A general LTO assessment project approach using IAEA guidelines applied to Borssele (The Netherlands) and Ringhals (Sweden)NPPs

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There is need for a generally accepted approach for Long Term Operation (LTO) assessment of Nuclear Power Plants, as an increasing part of the nuclear fleet approaches the original design lifetime. Specific IAEA guidelines are written to provide such an approach. Two examples will be given of LTO assessment projects which have used these IAEA guidelines. Borssele NPP in The Netherlands used IAEA safety guide 57 as a basis for their LTO assessment project.
The experience gained in the Borssele LTO assessment project has been used for the set-up of the LTO assessment project for Ringhals NPPs in Sweden.

Conforme se vaya acercando una parte cada vez mayor del parque nuclear al final de la vida de diseño original, existe la necesidad de un enfoque generalmente aceptado para la evaluación de la Operación a Largo Plazo (OLP) de las Centrales Nucleares. Se han elaborado directrices específicas del OIEA para dar ese enfoque. Se darán dos ejemplos de proyectos de evaluación de OLP en los que se han empleado dichas directrices del OIEA. En la CN de Borssele en Holanda, se ha utilizado la Guía de Seguridad 57 del OIEA como base para su proyecto de evaluación de OLP.
La experiencia acumulada en el proyecto de evalaución de OLP de Borssele se ha aprovechado para la configuración del proyecto de evaluación de OLP de la CN Ringhals en Suecia.

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INTRODUCTION

This article describes the LTO assessment project of Borssele NPP in the Netherlands and the set-up of the LTO assessment project at Ringhals NPPs in Sweden. The Borssele project was carried out by three parties: EPZ (utility), AREVA (design and constructor) and NRG (independent consultant). The experience NRG gained during this project is used to support Ringhals in their LTO project.

BORSSELE LTO ASSESSMENT PROJECT

The Borssele Nuclear Power Plant ("KernCentrale Borssele", KCB) planned for operation until 2034 (60 years). On june 16th 2006 a covenant between the owners and the government was signed in which operation until December 31th 2033 was agreed upon.

In the original safety report (SAR) 40 years was assumed. To revalidate the SAR for 60 years of operation a formal license change application process was performed based on a comprehensive LTO assessment project.

Regulatory Framework in The Netherlands

In the Netherlands, the nuclear regulatory requirements are contained in the Nuclear Energy Act. Within the Nuclear Energy Act the so called Nuclear Safety Rules (NVRs = Nucleaire VeiligheidsRegels) provide the basis for a system of more detailed safety regulations for nuclear power plants. The NVRs are based on the Requirements and Safety Guides in the IAEA Safety Standard Series (SSS). Application of the NVRs is monitored by the "Kernfysische Dienst" (KFD). KFD is the Dutch nuclear inspectorate.

IAEA Guidelines

The existing set of NVRs did not provide guidance on Long Term Operation assessment (LTO). Therefore, in consultation with the KFD, it was decided that IAEA guidelines on LTO will be used as the basis for the LTO "bewijsvoering". The regulatory framework for the LTO "bewijsvoering" of Borssele is accordingly defined by:

- IAEA Safety Report No. 57 [1];
- IAEA Safety Guide No. NS-G-2.12 [2].

Particularly IAEA Safety Report No. 57 gives specific guidelines for the LTO assessment, see figure 2. These guidelines can be seen as a high level version of US NRC License Renewal guidelines.

Additional Requirements

The preparatory work for the LTO assessment at KCB was reviewed in 2009 by an IAEA SALTO peer review team, on request of the KFD. The peer review mission had a limited scope restricted to the LTO assessment part of Safety Report 57. Based on the comments of this SALTO peer review team, the project LTO "bewijsvoering" was extended by the inclusion of the assessment of active safety and safety relevant components.

Based on the regulatory framework Borssele has conducted the project LTO "bewijsvoering" to demonstrate that sufficient assurance is provided that safety and safety relevant systems, structures and components will continue to perform their intended functions during long term operation.

