable trays and junction boxes	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Measure electrical and physical parameters (BWR) Power and reactivity control (PWR)	Insulation resistance, ageing management programme, visual inspection, accelerated ageing testing

Component Grouping	**Material**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Steam generator					
SG instrumentation (pressure, delta p, level, temperature)	Sensing element materials, copper, insulation materials (Various organic polymers)	Radiation, temperature, Humidity, vibrations	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	NO S/G for BWR, Measure thermal and hydraulic parameters within required limits to maintain design basis	Calibration, repair by replacement
Pressurizer and pressurizer safety valves					
Pressurizer instrumentation (pressure, level, temperature)	Sensing element materials, copper, insulation materials (Various organic polymers)	Radiation, temperature, Humidity, vibrations	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	NO pressurizer for BWR, Measure thermal and hydraulic parameters within required limits to maintain design basis	Calibration, repair by replacement
Pressurizer solenoid valves (power operated relief valve)	SS, inconel, copper, insulation materials (Various organic polymers)	Radiation, temperature, Humidity, vibrations	General corrosion, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Protect reactor pressure boundary	ISI testing, visual inspection
Pressurizer heaters and spray control valve	SS, inconel, copper, insulation materials (Various organic polymers)	Radiation, temperature, Humidity, vibrations	General corrosion, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Water Chemistry Control	ISI Testing, visual inspection, operational data analysis
Control and signal cables, connectors and junction boxes	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	No pressurizer (BWR) Power and reactivity control (PWR)	Insulation resistance measurement, ageing management programme, visual inspection, accelerated ageing testing

Table III.2. E I&C COMPONENTS THAT SHUT DOWN THE REACTOR AND MAINTAIN IT IN A SAFE SHUTDOWN CONDITION (including emergency systems)

Component Group	**Material**	**Environment or Stressors**	**Degradation Mechanism/Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Vessels and Tanks					
Ex–core neutron monitoring system	Copper, insulation materials (Various organic polymers)	Radiation, temperature	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Measure neutron flux and limit the core power, EQ programme	Calibration, repair by replacement 10 years
Ex core Instrumentation (level, pressure, delta p, flow, temperature)	Boron detection medium, copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity possible boric acid exposure	Boron detection medium, copper, insulation materials (Various organic polymers)	Measure thermal and hydraulic parameters within required limits to maintain design basis EQ programme	Calibration, repair by replacement
In core neutron	Boron detection	Radiation,	Boron detection	BWR only	Repair by

Component Group	Material	Environment or Stressors	Degradation Mechanism/Ageing Effect	Safety Strategy	Practice for Inspection or Testing
monitoring system	medium, copper, insulation materials	temperature, pressure, vibrations, Chemical impact (PWR only)	medium, copper, insulation materials (Various organic polymers)	Other reactors – Information system only EQ programme	replacement (BWR 10 years) (VVER 4–7 years)
Control and signal cables, connectors and junction boxes	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity,	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Measure electrical and physical parameters	Insulation resistance, partial discharge, ageing management programme, visual inspection, accelerated ageing testing
Compensation and connection boxes	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Measure electrical and physical parameters	Insulation resistance, ageing management programme, visual inspection, accelerated ageing testing
Control rod drives including position indicators	Copper, insulation materials (Various organic polymers)	Temperature, two (water and steam) phase environment, vibration, possible exposure to boric acid	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Measure electrical and physical parameters	CRD insertion rate testing, motor current, torque, insulation resistance
CRD power cables and connectors (0.4kV)	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity,	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Measure electrical and physical parameters (BWR) Power and reactivity control (PWR)	Insulation resistance, partial discharge, ageing management programme, visual inspection, accelerated ageing testing, TDR
ECCS and Refuelling Water Storage Tank Instrumentation (pressure, delta p, flow, temperature)	Copper, insulation materials (Various organic polymers)	Temperature, humidity	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Maintain calibration, operational data analysis	Calibration, repair by replacement, measure cable insulation resistance
Hydro accumulators (PWR only) Instrumentation (pressure, delta p, flow, temperature)	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Maintain calibration EQ programme	Calibration, repair by replacement measure cable insulation resistance
Condensate Storage Tank (PWR, BWR) Instrumentation (pressure, delta p, flow, temperature)	Copper, insulation materials (Various organic polymers)	Temperature, humidity	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness	Maintain calibration EQ Programme	Calibration, repair by replacement measure cable insulation resistance
Piping, fittings and miscellaneous items					
Containment spray system instrumentation (pressure, delta p, flow, temperature)	Copper, insulation materials (Various organic polymers)	Temperature, humidity, water impurities, bio fouling	Loss of sensor, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Maintain calibration	Calibration, repair by replacement Periodic performance testing data analysis
Heat Exchangers					
Heat exchanger Instrumentation (pressure, delta p, flow, temperature)	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity	Loss of sensor, loss of insulation resistance, electrical failure, loss of	Maintain calibration	Calibration, repair by replacement

Component Group	**Material**	**Environment or Stressors**	**Degradation Mechanism/Age-ing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
			physical properties (fracture toughness)		
Pumps, Fans, Duct heaters					
Motor, heater element, solenoid	Copper, insulation materials (Various organic polymers)	Temperature, humidity, heating cycles, overload, vibration	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Environmental control	ISI programme, PM Programme
Power cable	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity,	Loss of sensor, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Measure electrical and physical parameters	Insulation resistance, partial discharge, ageing management programme, visual inspection, accelerated ageing testing, TDR
Instrumentation and transmitter cable	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Measure electrical and physical parameters	Insulation resistance, ageing management programme, visual inspection, accelerated ageing testing
Connectors and connection boxes	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity	loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness), corrosion	Measure electrical and physical parameters	Insulation resistance, ageing management programme, visual inspection, accelerated ageing testing
Sensors	Various sensor materials, insulation materials (Various organic polymers),	Radiation, temperature, humidity	Corrosion, electrical failure, loss of physical properties	Measure thermal and hydraulic parameters within required limits to maintain design basis	Calibration, repair by replacement
Switches (motor control centres)	Various sensor materials, insulation materials (Various organic polymers)	Radiation, temperature, humidity, dirt, other foreign substances	Corrosion, dirt build–up causes sticking, set point drift	Measure thermal and hydraulic parameters within required limits to maintain design basis	Calibration, repair by replacement
Valves					
Motor, Solenoid	Copper, insulation materials (Various organic polymers)	Temperature, humidity, heating cycles, overload, vibration	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Environmental control	ISI programme, PM Programme
Power cable	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity,	Loss of sensor, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Measure electrical and physical parameters	Insulation resistance, partial discharge, ageing management programme, visual inspection, accelerated ageing testing, TDR
Instrumentation and transmitter cable	Copper, insulation materials (Various organic polymers)	Radiation, temperature, humidity	Loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Measure electrical and physical parameters	Insulation resistance, ageing management programme, visual inspection, accelerated ageing testing
Connectors and connection boxes	Copper, insulation materials (Various	Radiation, temperature,	Loss of insulation resistance, electrical	Measure electrical and physical	Insulation resistance, ageing

Component Group	Material	Environment or Stressors	Degradation Mechanism/Ageing Effect	Safety Strategy	Practice for Inspection or Testing
	organic polymers)	humidity	failure, loss of physical properties (fracture toughness)	parameters	management programme, visual inspection, accelerated ageing testing
Sensors	Various sensor materials, insulation materials (Various organic polymers),	Radiation, temperature, humidity	Corrosion, electrical failure, loss of physical properties	Measure thermal and hydraulic parameters within required limits to maintain design basis	Calibration, repair by replacement
Switches (motor control centres)	Copper, insulation materials Arc shoots	Radiation, temperature, humidity	Corrosion, dirt build–up causes sticking, set point drift, arc scoring	Measure closing/ opening time, visual inspection	Calibration, repair by replacement
Bus bars					
Bus bar	Copper	Moisture, temperature, excessive current		Prevent corrosion	Visual and IR inspection,
Outside Switchyards	Copper, ceramic	Moisture, temperature, Outside environmental conditions	Corrosion, dirt build–up causes sticking, set point drift, arc scoring	Isolate, maintain cleanliness	Periodic functional tests
Auxiliary transformer	Copper, ceramic	Moisture, temperature, Outside environmental conditions	Corrosion, dirt build–up causing overheating	Cleaning	Periodic functional tests, Oil breakdown testing
Diesel generator	Electro–mechanical components	Vibration, friction, high voltage transient, temperature, corrosion, chemical attack, operating environment	Corrosion, dirt build–up causes sticking, set point drift, arc scoring	Cleaning	Periodic functional tests, Preventive Maintenance
Breakers (indoor)	Copper, insulation materials Arc shoots	Temperature, electrical arc	Corrosion, dirt build–up causes sticking, set point drift, arc scoring	Measure closing/ opening time, visual inspection	Periodic functional tests, Calibration, repair by replacement
Essential uninterruptible power supply	Batteries, inverters	Temperature, humidity, electrical arc,	Contaminated electrolyte, poor maintenance, insufficient charge	Proper Maintenance, continuous monitoring	Periodic functional tests, visual inspections

Table III.3. E I&C COMPONENTS TO ENSURE OFFSITE RADIOACTIVE EXPOSURES ARE WITHIN NATIONAL LIMITS

Component Group	Material	Environment or Stressors	Degradation Mechanism/ Ageing Effect	Safety Strategy	Practice for Inspection or Testing
Piping, fittings and miscellaneous items					
Auxiliary and Radwaste Area Ventilation System Instrumentation (pressure, delta p, flow, temperature)	Copper, sensor materials, insulation materials (Various organic polymers)	Radiation, temperature, humidity	Loss of sensor, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Maintain calibration	Calibration, repair by replacement EQ Programme

Component Group	**Material**	**Environment or Stressors**	**Degradation Mechanism/ Ageing Effect**	**Safety Strategy**	**Practice for Inspection or Testing**
Spent Fuel Pool Instrumentation (level, temperature)	Copper, sensor materials, insulation materials (Various organic polymers)	Radiation, temperature, humidity	Loss of sensor, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Maintain calibration	Calibration, repair by replacement
Ducts					
Ducts, access doors and, airlocks Instrumentation (differential pressure, position switches, interlocks)	Copper, sensor materials, insulation materials (Various organic polymers)	Temperature, humidity, impact, vibration	Loss of sensor, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Maintain calibration	Calibration and testing, repair by replacement
Filters					
Spent Fuel Pool Instrumentation (pressure, differential pressure, flow, temperature)	Copper, sensor materials, insulation materials (Various organic polymers)	Temperature, humidity	Loss of sensor, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Maintain calibration	Calibration and testing, repair by replacement
Air Handler Heating/Cooling					
Already covered					
Heat Exchangers					
Already covered					
Pumps					
Already covered					
Valves					
Already covered					
Cable penetrations					
Power and instrumentation cable penetrations	Cable Penetration Materials	Radiation, temperature, humidity, pressure, flooding, movement	Reduced insulation resistance – loss of pressure boundary (physical integrity)	Measure electrical and physical parameters (Cable condition monitoring)	Leak tightness testing, Insulation resistance, ageing management programme, visual inspection, accelerated ageing testing
Cable Trays	Structural Steel – Ceramic Fibre	Radiation, temperature, humidity, pressure, flooding, movement	General corrosion – cracking due to movement	Maintain physical integrity	Visual inspections and vibration monitoring
Containment environmental monitoring					
Instrumentation (pressure, differential pressure, temperature, radiation)	Copper, sensor materials, insulation materials (Various organic polymers)	Radiation, temperature, humidity	Loss of sensor, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Maintain calibration	Calibration, repair by replacement
Combustible gas systems					
Oxygen and hydrogen monitoring	Copper, sensor materials, insulation materials (Various organic polymers)	Radiation, temperature, humidity	Loss of sensor, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Maintain calibration	Calibration, repair by replacement
Actuation system for hydrogen combustion	Copper, sensor materials, insulation materials (Various organic polymers)	Radiation, temperature, humidity	Loss of sensor, loss of insulation resistance, electrical failure, loss of physical properties (fracture toughness)	Maintain calibration	Calibration, repair by replacement

Appendix IV

STRUCTURES AND STRUCTURAL COMPONENTS

IV.1. INTRODUCTION

This report describes the result of WG 4 on Structures and Structural Components. The objectives of WG 4 were to:

- Develop tools to support the identification of safety criteria and practice for structures and structural components associated with the LTO;
- Identify operators approaches, process, practices associated with aging and aging management of structures and structural components;
- Establish guidance on approaches to LTO;
- Discuss future challenges;
- Provide recommendations.

The scope of WG 4 activities included the structures, systems and components (SSCs) that fall into the following three categories:

- All safety–related SSC that are important to the fundamental safety functions:
    - the control of the reactivity;
    - the removal of heat from the fuel; and
    - the confinement of radioactive materials and control of operational discharges, as well as limitation of accidental releases.
- All non–safety related systems, structures, and components whose failure could prevent satisfactory accomplishment of, or initiate challenges to, any of the safety functions defined above.
- Other areas dedicated to a specific functional purpose that may be essential to safe operation of the plant, such as:
    - fire protection;
    - environmental qualification;
    - pressurized thermal shock;
    - anticipated transients without scram;
    - severe accident management;
    - station blackout.

The activities of WG 4 were primarily focused on structures and structural components:

- that are needed through LTO;
- that are difficult or impossible to replace;
- whose integrity is essential to ensure safe LTO.

These structures and structural components included, but were not limited to:

- Containment/confinement/pressure boundary structures and including the spent fuel pool;
- Structures inside the pressure boundary (compartment box, reactor box, etc.) including anchorages, penetrations, hatches, etc.;
- Other safety classified buildings;
- Water intake structures including buried pipelines;

- Foundations;
- Other structures where significant degradation has been recorded.

In general, it was suggested that any conflicts of competences that should arise among different working groups would be solved through the application of special criteria. Therefore WG4 scope may include the following items:

- Items traditionally covered by design standards for civil structures;
- Items in the same scope of supply together with the civil structures (embedded part of the penetrations);
- Items which are part of the containment pressure boundary (doors, hatches) and which are not going to be operated on a regular basis (large equipment hatches);
- Structural items which are difficult to be replaced (large hatches);
- Structural items whose safety function is primarily to contain and support.

WG 4 coordinated its activity with WG 2 in relation to material aspects of ageing of steel containments and structural steel, support structures of mechanical components and the interfaces with the items identified above. WG 4 also coordinated its activity with both WG 2 and 3 in relation to procedures for environmental data acquisition.

IV.2. REQUIREMENTS

The safety requirements for structures and structural components are generally addressed in the national regulations of each Member State.

Most of the national regulations recently began requiring that ageing and ageing management be considered in the design and also during operation. The ageing is assessed and controlled by periodic safety reviews (PSRs).

The general safety regulations and requirements for long term operation (LTO) are described in Appendix I of this report and so only those requirements that are specific to structures and structural components are discussed here.

The national regulations define generic requirements for maintenance, in–service inspection and ageing management (M/ISI/AM). In some countries detailed requirements for ageing management are established at the regulatory guideline level. The IAEA documents on ageing and associated issues are widely used. In some countries they are the basis of ageing management (AM) implementation (e.g. the Czech Republic, where IAEA documents are used for development of procedures, methodologies and instructions at the utility level).

The generic requirements for the M/ISI/AM apply also to structures and structural components. Regulatory documents on M/ISI/AM requirements specific to structures and relevant to LTO exist in some countries. A list of relevant documents is given in Table IV.1., Section IV.8 of this Appendix.

In a few cases there are specific standards for nuclear power plant structures (e.g. Russian Federation, U.S.). In some countries generic industrial standards are used for monitoring and assessing ageing of civil structures (e.g. the Ukrainian reference document on “Rules of industrial building structures inspection, technical state assessment and certification”). Specific requirements and guidance documents were developed for some critical structures such as tendons, the reactor cavity and the spent fuel pool (e.g. the Ukrainian reference document on “Methodology for Tendon Force Prognosis in Containment Pre–Stress System of WWER 1000 NPPs”).

The utilities develop implementation programmes to respond to the requirements. In some cases the utility documents developed for M/ISI/AM directly address LTO. In the countries where the LTO decision is already made, the utilities develop LTO programmes, including specific programmes for structures and structural components.

In the U.S., a complete and consistent set of requirements has been documented in regulatory documents, implemented in the utility programmes and proven in the licence renewal process for a large number of plants. Most countries are developing a pyramid of requirements, starting with generic safety requirements for LTO of structures and ending with utility implementation documents. The completeness and depth of the regulations depend on the differences in countries' generic regulatory framework, and on the progress achieved in preparation and implementation of LTO programmes.

With respect to LTO, the members of Working Group 4 considered the country practices from the following points of view:

- whether the requirements exist for the definition of the scope of structures and structural components within the scope of LTO;
- whether the ageing management requirements for structures and structural components are established for LTO.

The structures within the scope of LTO have a significant safety role (safe storage of radioactive materials) after the shutdown of the reactor and before the completion of decommissioning. Although the time between removal of nuclear fuel from the reactor and the completion of decommissioning may be very long, this feature of structures is not mentioned in the regulation of LTO, and is considered outside the scope of LTO.

IV.3. SCOPING AND SCREENING

IV.3.1. Background

The scope of the structures and structural components[2] relevant to LTO is explicitly regulated only in some countries. It is recognised that the basis for defining the scope of LTO should be the safety and seismic classification of structures and structural components. High level regulatory documents on safety and seismic classification of structures, systems and components (SSCs) exist in the national regulations, and these are fully applicable to classification of structures and structural components. In some countries the safety and seismic classification of plant SSCs exist in the form of a document or database attached to the final safety analysis report (FSAR).

In the countries where the plant operational licences are permanent and PSR is the means of control of safe operation for the next PSR period, the scope of LTO is practically defined by the scope of PSR; that is, all safety classified SSCs are within scope. The plant life–time is limited by non–replaceable/non–repairable (in a reasonable manner), long–lived SSCs. This limits the scope of LTO.

In those countries where the operational licence that is limited in time has to be renewed, the scope of licence renewal is well defined. The scope to be considered for LTO in this system covers the safety SSCs and seismically classified SSCs, and, from the non–safety

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[2] From the generic plant structures, systems and components, the EBP SALTO Working Group 4 has considered only the structures and structural components. The abbreviation SSC is used in the text when the generic set is mentioned. The terms 'structures and structural components' is used here when the civil structural part of the plant is considered.

SSCs, those whose failure could prevent the performance of intended safety functions. From these the licence renewal addresses the lifetime–limiting, long–lived and passive SSCs.

It is obvious that most of the classified structures and structural components, that are a priori long–lived and passive, belong to the scope of LTO.

Flow charts of scoping and screening processes are shown in Section 2.5 of this report.

A formal or even regulatory required/approved list of LTO–related structures and structural components does not exist in all countries. The completeness of the definition of the scope of LTO depends on the regulatory framework the country and phase of the implementation of LTO project.

Typical lists of structures and structural components within the scope of LTO for different type of light water reactors are listed in Section IV.9 of this Appendix, Tables IV.3., IV.4., IV.5., IV.6. The lists are based on the countries' practices.

IV.3.2. Common elements and differences

All countries take essentially the same approach to safety. A common understanding of the scope of structures and structural components relevant to LTO was achieved during the work of the EBP SALTO Working Group 4 (WG4). Safety and seismically classified SSCs should be within scope, as should non–safety SSCs which may interact with safety–related SSCs and inhibit their intended safety functions.

In the Russian Federation, in addition to safety classification, the structures and structural components of WWER type NPPs are subdivided into three categories according to their impact on radiation and nuclear safety and on the functionality equipment and systems inside the structure. This is the third categorization parallel to the safety and seismic classification. Besides Russian Federation, this approach is followed in Bulgaria and the Ukraine.

Only Sweden uses a risk–informed approach for scoping (structures and structural components, locations and intervals). However, this approach should be developed to a larger extent for possible application in other Member States.

The scope of SSCs depends on the maturity of the LTO project, the level of detail and the regulatory framework in the particular country. The existing scope of structures and structural components relevant to LTO vary from country to country:

- interacting non–safety structures and structural components are not always included;
- sometimes non–safety considerations (economy, modernization, reparability) influence the scope;
- overlapping items (supports, buried pipelines) are not always consistently handled (e.g. in some countries structural supports are considered part of the scope of mechanical SSCs).

IV.3.3. Future challenges

The scope has to be defined properly and be all–inclusive to ensure the safety of LTO. In case of missing items or improperly managed SSCs, irreversible ageing processes may result in serious safety issues.

The interaction of non–safety related items with safety related items has to be considered. For structures and structural components, methodological support for identifying non–safety items within the scope of LTO may be needed.

Overlapping items (supports, buried pipelines) have to be properly handled. This is important for countries where the supports of mechanical SSCs are embedded in concrete.

IV.3.4. Recommendations

The typical scope of structures and structural components for each reactor type is presented in Tables IV.3., IV.4., IV.5., IV.6. of Section IV.9. We recommend that utilities use tables in developing their own scoping and screening processes. These recommendations help in the understanding of basic attributes of acceptable ageing management programme for LTO.

The scope covers the items mentioned in this Section in a conservative way during the preparation of LTO, taking into account the state–of–the–art techniques of repair, AM, etc. to avoid irreversible ageing processes. As techniques develop, it may be possible to relax scoping.

A coordinated research activity is needed to develop a risk–informed approach for scoping (structures and structural components, locations, and intervals) that could also be applicable in case of structural components[3].

IV.4. AGEING MANAGEMENT PROGRAMMES

IV.4.1. Background

It is well recognised that different countries take different approaches to the safety regulation of LTO, and that the requirements and practices vary significantly. However, once they are in place, they always include a review of the existing ageing management programmes (AMPs) as a key task of LTO.

This section addresses technical requirements, mainly in relation to ageing management programmes[4] (AMP) and the attributes that an acceptable AMP should have for civil structures in long term operation of NPPs.

It is further recognised that the AMP should have special characteristics from an LTO perspective: they must address the degradation mechanisms that limit the life of the structures. Other mechanisms may be addressed by standard maintenance activities.

The performance and safety margins of passive long–lived SSCs are assumed to be guaranteed by design. However operating experience has shown that unforeseen ageing phenomena may occur because of operating errors or shortcomings in design or construction. Therefore the implementation of AMP is definitely a condition for the operation within the limits of designed or licensed lifetime, as well as being a precondition for LTO.

Moreover, ageing management is intended to provide a cross–cutting connection among all maintenance and inspection activities, and to provide a unified understanding and treatment of the degradation phenomena. These later aspects are addressed in Section IV.5.

Most countries more or less take a systematic approach to the developments and implementation of AMPs, for LTO is a generic tendency. However, only a few countries have

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[3] See the analogy with, for example, the development of risk-informed ISI for piping.

[4] The terminology concerning ageing management and other plant programmes is varying. Most countries have a set of programmes which covers all the plant's ageing management needs, therefore they use the word in the plural. In IAEA terminology, AMP is used in the singular form, i.e. one integrated programme covers the plant's needs as a whole. We follow the terminology used by the majority of countries in WG4.

a set of AMPs covering all relevant ageing processes for all structures and structural components within the scope of LTO. An example of a consistent system of ageing management programmes for PWR and BWR type plants is given in Section IV.10, Table IV.7., as well as a description of some AM programmes.

In most countries, ongoing AMPs focused on the mechanisms that resulted in early degradation or were identified as important from operating feedback of experience. Some important AMPs (even if they were not called AMPs) have been in place from very beginning of plant operation, for example, AMPs for loss of pre–stress and rupture of tendons in a pre–stressed containment system and for the processes that increase the leak–rate for WWER–440 containments.

The formal establishment of the AMP depends on the regulatory framework of the given country, and the maturity of LTO project. The interface between AMPs and other plant processes are often confusing and need clear understanding.

It was recognised that the majority of the AM programmes required either already exist as plant programmes or are programmes that need to be enhanced to address attributes of an acceptable ageing management programme.

Only a few countries have formal requirements to review the adequacy of AMPs for LTO. The PSR includes the review of AMPs, but the PSR requirements generally do not provide specific attributes for the review. However, the review requirements and the review process for existing programmes are well developed in the license renewal framework.

