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Main deficiencies and corrective measures of nuclear power plants in ageing management for safe long term operation

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ABSTRACT

This paper presents the analysis of the main technical deficiencies of nuclear power plants (NPPs) in ageing management development, implementation, review and improvement to support safe long term operation (LTO) and the main corrective measures which are typically performed. It focuses on technical aspects connected with management of physical ageing of NPP structures, systems and components (SSCs). It uses as a basis results of IAEA Safety Aspects of Long Term Operation (SALTO) missions performed between 2005 and 2016 (see also paper NED8805 in Nuclear Engineering and Design in May 2016 and paper NED9185 in Nuclear Engineering and Design in March 2017) and the personal experiences of the authors with preparation of NPPs for safe LTO. Chapter 1 provides a brief introduction of the current status of the NPPs' ageing management in connection with LTO. Chapter 2 provides an overview of SALTO peer review service results with a focus on deficiencies related to ageing management and topics connected with development, implementation, review and improvement of systematic ageing management in NPPs. Chapter 3 discusses the main corrective measures NPPs typically face to develop, implement and review ageing management for safe LTO. Chapter 4 summarizes the current status of the NPP fleet in connection with LTO and outlines further steps needed in preparation for safe LTO.

1. Introduction

As described in paper NED9185 in Nuclear Engineering and Design in March 2017, the world's fleet of nuclear power plants (NPPs) is, on average, more than 30 years old (https://www.iaea.org/pris). Most of the countries are planning to extend the life time of their NPPs beyond the time frame originally anticipated (typically 30–40 years) to 50–60 years. The US NRC is currently finalizing the guidance to facilitate extending the safe operation of the US fleet up to 80 years.

In connection with these efforts, the importance of systematic and effective ageing management has significantly increased. Ageing management for NPPs is implemented to ensure that the effects of ageing will not prevent structures, systems and components (SSCs) from being able to accomplish their required safety functions throughout the lifetime of the NPP (including its long term operation (LTO) and decommissioning) and it takes account of changes that occur with time and use. This requires addressing both the physical ageing effects of SSCs, resulting in degradation of their performance characteristics, and the non-physical ageing (obsolescence) of SSCs, i.e. their becoming out of date in comparison with current knowledge, codes, standards and regulations, and technology.

To review the preparedness for safe LTO, the IAEA developed a Safety Aspects of Long Term Operation (SALTO) peer review service, the methodology of which is discussed in a paper NED8070 in Nuclear Engineering and Design in September 2014. Chapter 2 provides an overview of SALTO peer review service results with a focus on deficiencies related to ageing management and topics connected with development, implementation and review of systematic ageing management in NPPs as an outcome of 29 SALTO peer review missions and 4 LTO modules of Operational Safety Review Team (OSART) missions conducted at 22 NPPs in 18 Member States from 2005 to 2016.

As required by the IAEA document Safety of Nuclear Power Plants: Commissioning and Operation (Specific Safety Requirements SSR 2/2, Vienna, 2016), several steps shall be performed to demonstrate preparedness for safe LTO including setting the scope of SSCs for LTO assessment, revalidation of time limited ageing analyses (TLAAs), ageing management review (AMR); and review and improvement of ageing management programmes (AMPs). Chapter 3 discusses the main challenges which NPPs typically faced to in last decade to develop, implement, review and improve ageing management for safe LTO and their suitable solutions.

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2. IAEA SALTO peer review results

As described in paper NED8070 in Nuclear Engineering and Design in September 2014, the IAEA has developed a SALTO peer review service (IAEA Services Series No. 26, Vienna, 2014) to review preparedness of NPPs for safe LTO with focus on ageing aspects.

By 2016, 29 SALTO peer review missions had been conducted at 18 NPPs in 15 IAEA Member States. For 4 NPPs in 3 IAEA Member States, an LTO module was reviewed as a part of an OSART mission. Many other expert missions based on the SALTO guidelines were also performed. These missions resulted in more than 200 recommendations and suggestions. Their overview is provided in a paper NED8805 in Nuclear Engineering and Design in May 2016.

This chapter provides an overview of the most important deficiencies related to ageing management and topics connected with development, implementation, review and improvement of systematic ageing management in NPPs.