Overall Structure of LTO "Bewijsvoering" at KCB

The overall structure of the LTO "Bewijsvoering" is given in Figure 3. The figure gives a general overview of the elements in LTO "Bewijsvoering". The same three phases as identified in SR57 [1] are used in project LTO "bewijsvoering". The numbers used in Figure 3 refer to the chapter numbers in SR57.

Figure 1. Borssele NPP in The Netherlands.

Scoping, screening and Ageing Management Review

As a starting process for the assessment in LTO "Bewijsvoering" the scoping was performed. Within this step, all SSCs in Scope of LTO were identified on a system level based on the following criteria from IAEA Safety Report No. 57 [1]:

1. All SSCs important to safety:
   a. that ensure the integrity of the reactor coolant pressure boundary
   b. that ensure the capability to shut down the reactor and maintain it in a safe shutdown condition
   c. that ensure the capability to prevent accidents that could result in potential off-site exposure or that mitigate the consequences of such accidents
2. Other SSCs whose failure may impact upon the safety functions specified above.

In the subsequent Screening process further detailing of the scope on component or commodity group level was performed.

The Ageing Management Review (AMR) involved detailed technical evaluation of in-scope passive long-lived components (e.g. Main Coolant piping) as well as passive subcomponents of active long-lived SCs (e.g. Main Coolant Pump casing) to demonstrate that the effects of ageing are adequately managed such that the intended function(s) will remain consistent with the KCB licensing basis during Long-Term Operation.

During the KCB Ageing Management Review (AMR) process, different methodologies were used to evaluate different SCs and commodity groups. Mechanical A SCs form part of the fission product barrier, i.e. the barrier for radioactive release. Mechanical B SCs consist of the remaining safety related in-scope mechanical systems.

Mechanical SCs and Electrical and Structural/Civil commodity groups are differentiated from one another as follows:

- Mechanical A SCs,
- Mechanical B SCs,
- Structural/Civil commodity groups, and
- Electrical commodity groups.

A total of 17 Ageing Management Review reports were prepared for NPP Borssele in the framework of Long-Term Operation in the three disciplines. A catalog of relevant ageing mechanisms was also prepared for each of the 3 disciplines, to guide the performance of each AMR. As applicable, recommendations were made to improve KCB programs and/or practices to align the NPP with current nuclear industry.

With the fulfillment of the AMR recommendations the effects of ageing on in-scope SCs is adequately managed (i.e. the intended function(s) will be maintained consistent with the KCB licensing basis during LTO). All reports were reviewed by the Dutch nuclear regulatory authority.

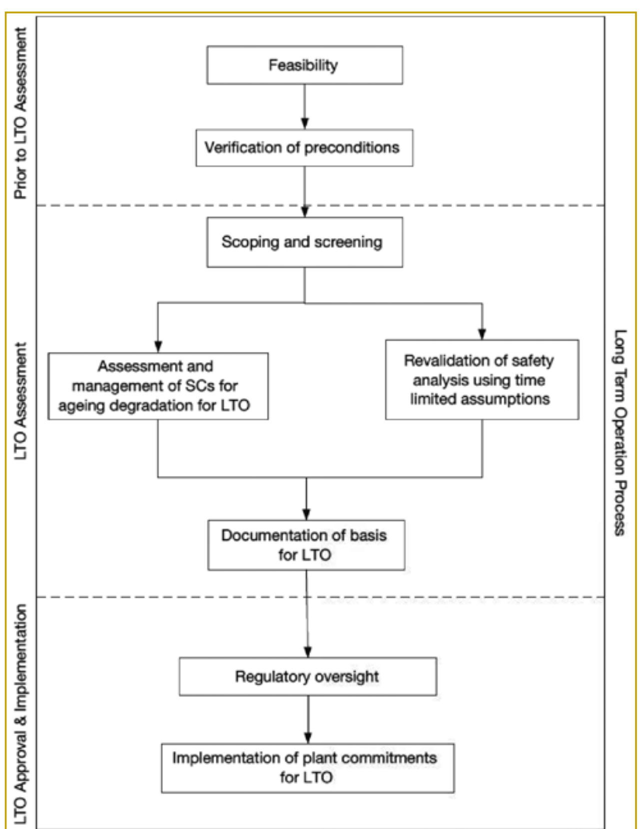

Figure 2. Overview of activities for LTO assessment; figure taken from SR57 [1].