On the basis of safety considerations and experience, WG4 considers the core tasks of LTO as follows:

– Systematic identification of the ageing effects on structures and components;
– Review of the relevant existing plant programmes;
– Evaluation of existing programmes against the attributes considered necessary for an acceptable ageing management programme;
– Improvement of the existing programme or development of new ageing management programmes based on the attributes, if necessary.

There are interactions between plant processes (e.g. operation, maintenance, safety upgrading measures) and ageing management. In some countries, the AMP is an integral part of other plant processes. There are cases where the generic programme of ensuring the required technical status of the plant includes or covers several attributes of AM programmes, although the term AMP is not even mentioned. In some countries, ageing management is included in other plant processes as a development of the plant or licence renewal programmes.

It is very important that the definition of ageing management and its attributes be fully understood. The formulation of the attributes and establishment of the procedures of the review of existing AM programmes are of common interest to all countries.

A risk–informed approach for scoping (definition of structures & structural components within the scope of LTO, identification of locations and in–service intervals) is being applied only in a single case. However, this approach should be developed to a larger extent for possible application to other Member States.

The AM practices of countries reflect the features of the plant design and also specific conditions related to the site (for example the issue of building settlement at soft soil sites, or the issue of aggressive chemical conditions in the soil).

The ageing mechanisms/effects and the mitigation measures are considered as the most important aspects of the AM and are discussed below in detail.

4.1.1. Applicable ageing effects

The study of ageing effects/degradation mechanisms and the identification of mechanisms relevant to LTO and of life–limiting mechanisms are the core tasks of the development of AM programmes. Some important ageing mechanisms have been studied in detail, e.g. ageing processes resulting in loss of pre–stress and rupture of tendons for a pre–stressed containment system, or ageing processes affecting the leak–rate in case of WWER–440 confinements. In some cases, site related effects such as soft soil conditions or the chemical composition of soil causing site specific ageing effects have been studied.

A systematic approach to the identification of ageing mechanisms relevant to LTO is important. The ageing mechanisms are identified for the different materials, environments, and the possible consequences are also defined. However, the formal establishment of the LTO relevant mechanisms for each structure depends on the experience of the given country and the maturity of LTO project. The identification of relevant ageing mechanisms for structures and structural components also includes the definition of parameters to be monitored, evaluation and trending of ageing effects, and corrective actions.

The consistent and all inclusive list of degradation mechanisms shall be sorted by structural material: concrete, bar reinforcement, steel lines, containment pre–stressing systems, metal structures, and protective coatings. Specific design features, material selection, the chemical regime, and site specific effects must be taken into consideration. For example, chloride penetration is highlighted as a degrading mechanism that has a great impact on the lifetime of marine structures such as cooling water tunnels and intake structures.

The importance of the development of acceptance criteria for the degradation effects is recognized, e.g. limiting values for the crack width and length in reinforced concrete structures. The procedures for evaluating the technical conditions of structures and the trending the ageing process needs great attention. According to the opinion of other countries, further effort is needed in the development of methodologies and establishment of criteria for acceptable level of degradation. These criteria and methodologies were studied and developed in some counties. The transfer of experience is of great importance for other countries.

The possible reference–degrading mechanisms are listed in Table IV.8. The table shows for each pair of material and environment (e.g. reinforced concrete structure) the reference degradation mechanism and its effect. Furthermore, there is a link in the table indicating for the particular structure and structural components their sensitive location, monitoring methodology, frequency and criterion to be applied.

4.1.2. Ageing mitigation measures

Development of the mitigation measures of relevant ageing mechanisms are a decisive and important part of the AM programmes. The focus of the different countries is quite varying. Only a few countries have a systematic and full–scope set of ageing mitigation measures addressing all relevant ageing mechanisms, and all structures and structural components which are within the scope of LTO.

The development of particular ageing mitigation measures is mainly triggered by recognizing the ageing of different structures and structural components. The practice in some countries shows that there are well developed mitigation measures for the most important ageing mechanisms and especially for specific items (e.g. insufficient containment leak–tightness due to liner ageing).

In some cases the ageing mitigation measures were connected with or were as a result of upgrading seismic safety or of other safety upgrading measures or reconstructions (e.g. improving the fire resistance).

Most of the ageing mitigation measures are integrated as part of plant processes such as operation, maintenance, chemical programmes, etc. Quite often the ageing mitigation measures are not distinguished from other measures and plant programmes. In some countries well established requirements and processes exist for the review and assessment of the efficiency of ageing mitigating measures.

There are cases where the monitoring, evaluation and trending of ageing processes are not integrated together with the corresponding mitigation measures into one coherent programme. The mitigating measures are stand alone programmes or they are part of another programme, e.g. the maintenance programme. Some effective mitigating and corrective measures and techniques could be and are transferred or shared between the operators of similar types of plant.

Table IV.7. Section IV.10 provides the safety strategy to be applied in case of mitigation of degradation identified for each material and environment pair and for each structure and structural component. Section IV.10. also shows a typical list of AMPs relevant to LTO for PWR/BWR power plants.

IV.4.2. Common elements and differences

Table IV.7. reflects the consensus based understanding of the ageing mechanisms, monitoring and preventive/mitigating measures. It does not mean that the country practices are on the same level of development. On the contrary, the depth of understanding the particular features of the given plant or type of plant depend very much on the maturity of LTO project in that country. Most sensitive and safety relevant ageing issues are addressed in the plant practices even if these are not named as ageing management (e.g. monitoring and improving the leak–tightness of the containments).

The practice shows the wide use of existing maintenance, surveillance, testing, and trending (M/S/T/T) programmes for the ageing management of ageing processes. However the systematic approach to the review of ongoing programmes and demonstration of their acceptability for LTO is established only in some countries. It was recognised that in many cases the monitoring, evaluation and trending of ageing processes are not integrated together with the corresponding mitigation measures and other plant processes into one coherent programme. An example of integrated approach is shown in Section IV.10., Figure IV.1.

In some countries the formal licence renewal process defines the process and procedures for the review of existing programmes and development of new AMPs.

While reviewing the country practices, the importance of the control of ageing at non–accessible places and of the definition of acceptance criteria and development of reliable trending methodology were recognized. Reliable trending and the definition of adequate criteria is an issue for many countries. The difficulty of ageing monitoring and assessment for the non–accessible places is quite a generic issue (some areas of liners, embedded structures, reactor supports). Because the experience of each particular country in these fields is quite limited, the need to exchange international experience was emphasized.

Modernization, safety upgrading measures and reconstructions may create a positive impact on the ageing, but should not replace the conscious ageing management of structures and structural components. The differences of the design features, material selection and site conditions are well reflected in the country practices.

IV.4.3. Future challenges

On the basis of the practices of countries, the following issues were recognised as decisive in relation to ageing management:

- Completeness of the identification of ageing mechanisms and of sensitive locations for each structure and structural component;
- Criteria for assessment of acceptability of ageing;
- Adequacy of trending methods;
- Evaluation of ageing at hidden, non accessible places;
- Crediting of existing programmes, attributes of adequate AMPs;
- Review methodology of ongoing programmes.

Trending the structural behaviour in the long term may be a challenge, due to the lack of environmental data and of reliable models for the structural behaviour.

There is a need to exchange experience on how to integrate the particular efforts, i.e. monitoring, evaluation, trending and mitigation, into a coherent ageing management programme.

The basic aim of the AMP is to ensure the intended safety function. It means that the actual condition of structures and structural components has to be compared with licence conditions and requirements in order to provide proof of the capability of the building structure to fulfil its assigned safety functions. Lack of design basis information and acceptance criteria is a real issue in some countries. There are ongoing projects to reconstitute the design basis information for the structures within the scope of LTO.

IV.4.4. Recommendations

A systematic approach to the identification of ageing mechanisms should be proposed for all countries. As starting information for the development of the list of relevant ageing mechanisms, Table IV.8. might be used.

The AMP given for PWR and BWR type plants is in Section IV.10. The short description of the most important AM programmes might be used as examples while developing AMP for a particular plant.

The review of the ageing management programmes should be conducted in the frame of LTO programme, in order to check whether the control of ageing is adequate to support a decision on LTO and to ensure the safety for long term. The AMP attributes should be reviewed with reference to the following grid:

1. A defined programme scope;
2. Identification of preventive actions or parameters to be monitored or inspected;
3. Detection of ageing degradation/effects;
4. Monitoring and trending including frequency and methodologies;
5. Pre–established acceptance criteria;
6. Corrective actions if a component fails to meet the acceptance criteria;
7. Confirmation that required actions have been taken;
8. Administrative controls that document the programme’s implementation and the actions taken;
9. Operating experience feedback.

Essential elements of the review are the assessment of the AMP experience. The plants should demonstrate the following for the extended operational lifetime:

- The safety and ageing analysis remain valid and could be projected to the end of intended operational lifetime;
- The effects of ageing on the intended function(s) will be adequately managed;
- There is a procedure to deal with unexpected ageing mechanisms that can surface in later years.

In many cases, the plant's existing ageing management programmes can be credited as acceptable programmes for LTO. For the remaining cases, either the plant's existing programme can be augmented to satisfy the attributes listed above or new programmes should be initiated.

The results of the AMP trend analysis on the civil structures and components should be evaluated through expert judgement or a risk–informed approach, considering the entity of extension of operational life–time and the time required to implement corrective actions.

In case of non–compliant items, one of the following measures could be implemented:

- Replacing or restoring the component (e.g. tendons);
- Changing the operational conditions and/or improving ISI (e.g. pre–stressing monitoring);
- Developing additional analyses (eliminating initial conservatism with more refined methods);
- Performing re–qualification tests with improved methodologies.

Usually the required safety margins can be maintained through implementation of state–of–the–art methods, reviewing the existing design analysis for conservatism which was built–in in the design due to rough design methods, making conservative assumptions on environmental conditions, and considering operational conditions.

The responsible plant personnel (engineer and operators) need to understand the importance of AM for structures and structural components. Therefore, it is necessary that appropriate training be provided to all plant personnel.

Lack of design basis information and acceptance criteria is a real issue in some countries. There are ongoing projects to reconstitute the design basis information for the structures within the scope of LTO. These projects have to be supported by international cooperation and effective information exchange may contribute to the success of national efforts.

On the basis of review of country practices and recognition of future challenges the following CRP recommendations might be formulated:

1. Coordinated research activities are needed for the analysis and comparison of ageing mechanisms and zones, taking into account the specific features of structures and structural components (e.g. reinforced concrete cracking).
2. The development of Member State LTO programmes of master ageing management programmes for selected, important structures and structural components seems to be important and should be supported.
3. For the evaluation of aged status of reactor cavity structures (evaluations of in–service inspection (ISI) and monitoring data) adequate methods and criteria are needed. Research results can be found and, in some countries, experience exists on how to develop criteria for assessment of acceptable parameters related to ageing effects and

what forecast methodologies are applicable. It is possible to generalize a particular experience and provide criteria and methodologies applicable for the Member States.

4. In the case of some important structures and structural components within the scope of LTO, sensitive locations cannot be accessed for the monitoring (e.g. parts of liner, reactor support structures. Adequate methods are needed for assessment of ageing in these locations.

The recommendations formulated in this section are also valid for ISI and monitoring programmes, maintenance and TLAA (see Sections IV.5, 6).

IV.5. OPERATIONAL PROGRAMMES

IV.5.1. In-service inspection

IV.5.1.1. Background

All countries have established in–service inspection (ISI) systems for building structures and structural components based on national regulations and guidance, procedures supplied by vendors, or utility programmes developed on the basis of industrial experience. Operating history has shown that the role of the feedback of experiences is very important in the ISI practice.

Although practically all countries have established ISI systems for structures, there are also a few countries where systematic review has been performed to demonstrate that the ISI programmes could be credited for LTO. These ISI programmes must:

- Address the identified ageing processes.
- Be adequate for LTO in sense of attributes mentioned above (see section 3 of this report).
- Cover all structures and structural components within the scope of LTO.

In some countries the licence renewal and other related requirements define the scope of ISI for structures in the context of LTO. Usually the scope of ISI and monitoring and the depth of the assessment of the condition of the structures and structural components depend on the building classification and its importance to nuclear safety.

The review of adequacy of ISI and monitoring programmes is required and regulated in the countries following the licence renewal (LR) rule. In the countries where the PSR has a controlling role for LTO, review of the ISI practice is also required in the framework of the PSR, but the criteria (safety factor description) for the review are rather generic.

The ISI programmes are usually tailor–made and take into account the specific features of the plant design, material selection, and construction practices. Site specific ISI programmes have been developed for the soft soil site control of the building settlement based on regular geodetic measurements.

The basic ISI methods are visual checks, destructive and non–destructive tests and continuous monitoring by permanently built–in systems. Operational inspections of the condition of buildings are carried out based on the annual schedule of inspections or based on the actual requirements from operation. The ISI programmes for structures are very often walk–down inspections, visual checks of external manifestations of material degradation and identification of possible defects.

The data and information obtained from the inspections and condition monitoring programmes are subject to evaluation and assessment. In some countries state–of–the–art databases and evaluation software were developed to store the ISI and monitoring data and to support the evaluation of the data. Results are to be compared with licence conditions and requirements in order to provide proof of the capability of the building structure to fulfil its assigned safety functions. Lack of design basis information and acceptance criteria is a real issue in some countries. There are ongoing projects to reconstitute the design basis information for the structures within the scope of LTO.

The inspection may result in further measures (repair, organizational measures, etc.) The procedure of definition of mitigating and corrective measures on the basis of ISI and monitoring results is usually formalized and properly documented procedures.

An acceptable ISI programmes should include the method of monitoring for each degradation factor important for long term operation including information on frequency of performed measurements and/or inspections (for example, see Section IV.11., Table IV.9.).

Comprehensive ISI programmes were developed for specific structural items and early ageing effects (e.g. containment liner and tendons). Attention should be paid to the inspections of containment leak–tightness for all types of nuclear power plants. In some cases the methods and frequency of inspections follow the vendor procedures; in some cases the utilities have developed their own procedures or have adopted the best known practice.

It is recognized that the main focus of ISI activities is the containment. In certain reactors, the basic issue is to control the ageing of the liner and to maintain the leak–tightness. In case of pre–stressed containments, the control and maintenance of pre–stressing is necessary. The scope of tests of pre–stressing system depends on the type of structure. Use of permanent monitoring systems is described together with measurements during outages. A special programme is determined to check systems with free cables. Besides the overall leak–tightness testing, local leak–tightness testing, testing of doors and hatches and inspection of surfaces (painting, coating), the ISI programmes for containment also includes some assessment of the condition at non–accessible locations.

The country practices show that the ISI and monitoring programmes of the structures other than containment, and for structural components are either missing or are not comprehensive. Only a few countries have existing programmes where the scope of structures and structural components within the scope of LTO is covered by comprehensive ISI and monitoring programmes.

IV.5.1.2. Common elements and differences

All countries have well established ISI and monitoring programmes covering the most important safety relevant structures (mainly containment). There are specific, tailor–made ISI and monitoring programmes focusing on issue cases.

The practical approach of the countries to the development and implementation of ISI and monitoring programmes are rather different:

- Some countries have their own internal guidance/requirements or standards to develop plant specific ISI and monitoring procedures for inspections of buildings and structures.
- Some countries follow the vendor provided programmes.
- Some plants have developed their own programmes on the basis of experience (especially for issue cases).

With few exceptions, the ISI and monitoring practices usually do not cover the full scope of structures and structural components within the scope of LTO. In the past, the ISI and monitoring of structural components were paid less than required attention.

In the case of containment, both the ISI and monitoring practices of countries and the deviations found are caused by differences in design and local practice. In the case of other structures within the scope of LTO the practice of countries is quite different. A variety of methods and technical tools are applied, but the basic method of ISI is visual inspection. The majority of the pre–stressed containments are fitted with a permanent monitoring system for monitoring pre–stress conditions. In some countries the ISI and monitoring data are stored, processed and analysed by computerized systems.

Monitoring the condition of safety significant structures is an essential assumption of long term operation and the knowledge of the structure history is the basis for residual lifetime assessment. It is evident from the country information reports that in all cases the condition monitoring and the execution of tests and inspections are carried out with appropriate attention and that all work is performed by staff with good technical knowledge.

It is understood that a comprehensive monitoring and ISI programme should cover the structures and structural components within the scope of LTO (Section IV.9., Tables IV.3., IV.4. and IV.5.), and those degradation mechanisms and locations indicated in Appendix IV, Table IV.8. This table contains descriptions of the monitored degradation mechanism or the structure parameter, and the location and frequency of inspections. The link of degradation mechanisms for selected buildings and structures important to safety is provided in Section IV.11., Table IV.10. Table IV.10 is the generalization of country practices considered by type of plant.

IV.5.1.3. Future challenges

The majority of current ISI and monitoring procedures follow common practices for routine operation of the plant without accentuation of requirements and considerations specific to long term operation beyond the framework of the original proposed lifetime.

Concerning ISI and monitoring practice of the countries, the basic issues requiring attention and effort in the future are the following:

1. It is important to ensure the adequacy of ISI and monitoring programmes by reviewing existing programmes to determine whether they:
    - Address the identified ageing processes.
    - Are adequate for LTO in the sense of attributes mentioned above (see Section IV.4.4).
    - Cover all structures and structural components within the scope of LTO.
2. It is important for this systematic review that a methodology and appropriate criteria are developed.
3. Collecting suitable data on the environmental variables that proved to be stressors for the selected ageing mechanisms.
4. Development of ISI and monitoring techniques and methodologies especially for the control of the ageing process at the non–accessible locations, hidden defects (for example liners in hidden places, reinforcement in massive structures).
5. Development of criteria for the assessment of ISI and monitoring findings to allow proper judgement about the condition of structures and structural components.
6. Some of the structures will be of safety significance after shut–down of the reactor. Some ISI and monitoring activity has to be on place in this post–operation period of time.

IV.5.1.4. Recommendations

NPP operators should prepare the detailed procedures covering the scope selected for LTO. These should be based on their operational experience and existing monitoring, surveillance and inspection programmes. The programmes should be credited for LTO if they are adequate.

ISI programmes compatible with LTO should show that they address all the selected/expected ageing mechanisms and that they include a feedback procedure to adapt the ISI to the outcome of the operational experience.

ISI programme should cover the structures and structural components within the scope of LTO (Section IV.9., Tables IV.3.,IV.4. and IV.5.), and those degradation mechanisms and locations indicated in Section IV.10, Table IV.8. This table contains descriptions of the monitored degradation mechanism or the structure parameter and of point of check and frequency of checks. The way to link together the degradation mechanisms and the ISI and monitoring is indicated in the Table IV.10.

The recommendations formulated in Section IV.4.4 are generally valid for the ISI and monitoring programmes too. Specific recommendations related to ISI activities are as follows:

- Development of master (generic) ISI programmes and requirements may support the Member State LTO programmes.
- Organization of information exchange on instrumentation applicable for ISI of structures and structural components might be needed to support further development in this area.
- Research effort should be made for the definition of the ISI and monitoring activities for the control of safety in the post–operation period of plant life.

IV.5.2. Maintenance

IV.5.2.1. Background

All countries have generic requirements for maintenance which are valid for the maintenance of structures and structural components, too. There are only a few cases of regulations where specific requirements are formulated with respect to the maintenance of structures and structural components. Maintenance is a rather traditional activity of plants. The scope of maintenance programmes almost always covers the safety relevant structures. Usually a detailed system of procedures, rules and methodical guidance is available for the maintenance (for example, see Section IV.11., Table IV.11.). The maintenance programmes were developed either by the vendors or were developed on the basis of industrial experience. Utilities have established a system of maintenance programmes complying with the national regulations and corresponding to the needs and experience of the particular plant. Specific maintenance programmes and techniques have been developed in response to early ageing processes (e.g. repair of the liner, filling the gap between liner and containment wall in non–accessible places). Particular attention is paid to information about operational maintenance and about repairs performed on containment structures. Here the repairs of liners, seals and closing mechanisms of doors and hatches on the hermetically sealed area boundary, and repairs of liner paints were implemented. The basic technologies for maintenance and repairs have been developed in several countries. The technology of repairs is a subject of fast development and the assortment of materials for repair changes with time. Experience has shown that less attention than needed is paid to the maintenance of structural components.

A systematic approach to the organisation of the maintenance with respect to the LTO is a generic tendency, but the progress in this field in different countries depends on the maturity of the LTO project and on the regulatory framework.

In some countries, requirements exist on the evaluation of efficiency of the maintenance with respect to safety criteria (maintenance rule (MR)). In these countries, the utilities have to develop and implement a systematic approach to the planning, performing and evaluation of the maintenance in response to the MR. Example of the proof of efficiency of the repair work is the containment leak–test.

According to the country practices, the PSR requires a review of the maintenance, but the requirements for the review (safety factor) are rather generic.

Implementation of condition dependent maintenance is also a generic tendency or practice. The success in this field in different countries is in correlation with progress in AM and adequacy of ISI and monitoring programmes. An integration of particular efforts (ISI and monitoring, trending, maintenance, replacements) for ensuring LTO is of great importance.

It is recognised that the maintenance programmes have to mitigate impacts of degradation and ageing as defined in IV.10., Table IV.8. The utilities have to perform evaluation and assess their maintenance activities to ensure that all structure systems and components are capable of fulfilling required functions for an entire lifetime period.

IV.5.2.2. Common elements and differences

The approach of different countries to the maintenance is similar but the particular programmes vary due to design, construction and site differences, and due to the differences of techniques applied.

It is understood that a well established and effective maintenance programme is one of the basic tools for ensuring long term operation, even for such a priori long–lived items such as structures.

It is acknowledged that the precise determination of the primary reason of degradation is essential for the correct definition of maintenance measures and evaluation of effectiveness of maintenance.

The repair technology is subject to fast development and the material assortment available in the market changes very quickly. Broad variation of applied techniques is in place at different plants. Information exchange could help in dissemination of good practices.

Differences in country practices are caused a by broad variety of resolved concerns, applied technique and partly by variety in organizational structure.

IV.5.2.3. Future challenges

The adequacy of ongoing programmes is very important for safe long term operation. Therefore the maintenance practice has to cover the scope of structures and structural components within the scope of LTO and should correspond to the identified degradation processes. Therefore, the proper maintenance of structures other than containment and the maintenance of structural components are also important.

The difficulties in the monitoring and assessment of ageing processes and in limitations of the mitigating measures are relevant and important for the maintenance programmes, i.e. repair of places/defects with difficult accessibility, development of techniques, adaptation of industrial experience and adequate evaluation of the efficiency of maintenance based on safety criteria. Development of the maintenance should be in line with the requirements of LTO and should address the ageing processes, locations and structures included. The maintenance programmes for structures and structural components should remain part of routine activities.

The definition of performance goals at the structural component level may not be trivial and type/site specific; it may require additional testing and/or analysis. However, performance goals and failure analysis are essential to support an LTO programme.

IV.5.2.4. Recommendations

The maintenance should be an effective tool of mitigation of ageing processes. Therefore the implementation of condition/ageing dependent maintenance should be enforced. It means that the particular efforts (ISI and monitoring, trending, maintenance, replacements) for ensuring LTO should be integrated.

It is recognized that maintenance programmes have to mitigate impacts of degradation and ageing as defined in Section IV.10, Table IV.8. The utilities have to perform evaluation and assessment of their maintenance activities to ensure that all structures, systems and components are capable of fulfilling their required functions for the entire lifetime period.

The efficiency of maintenance in terms of safety should be evaluated in terms of safety and in terms of LTO needs. Experience is available only in few countries in this field. Precise criteria and methodology should be established for the review of adequacy of maintenance programmes and evaluation of their efficiency.

The maintenance programme for the structures in the scope of the LTO based on standard preventive maintenance is not suitable to support an LTO programme. The maintenance programme should be oriented to the monitoring of its effectiveness and therefore to be of the ‘condition base’ type. The attributes of such a programme should be made clear in terms of target performance goal, identification of the functional failure, feedback on the ISI and feedback on the operational limits and conditions.

International information exchange is very important for the dissemination of knowledge and experiences.

NPP operators should prepare detailed procedures based on their own operational experiences and existing maintenance practices. It should be investigated whether ongoing programmes are adequate.