These issues can be divided into three categories:

1. Scope setting of SSCs;
2. AMR;
3. AMPs.

The main deficiencies in the category 'Scope setting of SSCs' are:

- Unclear methodology for scope setting of SSCs;
- Incomplete scope of SSCs for LTO assessment;
- The scoping methodology not addressing appropriately non-safety related SCs whose failure could affect the function of safety-related SCs;
- The scoping methodology not ensuring that active components are addressed adequately;
- Poorly documented scope of SSCs for LTO assessment.

The main deficiencies in the category 'Ageing management review ' are:

- Unclear description of AMR in plant documentation;
- Late initiation and completion of the condition assessment and AMR;
- Operating experience from the whole operational history of the plant not considered adequately for LTO;
- External operating experience not appropriately considered;
- Incomplete AMR (for all necessary structures and components (SCs)) or not appropriately documented;
- Not all potential ageing effects or degradation mechanisms addressed by AMR (e.g. environmentally assisted fatigue, thinning due to cavitation, vibration fatigue, thermal fatigue, boric acid corrosion, erosion corrosion of the welds, reactor pressure vessel (RPV) boric acid corrosion).

The main deficiencies in the category 'Ageing management programmes' are:

- Relevant data from existing plant activities not provided to and used in the AMPs for LTO;
- Lack of effective AMPs or existing plant programmes relevant for LTO (they do not contain all nine attributes of an effective programme as recommended in draft IAEA Safety Guide SSG-48, Vienna, 2017);
- Missing AMPs (that need to be developed) and AMPs that were identified as important but not implemented yet;
- Plant specific items missing from the scope of AMPs;
- AMPs not fully implemented or effective to properly address ageing effects (discrepancies are frequently found in AMPs for RPV, buried piping, cables, pre-stressed tendons, concrete containment, spent fuel pool);
- Codes, standards and guidance of different origin applied selectively or inconsistently without prudent reconciliation;
- The actual environmental conditions not monitored to ensure that ageing analyses are based on conservative data;
- Insufficient cooperation between ageing management and other plant programmes/ departments, e.g. maintenance, equipment qualification, chemistry, in service inspection surveillance and monitoring;
- No inspections and tests during the LTO period aiming at preserving qualification and functionality.

This overview demonstrates the range and nature of most frequent findings related to ageing management at the phase when NPP is in preparation for safe LTO.

3. Corrective measures of NNPs in ageing management for safe LTO

This chapter provides an overview of the most important technical corrective measures related to ageing management and topics connected with development, implementation, review and improvement of systematic ageing management in NPPs. Addressing these issues is a fundamental part of demonstration of preparedness for safe LTO:

- Establishment of systematic scope setting ('scoping') process to identify SSCs subject to AMR;
- Performance of AMR for in-scope SSCs to ensure and demonstrate that ageing will be effectively managed;
- Development, implementation, review and improvement of AMPs to efficiently manage identified ageing effects.

A draft IAEA Safety Guide entitled 'Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants' (draft IAEA Safety Guide SSG-48, Vienna, 2017) provide in its Section 5 the latest internationally agreed guidance on all of these three topics.

The IAEA publication entitled 'Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL)' (Safety Reports Series No. 82, IAEA, Vienna, 2015) provides practical guidance to assist Member States in implementing, maintaining and improving effective AMPs and in the revalidation of time limited ageing analyses.

3.1. Scope setting of SSCs

The IAEA requires in publication 'Safety of Nuclear Power Plants: Commissioning and Operation' (Specific Safety Requirements SSR 2/2, Vienna, 2016) in Requirement 16 'setting the scope of SSCs' for justification of safe LTO. Potential ageing effects and degradation mechanisms of these SSCs shall be assessed and managed for the intended period of LTO.

Draft IAEA Safety Guide SSG-48 recommends which SSCs should be included in the scope of ageing management and LTO and which SSCs can be excluded. It also provides guidance on documenting the scope setting process and results.

The plants should devote an adequate attention to the scope setting methodology, including appropriate and timely application, as well as the completeness of the outcome. Methodology should identify which list or database of plant SSCs will be used as a master list. A master list should contain IDs of all plants SSCs to the level of detail sufficient for managing ageing. If this kind of master list is not available, provisions should be described in the methodology to ensure the completeness of scope setting results.

Criteria for including SSCs in the scope should be clearly described. It should be also clearly stated which SSCs can be excluded from the