Active components

Safety Report 57 [1] is largely based on US-NRC rules, which assume that any plant implementing LTO also applies the Maintenance Rule (10 CFR 50.65) [4]. The Maintenance Rule ensures proper ageing management of active components, however, this aspect is not addressed in SR57. The Maintenance Rule is not mandatory in NPPs that do not fall under the regulations of the US-NRC.

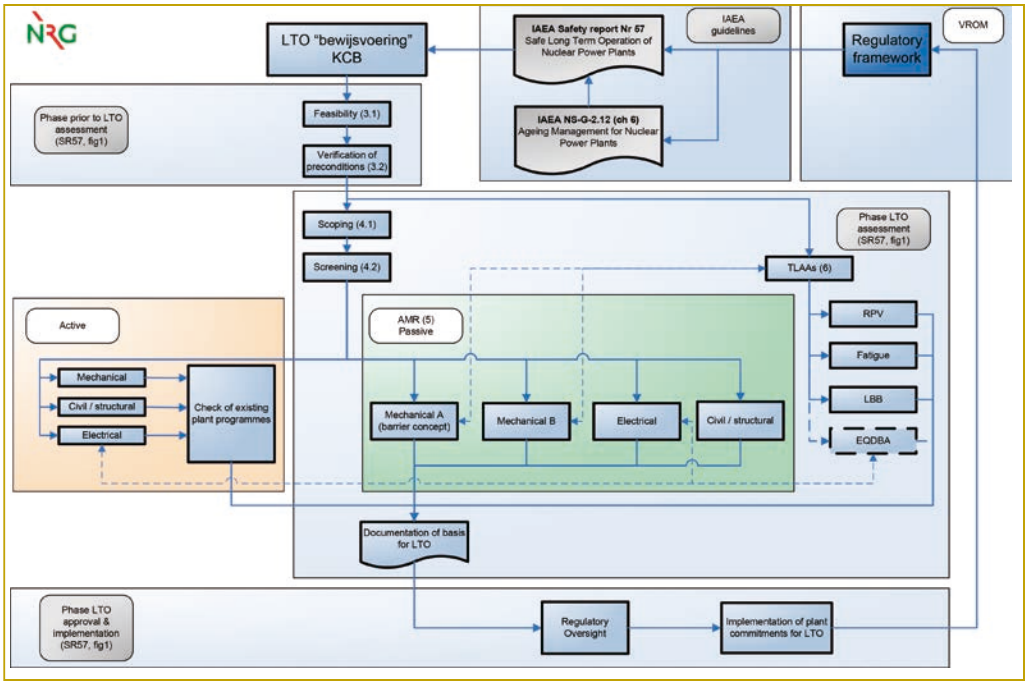

Figure 3. Overview of LTO "bewijsvoering" project (numbers as in SR57 [1]).

Therefore, evaluation of active components is included in the project LTO "bewijsvoering" in line with with the methodology of the Maintenance Rule [4].

KCB has a comprehensive set of plant programs. The purpose of these programs is to ensure that all activities have been established and applied, necessary to maintain the KCB plant compliant with design and applicable regulatory requirements. The active components are identified in the screening process. The active components are classified into three groups: Mechanical, Structural/Civil and Electrical.

Revalidation of TLAAs

The TLAAs identified at KCB are: Reactor Pressure Vessel, Fatigue, Leak Before Break and Qualification of Design Base Accident resistant electrical Equipment (EQDBA). These topics are discussed in the current section.

