SALTO project evaluation - WG4

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1. INTRODUCTION

Many of the operating nuclear power plants are approaching their design life. The operators are facing the choices of either decommissioning the plants or upgrading the plants for a longer operating life, providing that required safety can be maintained. Some Member States (MS) have already developed regulations and regulatory infrastructures for operations beyond the originally designed life, but many others have just started the development and/or planning.

In response, the IAEA initiated Extrabudgetary Programme on Safety Aspects of Long Term Operation (SALTO) of Water Moderated Reactors (Programme). The Programme's objectives are to assist those Member States considering LTO of water moderated reactors in how best to reconcile the related processes and practices; how to establish a general LTO framework; and finally, it provides a forum in which Member States can freely exchange information.

The main goal of project was to develop an internationally agreed document that will provide MS with specific guidance for long term operation.

Collection of WWER specific information by all participants increased quality and unification of national programmes. Original design plant life of 30 years is planned to be extended by 10 years to the overall period of 40 years of operation.

The Programme activities were guided by the Programme Steering Committee (SC), follow the overall SC Programme Workplan and SC Terms of Reference, and are implemented in 4 Working Groups (WG). The WGs focus on:

- general LTO framework (WG 1);
- mechanical components and materials (WG 2);
- electrical components and I&C (WG 3);
- structures and structural components (WG 4).

The Working Groups conduct their work in 4 task in line with:

- collect available information on long term operation;
- review and compare the information collected, identify common elements and differences;
- reconcile the differences, identify future challenges and open issues;
- develop a Final Working Group Report.

VUEZ, a.s., Levice participated on activities for structural components implemented in 4th Working Group. This programme was finished and final report was published. In this article we bring a short presentation of the SALTO project and the report.

Almost 100 experts from 13 MS and from the European Commission participated directly in the Programme activities in the period 2003-2006. Working Group activities were guided by Working Group leaders, assisted by Working Group secretary. To co-ordinate the

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work within Working Groups, 4 meetings of each Working Group were organized during the Programme. Most of the technical work was, however, conducted as ’homework assignment’, involvingmuch larger number of experts.

The Meetings were important for exchange information between nominated representatives of the participating MS and for reach agreement on the format and content of the final documentation.

2. IMPORTANT TASKS OF SALTO

To achieve the objective, the following associated tasks were implemented:

Task 1

Collect information on existing research, and regulatory and operational approaches, programs, and practices related to structures and structural components essential to safe LTO of PWRs.

Task 2

Upon receipt of the information (CIRs) as provided in Task 1, each WG member reviewed and compared the information from the MS to determine common aspects, as well as differences between applicable laws and regulatory requirements; approaches, processes and practices; research; outstanding technical and programmatic issues to be resolved, and operational experience, associated with the ageing and ageing management of structures and structural components essential to safe LTO of PWRs.

Task 3

The objective of Task 3 was to complete a final report and submit the report to the SC for review and approval.

3. COUNTRY INFORMATION REPORT

Country information report (CIR) of Slovak Republic for WG4 was made by VÚEZ, a.s., Levice with cooperation of UJD SR, Mochovce NPP and Bohunice NPP.

The outlines of CIR:

Working Group 4 – Structures and Structural Components

1.0 Applicable laws specific to structures and structural components for long term operation
2.0 Regulatory requirements applicable to LTO
- 2.1 Criteria for selection of items in the scope of Structures and Structural Components in the LTO program
- 2.2 Ageing management programs - organizational, management issues and interfaces with other plant processes

3.0 Operational approaches applicable to LTO
- 3.1 Reference degradation mechanisms of LTO civil structures, their effects and location
- 3.2 Monitoring, surveillance and inspections
- 3.3 Maintenance practice
- 3.4 Assessment techniques for existing structures. Trend analysis and evaluation of safety margin. Practices used to control design basis.

4.0 Compilation of a list of reference documents from which the above information was collected

Collection of information on SSCs

For the most important civil structures the summarising information sheets contain the following data:

- designation of the civil structure used in the Mochovce and Bohunice NPPs
- characteristics of the civil structure (purpose, architectural solution)
- design (technical description of the structure and materials used)
- identified potential ageing mechanisms and their relevance
- selection of hot spots stressed the most with degradation mechanisms – in a tabular form
- ways of degradation (encountered degradation mechanisms) and risks issuing from effects of material degradation on the civil structure
- description of implemented tests and inspections of the civil structure,
- results of tests and inspections (monitoring) of the civil structure, its parts and material properties,
- data on performed, planned or extraordinary repairs and maintenance from the standpoint of LTO
- data on planned repairs, reconstruction and modifications (test intervals, test procedure, operating procedures),
- acceptance criteria for evaluation of individual ageing mechanisms (STN standards, design documents, technological procedures - TP, regulations, safety analysis reports etc)
- summary of legislative regulations and safety analyses based on an explicitly assumed plant life or operation period.