Repair technology is subject to fast development and the material assortment available in the market also changes very quickly. Broad variation of applied techniques is in place at different plants. Information exchange could help in dissemination of good practices.

IV.6. TIME LIMITED AGEING ANALYSIS

IV.6.1. Background

This section describes two tasks connected with the evaluation of operational life of structures and structural components based on AMP results:

- Trend analysis;
- Time limited ageing analysis (TLAA). TLAAs are licensee calculations and analyses that satisfy the following:
  - Involve systems, structures, and components 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 the system, structure, and component to perform its intended functions; and
- Are contained or incorporated by reference in the current licensing basis (CLB).

The aim of the trend analysis is to predict changes of SSC status due to ageing, taking into account the environmental and operational conditions, as well as to determine whether the operational lifetime of an SSC may be longer or shorter than its design life. In case the results of trend analysis do not provide a guarantee for safe operation in the long term, a complete re–analysis of the ageing process is needed, with state–of–the–art methods and computer codes.

Plant specific analyses carried out at the design phase, which made explicit assumptions on the plant lifetime, needed to be re–evaluated for the SSCs in the scope of LTO. The outcome of the review could be:

- Projection of analysis for the time span of LTO;
- Existing analysis remains valid for the time span of LTO;
- Effects of ageing will be managed.

In some cases TLAAs are not available and can not be recovered from the designer. In these cases, depending on the safety relevance, a complete re–analysis of the ageing process might be needed and the time limits of safe operation should be set. This is performed either in the framework of the design basis reconstitution project or of the LTO project.

A very important condition of safe long term operation is knowledge about the time limits of safe operation due to ageing. The time–limited ageing analyses are part of the design information. In the case of structures and structural components, the number of TLAAs is relatively limited compared to those for mechanical equipment. Although the design lifetime of safety related structures is generally longer then the plant design life, the TLAAs have to be reviewed in the case of LTO and the time limitations, if any exist, should be resolved. Performed analyses include degradation processes due ageing beyond the limits of the originally designed lifetime. In this context the design basis information in relation to structures and structural components has to be available.

The review of TLAAs is a regulated part of the license renewal process. In the case of PSR, the resolution of the time limitation due to ageing should be valid at least for the next PSR period.

The knowledge of time limits set by TLAA is also recognised as very important from the point of view of condition monitoring. The assumptions made in TLAAs and the ISI and monitoring records provide a solid basis for the assessment of the time limits of safe operation.

All countries have recognised the importance of assessment of time limits of safe operation due to ageing, but the interpretation of the issue and the practices themselves vary among countries. Some of the countries perform state–of–the–art analyses using measured material properties to check the load bearing capacity and safety margins of essential structures. This type of analysis is also applied for trending changes in the condition of structures. This sophisticated approach could be verified in case of very important structures, such as pre–stressed containments, and if the TLAAs performed during the design need to be cross–checked. As an example, the prediction of the time dependent development for pre–stress losses is given for the Temelin nuclear power plant. The detailed description of the creep calculation model for concrete structures is provided as well as comparison with laboratory tests and with measurements on real structures. Using modern creep models, good agreement was reached between the behaviour of the real structure and the mathematical model that enables execution of high quality prediction for the time–span of the original design. In conclusion the deterministic and the probabilistic approaches are compared. In the case of cumulative acting of a high number of degradation factors, their random nature has a strong impact, and utilization of the reliability theory should provide deeper information about behaviour of the real structure in comparison with the deterministic approaches. It should be emphasized that this sophisticated approach can be applied only in the case of an important structure and in the case of a missing TLAA.

In the case where the structure lifetime needs to be extended, it is necessary to take into account changes in material parameters caused by ageing and then assess the residual lifetime and safety margin. As for the trends of further development, there are calculation models available for prediction of individual degradation factors. These phenomena are of random nature and in order to assess residual lifetime it is necessary to include also the cumulative impact of all the degradation factors acting on the structure.

Established requirements and methodologies for the review of TLAA and trending the ageing process exist only in some countries.

According to the experience of the countries, the methods for assessing the acceptance of ageing, i.e. strength, depth of carbonation, corrosion of concrete rebar, width of cracks, strength of anchoring elements, condition of hermetic liners and concrete water–tightness, need further development.

For the evaluation of trends and the time–limits due to ageing, deterministic and probabilistic approaches should be applied. Regarding the random nature of the input parameters it is recommended to apply reliability theory methods. The assessment of trends for further development and for residual lifetime evaluation must be performed as a combination of more approaches including experimental verification and numerical modelling.

IV.6.2. Common elements and differences

Although the importance of review of time limits of safe operation of structures due to ageing is widely recognised, relevant information and experience of TLAAs for structures and structural components exist in only few countries. There are ongoing studies and development works in the countries in this field, especially for the most important structures (pre–stressed containment). Sophisticated state–of–the–art methodologies are applied in these cases. The importance of design basis information is also recognized. In some countries design basis reconstitution projects are on–going. In case of a missing TLAA, re–analysis is performed.

Lack of appropriate methodologies for trending ageing processes and the need for research and experience exchange was underlined by the countries.

IV.6.3. Future challenges

The analysis of the time limits of safe operation due to multiple ageing processes in complex structures is a very difficult task. This knowledge is also required for the adequate trending and assessment of acceptability of ageing processes.

The level of the knowledge and experience is not sufficient to solve the problems, except of a small number of countries.

A set of open problems could be identified from the practices of the countries. These problems are related to:

- Uncertainties in the behaviour of massive concrete structures;

– Uncertainties of the effect of high temperatures on old structures (creep, shrinkage), of the effect of changes in the moisture field within the concrete structure in combination with the high temperature effect, of the effect of moisture on structures closed in liners, of the effect of higher temperature cyclic action on concrete surrounding hot penetrations.

These phenomena require relatively demanding experimental verification.

Another open problem is the assessment of structural resistance to extreme external and/or internal accident conditions and its cumulative impact on ageing.

The deterministic analyses of degraded structures have their own restrictions, thus the further development should be focused towards more sophisticated methods, including non–linear and probabilistic simulation methods for analyses of existing structures, which provide deeper information about the behaviour of real structures than the classical deterministic methods.

The impact of the degrading factors on the structure is of a random nature, as is the material data and loading. Further development of probabilistic assessment methods is needed for the lifetime assessment of safety important structures. For lifetime assessment, safety margin determination and trends evaluation, the probabilistic approach represents a very progressive and perspective method.

IV.6.4. Recommendations

The review of TLAAs and trending methodology is an important task of the LTO. It has to demonstrate the adequacy of the time limits of safe operation. Review of time–limits of operation due to ageing and resolution of the related problems is an obligatory task for LTO and it is included also in the PSR. Therefore the review methodology and resolution of issues should be developed on the basis of the experience of countries that have made progress in LTO.

In cases where TLAAs are not available and cannot be recovered from the designer, depending on the safety relevance, a complete re–analysis of the ageing process might be needed and the time limits of safe operation should be set. In difficult cases, when the margins are not large, it is reasonable to implement sophisticated state–of–the–art techniques, data on loads and cycles taken from operational history, experience based data on environmental conditions, etc. Coordinated research efforts are needed to develop requirements and adequate methodologies for the re–analysis of time limited ageing processes.

Assessment of the ultimate load–bearing capacity of the real structure damaged by the impact of degrading factors is a very demanding task. In addition, the prediction of trends of further progress for whole period of extended lifetime is equally difficult. International coordinated research efforts are needed for the resolution of the problems indicated in Section IV.6.3.

IV.7. RELATED NATIONAL DOCUMENTS

Bulgaria

- Investigations related to failure of pre–stressing tendons of Kozloduy NPP, Z. Bojadjiev, 1994
- Containment Pre–stressing System of Kozloduy NPP, A. Gerasimov, S. Ivanov, M. Milanov, Z. Madjarski, Berlin, GRS, 1998
- Containment and Civil Structures Ageing Monitoring of Kozloduy NPP, M. Milanov, Moscow, IAEA TM – TCP RER/4/027, 2005

Czech Republic

Basic legislative documents:

- SONS Regulation No. 214/97 Coll. On Quality Assurance during Activities Connected with Utilization of Nuclear Energy and Activities Leading to Irradiation and on Establishing of Criteria for Inclusion and Dividing of Selected Equipment into Safety Classes
- Czech Occupational Safety Office Regulation No. 76/89 Coll. Ensuring of Safety of Technical Equipment in Nuclear Power Engineering
- SONS Regulation 195/1999 on Requirements on Nuclear Installations for Assurance of Nuclear Safety
- Czech National Standard CSN 73 2030–94 Load Tests for Building Structures
- US standard ANSI/ANS–56.8 – 1994 Containment Leakage testing requirements
- Czech National Standard CSN 731201– 1986 Design of concrete structures

Utility instructions, procedures and methodologies:

- SM 025 – Diagnostics and equipment condition inspection
- PP 043 – Long–term operation assurance behind the frame of design lifetime.
- PP 053 – Ageing Management
- PP 064 – Technical part of the preparation for NPP decommissioning.
- PP 078 – Equipment safety assurance
- PP 058 – Maintenance time planning
- PP 050 – Maintenance evaluation
- PP 047 – Maintenance programme management
- ME 085 – Technical – economical review of the PLEX/LTO feasibility
- ME 086 – The basic data preparation for the PLEX/LTO assurance.
- Procedure TS 135 – Periodical Containment Structural integrity tests
- Procedure TS 136 – Periodical Containment leak rate tests

Other related documents:

- Lifetime evaluation of concrete structures, Czech Society of Civil Engineers, Prague 1999
- Life prediction and Ageing management of concrete structures, Proceedings of the 8th International Expertcentrum Conference, Expertcentrum Bratislava, 1999

- Workshop on the Instrumentation and Monitoring of Concrete Structures, OECD Nuclear Energy Agency, March 2000
- Finite Element Analysis of Ageing Reinforced and Prestressed Concrete Structures in Nuclear Plant, OECD NEA July 2002
- The Evaluation of Defects, Repair Criteria and Methods of Repair for Concrete Structures on Nuclear Power Plants, OECD NEA, September 2002
- Finite Element Analysis of Degraded Concrete Structures, OECD NEA, September 1999
- Joint WANO/OECD – NEA Workshop prestress loss in NPP containments, OECD, August 1997
- NUMARC – Design Basis Program Guidelines, NUMARC 90–12, October 1990
- Nuclear Energy Institute – Design Basis Program Guidelines, NEI 97–04, September 1997
- Pre–operational Safety Analysis Report – Dukovany NPP, 1995
- Pre–operational Safety Analysis Report – Temelin NPP – Unit 1,2, revision 2004

Hungary

Basic legislative documents:

- Act CXVI of 1996 on Atomic Energy
- Governmental Decree 89/2005. (V. 5.)
- Annex No. 1: Nuclear Safety Code Volume 1, Authority procedures applied to nuclear power plants
- Annex No. 2: Nuclear Safety Code Volume 2, Quality assurance code of nuclear power plants
- Annex No. 3: Nuclear Safety Code Volume 3, General requirements for the design of nuclear power plants
- Annex No. 4: Nuclear Safety Code Volume 4, Operational safety requirements of nuclear power plants

Guidelines to the Nuclear Safety Regulations issued by Hungarian Atomic Energy Authority:

- Guideline 1.19, Inspection of the efficiency of the maintenance program of the nuclear power plant
- Guideline 1.26, Regulatory Inspection of the Aging Management Program
- S1 The scope of aging management;
- Guideline 1.27, Regulatory control over equipment qualification and preservation of the qualified status
- Guideline 2.15, Quality Assurance in the Aging Management of Nuclear Power Plant Equipment
- Guideline 3.1, Safety classification of nuclear plant systems and equipment
- Guideline 3.13, Consideration of Aging during Nuclear Power Plant Design
- Guideline 3.15, Equipment qualification requirements during the design of nuclear power plants

- Guideline 4.6, Nuclear power plant maintenance program and maintenance efficiency monitoring
- Guideline 4.12, Management of ageing during operation of nuclear power plants
- Guideline 4.13, Equipment qualification requirement for operating nuclear power plants
- Draft Guidelines:
- Requirements related to the content of application for long term operation licence
- In–service inspection of civil engineering structures and structural components
- Ensuring the long–term operation during operation of nuclear power plants
- Building Authority inspection in nuclear power plants (under revision)

Utility licensing documents, procedures and methodologies:

- Updated FSAR of Paks NPP version 2004.
- In–service inspection plans and regular reports of the Paks NPP Ltd. (39 items)
- Detect and repair of defects on the confinement structure at Paks NPP. NEA/CSNI/R (2002) 7/VOL1

Other related documents:

- T. Katona, A. Jánosiné Bíró, S. Rátkai, Z. Ferenczi: Key Elements of the Ageing Management of the WWER–440/213 type Nuclear Power Plants, to be published at 18th International Conference on Structural Mechanics in Reactor Technology, Peking, August, 2005

Russian Federation

- PNAE G–01–001–85, Standard contents of safety analysis report for nuclear power plants
- PNAE G –1–028–91, Quality assurance programme requirements for nuclear power plants
- SP 53–102–2004, General design regulations for steel structures
- SNiP 2.01.02– 85, Fire protection regulations.
- SNiP 21–01–97, Fire safety of buildings and structures
- SNiP 2.01.07–85, Loads ad effects including section 10 “Deflections and displacements”.
- SNiP 2.02.05–85, Foundations of machines subjected to dynamic loads.
- NPB 114–2002, Fire protection of nuclear power plant. Standards of design.
- RTM 34 001–73, Rules of observations over settlements of buildings and structures at thermal power stations
- RD–EO–25–95, Standard programme of construction work inspection at radiation – dangerous sites
- RD–EO–0013–94, Basic regulations on NPP decommissioning.
- TP 1L–84, Standard manual on carrying out local tests of tightness of penetrations, isolating valves, process systems, hatches, doors and other sealing equipment at NPPs with VVER–1000

- TP 2L–84, Standard manual on carrying out local tests of tightness of penetrations, isolating valves, process systems, hatches, doors and other sealing equipment at NPPs with VVER–440
- 320XA.NV.PNE, NPPs with VVER–1000 RP V–320. System of hermetic fencing. Standard program and methodology of operational tests.
- Guide on observations over strains of bases and foundations of buildings ad structures (NII OSP by Gersevanov, 1975)
- Guide on assessment and determination of concrete strength in buildings ad structures (TSNIISK, NIIZHB, 1979)
- Guide on determining corrosion rate of cement stone, grout and concrete in aggressive fluids (NIIIZHB, 1975)
- Guide on conducting field observations of industrial buildings ad structures (TSNIIPROMZDANII, 1975)
- Recommendations on examination of steel structures of process buildings (TSNIIPSK, 1988).
- Recommendations on the assessment of reinforced concrete structures in aggressive environment (NIIZHB, 1984)

Slovak Republic

Basic legislative documents:

- Act No. 541 Coll. on Peaceful use of nuclear energy ("Atomic Act") and on amendment and alternations of several acts.
- Regulation No. 49/2006 Coll. on periodic assessment of nuclear safety.
- Regulation No. 50/2006 Coll. on details of the requirements for nuclear safety of nuclear installations during sitting, design, construction, commissioning, operation, decommissioning and closure of repositories as well as on criteria for the categorization of classified equipment into safety classes.
- Regulation No. 56/2006 Coll. on the requirements on documentation of quality systems of the authorization holders as well as details on quality requirements for nuclear facilities, details on quality requirements of classified equipment and on the scope of their approval.
- Regulation No. 58/2006 Coll. on details of the scope, content and manner of maintaining of documentation of nuclear facilities needed for the individual decisions.
- Regulation 66/1989 Coll (issued by SÚBP – Slovak Industrial Safety Authority) on safety of technical equipment in nuclear power industry (as amended)
- BNS I.9.2/2001 – Ageing management at NPPs – requirements

Utility instructions, procedures and methodologies:

- General method of repair hermetic liner and timetable of work at 1st and 2nd unit Bohunice NPP. VÚEZ, Ing. Csekey, 12/1990
- Sensitivity determination of local leakage rate tests in condition of NPP. VÚEZ, Ing. Surovčík, 6/1991
- Groundwork for safe report, Enhancement of containment leak tightness at V–1 Bohunice NPP. VÚEZ, Ing. Csekey, 6/1992

- Pre–operational Safe report of 1st and 2nd unit V–2 Bohunice NPP after 10 years of operating, VÚEZ, Ing. Prandorfy, 6/1994
- Leakage rate test of hermetic compartments with internal hermetic liner. VÚEZ, Ing. Michalko, 9/1994
- Structural analysis of hermetic compartments in over pressure 160 kPa of V–1 NPP, VÚEZ, Ing. Csekey, 12/1994
- Static analysis of technology elements in containment of V–2 Bohunice NPP during severe accident. VÚEZ, Ing. Tuhý, 12/1995
- Program of Enhancement of hermetic boundary leak tightness in 3rd and 4th unit of V–2 Bohunice NPP, VÚEZ, Ing. Csekey, 12/1995
- Program of leakage rate tests during additional tests of containment in Mochovce NPP. VÚEZ, Ing. Prandorfy, 8/1996
- Program of leakage rate tests of semi–accessible hermetic compartments and other hermetic compartments in Mochovce NPP. VÚEZ, Ing. Prandorfy, 10/1996
- Program of control integral leakage rate tests with locating of leaks of containment in Mochovce NPP, VÚEZ, Ing. Prandorfy, 11/1996
- Static analysis of leak and structural tightness of hermetic boundary during severe accident’s over pressure in containment of V–2 Bohunice NPP, VÚEZ, Ing. Tuhý, 11/1996
- Technological procedures of reprint leakage tests of removable joints, VÚEZ, Ing. Prandorfy, 2/1997
- Technological procedures of under pressure leakage tests of welds without control volume, VÚEZ, Ing. Prandorfy, 2/1997
- Technological procedures of over pressure leakage tests of weld joints with control volume, VÚEZ, Ing. Prandorfy, 2/1997
- Technological procedures of over pressure leakage rate tests of penetration, VÚEZ, Ing. Prandorfy, 2/1997
- Technological procedures of over pressure leakage rate tests of equipment with control space with flow measurement, VÚEZ, Ing. Prandorfy, 2/1997
- Qualification methodology of containment equipment in VVER 440 units with V213 reactor type at Bohunice and Mochovce NPPs. VÚEZ, Ing. Tuhý, 5/1997
- Program of pre–operation integral leakage rate and structural tests at Mochovce NPP, VÚEZ, Ing. Prandorfy, 11/1997
- Primary characterization of ageing reinforced concrete influence on safe operating VVER NPPs, VÚEZ, Ing. Hámornyíková, 12/1998
- Analysis of identification method of weak place in containment material NPPs VVER 440, VÚEZ, Ing. Hámornyíková, 12/1999
- Monitoring methodology of ageing reinforced concrete NPPs, VÚEZ, Ing. Prandorfy and collective, 3/2002
- Technological procedures of monitoring and removing unnecessary humidity in floor at +6,0m, VÚEZ, Ing. Prandorfy, 5/2002
- Technological procedures of repair rubber seal on hermetic doors of semi–accessible compartments, air–lock and air–traps in Mochovce NPP, VÚEZ, Ing. Novodomský, 2/2003

- Seek methodology of hide leak of hermetic liner in floor in direction „G“ between rooms A204 and A254, VÚEZ, Ing. Šurka, 5/2003
- Monitoring and controlling of ageing reinforced concrete at VVER 440 NPPs. VÚEZ, Ing. Hámornyíková, 11/2003
- Technological procedures of exchange gastight valves on hermetic doors at Mochovce NPP, VÚEZ, Ing. Novodomský, 11/2003
- Technological procedures of leak seek on hermetic cover frames with trace gas technique, VÚEZ, Ing. Hámornyík, 9/2004
- Technological procedures of monitoring pressure change under hermetic liner during under pressure and over pressure integral leakage rate test, VÚEZ, Mgr. Považan, 9/2004
- Technological procedures of monitoring hided hermetic liner in rooms A201/1,2; A204/1,2; A254/1,2 with trace gas technique, VÚEZ, Ing. Hámornyík, 9/2004
- Technological procedures of installation manhole and extensions for pressurization and temperature measurement during over pressure leakage rate test of hermetic cover in air–condition systems, VÚEZ, Mgr. Považan, 9/2004
- Evaluation of reasonable achievable level of leak tightness of VVER 440/V213 containments at Slovak republic, VÚEZ, Ing. Klinčok, 11/2004
- Technological procedures 7TP/1049 for containment
- Limits and requirements for safe operation of containment
- Executive project of building 800/1–01

Sweden

- Lag om tekniska egenskapskrav på byggnadsverk SFS 1994:847. (English translation: The Act on Technical Requirements for Construction Works.), The Swedish Government.
- Building Regulations BBR, BFS 1993:57, The Swedish Board of Housing.
- Design Regulations BKR, BFS 1993:58, The Swedish Board of Housing.
- Swedish Regulations for Steel Structures, BSK 99, The Swedish Board of Housing.
- The Swedish Nuclear Power Inspectorate’s Regulations Concerning Safety in Certain Nuclear Facilities, SKIFS 1998:1, The Swedish Nuclear Power
- Utomhusprovning av galvaniska anodsystem för katodiskt skydd av armerade betongkonstruktioner (eng. trans. Outdoors testing of galvanic anode system for cathodic protection of reinforced concrete structures), The Swedish Corrosion Institute report no. 1999:6
- Field investigation of easily installed anode systems for cathodic protection of railing posts and edge beams on the Öland bridge, The Swedish Corrosion Institute report 2002:3
- Technical Regulations for Surface Treatment, TBY. Ringhals, Barsebäck, Forsmarks Kraftgrupp och Oskarshamns Kraftgrupp.
- CONMOD–utvärdering av inneslutningen vid Barsebäck 1, Steg 1: Förberedande strukturanalys (eng. trans. CONMOD evalutating of the containment at Barsebäck 1, step 1: Preparing structural analyses) Scanscot Technology AB

Ukraine

- General provisions on the nuclear power plants safety assurance, NP 306.1.02/1.034–2000
- Norms of NPPs localisation safety systems concrete structures design, PNAE G–10–007–89
- Rules of organisation and operation of NPPs localisation safety systems, PNAE G–10–021–9
- Instruction of technical servicing for standardized units VVER–1000 NPP type B–320 containment pre–stressed system, Moscow, Orgenergostroy, 1989;
- Instruction of technical servicing for main series (non–standardized) units VVER–1000 NPP type 302, 338 and 187 containment pre–stressed system, Moscow, Orgenergostroy, 1989.
- Methodology for Tendon Force Prognosis in Containment Pre–Stress System of WWER–1000 NPPs, BND 306.7.02/3.006–98
- Typical contents of NPPs technical safety justification, PNAE G–1–001–85
- Regulations on issues of observation, certification, safe and reliable exploitation of industrial buildings and structures", Kyiv: Derzbud of Ukraine, 1999, that include 8 normative documents:
- Rules of industrial building structures inspection, technical state assessment and certification;
- Provisions on safe and reliable exploitation of industrial buildings and structures;Regulations on specialised organizations for inspection and certification performance of existing building structures aimed to their reliability and safety exploitation;
- Regulations on directing organisation for co–ordination activity, regulations development and on issues of inspection and certification of building structures aimed to their reliability and safety exploitation;
- Structure of the register of building and structures with risk of damage;
- List of specialised organizations for inspection and certification performance of existing building structures;
- List of organisations for design of strengthening measures of structures and foundations;
- Methodical recommendations on buildings and structures observation.
- Concrete and reinforced concrete structures, SNiP 2.03.01–84*,USSR Gosstroy, 1989.
- Concrete. Strength monitoring code, GOST 18105–86.
- Concrete. Method of the strength analysis based on specimens sampled from structures, GOST 28570–90
- Assessment of the technical condition of steel structures, production building and structures in operation, DBN 362–92, State Committee of Ukraine for Architecture, Construction and Historical Environment Protection, 1993.

United States of America

- NUREG/CR–4652, "Concrete Component Aging and its Significance Relative to Extension of Nuclear Power Plants," U.S. Nuclear Regulatory Commission, September 1986.