Reactor Pressure Vessel

The time limited ageing mechanism for the KCB Reactor Pressure Vessel is irradiation embrittlement. The TLAA for the RPV formally ends at the end of the design lifetime in 2013, therefore it needs to be revalidated in the project LTO "bewijsvoering". The revalidation of the RPV TLAA is performed by a new analysis.

A safety assessment of the Reactor Pressure Vessel (RPV), including the assessment of irradiation induced ageing of the KCB RPV, has been carried out. In the 70s one irradiation surveillance program (SOP, in Dutch "Staal Onderzoeks Programma") was performed on the KCB RPV with an unirradiated reference set SOP 0 and two irradiation sets SOP 1 and SOP 2. The evaluation of the fluence detectors was done in Petten/Arnhem. A second irradiation surveillance program with one unirradiated set SOP 0a and two irradiation sets SOP 3 and SOP 4 was started in 2007. The structural integrity of the RPV with respect to operation, irradiation surveillance and Pressurized Thermal Shock (PTS) analysis is assessed using fluence calculations validated by shadow calculations and scraping samples from the RPV. Moreover an analysis schedule for the in the RPV inserted irradiation sets SOP 3 and SOP 4 is provided. Finally, the RPV safety of KCB is evaluated in terms of the up-to-dateness of the assessment methods used (including Master Curve) and by a general benchmark of the KCB results with RPV safety assessment data worldwide. It could be proven that the safe operation of the KCB RPV is guaranteed by comprehensive state-of-the-art methods for all load cases with large safety margins.

Fatigue

In the design phase of NPP Borssele and during modifications of the plant, fatigue analyses with time limited assumptions were made for certain safety important components. For these components it was proven that the fatigue cumulative usage factor (CUF) is below 1.0 for operation until the end of 2013, based on conservative assumptions on the number of load cycles and stress ranges of transients. For the number of transients a load catalogue was specified. By monitoring the number of transients and comparing the actual number with the assumed number of transients in the load catalogue, the validity of the assumptions on the number of transients is checked on a yearly basis.

Revalidation of the existing analyses for LTO can in principle be done by showing that the assumed number of load cycles and stress ranges of transients in the original analyses will not be exceeded during the LTO period. However, during the last decade worldwide discussions emerged on the conservatism of the existing fatigue design curves and particularly the influence of the coolant environment on the fatigue life (environmental fatigue). Although this issue is still disputed by experts in the world and only based on laboratory tests, procedures were developed in the USA and Japan to address environmental fatigue. New design curves were developed together and correction factors to account for environmental fatigue. Depending on several parameters the influence of a water environment can be substantial in theory.

To be able to revalidate the fatigue analyses for LTO including the incorporation of possible environmental influence, best estimate calculations of the fatigue life are needed including realistic assumptions on the (thermal) loads. For this reason during the yearly outage in 2010 the FAMOS system was implemented which is able to precisely monitor thermal loads including stratification. The monitoring locations are based on an assessment of the thermal loads (the FAMOS manual). Based on the experience with FAMOS and similar systems in German NPPs it is expected that new representative load specifications can be produced with FAMOS after 5 cycles.

For all component locations in the scope, a systematic review is performed on the available fatigue assessments. Based on a comparison of the number of transients in the analysis with the expected number of transients in 2034 an expected CUF2034 is calculated for every in-scope component location. Further assessment is performed for the locations where CUF2034<1 could not be demonstrated before going into LTO to prove that adequate safety margins against crack initiation by fatigue are in place also during LTO. Environmental fatigue is addressed by following the KTA rules on environmental fatigue in which awareness threshold values for ferritic and austenitic steel are given. For component locations in contact with water and usage factors above the awareness threshold values further measures are specified.

With the assessment and the follow-up of the recommendations a sound basis is given for the prevention of crack initiation by fatigue for the period of LTO.

Leak Before Break

Leak Before Break (LBB) is part of the break preclusion concept at KCB. The TLAAs for leak before break are assessed first on their time dependent factors since this aspect is most important for LTO assessment.