In particular at meetings, it was noted that there is a large difference among the CIRs: one of the main reasons is that the national programmes follow different approaches to LTO, being intrinsically dependent on the national regulatory framework, technical tradition and also age of their nuclear fleet.

The WG Members provided 8 CIRs to the secretary.

4. OBJECTIVES AND REQUIREMENTS

The Programme's objective was to establish recommendations on the scope and content of activities to ensure safe long term operation of water moderated reactors. The Programme should assist regulators and operators of water moderated reactors.

The objectives of WG 4 were to:

- 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 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:
1. Containment/confinement/pressure boundary structures and including the spent fuel pool;
2. Structures inside the pressure boundary (compartment box, reactor box, etc.) including anchorages, penetrations, hatches, etc.;
3. Other safety classified buildings;
4. Water intake structures including buried pipelines;
5. Foundations;
6. Other structures where significant degradation has been recorded.

Working Group 4 collected information in relation to the following areas:
1. Regulatory position - Collect regulatory docs: only those relevant to structures
2. Scope of the LTO program
3. Reference degradation mechanisms.
4. Maintenance, Surveillance and Inspection
5. Trend analysis and evaluation of the safety margin
6. Maintenance practice, mitigation measures and repair technology
7. AMP characteristics
8. References

The general safety regulations and requirements for long-term operation (LTO) are described in the EBP SALTO Working Group 1 Report. Therefore, only those requirements are discussed in report, which are specific to structures and structural components.

Sections 1-5 of report 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 MS, future challenges, and recommendations. Section 6 of report provides a list of related technical reference documents for each participating MS. Section 7, Appendices, provides information on requirements relevant for LTO and examples of utility documents and classification of the structures. Also a summary and examples of ageing programs for SSC of various types reactors is provided in this section.

In some countries detailed requirements for ageing management are established at the regulatory guideline level. The International Atomic Energy Agency (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).

In a few cases there are specific standards for nuclear power plant structures (e.g. Russia, U.S.). In some countries generic industrial standards are used for monitoring and assessing ageing of civil structures (e.g. the Ukrainian)

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.

With respect to LTO we considered the country practices from the point 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

2. SCOPING OF SYSTEMS, STRUCTURES AND COMPONENTS

The scope of the structures and structural components[1] relevant to LTO is explicitly regulated only in some countries. It is recognized 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 regulation, which are fully applicable to classification of structures and structural components.

Formal or even regulatory required/approved list of LTO-related structures and structural components do 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 list of structures and structural components within the scope of LTO for different type of light water reactors are listed in the Tables A2-2, A2-3, and A2-4 of the report. The lists are based of the countries practices.

Common elements and differences

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

Sweden is using a risk-informed approach for scoping (structures and structural components, locations and intervals). This approach could be applicable and should be developed.

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, modernisation, 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)

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 the improperly managed SSCs, irreversible ageing processes may result in serious safety issues.

Recommendations

The typical scope of structures and structural components for each reactor type is presented in Tables A2-2, A2-3 and A2-4 of the appendix, Chapter 2.

3. AGEING MANAGEMENT PROGRAMMES

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

The 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.

The formal establishment of the AMP depends on the regulatory framework of the given country, and maturity of LTO project.

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

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

It is very important that the definition of ageing management and attributes needs a clear interpretation. The formulation of the attributes and establishment of the procedures of the review of existing AM programmes are of common interest of the countries.

Applicable ageing effects

Study of ageing effects/degradation mechanisms and identification of the LTO relevant and life-limiting mechanisms is the core task of development of AM programmes.

Systematic approach to the identification of LTO relevant ageing mechanisms is important. The ageing mechanisms are identified for the different materials, environments, and the possible consequences are also defined.

The importance of development of acceptance criteria for the degradation effects is recognised, e.g. limiting values for the crack width and length in reinforced concrete structures. The procedures for evaluating the technical condition of structures and trending the ageing process needs great attention.

The table A3-2 shows for each material and environment (e.g. reinforced concrete structure) pairs the reference degradation mechanism and its effect.

Ageing Mitigation Measures

Development of the mitigation measures of relevant ageing mechanisms are a decisive and important part of the AM programmes.

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

Table A3-2 provides the safety strategy to be applied in case of mitigation of degradation identified for each material and environment pairs and for each structure and structural components. Table A3-1 (Appendix to Chapter 3) also shows a typical list of AMP relevant to LTO for PWR/BWR power plants.

Common elements and differences

Table A3-1 reflects the consensus based understanding of the ageing mechanisms, monitoring and preventive/mitigating measures.

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).

Future challenges

On the basis of the practice of countries the following issues were recognized as decisive in relation to ageing management:

- Completeness of the identification of ageing mechanisms, sensitive locations for each structures and structural components
- 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 AMP
- Review methodology of ongoing programmes

Recommendations

Systematic approach to the identification of ageing mechanisms has to be proposed for the countries. As starting information for the development of the list of relevant ageing mechanisms Table A3-2 might be used.