- NUREG/CR–6679, “Assessment of Age–Related Degradation of Structures and Passive Components for U.S. Nuclear Power Plants,” U.S. Nuclear Regulatory Commission, August 2000.
- ASME Section XI, “Rules for In-service Inspection of Nuclear Power Plant Components, Subsection IWE, Requirements for Class MC and Metallic Liners of Class CC Components of Light–Water Cooled Power Plants,” 1992 Edition with 1992 Addenda; 1995 Edition with 1996 Addenda, The ASME Boiler and Pressure Vessel Code, The American Society of Mechanical Engineers, New York, NY.
- ASME Section XI, “Rules for In-service Inspection of Nuclear Power Plant Components, Subsection IWL, Requirements for Class CC Concrete Components of Light–Water Cooled Power Plants,” 1992 Edition with 1992 Addenda; 1995 Edition with 1996 Addenda, The ASME Boiler and Pressure Vessel Code, The American Society of Mechanical Engineers, New York, NY.
- ASME Section XI, “Rules for In-service Inspection of Nuclear Power Plant Components, Subsection IWF, Requirements for Class 1, 2, 3, and MC Component Supports of Light–Water Cooled Power Plants,” 1989 Edition through the 1995 Edition with 1996 Addenda. The ASME Boiler and Pressure Vessel Code, The American Society of Mechanical Engineers, New York, NY.
- ACI Standard 349.3R–96, “Evaluation of Existing Nuclear Safety–Related Concrete Structures, American Concrete Institute.
- NRC Information Notice 99–10, Revision 1, “Degradation of Prestressing Tendon Systems in Prestressed Concrete Containment,” U.S. Nuclear Regulatory Commission, October 7, 1999.
- NRC Information Notice 95–10, Revision 6, “Industry Guideline for Implementing the Requirements of 10 CFR Part 54 – The License Renewal Rule,” U.S. Nuclear Regulatory Commission, June 15, 2005.
- ASTM D 5163–96, “Standard Guide for Establishing Procedures to Monitor the Performance of Safety Related Coatings in an Operating Nuclear Power Plant,” American Society for Testing and Materials.
- Nuclear Energy Institute, “Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants,” NUMARC 93–01, Rev. 2, April 1996.
- NUREG 1801, Vol. 2, Revision 2, “Generic Aging Lessons Learned (GALL) Report,” September 2005.

IV.8. EXAMPLE OF REQUIREMENTS FOR LONG TERM OPERATION OF SYSTEMS, STRUCTURES AND COMPONENTS

TABLE IV.1. Requirements relevant for long term operation of structures and structural components

No	Country	Requirements of ageing management and AMP
1	Bulgaria	Guideline for Regulatory Review of Ageing Management Programmes and their Implementation; Act on Safe Use of Nuclear Energy (ASUNE) –2002; National Regulation on power plants and networks technical operation; OPB–88 – "General Considerations Ensuring Safety of NPPs"; 50–SG–012 „Periodic Safety Review of Operational Power Plants";
2	Czech Republic	**Acts and Regulatory Requirements** Atomic Act No. 18/1997 Building Act No. 50/1976 Act No. 100/2001 on Evaluation of Environmental Impacts SONS Decree No. 214/1997 on Quality assurance in activities related to nuclear energy SONS Decree No.195/1999 on Requirements on Nuclear Installations for Assurance of Nuclear Safety SONS Decree No. 106/1998 on Providing Nuclear Safety and radiation protection of Nuclear Installations **Basic Industrial and Utility level standards, procedures and methodologies** CSN 73 00 38 Design and Assessment of existing building structures Procedure PP 043 –Long term operation assurance behind the frame of design lifetime Procedure PP 052 – MS & I management Procedure PP 053 – Ageing Management Methodology ME 085 – Technical and economical review of the PLEX/LTO feasibility Methodology ME 086 – The basic data preparation for the PLEX/LTO assurance
3.	Hungary	**Acts and Regulatory Requirements and Guidelines** Act CXVI of 1996 on Atomic Energy Governmental Decree 89/2005. (V. 5.) Annex No. 1: Nuclear Safety Code Volume 1, Authority procedures applied to nuclear power plants Annex No. 2: Nuclear Safety Code Volume 2, Quality assurance code of nuclear power plants Annex No. 3: Nuclear Safety Code Volume 3, General requirements for the design of nuclear power plants Annex No. 4: Nuclear Safety Code Volume 4, Operational safety requirements of nuclear power plants Guidelines to the Nuclear Safety Regulations issued by Hungarian Atomic Energy Authority: Guideline 1.19, Inspection of the efficiency of the maintenance program of the nuclear power plant Guideline 1.26, Regulatory Inspection of the Aging Management Program S1 The scope of aging management; Guideline 1.27, Regulatory control over equipment qualification and preservation of the qualified status

No	Country	Requirements of ageing management and AMP
		Guideline 2.15, Quality Assurance in the Aging Management of Nuclear Power Plant Equipment Guideline 3.1, Safety classification of nuclear plant systems and equipment Guideline 3.13, Consideration of Aging during Nuclear Power Plant Design Guideline 3.15, Equipment qualification requirements during the design of nuclear power plants Guideline 4.6, Nuclear power plant maintenance program and maintenance efficiency monitoring Guideline 4.12, Management of ageing during operation of nuclear power plants Guideline 4.13, Equipment qualification requirement for operating nuclear power plants Draft Guidelines: Requirements related to the content of application for long term operation licence In–service inspection of civil engineering structures and structural components Ensuring the long–term operation during operation of nuclear power plants Building Authority inspection in nuclear power plants (under revision) **Utility licensing documents, procedures and methodologies:** Updated FSAR of Paks NPP version 2004. In–service inspection plans and regular reports of the Paks NPP Ltd. (39 items) Detect and repair of defects on the confinement structure at Paks NPP. NEA/CSNI/R (2002) 7/VOL1
4	Russian Federation	NP–017–2000 Basic requirements for extension of NPP unit service life PiNAE G –01–011–88/97 (NP–001–97) General regulations for ensuring safety of nuclear power plants (OPB–88/97) PiNAE G –5–006–87 NPP seismic design regulations PiNAE–5,6 Structural design regulations for nuclear power plants with reactors of different types PiNAE G –10–021–90 (NP–010–98) Rules for design and operation of localizing safety systems at nuclear power plants PNAE G –10–007–89 Regulations for design of reinforced concrete structures of NPP localizing safety systems PNAE G –10–31–92 Main provisions on welding of NPP localizing safety systems elements PNAE G –10–32–92 Rules for inspection of weld joints of NPP localizing safety systems PPB–AS–93 Fire safety regulations during operation of nuclear power plants SP AS–03 Sanitary rules for design and operation of nuclear power plants SNiP 2.03.01–84 Concrete and reinforced concrete structures SNiP 2.06.08–87 Concrete and reinforced concrete structures of waterworks SNiP 3.01.03–84 Geodetic works during construction SNiP 3.02.01–87 Earthworks, bases ad foundations SNiP 3.03.01–87 Load –bearing and enclosing structures SNiP 2.03.11–85 Corrosion protection of structures SNiP 3.04.03–85 Corrosion protection of buildings and structures SNiP 11–23–81 Steel structures SP 52–101–2003 Concrete and reinforced concrete structures without reinforcement prestressing SP 53–101–98 Manufacture and quality control of steel structures RD–EO–0281–01 Provision on life management of NPP unit structures and systems RD–EO–0283–01 Standard programme of NPP unit review for extension of life RD–EO–0447–03 Methodology of assessment of condition and remaining life of NPP reinforced concrete structures important to safety RD–EO–0141–98 Standard technical requirements for assessment of technical condition and remaining life of NPP unit structures RD–EO–0007–93 Standard service instructions of NPP production buildings and structures RD–OE–0129–98 Requirements for maintenance and repair of prestressing systems for containments at NPPs with reactor V320 RD–EO–0130–98 Requirements for maintenance and repair of prestressing systems for containments at NPPs with reactor V320, V–338 and V–187 RD–EO–0461–03 Provision on surveillance of safety of NPP hydraulic structures RD–EO–0538–00 Methodology on service life validation for containments of NPPs with VVER reactors RD–EO–0624–2005 Inspection of NPP structures P–69–97 Manual on assessment methodology for safe service life of concrete and reinforced concrete structures of waterworks (VNIIG). Recommendations on reliability assessment of structural components of buildings and structures during visual examination (TSNIIPROMZDANII 2001.) MDS 53–2.2004 Diagnostics of steel building structures (TSNIIPROMZDANII 2001.)

No	Country	Requirements of ageing management and AMP
5	Slovak Republic	Regulation 121/2003 Coll (issued by ÚJD SR) on assessment of nuclear safety (as amended) § 6 – Ageing management: When assessing ageing management, changes in characteristics of civil structures, systems and equipment are analysed, capability to fulfil designed tasks is evaluated and it includes a) ageing management programme documentation, b) specification of civil structures, systems and components susceptible to ageing, c) selection and recording of data influencing the ageing process, d) results of residual lifetime monitoring, e) possibilities to mitigate the impacts of ageing. BNS I.9.2/2001 – Ageing management at NPPs – requirements
6	Sweden	General requirements in the Regulatory Guides (SKIFS 2004:1) include structures and structural components.
7	United States	10CFR Part 54 – Requirements For Renewal of Operating Licenses For Nuclear Power Plants. Regulatory Guide 1.160, Rev. 2, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants,” U.S. Nuclear Regulatory Commission, March 1997. Regulatory Guide 1.127, “Inspection of Water–Control Structures Associated with Nuclear Power Plants,” Revision 1, U.S. Nuclear Regulatory Commission, March 1978. Regulatory Guide 1.29 – Quality Assurance Program Requirements (Design and Construction) (Rev. 3) Regulatory Guide 1.142 – Safety–Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments) (Rev. 2) Regulatory Guide 1.107 – Qualifications for Cement Grouting for Prestressing Tendons in Containment Structures (Rev. 1) Regulatory Guide 1.132 – Site Investigations for Foundations of Nuclear Power Plants (Rev. 2) Regulatory Guide 1.136 – Materials, Construction, and Testing of Concrete Containments (Rev. 2)
8	Ukraine	“General requirements on the extension of NPP unit operation beyond its design lifetime based on the results of PSR” NP 306.2/099–2004 establish requirements to PSR in the line of Safety Reports Series No.15 „Implementation and Review of a Nuclear Power Plant Ageing Management Programme“ Utility guides: “Model NPP unit’ AMP”, Model AMPs for specific structures (in progress). Industrial guidelines

TABLE IV.2 Example for the utility documents
(CZECH REPUBLIC)

1	SM 025 – Diagnostics and equipment condition inspection
2	PP 043 – Long–term operation assurance behind the frame of design lifetime.
3	PP 053 – Ageing Management
4	PP 064 – Technical part of the preparation for NPP decommissioning.
5	PP 078 – Equipment safety assurance
6	PP 058 – Maintenance time planning
7	PP 050 – Maintenance evaluation
8	PP 047 – Maintenance programme management
9	ME 085 – Technical – economical review of the PLEX/LTO feasibility – (under preparation)
10	ME 086 – The basic data preparation for the PLEX/LTO assurance.
11	ME 148 – Classification and methods of equipment maintenance
12	ME 094 – Capital repair management
13	ME 069 – Ageing monitoring for EDU
14	ME 053 – Maintenance data records
15	ME 043 – Equipment cost evaluation and management for EDU
16	ME 240 – Methods for leak test of hermetic equipment on containment boundary ETE
17	ME 241 – Local leak test of Temelin containment ETE
18	ME 242 – Local leak test of airlocks ETE
19	ME 243 – Local leak test of penetration of cables ETE
20	ME 244 – Local leak test of hermetic systems ETE
21	ME 245 – Local leak test of valve sets on pipe penetrations ETE
22	ME 246 – Local test of structural joints ETE
23	ME 247 – Local leak test of blind penetrations ETE
24	ME 250 – PERILRT ETE tests – Measuring for structural integrity test
25	ME 251 – PERILRT ETE tests – Detection of leakages for under pressure test
26	ME 252 – PERILRT ETE tests – Detection of leakages
27	ME 253 – PERILRT ETE tests – Measuring AMVS
28	ME 256 – Containment in service inspections ETE
29	SM 027 – Maintenance technological preparation
30	SM 019 – Technical safety assurance
31	SM 021 – Project management
32	TL 001 – Limits and conditions
33	Procedure TS 135 – Periodical Containment Structural integrity tests
34	Procedure TS 136 – Periodical Containment leak rate tests
35	Procedure 106 rev 001 – ETE containment testing

IV.9. EXAMPLE OF SCOPE OF SYSTEMS, STRUCTURES AND COMPONENTS FOR LONG TERM OPERATION

TABLE IV.3. Example for the classification to be applied for structures (RUSSIAN FEDERATION)

General regulations for ensuring safety of nuclear power plants (OPB88/97)	**NPP seismic design regulations (NPO31–01)**	**Regulations for structural design of nuclear power plants (PINAE–5.6)**
Safety Class 1 NPP components whose failures are initiating events leading to damage of fuel elements beyond the established limits	Seismic Category 1 NPP components of safety classes 1 and 2 as per OPB 88/97 – safety systems –components whose failures during seismic effects up to the safety shutdown earthquake (SSE) may lead to escape of radioactive substances to the environment beyond the specified limits.	Radiation and Nuclear Safety category I Buildings, structures, structural components whose collapse or damage has an impact on systems important to safety, leads to malfunctions in operation of safety systems or release of radioactive products beyond the specified limits for design basis accident.
Safety Class 2 – safety systems components and components whose failures are initiating events leading to damage of fuel elements	–buildings, structures and their components mechanical damage of which may cause failure of safety systems during seismic effects.	
Safety Class 3 systems containing radioactive substances release of which to the environment on failures exceeds the limits specified for normal operation systems performing functions of biological shielding for personnel and population components of systems important to safety not included into Classes 1 and 2	Seismic Category II – NPP systems and components assigned to Safety Class 3 as per OPB 88/97 –NPP components failures of which may lead to interruption of electric power generation	Radiation and Nuclear Safety Category II – buildings, structures, structural components damage of which may cause interruption of electric power generation or release of radioactive substances to the environment beyond the limits established for normal operation and those not included into to Category I.
Safety Class 4 –non–safety normal operation components not included into Classes 1,2 and 3	Seismic Category III –NPP systems and components not assigned to Seismic Category I and II	Radiation and Nuclear Safety Category III –buildings, structures, structural components and items not included into Category I and II

TABLE IV.4. Structures and structural components of WWER–1000 within the scope of LTO

No	Names of facilities, structures and components	Safety class	Seismic category	Note
1. REACTOR BUILDING				
1.1.	Foundation soil of the building – natural or artificial	2	I	LTO /Not repairable/
1.2.	Foundation part of the building	2	I	LTO /Not repairable/
1.3.	Containment	2	I	LTO /Not repairable/*
1.4.	Internal structures of containment	2	I	LTO /Not repairable/
1.5.	Polar crane’s cantilevers	1	I	LTO /Not repairable/*
1.6.	Spent fuel storage pool	2	I	LTO /Not repairable/
1.6.1	Hermetic steel liner of the spent fuel storage pool	1	I	LTO
1.7.	Emergency boric solution tank	2	I	LTO /Not repairable/
1.8.	Rooms adjacent to containment	2	I	LTO /Not repairable/
1.9.	Steel ventilation stack	2	I	LTO
2. OTHER BUILDINGS AND FACILITIES				
2.1.	Turbine’s soil foundation	3	II	LTO /Not repairable/
2.2.	Turbine’s foundation structure	3	II	LTO /Not repairable/
2.3.	Turbine hall	3	II	LTO /Not repairable/*
2.4.	Cooling pump station and service water pump station	3	II	LTO /Not repairable/*
2.5.	Diesel generator building	3	I	LTO /Not repairable/*
2.6.	Spray cooling pools or cooling towers for responsible consumers	3	I	LTO /Not repairable/
2.7.	Pump stations and channels for responsible consumers	3	I	LTO /Not repairable/*
2.8.	Underground pipe and cable ducts of safety systems	3	I	LTO /Not repairable/
2.9	Auxiliary building with vent. Stack	3	II	LTO /Not repairable/
2.9.1	Liquid RAW storage	2	I	LTO /Not repairable/
2.9.2	Solid RAW storage	3	II	LTO /Not repairable/
2.10	Spent nuclear fuel storage building	3	I	LTO /Not repairable/
2.11	Fresh nuclear fuel storage building	3	I	LTO /Not repairable/
2.12	Protected control building	3	I	LTO /Not repairable/
2.13	Building and civil structures of the fire protection system	2 – 3	I – II	LTO /Not repairable/
3. STRUCTURAL COMPONENTS				
3.1	Anchorage and supporting structures for safety classified SSC (equipment piping, electrical and I&C)	2 – 3	I – II	LTO /Not repairable/
3.2	HELB protection structures	2 – 3	I– II	LTO
3.3	Air locks, hatches	2	I – II	LTO /Not repairable/*
3.4	Cable and Piping penetration assemblies	2 – 3	I – II	LTO /Not repairable/
3.5	Fire barriers	3	I – II	LTO /Not repairable/*

TABLE IV.5. Structures and structural components of WWER–440 within the scope of LTO

Name of buildings, structures, structural components and items	Safety Class	Seismic Category	Note
1. Reactor building	2	I	LTO (NR)
1.1 Building basement	2	I	LTO(NR)
1.2 Containment or confinement (hermetic boundary)	2	I	LTO (NR)
1.2.1 Concrete part			heavy concrete shielding
1.2.2 Hermetic liner B			
1.3 Containment internal structures	2	I	LTO (NR)
1.4 Crane in reactor hall	2	I	LTO
1.5 Liner of spent fuel pool	2	I	LTO
2. Other buildings and structures	2	I	LTO
2.1 Longitudinal and cross–wise connection buildings	2–3	I	LTO
2.2 Auxiliary building			
2.2.1 Liquid waste storage	2	I	LTO
2.2.2 Solid waste storage	3	II	LTO
2.3 Vent stack	3	II	LTO
2.4 Emergency diesel stations	3	I	LTO (NR)
2.5 Service water systems structures of essential consumers, pumping stations	3	I	Need considerations site specific (spray pond, towers or fresh water)
2.6 Piping bridges of safety systems			
2.7 Underground piping and cable ducts of safety systems	3	I	LTO
2.8 Emergency feedwater system structures (piping station, tanks and connections)	3	I	LTO
2.9 Turbine building	3	II	LTO only essential parts
2.10 Shelter, emergency control centre	3	II	LTO(NR)
2.11 Fire protection system structures (piping station, underground piping)	2–3	II–III	
3. Structural components			
3.1 Anchorage and supporting structures for safety classified SSC (equipment piping electrical and I&C)	1–3	I–II	LTO
3.2 HELB protection structures	3	II	
3.3 Air locks, hatches	2	I–II	
3.4 Cable and Piping penetration assemblies			
3.5 Fire barriers	3	II	
3.6 Cable trays	3	I–II	

NR – Not Repairable

TABLE IV.6. Structures and structural components of BWR and PWR within the scope of LTO

No	Names of facilities, structures and components	Safety class	Seismic category	Notes
1. REACTOR BUILDING				
1.1.	Foundation soil or rock of the building – natural or artificial	2	1	LTO
1.2.	Foundation part of the building	2	1	LTO
1.3.	Containment (prestressed or reinforced concrete/steel)	2	1	LTO
1.4	Internal structures of containment pressure suppression function (BWR)	2	1	LTO
1.5.	Internal structures of containment	3	1	LTO
1.6.	Polar crane's cantilevers	3	1	LTO
1.7.	Spent fuel storage pool, refuelling canal (liner)(BWR)	3	1	LTO
1.8	Reactor cavity (liner)	3	1	LTO
1.9.	Reactor building BWR	3	1	LTO
1.10.	Ventilation stack (BWR)	3	1	LTO
1.11	PWR–shield building	3	1	LTO
2. OTHERS BUILDINGS AND FACILITIES				
2.1.	Water–control structures (e.g. intake structures, cooling towers, spray ponds, cooling water tunnels) safety related	3	1	LTO
2.2.	Turbine building	3	1	LTO Safety related parts
2.3.	Cooling pump station and service water pump station	3	1	LTO
2.4.	Diesel generator building	3	1	LTO
2.5.	Underground pipe and cable ducts of safety systems	3	1	LTO
2.6.	Auxiliary building with vent. Stack	3	1	LTO
2.7	Rad–waste storage building	3	1	
2.8	Fuel building	3	1	LTO
2.9	Spent fuel storage pool, refuelling canal (liner)	3	1	LTO
2.10	Control building	3	1	LTO
2.11	Station Black Out structures (transmission towers, start–up transformer, circuit breaker foundation, electrical enclosure)	3	1	LTO
2.12	Water tanks (concrete or steel)	3	1	
2.13	Turbine's foundation structure	NNS	NA	
2.14	Water cooling structures non–safety related	NNS	NA	
3. STRUCTURAL COMPONENTS				
3.1	Foundation, Anchorage and Supporting structures for safety classified SSC (equipment piping, electrical and I&C)	1–3	1	LTO
3.2	Supports for class MC components (embedded parts)	2	1	
3.2	HELB protection structures	3	1	
3.3	Air locks, hatches	2	1	
3.4	Cable and Piping penetration assemblies	2	1	
3.5	Fire barriers	3	NA	
3.6	Pipe Whip Restraints, Jet Impingement Shields	3	NA	
3.7	Supports for cable tray, conduit, HVAC ducts, tube track, instrument tubing, non–ASME piping and components	3	1	
3.8	Anchorage of racks, panels, cabinets, and enclosures for electrical equipment and instrumentation	3	1	
3.9	Supports for miscellaneous equipment (e.g. EDG, HVAC components), support for miscellaneous structures (e.g. platforms, pipe whip restraints, jet impingement shields, masonry walls)	3	1	
3.10	Cable trays safety related cables	3	1	
3.11	Equipment supports and foundations	NNS	NA	
3.12	Off–gas stack and flue	3	NA	
3.13	Compressible joints and seals	3	NA	
3.14	Penetration seals	2	NA	
3.15	Controlled leakage hatches and doors	3	NA	
3.16	Concrete Curbs	3	NA	

IV.10.EXAMPLE OF AGEING MANAGEMENT PROGRAMMES FOR SYSTEMS, STRUCTURES AND COMPONENTS

TABLE IV.7. Summary of ageing management programmes for structures and component supports for BWR and PWR

The following describes the information presented in each column of the following Table in this section.

The safety–related and other structures (structures other than containments) are organized into nine groups: Group 1: BWR reactor building, PWR shield building, control room/building; Group 2: BWR reactor building with steel superstructure; Group 3: auxiliary building, diesel generator building, radwaste building, turbine building, switchgear room, yard structures (auxiliary feedwater pump house, utility/piping tunnels, security lighting poles, manholes, duct banks), SBO structures (transmission towers, start–up transformer circuit breaker foundation, electrical enclosure); Group 4: containment internal structures, excluding refuelling canal; Group 5: fuel storage facility, refuelling canal; Group 6: water–control structures (e.g., intake structure, cooling tower, and spray pond); Group 7: concrete tanks and missile barriers; Group 8: steel tanks and missile barriers; and Group 9: BWR unit vent stack.

Column Heading	**Description**
ID	A unique row identifier.
Type	Identifies the plant design that the item applies to (i.e., BWR or PWR or both).
Component	Identifies the structure of components to which the row applies
Ageing Effect/ Mechanism	Identifies the applicable ageing effect and mechanism(s).
Ageing Management Programmes	Identifies the time limited ageing analysis or ageing management programme found acceptable for properly managing the affects of ageing.
Further Evaluation Recommended	Identifies whether further evaluation is required.