The scope for Break Preclusion for LBB is:

- Primary Piping
- Main steam and Feedwater Lines within the secondary containment

In particular, the Leak Before Break argumentation contains time dependent assumptions regarding the growth of defects.

The goal of the review is to demonstrate that the Break Preclusion concept (Bruchausschluß) as entered in 1997 remains valid in case of life time extension to 2034.

Two steps of LBB include time dependency:

- Time for growth of surface defect to through wall defect, the number of Reactor Lives from this step has to allow for 60 years of operation.
- Time for growth of through wall defect to critical through wall defect – only when through wall defect occurs. Since no through wall defect has been detected, this time dependency always occurs after the step mentioned above and is therefore not relevant for life time extension to 2034.

The relevance of time dependency in Break Preclusion for KCB 2034 is concentrated in the first step.

From the assessment it is concluded that the time dependent assumptions in LBB TLAAs are not restricting operation for 60 years.

Qualification of Design Base Accident resistant electrical Equipment (EQDBA)

Due to the Harrisburg accident it was realized in the mid-'80s of the twentieth century that the electrical components didn't have a qualification for harsh environment conditions. Subsequently, a list of electrical equipment needed to manage the various accidents was developed based on design base accident scenarios and required safety functions. The selected hardware was qualified in conformity with the German KTA standards.

Figure 4, Ringhals NPPs in Sweden.

The EQDBA TLAA is assessed by the implementation of a method to establish the qualified life of each component with a harsh environment qualification for LTO. First an environment condition monitoring program has been performed over the period 2007-2009. Then it is verified if the design base accident resistant electric components are in the standard component library of the AUREST database. Otherwise, the component is forwarded to a KCB specific component library. The actual qualified life calculations are performed using AUREST.

The EQDBA project has led to the qualification of design base accident resistant electrical equipment, where for components with insufficient data requalification and replacement programmes are carried out.

RINGHALS LTO ASSESSMENT PROJECT

NRG has used the experience of the Borssele LTO assessment project to set up a plan of approach for the LTO assessment project of Ringhals NPPs. In the beginning of 2013 several expert meetings were scheduled with contributors from NRG and Ringhals NPP 2. In these meeting the existing plant programmes at Ringhals NPP2 were discussed and the major gaps with respect to IAEA safety guide 57 were identified. In the plan of approach gives an overview of the LTO requirements, the current situation at Ringhals NPP2 and the identified major gaps for each LTO activity.

After the plan of approach Ringhals and NRG have set-up a more detailed LTO methodology for all four Ringhals NPPs. In several workshops NRG explained the LTO activities mentioned in Safety report 57. Based on these workshops Ringhals, in consultation with NRG, defined their LTO methodology. Ringhals decided to make use of the IAEA IGALL project to define the TLAAs for the LTO project.

The LTO methodology of the Ringhals NPPS wille be assessed during the first IAEA SALTO peer review, which is scheduled for March 2014.

CONCLUSIONS

The IAEA guidelines provide a generally and globally accepted methodology for LTO assessment. Two examples of LTO projects which have used these guidelines were presented.

Borssele NPP in The Netherlands used IAEA safety guide 57 "Safe Long Term Operation of Nuclear Power Plants" as a basis for their LTO assessement project. The outcome of the LTO assessment project was submitted to the Dutch regulator for a license change application to revise the Safety Report for long term operation until 2034. In 2013 the license change was approved by the Dutch regulator.

The experience gained in the Borssele LTO assessment project is used for the set-up of the LTO assessment project for Ringhals NPPs in Sweden. Ringhals also adopted IAEA Safety report 57 for the general structure of their LTO project.

REFERENCES

[1] IAEA Safety Report Series No. 57, Safe Long Term Operation of Nuclear Power Plants, 2008.

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[4] 10CFR 50.65, Requirements for monitoring the effectiveness of maintenance at nuclear power plants, august 28, 2007.