The AMP given for PWR and BWR type plants in the Appendix to Chapter 3, Table A3-1 and the short description of the most important AM programmes might be used as examples while developing AMP for a particular plant.

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

1. Coordinated research activities needed for the analysis and comparison of ageing mechanisms
2. To support the MS LTO programmes development of muster ageing management programmes
3. For the evaluation of aged status of RC structures (evaluations of ISI and monitoring data) adequate methods and criteria needed.
4. In case of some important structures and structural components within the scope of LTO sensitive locations could not be accessed for the monitoring (e.g. parts of liner, reactor support structures in case of WWER-440). Adequate methods are needed for assessment of ageing in these locations.
5. One of the outcomes of the SALTO program report will be a database containing information on environment/material/degradation mechanisms/inspection/mitigation measures for a given structure or a structural component.
6. The IAEA should consider providing audit services to MS undertaking long-term operation (LTO) of nuclear power plants.

4. OPERATIONAL PROGRAMMES

In-service inspection

Although practically all countries have established ISI system for structures, there are only few countries, where systematic review has been performed to demonstrate that the ISI programmes could be credited for LTO.

In some cases the methods and frequency of inspections follow the vendor procedures, in some cases the utilities developed their own procedures (Paks NPP) or the utilities adopted the best known practice (For example, in the Czech Republic the containment tightness tests corresponds to the US procedure ANSI/ANS-56.8-1999).

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 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.

Common elements and differences

The 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.

It is understood that a comprehensive monitoring and ISI programme should cover the structures and structural components within the scope of LTO (Tables A2-2, A2-3 and A2-4), and those degradation mechanisms and locations, which are indicated in the table A3-2. This table comprises description of the monitored degradation mechanism or the structure parameter, location, and frequency of inspections. The link of degradation mechanisms for selected buildings and structures important to safety is provided in Table A4-2. The Table A4-2 is the generalisation of country practices per type of plants.

Future Challenges

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

- Ensure the adequacy of ISI and monitoring programmes by review of existing programmes
- Collecting suitable data on the environmental variables
- Development of ISI and monitoring techniques and methodologies
- Development of criteria for the assessment of ISI and monitoring
- Some ISI and monitoring activity has to be on place in this post-operation period of time.

Recommendations

NPP operators should prepare the detail procedures covering the scope selected for LTO. It has to be based on their operational experiences and existing MS&I programs. The programs should be credited for LTO if they are adequate.

5. TIME-LIMITED AGEING ANALYSIS

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

- Trend analysis;
- Time Limited Ageing Analysis (TLAA)

The aim of the trend analysis is to predict changes of the SSC status due to ageing, taking into account the environmental and operational conditions, as well as to justify operational lifetime of SSC that could be longer or shorter than design life.

Very important condition of the safe long-term operation is the knowledge about time limits of safe operation due to ageing. Although the design lifetime of safety related structures is generally longer then the plant design life, the TLAAs has to be reviewed in case of LTO and the time limitations, if any exist, they should be resolved.

For the evaluation of trends and the time-limits due to ageing, deterministic and the 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 numeric modeling.

Future Challenges

A set of open problems could be identified from the practice of the countries. These problems are related to the:

– Uncertainties in the behaviour of massive concrete structures

– Uncertainties in the case of sudden impact of high temperatures on the old structures (creep, shrinkage), in the case of impact of moisture field change within the concrete structure in combination with the high temperature effect, in the case of moisture impact within structure closed in liners, in the case of higher temperature cyclic action on concrete surrounding hot penetrations

These phenomena require relatively demanding experimental verification.

Another open problem is assessment of the structure resistance against the extreme external and/or internal accident conditions regarding the cumulative impact of ageing.

The deterministic analyses of degraded structures have their own restrictions, thus the further development should be focused toward more sophisticated methods, including non linear and probabilistic simulation methods for analyses of existing structures, which provide deeper information about behaviour of the real structure than the classical deterministic methods.

Impact of the degrading factors to the structure is of random nature similar as the material data and loading. Further development of probabilistic assessment methods is needed for lifetime assessment of safety important structures. In the case of the lifetime assessment, the safety margin determination and trends evaluation the probabilistic approach represents very progressive and perspective methods.

LIST OF REFERENCES

[1] Final Working Group 4 Report, Structures and Structural Components, IAEA-EBP-LTO-23, Vienna, 2005
[2] Minutes of the Programme's Planning Meeting, IAEA-EBP-LTO-02, Vienna, 2004.
[3] Standard review processIAEA-EBP-LTO-03 Vienna, 2004.
[4] Slovak Republic Country Information Report WG4, VÚEZ,a.s., Levice