ID	**Type**	**Component**	**Ageing Effect/Mechanism**	**Ageing Management Programmes**	**Further Evaluation Recommended**
PWR Concrete (Reinforced and Prestressed) and Steel Containment					
BWR Concrete (Mark II and III) and Steel (Mark I, II, and III) Containment					
1	BWR/PWR	Concrete elements: walls, dome, basement, ring girder, buttresses, containment (as applicable)	Ageing of accessible and inaccessible concrete areas due to aggressive chemical attack, and corrosion of embedded steel	ISI (IWL) and for inaccessible concrete, an examination of representative samples of below–grade concrete and periodic monitoring of groundwater if environment is non–aggressive. A plant specific programme is to be evaluated if environment is aggressive.	Yes, plant–specific, if the environment is aggressive
2	BWR/PWR	Concrete elements; All	Cracks and distortion due to increased stress levels from settlement	Structures Monitoring Programme. If a de–watering system is relied upon for control of settlement, then the licensee is to ensure proper functioning of the de–watering system through the period of extended operation.	Yes, if not within the scope of the applicant's structures monitoring programme or a de–watering system is relied upon
3	BWR/PWR	Concrete elements: foundation, sub–foundation	Reduction in foundation strength, cracking, differential settlement due to erosion of porous concrete subfoundation	Structures Monitoring Programme. If a de–watering system is relied upon to control erosion of cement from porous concrete subfoundations, the licensee is to ensure proper functioning of the de–watering system through the period of extended operation.	Yes, if not within the scope of the applicant's structures monitoring programme or a de–watering system is relied upon

4	BWR/PWR	Concrete elements: walls, dome, basement, ring girder, buttresses, concrete fill–in annulus (as applicable)	Reduction of strength and modulus due to elevated temperature	Plant–specific	Yes, plant–specific if temperature limits are exceeded
5	BWR	Steel elements: Drywell; torus; drywell head; embedded shell and sand pocket regions; drywell support skirt; torus ring girder; downcomers; liner plate, ECCS suction header, support skirt, region shielded by diaphragm floor, suppression chamber (as applicable)	Loss of material due to general, pitting and crevice corrosion	ISI (IWE) and 10 CFR Part 50, Appendix J	Yes, if corrosion is significant for inaccessible areas
6	BWR/PWR	Steel elements: steel liner, liner anchors, integral attachments	Loss of material due to general, pitting and crevice corrosion	ISI (IWE) and 10 CFR Part 50, Appendix J	Yes, if corrosion is significant for inaccessible areas
7	BWR/PWR	Prestressed containment tendons	Loss of prestress due to relaxation, shrinkage, creep, and elevated temperature	TLAA evaluated in accordance with 10 CFR 54.21 9(c)	Yes, TLAA
8	BWR	Steel and stainless steel elements: vent line, vent header, vent line bellows; down–comers;	Cumulative fatigue damage)CLB fatigue analysis exists)	TLAA evaluated in accordance with 10 CFR 54.21 9(c)	Yes, TLAA
9	BWR/PWR	Steel. Stainless steel elements, dissimilar metal welds: penetration sleeves, penetration bellows; suppression pool shell, unbraced downcomers	Cumulative fatigue damage)CLB fatigue analysis exists)	TLAA evaluated in accordance with 10 CFR 54.21 9(c)	Yes, TLAA
10	BWR/PWR	Stainless steel penetration sleeves, penetration bellows, dissimilar metal welds	Cracking due to stress corrosion cracking	ISI (IWE) and 10 CFR Part 50, Appendix J and additional appropriate examinations/evaluation for bellows assemblies and dissimilar metal weld	Yes, detection of ageing effects is to be evaluated
11	BWR	Stainless steel vent line bellows	Cracking due to stress corrosion cracking	ISI (IWE) and 10 CFR Part 50, Appendix J and additional appropriate examinations/evaluation for bellows assemblies and dissimilar metal weld	Yes, detection of ageing effects is to be evaluated
12	BWR/PWR	Steel, stainless steel elements, dissimilar metal welds: penetration sleeves, penetration bellows; suppression pool shell, unbraced downcomers	Cracking due to cyclic loading	ISI (IWE) and 10 CFR Part 50, Appendix J supplemented to detect fine cracks	Yes, detection of ageing effects is to be evaluated
13	BWR	Steel, stainless steel elements, dissimilar metal welds: torus ; vent line; vent header; vent line bellows; downcomers	Cracking due to cyclic loading	ISI (IWE) and 10 CFR Part 50, Appendix J supplemented to detect fine cracks	Yes, detection of ageing effects is to be evaluated
14	BWR/PWR	Concrete elements: dome, wall, basemat ring girder, buttresses. Containment (as applicable)	Loss of material (Scaling, cracking, and spalling) due to freeze–thaw	ISI (IWL) Evaluation is needed for plants that are located in moderate to severe weathering conditions (weathering index > 100 day–inch/yr) (NUREG–1557)	Yes, for inaccessible areas of plants located in moderate to severe weathering conditions

15	BWR/PWR	Concrete elements: walls, dome, basemat, ring girder, buttresses containment, concrete fill–in annulus (as applicable)	Increase in porosity, permeability due to leaching of calcium hydroxide; cracking due to expansion and reaction with aggregate	ISI (IWL) for accessible areas. None for inaccessible areas if concrete was constructed in accordance with the recommendations in ACI 201.2R	Yes, if concrete was not constructed as stated for inaccessible areas
16	BWR/PWR	Seals, gaskets, and moisture barriers	Loss of sealing and leakage through containment due to deterioration of joint seals, gaskets, and moisture barriers (caulking, flashing, and other sealants)	ISI (IWE) and 10 CFR Part 50, Appendix J	No
17	BWR/PWR	Personal airlock, equipment hatch and CRD hatch locks, hinges, and closure mechanisms	Loss of leak tightness in closed position due to mechanical wear of locks, hinges and closure mechanisms	10 CFR Part 50, Appendix J and Plant Technical Specifications	No
18	BWR/PWR	Steel penetration sleeves and dissimilar metal welds; personnel airlock, equipment hatch and CRD hatch	Loss of material due to general, pitting and crevice corrosion	ISI (IWE) and 10 CFR Part 50, Appendix J	No
19	BWR	Steel elements: stainless steel suppression chamber shell (inner surface)	Cracking due to stress corrosion cracking	ISI (IWE) and 10 CFR Part 50, Appendix J	No
20	BWR	Steel elements: suppression chamber shell (inner surface)	Loss of material due to general, pitting and crevice corrosion	ISI (IWE) and 10 CFR Part 50, Appendix J	No
21	BWR	Steel elements: drywell head and downcomer pipes	Fretting or lock up due to mechanical wear	ISI (IWE)	No
22	BWR/PWR	Prestressed containment: tendons and anchorage components	Loss of material due to corrosion	ISI (IWL)	No
Safety–Related and Other Structures; and Component Supports					
23	BWR/PWR	All Groups except Group 6: Interior and above grade exterior concrete	Cracking, loss of bond, and loss of material (spalling, scaling) due to corrosion of embedded steel	Structures Monitoring Programme	Yes, if not within the scope of the applicant's structures monitoring programme
24	BWR/PWR	All Groups except Group 6: Interior and above grade exterior concrete	Increase in porosity, permeability, cracking, loss of material (spalling, scaling) due to aggressive chemical attack	Structures Monitoring Programme	Yes, if not within the scope of the applicant's structures monitoring programme
25	BWR/PWR	All Groups except Group 6: steel components: all structural steel	Loss of material due to corrosion	Structures Monitoring Programme. If protective coatings are relied upon to manage the effects of ageing, the structures monitoring programme is to include provisions to address protective coating monitoring and maintenance	Yes, if not within the scope of the applicant's structures monitoring programme
26	BWR/PWR	All Groups except Group 6: accessible and inaccessible concrete: foundation	Loss of material (spalling, scaling) and cracking due to freeze–thaw	Structures Monitoring Programme. Evaluation is needed for plants that are locate in moderate to severe weathering conditions (weathering index > 100 day–inch/yr) (NUREG–1557)	Yes, if not within the scope of the applicant's structures monitoring programme or for inaccessible areas of plants located in moderate to severe

					weathering conditions
27	BWR/PWR	All Groups except Group 6: accessible and inaccessible interior/exterior concrete	Cracking due to expansion due to reaction with aggregates	Structures Monitoring Programme. None for inaccessible areas if concrete was constructed in accordance with the recommendations in ACI 201.2R–77	Yes, if not within the scope of the applicant's structures monitoring programme or concrete was not constructed as stated for inaccessible areas
28	BWR/PWR	Group 1–3, 5–9: All	Cracks and distortion due to increased stress levels from settlement	Structures Monitoring Programme. If a de–watering system is relied upon for control of settlement, then the licensee is to ensure proper functioning of the de–watering system through the period of extended operation.	Yes, if not within the scope of the applicant's structures monitoring programme or a de–watering system is relied upon
29	BWR/PWR	Group 1–3, 5–9: foundation	Reduction in foundation strength, cracking, differential settlement due to erosion of porous concrete sub–foundation	Structures Monitoring Programme. If a de–watering system is relied upon for control of settlement, then the licensee is to ensure proper functioning of the de–watering system through the period of extended operation.	Yes, if not within the scope of the applicant's structures monitoring programme or a de–watering system is relied upon
30	BWR/PWR	Group 4: radial beam seats in BWR drywell; RPV support shoes for PWR with nozzle supports; steam generator supports	Lock–up due to wear	ISI (IWF) or Structures Monitoring Programme	Yes, if not within the scope of ISI or structures monitoring programme
31	BWR/PWR	Group 1–3, 5, 7–9: below–grade concrete components, such as exterior walls below grade and foundation	Increase in porosity and permeability, cracking, loss of material (spalling, scaling)/ aggressive chemical attack; Cracking, loss of bond, and loss of material (spalling, scaling)/ corrosion of embedded steel	Structures Monitoring Programme; Examination of representative samples of below–grade concrete, and periodic monitoring of groundwater, if the environment is non–aggressive. A plant specific programme is to be evaluated if environment is aggressive.	Yes, plant–specific if environment is aggressive
32	BWR/PWR	Groups 1–3, 5, 7–9: exterior above and below grade reinforced concrete foundation	Increase in porosity and permeability, loss of strength due to leaching of calcium hydroxide	Structures Monitoring Programme for accessible areas. None for inaccessible areas if concrete was constructed in accordance with the recommendations in ACI 201.2R–77	Yes, if concrete was not constructed as stated for inaccessible areas
33	BWR/PWR	Group 1–5: Concrete	Reduction of strength and modulus due to elevated temperature	Plant–specific	Yes, plant–specific if temperature limits are exceeded
34	BWR/PWR	Group 6: Concrete; all	Cracking, loss of bond, and loss of material due to corrosion of embedded steel; increase in porosity and permeability, cracking, loss of material due to aggressive chemical attack	Inspection of Water–Control Structures Assoc. with Nuclear Power Plants and for inaccessible concrete, exam of rep. samples of below–grade concrete, and periodic monitoring of groundwater, if environment is non–aggressive. Plant specific if environment is aggressive.	Yes, plant–specific if environment is aggressive

35	BWR/PWR	Group 6: exterior above and below grade concrete foundation	Loss of material (spalling, scaling) and cracking due to freeze–thaw	Inspection of Water–Control Structures Assoc. with Nuclear Power Plants. Evaluation is needed for plants that are located in moderate to severe weathering conditions (weathering index > 100 day–inch/yr) (NUREG–1557)	Yes, for inaccessible areas of plants located in moderate to severe weathering conditions
36	BWR/PWR	Group 6: all accessible/ inaccessible reinforced concrete	Cracking due to expansion due to reaction with aggregates	Accessible areas: Inspection of Water–Control Structures Assoc. with Nuclear Power Plants. None for inaccessible areas if concrete was constructed in accordance with the recommendations in ACI 201.2R–77	Yes, if concrete was not constructed as stated for inaccessible areas
37	BWR/PWR	Group 6: exterior above and below grade reinforced concrete foundation interior slab	Increase in porosity and permeability, loss of strength due to leaching of calcium hydroxide	Accessible areas: Inspection of Water–Control Structures Assoc. with Nuclear Power Plants. None for inaccessible areas if concrete was constructed in accordance with the recommendations in ACI 201.2R–77	Yes, if concrete was not constructed as stated for inaccessible areas
38	BWR/PWR	Group 7, 8: Tank liners	Cracking due to stress corrosion cracking; loss of material due to pitting and crevice corrosion	Plant–specific	Yes, plant specific
39	BWR/PWR	Support members; welds; bolted connections; support anchorage to building structure	Loss of material due to general, pitting and crevice corrosion	Structures Monitoring Programme	Yes, if not within the scope of the applicant's structures monitoring programme
40	BWR/PWR	Building concrete at locations of expansion and grouted anchors; grout pads for support base plates	Reduction in concrete anchor capacity due to local concrete degradation/ service–induced cracking or other concrete ageing mechanisms	Structures Monitoring Programme	Yes, if not within the scope of the applicant's structures monitoring programme
41	BWR/PWR	Vibration isolation elements	Reduction or loss of isolation function/ radiation hardening, temperature, humidity, sustained vibratory loading	Structures Monitoring Programme	Yes, if not within the scope of the applicant's structures monitoring programme
42	BWR/PWR	Groups B1.1, B1.2, and B1.3: support members: anchor bolts, welds	Cumulative fatigue damage) CLB fatigue analysis exists)	TLAA evaluated in accordance with 10 CFR 54.21 9(c)	Yes, TLAA
43	BWR/PWR	Groups 1–3, 5, 6: all masonry block walls	Cracking due to restraint shrinkage, creep, and aggressive environment	Masonry Wall Programme	No
44	BWR/PWR	Group 6 elastomer seals, gaskets, and moisture barriers	Loss of sealing due to deterioration of seals, gaskets, and moisture barriers (caulking, flashing, and other sealants)	Structures Monitoring Programme	No
45	BWR/PWR	Group 6: exterior above and below grade concrete foundation; interior slab	Loss of material due to abrasion, cavitation	Inspection of Water–Control Structures Associated with Nuclear Power Plants	No
46	BWR/PWR	Group 5: Fuel pool liners	Cracking due to stress corrosion cracking; loss of material due to pitting and crevice corrosion	Water Chemistry and Monitoring of spent fuel pool water level and level of fluid in the leak chase channel	No

47	BWR/PWR	Group 6: all metal structural members	Loss of material due to general (steel only), pitting and crevice corrosion	Inspection of Water–Control Structures Associated with Nuclear Power Plants. If protective coatings are relied upon to manage ageing, protective coating monitoring and maintenance provisions should be included	No
48	BWR/PWR	Group 6: earthen water control structures – dams, embankments, reservoirs, channels, canals, and ponds	Loss of material, loss of form sue to erosion, settlement, sedimentation, frost action, waves, currents, surface runoff, seepage	Inspection of Water–Control Structures Associated with Nuclear Power Plants.	No
49	BWR	Support members; welds; bolted connections; support anchorage to building structure	Loss of material due to general, pitting and crevice corrosion	Water Chemistry and ISI (IWF)	No
50	BWR/PWR	Group B2, and B4: galvanized steel, aluminium, stainless steel support members; welds; bolted connections; support anchorage to building structure	Loss of material due to pitting and crevice corrosion	Structures Monitoring Programme	No
51	BWR/PWR	Group B1.1: high strength low–alloy bolts	Cracking due to stress corrosion cracking; loss of material due to general corrosion	Bolting Integrity	No
52	BWR/PWR	Groups B2, and B4: sliding support bearings and sliding support surfaces	Loss of mechanical function due to corrosion, distortion, dirt, overload, fatigue due to vibratory and cyclic thermal loads	Structures Monitoring Programme	No
53	BWR/PWR	Group B1.1, B1.2, and B1.3: support members: welds; bolted connections; support anchorage to building structure	Loss of material due to general pitting and corrosion	ISI (IWF)	No
54	BWR/PWR	Groups B1.1, B1.2, and B1.3: Constant and variable load spring hangers; guides; stops	Loss of mechanical function due to corrosion, distortion, dirt, overload, fatigue due to vibratory and cyclic thermal loads	ISI (IWF)	No
55	PWR	Steel, galvanized steel, and aluminium support members; welds; bolted connections; support anchorage to building structure	Loss of material due to boric acid corrosion	Boric Acid Corrosion	No
56	BWR/PWR	Groups B1.1, B1.2, and B1.3: Sliding surfaces	Loss of mechanical function due to corrosion, distortion, dirt, overload, fatigue due to vibratory and cyclic thermal loads	ISI (IWF)	No
57	BWR/PWR	Groups B1.1, B1.2, and B1.3: Vibration isolation elements	Reduction or loss of isolation function/ radiation hardening, temperature, humidity, sustained vibratory loading	ISI (IWF)	No

58	BWR/PWR	Galvanized steel, and aluminium support members; welds; bolted connections; support anchorage to building structure exposed to air – indoor uncontrolled	None	None	NA – No AMP
59	BWR/PWR	Stainless steel support members: welds; bolted connections; support anchorage to building structure	None	None	NA – No AMP

IV.10.1. Typical ageing management programmes for structures and structural components

The following summarizes typical ageing management programmes which have been found to address age related degradation for structures and structural components.

IV.10.1.1. ASME Section XI, Subsection IWE

Programme Description

10 CFR 50.55a imposes the in–service inspection (ISI) requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section XI, Subsection IWE for steel containments (Class MC) and steel liners for concrete containments (Class CC). The full scope of IWE includes steel containment shells and their integral attachments; steel liners for concrete containments and their integral attachments; containment hatches and airlocks; seals, gaskets and moisture barriers; and pressure–retaining bolting. This evaluation covers both the 1992 Edition with the 1992 Addenda and the 1995 Edition with the 1996 Addenda, as approved in 10 CFR 50.55a. ASME Code Section XI, Subsection IWE and the additional requirements specified in 10 CFR 50.55a(b)(2) constitute an existing mandated programme applicable to managing ageing of steel containments, steel liners of concrete containments, and other containment components for licence renewal.

The primary ISI method specified in IWE is visual examination (general visual, VT–3, VT–1). Limited volumetric examination (ultrasonic thickness measurement) and surface examination (e.g., liquid penetrant) may also be necessary in some instances. Bolt preload is checked by either a torque or tension test. IWE specifies acceptance criteria, corrective actions, and expansion of the inspection scope when degradation exceeding the acceptance criteria is found.

IV.10.1.2. ASME Section XI, Subsection IWL

Programme Description

10 CFR 50.55a imposes the examination requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section XI, Subsection IWL for reinforced and prestressed concrete containments (Class CC). The scope of IWL includes reinforced concrete and unbonded post–tensioning systems. This evaluation covers both the 1992 Edition with the 1992 Addenda and the 1995 Edition with the 1996 Addenda, as approved in 10 CFR 50.55a. ASME Code Section XI, Subsection IWL and the additional requirements specified in 10 CFR 50.55a(b)(2) constitute an existing mandated programme applicable to managing ageing of containment reinforced concrete and unbonded post–tensioning systems for licence renewal.

The primary inspection method specified in IWL is visual examination (VT–3C, VT–1, VT–1C). For prestressed containments, tendon wires are tested for yield strength, ultimate tensile strength, and elongation. Tendon corrosion protection medium is analyzed for alkalinity, water content, and soluble ion concentrations. Prestressing forces are measured in selected sample tendons. IWL specifies acceptance criteria, corrective actions, and expansion of the inspection scope when degradation exceeding the acceptance criteria is found.

IV.10.1.3. ASME Section XI, Subsection IWF

Programme Description

10 CFR 50.55a imposes the in–service inspection (ISI) requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, for Class 1, 2, 3, and MC piping and components and their associated supports. In-service inspection of supports for ASME piping and components is addressed in Section XI,

Subsection IWF. This evaluation covers the 1989 Edition through the 1995 Edition and addenda through the 1996 Addenda, as approved in 10 CFR 50.55a. ASME Code Section XI, Subsection IWF constitutes an existing mandated programme applicable to managing ageing of ASME Class 1, 2, 3, and MC supports for licence renewal.

The IWF scope of inspection for supports is based on sampling of the total support population. The sample size varies depending on the ASME Class. The largest sample size is specified for the most critical supports (ASME Class 1). The sample size decreases for the less critical supports (ASME Class 2 and 3). Discovery of support deficiencies during regularly scheduled inspections triggers an increase of the inspection scope, in order to ensure that the full extent of deficiencies is identified. The primary inspection method employed is visual examination. Degradation that potentially compromises support function or load capacity is identified for evaluation. IWF specifies acceptance criteria and corrective actions. Supports requiring corrective actions are re–examined during the next inspection period.

IV.10.1.4. 10 CFR Part 50, Appendix J

Programme Description

As described in 10 CFR Part 50, Appendix J, containment leak rate tests are required "to assure that (a) leakage through the primary reactor containment and systems and components penetrating primary containment shall not exceed allowable leakage rate values as specified in the technical specifications or associated bases and (b) periodic surveillance of reactor containment penetrations and isolation valves is performed so that proper maintenance and repairs are made during the service life of the containment, and systems and components penetrating primary containment."

Appendix J provides two options, A and B, either of which can be chosen to meet the requirements of a containment LRT programme. Under Option A, all of the testing must be performed on a periodic interval. Option B is a performance–based approach. Some of the differences between these options are discussed below, and more detailed information for Option B is provided in the Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.163 and NEI 94–01, Rev. 0.

IV.10.1.5. Masonry wall programme

Programme Description

Nuclear Regulatory Commission (NRC) IE Bulletin (IEB) 80–11, "Masonry Wall Design," and NRC Information Notice (IN) 87–67, "Lessons Learned from Regional Inspections of Licensee Actions in Response to IE Bulletin 80–11," constitute an acceptable basis for a masonry wall ageing management programme (AMP). IEB 80–11 required the identification of masonry walls in close proximity to, or having attachments from, safety–related systems or components, and the evaluation of design adequacy and construction practice. NRC IN 87–67 recommended plant–specific condition monitoring of masonry walls and administrative controls to ensure that the evaluation basis developed in response to NRC IEB 80–11 is not invalidated by (1) deterioration of the masonry walls (e.g., new cracks not considered in the re-evaluation), (2) physical plant changes such as installation of new safety–related systems or components in close proximity to masonry walls, or (3) reclassification of systems or components from non–safety–related to safety–related.

Important elements in the evaluation of many masonry walls during the NRC IEB 80–11 programme included (1) installation of steel edge supports to provide a sound technical basis for boundary conditions used in seismic analysis and (2) installation of steel bracing to ensure containment of unreinforced masonry walls during a seismic event. Consequently, in addition to the development of cracks in the masonry walls, loss of function of the structural steel supports and bracing would also invalidate the evaluation basis.

The objective of the masonry wall programme is to manage ageing effects so that the evaluation basis established for each masonry wall within the scope of licence renewal remains valid through the period of extended operation. Since the issuance of NRC IEB 80–11 and NRC

IN 87–67, the NRC promulgated 10 CFR 50.65, the Maintenance Rule. Masonry walls may be inspected as part of the Structures Monitoring Programme (XI.S6) conducted for the Maintenance Rule, provided the ten attributes described below are incorporated.

IV.10.1.6. Structures monitoring programme

Programme Description

Implementation of structures monitoring under 10 CFR 50.65 (the Maintenance Rule) is addressed in Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.160, Rev. 2, and NUMARC 93–01, Rev. 2. These two documents provide guidance for development of licensee–specific programmes to monitor the condition of structures and structural components within the scope of the Maintenance Rule, such that there is no loss of structure or structural component intended function.

Because structures monitoring programmes are licensee–specific, the Evaluation and Technical Basis for this ageing management programme (AMP) is based on the implementation guidance provided in Regulatory Guide 1.160, Rev. 2, and NUMARC 93–01, Rev. 2. Existing licensee–specific programmes developed for the implementation of structures monitoring under 10 CFR 50.65 are acceptable for licence renewal provided these programmes satisfy the 10 attributes described below.

If protective coatings are relied upon to manage the effects of ageing for any structures included in the scope of this AMP, the structures monitoring programme is to address protective coating monitoring and maintenance.

IV.10.1.7. RG 1.127, Inspection of water–control structures associated with nuclear power plants

Programme Description

Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.127, Revision 1, "Inspection of Water–Control Structures Associated with Nuclear Power Plants," describes an acceptable basis for developing an in–service inspection and surveillance programme for dams, slopes, canals, and other water–control structures associated with emergency cooling water systems or flood protection of nuclear power plants. The RG 1.127 programme addresses age–related deterioration, degradation due to extreme environmental conditions, and the effects of natural phenomena that may affect water–control structures. The RG 1.127 programme recognizes the importance of periodic monitoring and maintenance of water–control structures so that the consequences of age–related deterioration and degradation can be prevented or mitigated in a timely manner.

RG 1.127 provides detailed guidance for the licensee's inspection programme for water–control structures, including guidance on engineering data compilation, inspection activities, technical evaluation, inspection frequency, and the content of inspection reports. Water–control structures covered by the RG 1.127 programme include concrete structures; embankment structures; spillway structures and outlet works; reservoirs; cooling water channels and canals, and intake and discharge structures; and safety and performance instrumentation. RG 1.127 delineates current NRC practice in evaluating in–service inspection programmes for water–control structures.

IV.10.1.8. Protective coating monitoring and maintenance programme

Programme Description

Proper maintenance of protective coatings inside containment (defined as Service Level I in Nuclear Regulatory Commission [NRC] Regulatory Guide [RG] 1.54, Rev. 1) is essential to ensure operability of post–accident safety systems that rely on water recycled through the containment sump/drain system. Degradation of coatings can lead to clogging of strainers, which reduces flow through the sump/drain system. This has been addressed in NRC Generic Letter (GL) 98–04.

Maintenance of Service Level I coatings applied to carbon steel surfaces inside containment (e.g., steel liner, steel containment shell, penetrations, hatches) also serves to prevent or minimize loss of material due to corrosion. Regulatory Position C4 in RG 1.54, Rev. 1, describes an acceptable technical basis for a Service Level I coatings monitoring and maintenance programme that can be credited for managing the effects of corrosion for carbon steel elements inside containment.

A comparable programme for monitoring and maintaining protective coatings inside containment, developed in accordance with RG 1.54, Rev. 0 or the American National Standards Institute (ANSI) standards (since withdrawn) referenced in RG 1.54, Rev. 0, and coatings maintenance programmes described in licensee responses to GL 98–04, is also acceptable as an ageing management programme (AMP) for licence renewal.

IV.10.1.9. Water chemistry

Programme Description

The main objective of this programme is to mitigate damage caused by corrosion and stress corrosion cracking (SCC). The water chemistry programme for boiling water reactors (BWRs) relies on monitoring and control of reactor water chemistry based on industry guidelines such as the boiling water reactor vessel and internals project (BWRVIP)–29 (Electric Power Research Institute [EPRI] TR–103515) or later revisions. The BWRVIP–29 has three sets of guidelines: one for primary water, one for condensate and feedwater, and one for control rod drive (CRD) mechanism cooling water. The water chemistry programme for pressurized water reactors (PWRs) relies on monitoring and control of reactor water chemistry based on industry guidelines for primary water and secondary water chemistry such as EPRI TR–105714, Rev. 3 and TR–102134, Rev. 3 or later revisions.

The water chemistry programmes are generally effective in removing impurities from intermediate and high flow areas. The Generic Ageing Lessons Learned (GALL) report identifies those circumstances in which the water chemistry programme is to be augmented to manage the effects of ageing for licence renewal. For example, the water chemistry programme may not be effective in low flow or stagnant flow areas. Accordingly, in certain cases as identified in the GALL Report, verification of the effectiveness of the chemistry control programme is undertaken to ensure that significant degradation is not occurring and the component's intended function will be maintained during the extended period of operation. As discussed in the GALL Report for these specific cases, an acceptable verification programme is a one–time inspection of selected components at susceptible locations in the system.

IV.10.1.10. Boric acid corrosion

Programme Description

The programme relies in part on implementation of recommendations in Nuclear Regulatory Commission (NRC) Generic Letter (GL) 88–05 to monitor the condition of the reactor coolant pressure boundary for borated water leakage. Periodic visual inspection of adjacent structures, components, and supports for evidence of leakage and corrosion is an element of the NRC GL 88–05 monitoring programme. Potential improvements to boric acid corrosion programmes have been identified as a result of recent operating experience with cracking of certain nickel alloy pressure boundary components (NRC Regulatory Issue Summary 2003–013).

Borated water leakage from piping and components that are outside the scope of the programme established in response to GL 88–05 may affect structures and components that are subject to ageing management review. Therefore, the scope of the monitoring and inspections of this programme includes all components that contain borated water that are in proximity to structures and components that are subject to ageing management review. The scope of the evaluations, assessments and corrective actions include all observed leakage sources and the affected structures and components.

Borated water leakage may be discovered by activities other than those established specifically to detect such leakage. Therefore, the programme includes provisions for triggering evaluations and assessments when leakage is discovered by other activities.

TABLE IV.8. Degradation mechanisms

(In the column "Criterion" reference is made to ASME Section XI and other US sources. It is relevant for countries where the ASME Section XI is applicable. For other countries relevant national documents are in use).

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
Air – Indoor	Concrete	Carbonation	Corrosion of reinforcement, cracks on surface	Any concrete structure, outer surfaces	Visual inspection, measuring crack width	In a period of inspections and acceptance tests	Permissible crack with according to design, ASME Section XI, Subsection IWL, Structures Monitoring programme	cracks are not prone to grow because they occurs during hardening period	Surface towelling, applying protective coatings
			Collapse of concrete cover area, reinforcement corrosion, reduction in design section value	Outer surfaces reinforcement covering layer area	Examination by instrumental method	In a period of inspections, testing	Reinforcement covering layer thickness	Inspections, examinations	Protective corrosion–proof painting
		Alkali–silica reaction	Concrete cracking, corrosion of reinforcement	Any concrete structure	Visual inspection, testing	During inspections	ASME Section XI, Subsection IWL, Structures Monitoring Programme, ASTM C295–54, ASTM C227–50	Monitoring of affected area condition	Repair
		Effect of aggressive acids	Material fracture, susceptibility	Local areas prone to effect of aggressive fluids	Visually, by instrumental method and sampling in affected areas	During inspections	Material strength	Monitoring of affected area condition	Repair, applying protective coating resisting to chemical effects
		Cracking in the concrete, shrinkage, creep, stresses	Concrete cracking, corrosion of reinforcement, loss of prestress in prestressed structures	Any concrete structure	Visual inspection, instrumental methods of stress state monitoring	Monitoring during read–out of instrument indications, during inspections	Design value for creep, shrinkage, ASME Section XI, Subsection IWL, Structures Monitoring programme	Stress state monitoring and analysis of trends in measured values.	Considering effects during survey and preventive maintenance
		Irradiation	Deterioration of material structure	Biological shield	Visual inspection if possible	During inspections	Structures Monitoring	Monitoring of affected area	Repair

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
							programme	condition	
		Settlement	Cracking, stresses	Base mat, supporting framework	Visual inspections, levelling	During inspections	Permissible design values, ASME Section XI, Subsection IWL, Structures Monitoring programme	Monitoring of levelling values and analysis of measured values	Considering effects during survey and preventive maintenance
		Fatigue, vibration	Cracking	Machine foundations in general, turbine foundation	Visual inspections, monitoring vibration	During inspections, monitoring during read–out of instrument indications	Permissible values, Structures Monitoring programme	Monitoring of vibration values and analysis of measured values	Considering effects during survey and preventive maintenance, repair
	Reinforced concrete, grout	Elevated temperature	Reduction of strength and modulus, stress redistribution, prestressing losses	Containment, wall, base mat, internal structures, around pipe penetrations	Plant specific instrumental testing methods	In a period of inspections, testing	Average temperature < 66 deg C (150 deg. F), local in the structure < 93 deg. C(200 deg. F)	Monitoring of conditions in the areas exposed to high temperature	Repair of hot penetrations considering permissible concrete temperatures
	Reinforcing steel	Service–induced cracking or other concrete ageing mechanisms as carbonization, aggressive fluids, alkali	Protective film failure, reduction in concrete anchor capacity due to local concrete degradation	rebar located near the outer surface, locations of expansion and grouted anchors, grout pads for support base plates	See "Structures Monitoring Programme", instrumental testing	During periodic testing	Permissible corrosion rate considering carrying capacity of the concrete, ASME Section XI, Subsection IWL, Structures Monitoring programme	Evaluating observations	Treatment of concrete surfaces with corrosion inhibitors, repairs, applying protective coatings
		Corrosion of embedded steel	Cracking, loss of bond and loss of material	Any concrete structure	Visual inspections, Inspections in accordance with IWL containments.	During periodic testing	ASME Section XI, Subsection IWL	Evaluating observations	Treatment of concrete surfaces with corrosion inhibitors, repairs, applying protective coatings
		Elevated temperature	Structural (inter–crystalline) changes	Rebar near penetrations of hot	Instrumental testing	During periodic testing	Not exceeding temperature	Evaluating observations	Complicated

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
				pipelines			gradient (~200 degree C)		
		Fatigue		Machine foundations in general, turbine foundation	Visual inspections				
	Prestressed reinforcement	Breakage of tendon parts and wire reinforcement	Prestressing losses, reduction in carrying capacity of reinforcement and the structure as a whole	Along the length of the tendon	Visual inspection and indication of force cell in tendons for un–grouted tendons	During inspections and preventive maintenance using force cells installed also tensioning end of tendons (un–grouted tendons)	In compliance with requirements for maintenance and repair of the containment prestressing system (un–grouted tendons)	Stress state measuring of the containment prestressing system and the structure (un–grouted tendons)	Stress–strain state analysis of tendon, replacement of tendon (un–grouted tendons)
		Effect of fluid penetrating tendon ducts	Local or total corrosion of prestressing tendon	Along the length of the tendon	Visually determining the moisture content , measuring tendon section after removal of corrosion	During inspections and preventive maintenance (un–grouted tendons)	In compliance with requirements for maintenance and repair of the containment prestressing system (un–grouted tendons)	Stress state measuring of the containment prestressing system according to maintenance schedule (un–grouted tendons)	Condition monitoring and recovery of grease (un–grouted tendons)
		Long term prestressing loading	Tendon relaxation	Along the length of the tendon	By indication of check test pieces and I&C (un–grouted tendons)	Permanently on data reading (un–grouted tendons)	Permissible value in compliance with design requirements (un–grouted tendons)	When data reading in the automatic stress–strain state monitoring system of the structure if existing (un–grouted tendons)	Tensioning and replacement of prestressing tendon (un–grouted tendons)
	Anchorage devices of prestressed reinforcement	Long term loading of prestressed reinforcement, metal defects	Cracks in anchorage metal	At the end of the tendon	Visually , presence of chips, and collapse, measuring crack opening value (available anchorage)	During inspections and preventive maintenance, maintenance acceptance test (available anchorage)	Absence of cracks, collapse, chips	analysis of defect occurrence, instrumental testing	Tendon replacement (un–grouted tendons)

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
	Corrosion protection system of prestressed reinforcement and anchorage devices	Lack of corrosion protection in separate areas or its degradation	Reinforcement corrosion	Along the length of the tendon and in the anchorage area	Visually (un–grouted tendons)	During inspections and preventive maintenance (un–grouted tendons)	Availability of corrosion protection (un–grouted tendons)	Inspections, examination during survey and preventive maintenance, analysis of the area affected by corrosion (un–grouted tendons)	Recovery of corrosion protection and if necessary replacement of stressed member (un–grouted tendons)
	Containment prestressing system	Prestressed reinforcement relaxation, concrete creep due to stress etc	Reduction prestressing level	Cylindrical an/or dome part of containment	SRP Section 4.5, Lift–off tests, automatic stress–strain state monitoring by means of I&C in structural body and force cells on tensioning ends of tendons (un–grouted tendons)	During inspections, readout of indications according to the schedule of observations (un–grouted tendons)	Permissible value of structural stress–strain state, 10 CFR 54.21(c)(1)(i), (ii) and (iii)	Structural stress–strain monitoring (un–grouted tendons)	Tensioning and replacement of prestressing tendon (un–grouted tendons)
	Carbon steel, hermetical liner	Mechanical wear	Fretting or lockup	Drywall head, downcomers	See ASME Section XI, Subsection IWE		ASME Section XI, Subsection IWE		
		Humidity	General, pitting and crevice corrosion, loss of material, leakage	Places with moisture condensation (VVER 440: ventilation centre, air traps, bubble condenser, Bottom of the SG compartment, VVER 1000: bottom of containment, PWR: junction of the containment cylinder and intermediate floors and base mat concrete, adjacent to crane girder rails and supports attached to the liner plate)	Plant specific, See "Structures Monitoring Programme. Visual and ultrasound: measurement of corrosion, measurement of liner thickness. (The Eddy–current scanning is applicable for monitoring the condition of liner wall thickness). Surface examination (e.g., liquid penetrant)	Inspection programmes, (Visual examination 1 times a year), From the time the plant is placed into service, there is an initial inspection interval of 10 years, during which 100% of the required examinations are to be completed	ASME Section XI, Subsection IWE, 10 CFR Part 50, Appendix J, Chapter XI.S6, "Structures Monitoring Program". Loss of thickness under lower productive tolerance (10 % of the nominal thickness),	Engineering analysis should be performed to establish that a reduced liner thickness does not degrade the design basis of the liner	Re–paint in case of paint deterioration. In case of degradation impacts on larger surfaces, replacement of part of the liner.

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
		Cyclic loading	Cracking, deformations, loss of tightness	All steel structures including liners and its integral attachments	See Chapter XI.S1 and XI.S4. Local leak tests, ILRT at reduced over pressure: VVER440 0,5 bar (0,2 bar); VVER1000 0,7 bar, at design over pressure VVER440 1,5 bar; VVER1000 4 bar.	1 x per 1 year reduced pressure, 1 x per 10 year (or No test) high pressure.	ASME Section XI, Subsection IWE 10 CFR Part 50, Appendix J, design code parameters	Early detection of damage, identification of material fatigue	Making ILRT at reduced pressure, at design pressure max 1 x per 10 years or no test
		Fatigue	Cumulative fatigue damage	Support members, welds, bolted connections, support anchorage to building structure, penetration sleeves, penetration bellows	See SRP, Section 4.6, "Containment Liner Plate and Penetration Fatigue Analysis"		ASME Section XI, Subsection IWE, 10 CFR Part 50, Appendix J, 10 CFR 54.21(c)(1)Chapter XI.S6, "Structures Monitoring Program"	TLAA	
		Stress corrosion cracking	Cracking	Vent line bellows, suppression chamber shell, penetration sleeves, penetration bellows	See Chapter XI.S1 and XI.S4		ASME Section XI, Subsection IWE 10 CFR Part 50, Appendix J		
		Elevated temperature	Reduction of strength and modulus, cracking, deformations, loss of tightness	Base mat, concrete fill–in annulus, Hermetic welds of steel plates and liner to penetrations, Mainly vicinity of high temperature	Plant specific, leak test inspection (pressure decrease, acoustic – ultrasound emission and helium leak tests)	Leak inspection during ILRT, local leak test of welds of hermetic piping penetration – 1 times a year (defined scope of welds)	CC–3400 of ASME Section III, Division 2, design code parameters, no registered leakage	If examination results require evaluation of areas of degradation or repairs, component shall be re–examined during the next inspection period	Repair of defects: welding, injecting, etc
		Mechanical Wear of locks, hinges and closure mechanisms	Loss of leak tightness	Personnel airlock, equipment hatch, CRD hatch	Plant specific		10 CFR Part 50, Appendix J		
		Irradiation	Micro–structural	In the vicinity of the	VVER 440: Special	Normally 1 times in	Amount of leakage		To maintain

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
			changes, cracks, reduced stiffness, reduced elasticity	reactor vessel and similar equipment (spent fuel storage pool)	leak test and additional measurement on hidden hermetic liner of spent fuel storage pool (during ILRT)	4 years, or according special Inspection programme			irradiation below levels resulting in degradation
		Chemical (liquids on the walls, inside of concrete	Corrosion, Loss of material, Erosion of the surface layer, Loss of leak tightness	Inaccessible hermetic liner –both sides, inaccessible side of liner – surface between liner and concrete, VVER 440: floor 6,0 m, 2.8m, –6.5m, Hermetic liner in spent fuel pool, PWR: bottom of the containment, voids in concrete, etc	Inspection of corrosion, VVER 440: Measurement of humidity and surplus of the solutions inside concrete structures (through special nozzle), and drain solutions. Special monitoring of tightness of spent fuel pool carbon steel liners.	1 – 2 x per year, spent fuel pool according special Inspection programme	Presence and quantum of acids and hydroxides	Evaluate the acceptability of liners in inaccessible areas	Specify additional requirements for inaccessible areas, e.g. prevention of excessive humidity in reinforced–concrete structures and prevention of ingress of aggressive solutions: drainage of surplus solutions
	Austenitic steel	High and low temperature cycles	Cracking, deformations, loss of tightness	Spent fuel pool, refuelling pool, emergency H3BO3 tank	Monitoring of seepage–flow in system drain, visual inspections, Measuring of leak tightness (pressure decrease, acoustic emission or helium leak tests	Continuous (Spent fuel pool), 1–times in 7 day (Emergency H3BO3 tank), 1 times a year or in case of excessive leakage	Presence and quantum of water, no leakage is acceptable,		Repair of defects: welding, injecting, etc
		Chemical (liquids on the walls, inside of concrete	Corrosion, loss of material, loss of leak tightness	Spent fuel pool, emergency H3BO3 tank	Monitoring of seepage–flow in system drain. Pool water level may be monitored. Visual, measuring of leak tightness,	Continuous (Spent fuel pool), 1–times in 7 day (Emergency H3BO3 tank), 1 times a year.	Presence and quantum of water, no leakage is acceptable, limiting sheet thickness 3mm –0.5mm		Repair of defects: welding, injecting, etc. Water Chemistry Programme for

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
					measuring of thickness.				ageing management of the spent fuel pool liner.
		Cyclic loading	Cracking, deformations, loss of tightness	Spent fuel pool, emergency H3BO3 tank	Monitoring of seepage–flow in system drain. Pool water level may be monitored. Visual, measuring of leak tightness, measuring of thickness.	Continuous (Spent fuel pool), 1–times in 7 day (Emergency H3BO3 tank), 1 times a year.	Presence and quantum of water, no leakage is acceptable, limiting sheet thickness 3mm –0.5mm		Repair of defects: welding, injecting, etc. Water Chemistry Programme for ageing management of the spent fuel pool liner.
		Irradiation	Micro–structural changes, cracks, reduced stiffness, reduced elasticity	In the vicinity of the reactor vessel and similar equipment (spent fuel storage pool and refuelling pool above reactor)	Visual inspections, measuring of leak tightness (pressure decrease, acoustic emission or helium leak tests)	1 times a year or in case of excessive leakage from pools	No leakage is acceptable		
	Elastomers, rubber and other similar materials	Deterioration of seals, gaskets, and moisture barriers	Loss of sealing, leakage through containment	Seals, gaskets, and moisture barriers	Leak Rate Tests, tests of material properties	Inspection programmes, visual examination	10 CFR Part 50, Appendix J, permissible material properties	Examination of results from leak–rate tests an material tests	Repair by replacing material
	Low allow steel, yield strength > 150 ksi	Stress corrosion cracking	Cracking	High strength bolting for NSSS component supports	See "Bolting Integrity"	Inspection programmes, visual examination, tests	Bolting Integrity	Examination of results tests an tests	Repair by replacing material if possible
	Galvanized steel, aluminium	Pitting and crevice corrosion	Loss of material	Support members, welds, bolted connections, support anchorage to building structure	See "Structures Monitoring Programme"	Inspection programmes, visual examination	Structures Monitoring Programme	Examination of results from visual inspections	Repair by replacing material
	Concrete block	Restraint shrinkage, creep and aggressive environment	Cracking	All masonry wall	See "Masonry Wall Programme"	Inspection programmes, visual examination	Masonry Wall Programme	Examination of results from visual inspections	Repair by replacing material
	Lubrite	Wear	Lock–up	Radial beam seats in BWR drywell, RPV	See IWF or "Structures	Inspection programmes, visual	ASME Section XI, Subsection IWL	Examination of results from	Repair by replacing

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
				support shoes for PWR with nozzle supports, steam generator supports	Monitoring Programme"	examination	Structures Monitoring Programme	visual inspections	material
Air – Outdoor	Concrete	Carbonation	Surface cracks, reinforcement corrosion	Any concrete structure, outer surfaces	Visual inspection, measuring crack width	In a period of inspections and acceptance tests	Permissible crack with according to design, ASME Section XI, Subsection IWL, Structures Monitoring programme	Cracks are not prone to grow because they occurs during hardening period	Surface towelling, applying protective coatings, cathodic protection
			Collapse of concrete cover area, reinforcement corrosion, reduction in design section value	Outer surfaces reinforcement covering layer area	Examination by instrumental method	In a period of inspections, testing	Reinforcement covering layer thickness	Inspections, examinations	Protective corrosion–proof painting, cathodic protection
		Cracking in the concrete, shrinkage, creep, stresses	Concrete cracking, corrosion of reinforcement, loss of prestress in prestressed structures	Any concrete structure	Visual inspection, instrumental methods of stress state monitoring	Monitoring during read–out of instrument indications, during inspections	Design value for creep, shrinkage, ASME Section XI, Subsection IWL, Structures Monitoring programme	Stress state monitoring and analysis of trends in measured values.	Considering effects during survey and preventive maintenance
		Freeze–thaw, Effect of humidity in combination with negative temperatures	Loss of material, cracking, spalling, creep increase	Dome, wall, base mat, ring girders, buttresses, outer surfaces particularly in locations promoting water accumulation	Inspections in accordance with IWL. Inspect in accordance with "Structures Monitoring Programme", measuring crack width and length	During inspections	Permissible crack opening according to design, ASME Section XI, Subsection IWL, containments, Chapter XI.S6, "Structures Monitoring Programme"	Examination of areas with affected protective coating of concrete surface	Repair, applying protective coating
		Chloride penetration	Surface cracks, reinforcement corrosion	Any concrete structure, outer surfaces	Visual inspection, measuring crack width	In a period of inspections and acceptance tests	Permissible crack with according to design, ASME Section XI, Subsection IWL,	Cracks are not prone to grow because they occurs during hardening	Surface towelling, applying protective coatings

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
							Structures Monitoring programme	period	
			Collapse of concrete cover area, reinforcement corrosion, reduction in design section value	Outer surfaces reinforcement covering layer area	Examination by instrumental method	In a period of inspections, testing	Reinforcement covering layer thickness	Inspections, examinations	Protective corrosion–proof painting
		Alkali–silica reaction	Concrete cracking, corrosion of reinforcement	Any concrete structure	Visual inspection, testing	During inspections	ASME Section XI, Subsection IWL, Structures Monitoring Program, ASTM C295–54, ASTM C227–50	Monitoring of affected area condition	Repair
		Effect of aggressive acids	Material fracture, susceptibility	Local areas prone to effect of aggressive fluids	Visually, by instrumental method and sampling in affected areas	During inspections	Material strength	Monitoring of affected area condition	Repair, applying protective coating resisting to chemical effects
		Elevated temperature	Reduction of strength and modulus, stress redistribution, prestressing losses	Containment, wall, base mat, internal structures, around pipe penetrations	Plant specific instrumental testing methods	In a period of inspections, testing	Average temperature < 66 deg C (150 deg. F), local in the structure < 93 deg. C(200 deg. F)	Monitoring of conditions in the areas exposed to high temperature	Repair of hot penetrations considering permissible concrete temperatures
	Reinforcing steel	Service–induced cracking or other concrete ageing mechanisms as carbonization, aggressive fluids, alkali	Protective film failure, reduction in concrete anchor capacity due to local concrete degradation	rebar located near the outer surface, locations of expansion and grouted anchors, grout pads for support base plates	See "Structures Monitoring Programme", instrumental testing	During periodic testing	Permissible corrosion rate considering carrying capacity of the concrete, ASME Section XI, Subsection IWL, Structures Monitoring program	Evaluating observations	Treatment of concrete surfaces with corrosion inhibitors, repairs, applying protective coatings
		Corrosion of embedded steel	Cracking, loss of bond and loss of material	Any concrete structure	Visual inspections, Inspections in accordance with	During periodic testing	ASME Section XI, Subsection IWL	Evaluating observations	Treatment of concrete surfaces with

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
					IWL containments.				corrosion inhibitors, repairs, applying protective coatings
		Elevated temperature	Structural (inter–crystalline) changes	Rebar near penetrations of hot pipelines	Instrumental testing	During periodic testing	Not exceeding temperature gradient (~200 degree C)	Evaluating observations	Complicated
	Pre–stressed reinforcement	Breakage of tendon parts and wire reinforcement	Pre–stressing losses, reduction in carrying capacity of reinforcement and the structure as a whole	Along the length of the tendon	Visual inspection and indication of force cell in tendons for un–grouted tendons	During inspections and preventive maintenance using force cells installed also tensioning end of tendons (un–grouted tendons)	In compliance with requirements for maintenance and repair of the containment pre–stressing system (un–grouted tendons)	Stress state measuring of the containment prestressing system and the structure (un–grouted tendons)	Stress–strain state analysis of tendon, replacement of tendon (un–grouted tendons)
		Effect of fluid penetrating tendon ducts	Local or total corrosion of prestressing tendon	Along the length of the tendon	Visually determining the moisture content , measuring tendon section after removal of corrosion	During inspections and preventive maintenance (un–grouted tendons)	In compliance with requirements for maintenance and repair of the containment prestressing system (un–grouted tendons)	Stress state measuring of the containment prestressing system according to maintenance schedule (un–grouted tendons)	Condition monitoring and recovery of grease (un–grouted tendons)
		Long term prestressing loading	Tendon relaxation	Along the length of the tendon	By indication of check test pieces and I&C (un–grouted tendons)	Permanently on data reading (un–grouted tendons)	Permissible value in compliance with design requirements (un–grouted tendons)	When data reading in the automatic stress–strain state monitoring system of the structure if existing (un–grouted tendons)	Tensioning and replacement of prestressing tendon (un–grouted tendons)
	Anchorage devices of prestressed	Long term loading of prestressed reinforcement, metal	Cracks in anchorage metal	At the end of the tendon	Visually , presence of chips, and collapse, measuring	During inspections and preventive maintenance,	Absence of cracks, collapse, chips	analysis of defect occurrence,	Tendon replacement (un–grouted

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
	reinforcement	defects			crack opening value (available anchorage)	maintenance acceptance test (available anchorage)		instrumental testing	tendons)
	Corrosion protection system of prestressed reinforcement and anchorage devices	Lack of corrosion protection in separate areas or its degradation	Reinforcement corrosion	Along the length of the tendon and in the anchorage area	Visually (un–grouted tendons)	During inspections and preventive maintenance (un–grouted tendons)	Availability of corrosion protection (un–grouted tendons)	Inspections, examination during survey and preventive maintenance, analysis of the area affected by corrosion (un–grouted tendons)	Recovery of corrosion protection and if necessary replacement of stressed member (un–grouted tendons)
	Containment prestressing system	Prestressed reinforcement relaxation, concrete creep due to stress etc	Reduction prestressing level	Cylindrical an/or dome part of containment	SRP Section 4.5, Lift–off tests, automatic stress–strain state monitoring by means of I&C in structural body and force cells on tensioning ends of tendons (un–grouted tendons)	During inspections, readout of indications according to the schedule of observations (un–grouted tendons)	Permissible value of structural stress–strain state, 10 CFR 54.21(c)(1)(I), (ii) and (iii)	Structural stress–strain monitoring (un–grouted tendons)	Tensioning and replacement of prestressing tendon (un–grouted tendons)
	Carbon steel	Elevated temperature	Reduction of strength and modulus, cracking, deformations, loss of tightness	Base mat, concrete fill–in annulus, Hermetic welds of steel plates and liner to penetrations, Mainly vicinity of high temperature	Plant specific, leak test inspection (pressure decrease, acoustic – ultrasound emission and helium leak tests)	Leak inspection during ILRT, local leak test of welds of hermetic piping penetration – 1 times a year (defined scope of welds)	CC–3400 of ASME Section III, Division 2, design code parameters, no registered leakage	If examination results require evaluation of areas of degradation or repairs, component shall be re–examined during the next inspection period	Repair of defects: welding, injecting, etc
		Humidity	General, pitting and crevice corrosion, loss of material, leakage	Places with moisture condensation (VVER 440: ventilation centre,	Plant specific, See "Structures Monitoring Programme. Visual	Inspection programmes, (Visual examination 1 times a year),	ASME Section XI, Subsection IWE, 10 CFR Part 50, Appendix J,	Engineering analysis should be performed to establish that a	Re–paint in case of paint deterioration. In case of

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
				air traps, bubble condenser, Bottom of the SG compartment, VVER 1000: bottom of containment, PWR: junction of the containment cylinder and intermediate floors and base mat concrete, adjacent to crane girder rails and supports attached to the liner plate)	and ultrasound: measurement of corrosion, measurement of liner thickness. (The Eddy–current scanning is applicable for monitoring the condition of liner wall thickness). Surface examination (e.g., liquid penetrant)	From the time the plant is placed into service, there is an initial inspection interval of 10 years, during which 100% of the required examinations are to be completed	Chapter XI.S6, "Structures Monitoring Program". Loss of thickness under lower productive tolerance (10 % of the nominal thickness),	reduced liner thickness does not degrade the design basis of the liner	degradation impacts on larger surfaces, replacement of part of the liner.
		Cyclic loading	Cracking, deformations, loss of tightness	All steel structures outside	See Chapter XI.S1 and XI.S4.	During inspections and preventive maintenance	ASME Section XI, Subsection IWE 10 CFR Part 50, Appendix J, design code parameters	Early detection of damage, identification of material fatigue	Repair
Seawater	Concrete	Chloride penetration	Corrosion of reinforcement	Seawater channels, tunnels, intake structures	See "Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants"	Inspection programmes, visual examination	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants	Analysis of defect occurrence, instrumental testing	Repair, installing cathodic protection
		Carbonation	Corrosion of reinforcement	Seawater channels, tunnels, intake structures	See "Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants"	Inspection programmes, visual examination	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants	Analysis of defect occurrence, instrumental testing	Repair, installing cathodic protection
		Cracking in the concrete, shrinkage, creep, stresses	Concrete cracking, corrosion of reinforcement	Seawater channels, tunnels, intake structures	See "Regulatory Guide 1.127, Inspection of Water–Control Structures	Inspection programmes, visual examination	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with	Analysis of defect occurrence, instrumental testing	Repair

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
					Associated with Nuclear Power Plants"		Nuclear Power Plants		
		Leeching/efflorence	Deterioration of material structure	Seawater channels, tunnels, intake structures	See "Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants"	Inspection programmes, visual examination	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants	Analysis of defect occurrence, instrumental testing	Repair, inject concrete
		Corrosion of embedded steel	Cracking, loss of bond and loss of material	Seawater channels, tunnels, intake structures	See "Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants"	Inspection programmes, visual examination	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants	Analysis of defect occurrence, instrumental testing	Repair, installing cathodic protection
	Reinforcing steel	General, pitting and crevice corrosion	Loss of material	Steel structures in seawater channels, tunnels and intake structures	See "Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants"	Inspection programmes, visual examination	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants	Analysis of defect occurrence, instrumental testing	Repair, installing cathodic protection
	Steel	Erosion, settlement, sedimentation, frost action, waves, currents, surface runoff, seepage	Loss of material, loss of form	Structures, dams, embankments, reservoirs, channels, canals and ponds	See "Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants"	Inspection programmes, visual examination	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants	Analysis of defect occurrence, instrumental testing	Repair, installing cathodic protection
	Various	Leaching of calcium hydroxide	Increase in porosity and permeability, loss of strength	Exterior above and below grade, foundation	Inspect in accordance with "Structures Monitoring Programme" or	Inspection programmes, visual examination	Chapter XI.S6, "Structures Monitoring Programme"	Analysis of defect occurrence	Repair

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
					"Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants"		Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants		
Water — flowing [2]	Reinforced concrete	Erosion of porous concrete sub foundation	Reduction in foundation strength, cracking, differential settlement	Foundation, sub foundation	Analysis of de–watering system	Inspection programmes, visual examination	Chapter XI.S6, "Structures Monitoring Programme"	Analysis of defect occurrence	Repair, injection of concrete
		Abrasion, cavitations	Loss of material	Exterior above and below grade, foundation, interior slab	See "Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants"	Inspection programmes, visual examination	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants	Analysis of defect occurrence	Repair, protective coating
		Erosion, settlement, sedimentation, frost action, waves, currents, surface runoff, seepage	Loss of material, loss of form	Structures, dams, embankments, reservoirs, channels, canals and ponds	See "Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants"	Inspection programmes, visual examination	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants	Analysis of defect occurrence	Repair
	Various	Pitting and crevice corrosion	Cracking/stress corrosion cracking, loss of material	Tank liner	Plant specific	Inspection programmes, visual examination		Analysis of defect occurrence	Repair
Water — standing [3]	Stainless steel	Pitting and crevice corrosion	Cracking/stress corrosion cracking, loss of material	Fuel pool liner	See "Water Chemistry Programme"	Inspection programmes, visual examination	Water Chemistry Programme	Analysis of defect occurrence	
Treated water or treated borated water	Stainless steel	Chemical attack	Deterioration of material structure	Foundations structures	Visual inspections if possible	Inspection programmes, visual examination	Chapter XI.S6, "Structures Monitoring Programme"	Analysis of defect occurrence	Repair if possible
Soil	Concrete	Settlements	Cracking, stresses	Foundations structures	Visual inspections, levelling	Inspection programmes, visual examination		Analysis of defect occurrence	Repair if possible

Environment	Material	Degradation Mechanisms		Structure Structural Component Inspection / Monitoring				Safety Strategy (AM)	
		Mechanisms	Effect	Location	Method	Frequency	Criterion*	Trending	Mitigation
	Reinforcing steel	Corrosion of embedded steel	Cracking, loss of bond and loss of material	Foundations structures	Visual inspections if possible	Inspection programmes, visual examination	Chapter XI.S6, "Structures Monitoring Programme"	Analysis of defect occurrence	Repair if possible, cathodic protection can be an option
Rock	Concrete	Chemical attack	Deterioration of material structure	Foundations structures	Visual inspections if possible	Inspection programmes, visual examination	Chapter XI.S6, "Structures Monitoring Programme"	Analysis of defect occurrence	Repair if possible
	Reinforcing steel	Corrosion of embedded steel	Cracking, loss of bond and loss of material	Foundations structures	Visual inspections if possible	Inspection programmes, visual examination	Chapter XI.S6, "Structures Monitoring Programme"	Analysis of defect occurrence	Repair if possible, cathodic protection can be an option
Air with borated water leakage [4]	Galvanized steel, aluminium	Boric acid corrosion	Loss of material	Support members, welds, bolted connections, support anchorage to building structure	See "Boric Acid Corrosion"	Inspection programmes, visual examination	Boric Acid Corrosion	Analysis of defect occurrence	Repair of defects
	Steel	Boric acid corrosion	Loss of material	Support members, welds, bolted connections, support anchorage to building structure	See "Boric Acid Corrosion"	Inspection programmes, visual examination	Boric Acid Corrosion	Analysis of defect occurrence	Repair of defects
Aggressive Environment [1]	Reinforced concrete	Corrosion of embedded steel	Cracking, loss of bond and loss of material	Below–grade exterior, foundation	Inspect in accordance with "Structures Monitoring Programme"	Inspection programmes, visual examination	ASME Section XI, Subsection IWL	Analysis of defect occurrence	Repair of defects if possible
		Aggressive chemical attack	Increase in porosity and permeability, cracking, loss of material	Below–grade exterior, foundation	Examine samples of below–grade concrete when excavated	Inspection programmes, visual examination	Chapter XI.S6, "Structures Monitoring Programme"	Analysis of defect occurrence	Repair of defects if possible
				Interior and above–grade exterior	Inspect in accordance with "Structures Monitoring Programme"	Inspection programmes, visual examination	Chapter XI.S6, "Structures Monitoring Programme"	Analysis of defect occurrence	Repair of defects

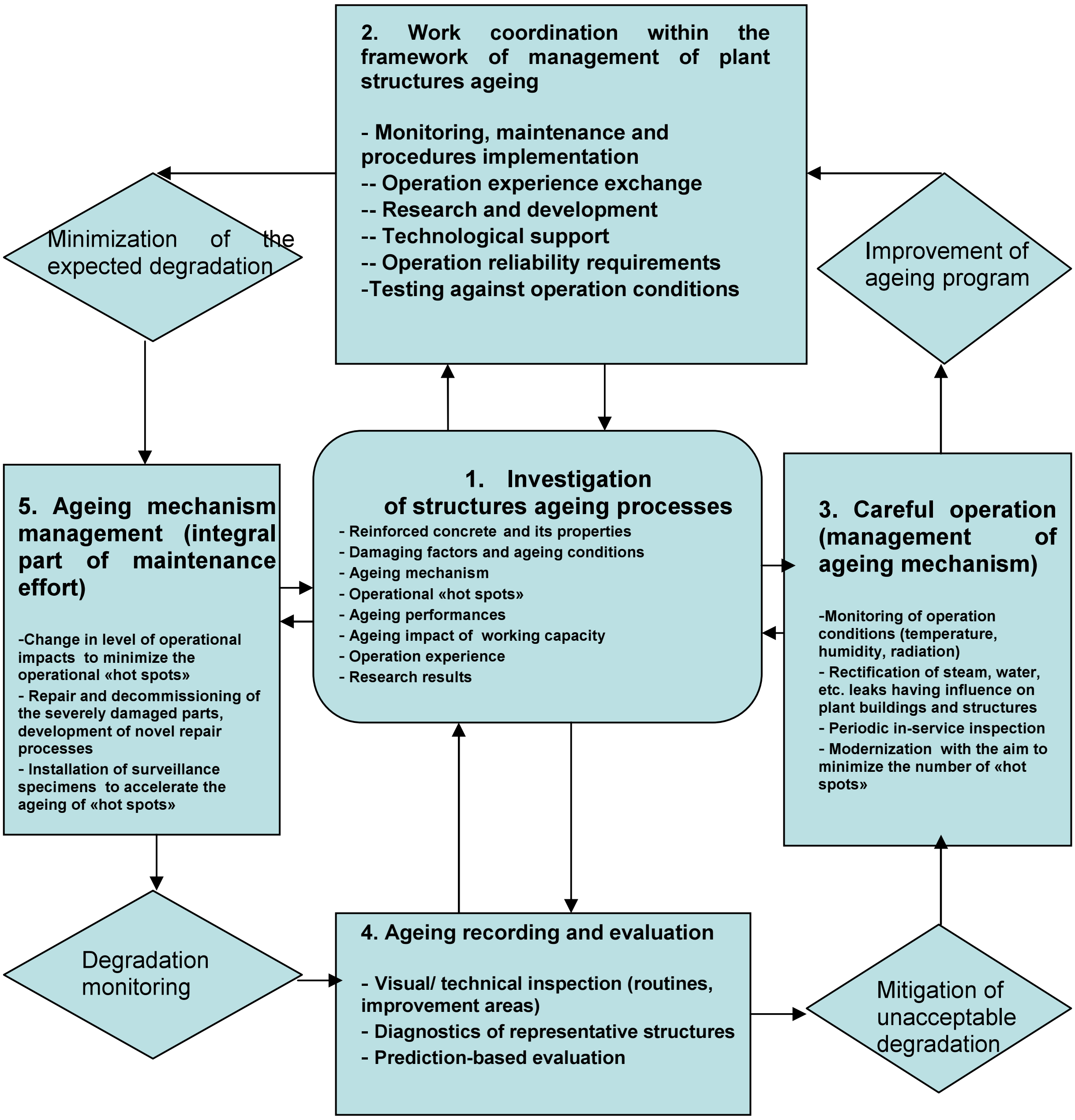

Fig.IV.1. Example of integration of processes into AMP (Russian Federation).

Ageing management programme for plant buildings and structures (example Russian Federation).

IV.11. EXAMPLE OF IN-SERVICE INSPECTION AND MAINTENANCE OF SYSTEMS, STRUCTURES AND COMPONENTS

TABLE IV.9. In-service inspections and monitoring (example WWER–440/213, Hungary)

Identification No of building	**Unit**	**Part of the Building**	**Structure**	**Aim of the monitoring**	**Schedule**	**Description of the measurements**	**evaluation and criteria**
turbine building	all units	turbine foundation	reinforced concrete	vibration monitoring	regularly, start up and stop of turbine	fixed measuring points;	ExpertAlert; evaluation of bending moments
technological and fire water pumping house	all units	the whole building	all structural members;	overall condition of building	yearly	walk down and visual control according to checklist	expert judgment
12 bar fire water pumping house	all units	the whole building	all structural members;	overall condition of building	yearly	walk down and visual control according to checklist	expert judgment
building for xxWP–34b001 tanks	all units	the whole building	all structural members;	overall condition of building	yearly	walk down and visual control according to checklist	expert judgment
auxiliary building	all units	structural members	steel frames and joints	overall condition of building	yearly	walk down and visual control according to checklist; control of joint bolts	expert judgment
cooling water outlet		structural members	reinforced concrete structure	concrete cracking and overall condition	yearly	walk down and visual control; NDE of concrete	expert judgment
main building complex	all units	all buildings, including reactor and auxiliary buildings, stacks, diesel–building and other structures	reference points	building movements; settlement; control of stability of cracks caused by movements	yearly	fixed geodetical measuring points;	3D database; evaluation of building movements; correlation with ground–water table; Criteria: declination of vertical axis of reactor pressure vessel, the functioning of control rods should not be limited.
reactor building	all units	Floor slabs and walls	heavy reinforced concrete	interaction with boric acid media	regularly	investigation of samples; inspection of check–holes	control of mechanical and chemical condition of concrete; comparison of mechanical and chemical properties with reference values
reactor building	all units	Floor slabs and walls	reinforced concrete	control of possible leakages and consequent leaching of concrete	regularly	investigation of samples; inspection of check–holes	control of mechanical and chemical condition of concrete; comparison of mechanical and chemical properties with reference values
reactor building	all units	walls, members	reinforced concrete	control of stability of cracks	regularly	measuring of crack sizes	control of mechanical condition of concrete, comparison of parameters with reference values
turbine building; intermediate	all units	floor slabs and walls	reinforced concrete	control of possible leakages and consequent	regularly	investigation of samples; inspection of check–holes	control of mechanical and chemical condition of concrete; comparison of mechanical and

Identification No of building	**Unit**	**Part of the Building**	**Structure**	**Aim of the monitoring**	**Schedule**	**Description of the measurements**	**evaluation and criteria**
building and galleries				leaching of concrete			chemical properties with reference values
reactor building	all units	Liner	carbon steel	control of corrosion rate	regularly	US measuring of liner wall thickness at the identified places	control of corrosion rate and thickness; focused investigation if the overall leak–tightness is less than the reference value for the given unit (the reference leak rate is less than the allowable)
reactor building	all units	Floor slabs and walls	decontaminable coating and painting	control of condition of coating and painting	regularly	walk down and visual control according to checklist	expert judgment
auxiliary building	all units	Floor slabs and walls	decontaminable coating and painting	control of condition of coating and painting	regularly	walk down and visual control according to checklist	expert judgment
main building complex	all units	all building parts	fire protection doors	control of condition of doors	regularly	walk down and visual control according to checklist, fluorescent test	expert judgment

TABLE IV.10 Monitoring of plant specific LTO significant degradation mechanisms for selected buildings and structures important to safety (WWER–440, WWER–1000, BWR and PWR)

WWER 440 Containment Structures					
Structure / building	Component/ part	Materials	Stressors (Environment, loading, etc)	Location/Zone	Good practice
Hermetic zone of the Reactor Building including Bubble condenser tower and Air trop. Chambers	Reinforced structure, foundations	Concrete	Freeze–thaw	Locations of surface cracking and spalling	Frequency of inspections 1 times a year
		Concrete	Aggressive chemical attack	Locations of increased porosity or spalling	Frequency of inspections 1 times a year
		Concrete – reinforcing bars	Corrosion carbon steel	Locations of cracking or spalling occurrence	Frequency of inspections 1 times a year
		Concrete	Settlement	Settlement monitoring of building	Frequency of inspections 1 times a year
		Concrete	Elevated temperature	Locations of cracking near hot pipe penetrations	Frequency of inspections 1 times a year
		Concrete	Irradiation	Monitoring and specimen testing	Frequency of inspections 1 times a year
		Concrete	Action of moisture	Deterioration of crystalline structure in locations with elevated temperatures	Frequency of inspections 1 times a year
	Liner, liner anchors, welds	Carbon steel	Corrosion	Loss of leak–tightness	Frequency of inspections 1 times a year
		Carbon steel – paints	Mechanical and heat effects	Locations of paint delamination	Frequency of inspections 1 times a year
		Stainless steel	Corrosion, Mechanical and heat effects	Locations of surface deterioration or cracks	Frequency of inspections 1 times a year
	Load bearing steel structures	Carbon steel	Loading effect, settlement	Locations of increased deformations or crack occurrence	Frequency of inspections 1 times a year
	Personnel airlocks, equipment hatch	Carbon steel	Corrosion	Locations of paint delamination	Frequency of inspections 1 times a year
		Carbon steel	Mechanical wear of locks, hinges and closure mechanisms	Locations of surface deterioration	Frequency of inspections 1 times a year
	Seals and gaskets of airlocks and hatch	Various	Deterioration of seals and gaskets	Loss of leak–tightness	Frequency of inspections 1 times a year; after use

WWER 440 Reactor building (Including spent fuel pool)					
Structure / building	Component/ part	Materials	Stressors (Environment, loading, etc)	Location/Zone	Good practice
Non Hermetic part of the Reactor Building and spent fuel pool	Wall, bottom ceiling	Concrete	Aggressive chemical attack	Locations of increase porosity and cracking or spalling	Frequency of inspections as may be required
		Concrete – reinforcing bars	Corrosion carbon steel	Locations of cracking and spalling	Frequency of inspections as may be required
		Concrete	Settlement	Monitoring of building settlement	Frequency of inspections 1 times a year
		Concrete	Displacement	Overloaded locations, distortions, increased stress	Frequency of inspections 2 times a year
	Inside stainless liner	Stainless steel	Corrosion	Loss of leak tightness of the pool	Continuous monitoring (Spent fuel pool), Frequency of inspections 1–times in 7 day (Emergency H_3BO_3 tank)
					Frequency of inspections 1 times a year
		Stainless steel	Aggressive chemical attack	Loss of leak tightness of the pool	Continuous monitoring (Spent fuel pool), Frequency of inspections 1–times in 7 day (Emergency H_3BO_3 tank)
					Frequency of inspections 1 times a year
		Stainless steel	Mechanical and heat effects	Locations of deformations or crack occurrence	Continuous monitoring (Spent fuel pool), Frequency of inspections 1–times in 7 day (Emergency H_3BO_3 tank)
					Frequency of inspections 1 times a year

Main concrete and steel structures of other buildings					
Structure / building	Component/ part	Materials	Stressors (Environment, loading, etc)	Location/Zone	Good practice
Longitudinal and Transversal intermediate buildings, Auxiliary building, Diesel generator station, Pump station for technical service water	Wall, bottom ceiling	Concrete	Aggressive chemical attack	Locations of increase porosity or cracking and spalling	Frequency of inspections 1 times a year.
		Concrete – reinforcing bars	Corrosion carbon steel	Locations of surface cracking and spalling	Frequency of inspections 1 times a year
		Concrete	Settlement	Locations of cracks occurrence or deformations	Frequency of inspections 1 times a year
		Concrete	Displacement	Locations of overloaded areas	Frequency of inspections 1 times a year
	Inside stainless liner, carbon steel liner	Stainless and carbon steel	Corrosion	Locations of observed loss of material or loss of leak–tightness	Frequency of inspections 1 times a year
		Stainless and carbon steel	Aggressive chemical attack	Locations exposed to chemical attack	Frequency of inspections 1 times a year
		Stainless and carbon steel	Mechanical effects	Locations of cracking or deformations	Frequency of inspections 1 times a year
	Load bearing steel structures	Carbon steel	Loading effect, settlement,	Locations of joint defects or deformations	Frequency of inspections 1 times a year

WWER 1000 – prestressed containment					
Structure / building	**Component/ part**	**Materials**	**Stressors (Environment, loading, etc)**	**Degradation consequences**	**Good practice**
Containment WWER–1000 Sealed Enclosure System	*Pre–stressed reinforcing cable (PRC)*	Reinforcing–bar steel	Moisture in channelling devices (plastic tubes intended for housing bandled bars) Fallibility of the technology of PRC manufacturing	Corrosion of PRC wires, early failure of PRC.	Repairing waterproofing on the containment's dome, installing drains at channelling devices, improving the PRC manufacturing technology
	Steel containment liner	Corrosion–resistant protective lining	Deviations from the technology of corrosion–resistant lining laying during installation and repair	Failure of integrity of the corrosion–resistant lining	Repair of the protective lining by applying a well–proven technology
	Penetrations (isolating valves of the ventilation system passing through the containment).	Carbon steel	Imperfection of the isolating valve design, failure to comply with the isolating valve maintenance technology	Isolating valve leak–tightness failure	Replacing isolating valves with the new ones made by another manufacturer; Improvement of the isolating valve maintenance technology
	Air locks (the main and emergency ones).	Carbon steel equipment	Deviations from the air lock maintenance technology There is no automatic system for air lock tightness monitoring	Air lock leak–tightness failure during operation	A new technology of maintenance should be developed and local leak tightness tests should be performed in course of an outage

WWER 1000 – prestressed containment

Structure / building	**Component/ part**	**Materials**	**Stressors (Environment, loading, etc)**	**Degradation consequences**	**Good practice**
Containment WWER–1000	*Automated monitoring system of the containment deflected mode (AMS CDM)*	Sensors installed in the containment concrete during construction	Deviations from the sensor (containment deflected mode monitoring system) installation technology. Deviations from the maintenance technology intended for the secondary communication circuits and sensor indication recording instruments. Physical ageing and obsolescence of instrumentation of the automated monitoring system of the containment deflected mode within a containment	Failure of sensor of the containment deflected mode monitoring system	Installing the force sensor measurement system at "pulling" ends of bundled bars to monitor the containment deflected mode
	Pre–stressed system	Tendon's wires	Pre–stressing loading 1000 ton–forces		Number of wires in tendon was increased from 450 till 456. It was justified that maximal pre–stressing force may be decreased from 1000 till 875 ton–forces.
	Pre–stressed system	Tendon's wires	Design of thimble		Design of thimble was modified
Containment WWER 1000	*Automatic monitoring system of the containment deflected mode (AMS CDM)*	Sensors installed in the containment concrete and reinforcement during construction.	Deviations from the sensor's (containment deflected mode monitoring system) installation technology. Physical ageing and obsolescence of instrumentation.	Failure of sensors of the containment deflected mode monitoring system	Installing of new additional Automatic Monitoring System for the Tendons Stressing Forces /AMSTSF/ for real–time control of the forces in bundles /tendons/.
	Pre–stressed system	Pre–stressing tendons.	Design and technological features of the pre–stressing tendons preparing.	Accelerated relaxation of the design–type pre–stressing tendons.	Development and implementation of new–type pre–stressing tendons with respective anchor details.

PWR Building

Structure/ building	Component/part	Materials	Stressors (Environment, loading, etc)	Location/zone	Good practice
Containment structures	Basemat	Reinforced concrete	Groundwater or soil (aggressive chemical attacks followed of corrosion on reinforcement)	Underground	Inspections in accordance with ASME Section XI, Subsection IWL
			Water– flowing (Leaching)	Underground	Inspections in accordance with ASME Section XI, Subsection IWL
			Settlements (Basemats founded on soil)	Underground	Levelling and trending of measurements to see changes, Inspections in accordance with ASME Section XI, Subsection IWL
	Cylindrical wall, buttresses	Reinforced concrete	Air – indoor uncontrolled or outdoor	Indoor or outdoor	Inspections in accordance with ASME Section XI, Subsection IWL
	Dome, ring girder	Reinforced concrete	Air – indoor uncontrolled or outdoor	Indoor or outdoor	Inspections in accordance with ASME Section XI, Subsection IWL
	Tendons, anchorage components	Steel	Air – indoor uncontrolled or outdoor	Indoor or outdoor	For ungrouted tendons measuring prestress forces and trending results, Inspections in accordance with ASME Section XI, Subsection IWL or Concrete Containment Tendon Prestress TLAA
	Liner, liner anchors, integral attachments	Carbon steel	Corrosion caused by impurities, low pH–value (especially embedded parts and junctions	Indoor or outdoor	ASME Section XI, Subsection IWE or 10 CFR Part 50, Appendix J
	Penetration sleeves, penetration bellows	Steel, stainless steal, dissimilar metal welds	Air – indoor uncontrolled or outdoor	Indoor or outdoor	ASME Section XI, Subsection IWE and 10 CFR Part 50, Appendix J or Containment Liner plate and Penetration Fatigue Analysis

	Personnel airlock, equipment hatch, CRD hatch	Steel	Air – indoor uncontrolled or outdoor	Indoor or outdoor	ASME Section XI, Subsection IWE or 10 CFR Part 50, Appendix J
	Locks, hinges and closure mechanisms	Steel	Air – indoor uncontrolled or outdoor	Indoor or outdoor	
	Seals, gaskets and moisture barriers (caulking, flashing, and other sealants)	Elastomers, rubber and other similar materials	Air – indoor uncontrolled or outdoor	Indoor or outdoor	ASME Section XI, Subsection IWE
	Internal structures	Reinforced concrete	High temperatures (Extremely high temperatures during long time causing decomposition of the concrete	Biological shield, indoor	
Safety Related Structures	All concrete elements	Reinforced concrete	Air – indoor uncontrolled	Indoor	Plant Specific or Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants
			Any	Indoor or outdoor	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants
			Ground water/soil	Indoor or outdoor	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants
	Below–grade exterior, foundation	Reinforced concrete	Aggressive environment	Underground	
			Ground water/soil	Underground	
	Exterior above and below grade, foundation, interior slab	Reinforced concrete	Air – Indoor uncontrolled or outdoor	Indoor or outdoor	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants

			Water – flowing	Underground	ASME Section XI, Subsection IWL or Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants
	Foundation, subfoundation	Reinforced concrete, porous concrete	Water – flowing under foundation	Underground	
	Interior and above grade exterior	Reinforced concrete	Aggressive environment	Indoor or outdoor	
			Air – indoor uncontrolled or outdoor	Indoor or outdoor	
	All structural steel	Steel, copper alloys	Air – indoor uncontrolled or outdoor	Indoor or outdoor	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants
	RPV support shoes for PWR with nozzle supports, steam generator supports	Lubrite	Air – indoor uncontrolled	Indoor	ASME Section XI, Subsection IWF
	Fuel pool liner	Stainless steel, dissimilar metal welds	Treated water or treated borated water	Indoor	Water Chemistry Programme
	Cooling water channels and tunnels	Reinforced concrete	Seawater (chloride penetration causing corrosion of the reinforcement)	Tunnels, splash zones	
	Dams, embankments, reservoirs, channels, canals and ponds	Various	Water – flowing or standing	Outdoor	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants
	Tank liner	Stainless steel	Water – standing	Indoor	

Component supports and other structures	Building concrete at locations of expansion and grouted anchors, grout pads for support base plates	Reinforced concrete, grout	Air – indoor uncontrolled or outdoor	Indoor or outdoor	
	Constant and variable load spring hangers, guides, stops, sliding surfaces, design clearances, vibration isolators	Steel and non–steel materials	Air – indoor uncontrolled or outdoor	Indoor or outdoor	ASME Section XI, Subsection IWF
	Support members, welds, bolted connections, support anchorage to building structure	Galvanized steel, aluminium	Air – indoor uncontrolled	Indoor	
			Air with borated water leakage	Indoor	
			Air – outdoor	Outdoor	
		Stainless steel	Air – indoor uncontrolled	Indoor	
			Air with borated water leakage	Indoor	
		Steel	Air – indoor uncontrolled	Indoor	Metal Fatigue or Structures Monitoring Programme
			Air – indoor uncontrolled or outdoor	Indoor or outdoor	ASME Section XI, Subsection IWF
			Air with borated water leakage	Indoor	
		Aluminium	Air – indoor uncontrolled	Indoor	
	Sliding support bearings and sliding support surfaces	Lubrite	Air – outdoor	Outdoor	
	RPV support shoes for PWR with nozzle supports, other supports	Lubrite	Air – indoor uncontrolled	Indoor	
	Vibration isolation elements	Non–metallic	Air – indoor uncontrolled or outdoor	Indoor or outdoor	

BWR Buildings

Structure/ building	Component/part	Materials	Stressors (Environment, loading, etc)	Location/zone	Good practice
Containment structures	Basemat	Reinforced concrete	Groundwater or soil (aggressive chemical attacks followed by corrosion of reinforcement)	Underground	ASME Section XI, Subsection IWL
			Water– flowing (Leaching)	Underground	ASME Section XI, Subsection IWL
			Settlements (Basemats founded on soil)	Underground	Levelling and trending of measurements to see changes
	Cylindrical wall, containment wall	Concrete	Air –Indoor uncontrolled or outdoor	Indoor or outdoor	ASME section XI subsection IWL
	Prestressed tendons, tendon anchorage components	Steel	Shrinkage, creep and relaxion causing prestress losses, Air – indoor uncontrolled or outdoor	Indoor or outdoor	For ungrouted tendons measuring prestress forces and trending results, ASME Section XI, Subsection IWL or Concrete Containment Tendon Prestress
	Liner, liner anchors, integral attachments	Carbon steel	Corrosion caused by impurities, low pH–value (especially embedded parts and junctions)	Indoor	ASME Section XI, Subsection IWE and 10 CFR Part 50, Appendix J or Containment Liner Plate and Penetration Fatigue Analysis
	Penetration sleeves, penetration bellows	Steel, dissimilar metal welds	Air – indoor uncontrolled	Indoor	ASME Section XI, Subsection IWE or 10 CFR Part 50, Appendix J or Containment Liner Plate and Penetration Fatigue Analysis
	Personnel airlock, equipment hatch, CRD hatch	Steel	Air – indoor uncontrolled or outdoor	Indoor or outdoor	ASME Section XI, Subsection IWE or 10 CFR Part 50, Appendix J
	Locks, hinges, and closure mechanisms	Steel	Air – indoor uncontrolled or outdoor	Indoor or outdoor	

	Seals, gaskets and moisture barriers	Elastomers, rubber and other similar materials	Air – indoor uncontrolled or outdoor	Indoor or outdoor	ASME Section XI, Subsection IWE
	Drywell, torus, drywell head, embedded shell and sand pocket regions, drywell support skirt, torus ring girder, downcomers, ECCS suction header, suppression chamber, downcomer pipes, region shielded by diaphragm floor	Steel	Air – indoor uncontrolled or treated water	Indoor	ASME Section XI, Subsection IWE or 10 CFR Part 50, Appendix J
	Torus, vent line, vent line bellows, downcomers	Stainless steel, steel	Air – indoor uncontrolled	Indoor	ASME Section XI, Subsection IWE and 10 CFR Part 50, Appendix J or Containment Liner Plate and Penetration Fatigue Analysis
	Suppression pool shell, unbraced downcomers	Steel, stainless steel, dissimilar metal welds	Air – indoor uncontrolled	Indoor	ASME Section XI, Subsection IWE and 10 CFR Part 50, Appendix J or Containment Liner Plate and Penetration Fatigue Analysis
	Vent header, downcomers	Stainless steel, steel	Air– indoor uncontrolled or treated water	Indoor	ASME Section XI, Subsection IWE or 10 CFR Part 50, Appendix J or Containment Liner Plate and Penetration Fatigue Analysis

	Internal structures	Reinforced concrete	High temperatures (Extremely high temperatures during long time causing decomposition of the concrete	Biological shield, indoor	
Safety Related Structures	All concrete elements	Reinforced concrete	Air – indoor uncontrolled	Indoor	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants
			Any	Indoor or outdoor	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants
			Ground water/soil	Underground	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants
	Below–grade exterior, foundation	Reinforced concrete	Aggressive environment	Underground	
			Ground water/soil	Underground	
	Exterior above and below grade, foundation, interior slab	Reinforced concrete	Air – outdoor	Underground	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants
			Water – flowing	Underground	ASME Section XI, Subsection IWL or Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants
	Foundation, subfoundation	Reinforced concrete, porous concrete	Water – flowing under foundation	Underground	
	Interior and above grade exterior	Reinforced concrete	Aggressive environment	Indoor or outdoor	
			Air – indoor uncontrolled or outdoor	Indoor or outdoor	

	All structural steel	Steel, copper alloys	Air – indoor uncontrolled or outdoor	Indoor or outdoor	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants
	Radial beam seats in BWR drywell, steam generator supports	Lubrite	Air – indoor uncontrolled	Indoor	ASME Section XI, Subsection IWF or Structures Monitoring Programme
	Fuel pool liner	Stainless steel, dissimilar metal welds	Treated water or treated borated water	Indoor	Water Chemistry Programme
	Dams, embankments, reservoirs, channels, canals and ponds	Various	Water – flowing or standing	Outdoor	Regulatory Guide 1.127, Inspection of Water–Control Structures Associated with Nuclear Power Plants
	Cooling water channels and tunnels	Reinforced concrete	Seawater (chloride penetration causing corrosion of the reinforcement)	Tunnels, splash zones	
	Tank liner	Stainless steel	Water – standing	Indoor	
Component supports and other structures	Building concrete at locations of expansion and grouted anchors, grout pads for support base plates	Reinforced concrete, grout	Air – indoor uncontrolled or outdoor	Indoor or outdoor	
	Constant and variable load spring hangers, guides, stops, sliding surfaces, design clearances, vibration isolators	Steel and non–steel materials	Air – indoor uncontrolled or outdoor	Indoor or outdoor	ASME Section XI, Subsection IWF
	Support members, welds, bolted	Galvanized steel,	Air – indoor uncontrolled	Indoor	

	connections, support anchorage to building structure	aluminium	Air with borated water leakage	Indoor	
			Air – outdoor	Outdoor	
		Stainless steel	Air – indoor uncontrolled	Indoor	
			Air with borated water leakage	Indoor	
		Steel	Air – indoor uncontrolled	Indoor	Metal Fatigue or Structures Monitoring Programme
			Air – indoor uncontrolled or outdoor	Indoor or outdoor	ASME Section XI, Subsection IWF
			Air with borated water leakage	Indoor	
		Aluminium	Air – indoor uncontrolled	Indoor	
	Sliding support bearings and sliding support surfaces	Lubrite	Air – outdoor	Outdoor	
	Radial beam seats in BWR drywell, other supports	Lubrite	Air – indoor uncontrolled	Indoor	
	Vibration isolation elements	Non–metallic	Air – indoor uncontrolled or outdoor	Indoor or outdoor	

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GLOSSARY

Ageing management

Engineering, operations and maintenance actions to control within acceptable limits ageing degradation and wear out of structures, systems or components.

Examples of engineering actions include design, qualification, and failure analysis. Examples of operations actions include surveillance, carrying out operational procedures within specified limits, and performing environmental measurements.

Design basis

The range of conditions and events taken explicitly into account in the design of a facility, according to established criteria, such that the facility can withstand them without exceeding authorized limits by the planned operation of safety systems.

Design life

Period during which a System, Structure or Component is expected to function within criteria

Items important to safety

See plant equipment.

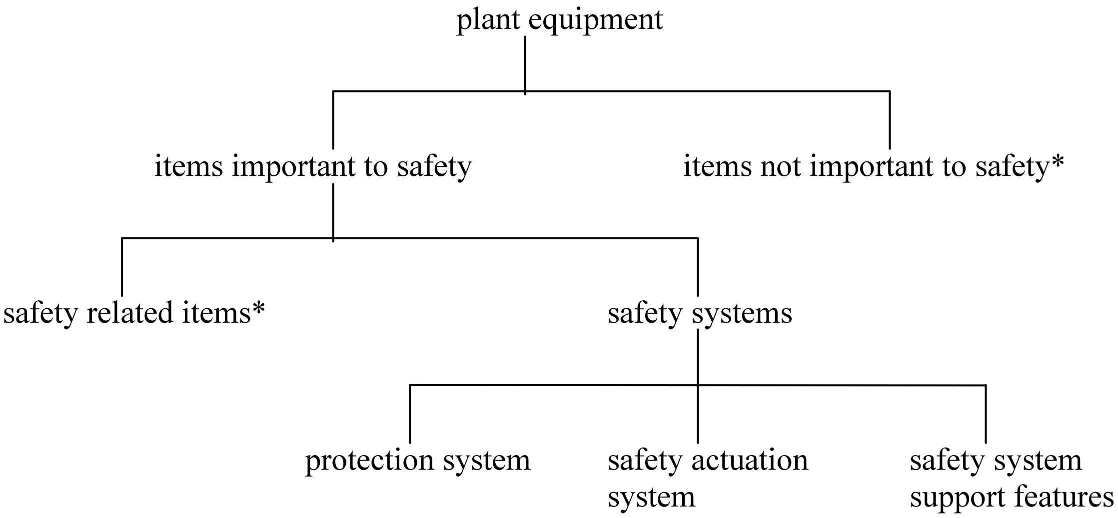
Long term operation

Operation beyond an initial time frame set forth in design, standards, licence, and/or regulations, that is justified by safety assessment, considering life limiting processes and features for systems, structures and components.

Periodic safety review

A systematic reassessment of the safety of a nuclear power plant carried out at regular intervals to deal with the cumulative effects of ageing, modifications, operating experience, technical developments and site aspects that are aimed at ensuring a high level of safety throughout plant service life.

Plant equipment



* In this context, an ‘item’ is a structure, system or component.

Item important to safety

An item that is part of a safety group and/or whose malfunction or failure could lead to radiation exposure of the site personnel or members of the public.

– Items important to safety include:

  - those structures, systems and components whose malfunction or failure could lead to undue radiation exposure of site personnel or members of the public;
  - those structures, systems and components which prevent anticipated operational occurrences from leading to accident conditions; and
  - those features which are provided to mitigate the consequences of malfunction or failure of structures, systems or components.

Protection system

System which monitors the operation of a reactor and which, on sensing an abnormal condition, automatically initiates actions to prevent an unsafe or potentially unsafe condition.

– The “system” in this case encompasses all electrical and mechanical devices and circuitry, from sensors to actuation device input terminals.

Safety actuation system

The collection of equipment required to accomplish the necessary safety actions when initiated by the protection system.

Safety related item

An item important to safety which is not part of a safety system.

Qualified life

Period for which a system, structure or component has been demonstrated, through testing, analysis or experience, to be capable of functioning within acceptance criteria during specified operating conditions while retaining the ability to perform its safety function in a design basis accident or earthquake

Safety limit

The safety limit is a critical value of an assigned parameter associated with the failure of a system or a component (e.g. loss of coolable core geometry).

Safety margin (absolute terms)

The safety margin is the distance between an acceptance criterion and a safety limit in figure I.1. below. If an acceptance criterion is met, the available safety margin is preserved. (Definition from IAEA-TECDOC-1418)

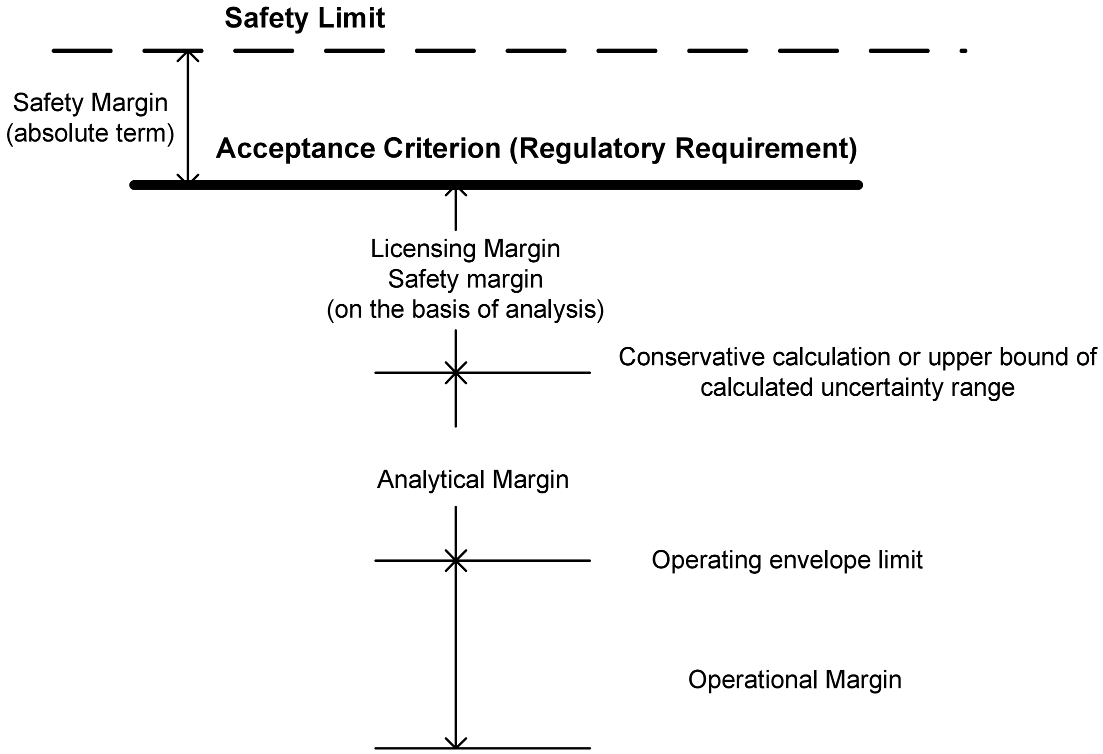


FIG. I.1. The various types of margins for a nuclear power plant.

Safety system

A system important to safety, provided to ensure the safe shutdown of the reactor or the residual heat removal from the core, or to limit the consequences of anticipated operational occurrences and design basis accidents.

Safety systems consist of the protection system, the safety actuation systems and the safety system support features. Components of safety systems may be provided solely to perform safety functions or may perform safety functions in some plant operational states and non-safety functions in other operational states.

Safety system support features

The collection of equipment that provides services such as cooling, lubrication and energy supply required by the protection system and the safety actuation systems.

SC

Abbreviation for the terms Structure or Component

SSC

Abbreviation for the terms System, Structure or Component

Time limited ageing analysis (TLAA)

Time limited ageing analysis (TLAA) or residual life assessment is an assessment of an identified ageing effect (time-dependent degradation due to normal service conditions) and certain plant-specific safety analyses that are based on an explicitly specified length of plant life (e.g., 40 years).

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WORKING GROUP 1 MEETINGS

IAEA, Vienna, Austria: 13–15 January 2004
SIP, Stockholm, OKG, Oskarshamn, Sweden: 23–27 August 2004
US NRC, Washington D.C., USA, 16–20 May 2005
NRI, Prague, Czech Republic: 14–16 November 2005

WORKING GROUP 2 MEMBERS

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Ratkai, S.	Paks NPP, Hungary
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WORKING GROUP 2 MEETINGS

IAEA, Vienna, Austria: 4–6 February 2004
IAEA, Vienna, Austria: 16–18 November 2004
OKG NPP, Oskarshamn, Sweden: 30 May–2 June 2005
IAEA, Vienna, Austria: 31 Oct–2 November 2005

WORKING GROUP 3 MEMBERS

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WORKING GROUP 3 MEETINGS

IAEA, Vienna, Austria: 10–12 February 2004
G.Kuzmich Training Centre, Kiev, Ukraine: 25–27 May 2004
OKG NPP, Oskarshamn, Sweden: 30 May–2 June 2005
IAEA, Vienna, Austria: 15–17 November 2005

WORKING GROUP 4 MEMBERS

Auluck, R. (Secretary)	Nuclear Regulatory Commission, USA
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Benacka, D.	Mochovce NPP, Slovak Republic
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WORKING GROUP 4 MEETINGS

IAEA, Vienna, Austria: 3–5 March 2004
IAEA, Vienna, Austria: 17–19 January 2005
IAEA, Vienna, Austria: 17–19 May 2005
IAEA, Vienna, Austria: 19–21 October 2005