Conceptual Document
LTO "Bewijsvoering" KCB

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name:	R103460 Conceptual Document	approved:	[redacted]
reference:	NRG-22701/10.103460		
56 pages	9 September 2011		

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Summary

KCB plans to extend its operating life with 20 years until 2034. EPZ has started the project LTO "bewijsvoering" in order to meet the requirements of the Dutch regulator. The outline of the project is based on IAEA safety guide 57 "Safe Long Term Operation of Nuclear Power Plants". This conceptual document describes the contents and coherence of the different parts in the project and how these respond to the IAEA guidelines on LTO.

The goal of the project LTO "bewijsvoering" is to ensure that safety and safety relevant systems, structures and components continue to perform their intended functions during long term operation.

The outcome of the project LTO "bewijsvoering" will be used for a license change application and this will be submitted to the Dutch regulator KFD for approval of prolonged operation of KCB after 2013.

List of Definitions and Abbreviations

Table 1 List of definitions and abbreviations

10EVA	"10 jaarlijkse EVAluatie" (Dutch for Periodic Safety Review, PSR)
10EVA13	Project name of next KCB Periodic Safety Review
AMR	Ageing Management Review
AREVA NP	Formerly KWU/Siemens, constructor of Borssele NPP
ASME	American Society of Mechanical Engineers
AUREST	Database for design base accident resistant electrical equipment
CLB	Current Licensing Basis, collection of documents or technical criteria that provides the basis upon which the regulatory body issues a licence for the siting, design, construction, commissioning, operation or decommissioning of a nuclear installation valid for the current authorized period
CRDM	Control Rod Drive Mechanism
EFPY	Electric Full Power Years
ELI	Dutch Ministry Economic affairs, Agriculture and Innovation
EPZ	N.V. Elektriciteits-Productiemaatschappij Zuid-Nederland
EQDBA	Qualification of Design Base Accident resistant electrical Equipment
FAMOS	Fatigue Monitoring System
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit
IAEA	International Atomic Energy Agency
I&C	Instrumentation and Control
KCB	Kerncentrale Borssele (Nuclear Power Plant Borssele)
Kew	Kernenergie wet (Nuclear Energy Act)
KFD	Kernfysische Dienst (Dutch nuclear inspectorate, resorting under the Department for Nuclear Safety Security and Safeguards, reporting to the Dutch Ministry Economic affairs, Agriculture and Innovation, ELI)
KTA	Kerntechnische Ausschuss
KWU	Kraftwerk Union, constructor of Borssele NPP (later Siemens, now AREVA)
LBB	Leak Before Break
LTO	Long Term Operation
LTOB	Project LTO "bewijsvoering"

MCP	Main Coolant Pump
MCPB	Main Coolant Pressure Boundary
MCS	Main Coolant System
MOX	Mixed Oxide fuel
NPP	Nuclear Power Plant
NRG	Nuclear Research and consultancy Group
NVR	Nucleaire VeiligheidsRegels en Richtlijnen (Nuclear Safety Rules)
PSR	Periodic Safety Review
PTS	Pressurized Thermal Shock
PZR	Pressurizer
RPV	Reactor Pressure Vessel
SALTO	Safe Long Term Operation
SC	Structures and Components
SG	Steam Generator
SOP	"Staal Onderzoeks Programma" RPV Ageing monitoring programme at KCB
SR57	IAEA Safety Report nr. 57 [1]
SSC	Systems, Structures and Components
TLAA	Time Limited Ageing Analysis
TÜV	Technischer Überwachungs Verein
US-NRC	United States - Nuclear Regulatory Committee
VGB	Technische Vereinigung der Großkraftwerksbetreiber
VROM	Dutch ministry of Housing, Spatial Planning and the Environment, in 2010 changed to Ministry of Infrastructure and Environment

Introduction

The Borssele Nuclear Power Plant (Kerncentrale Borssele, KCB) plans to extend its operating life to 60 years, until 2034. Government agreement for this life extension was obtained on June 16th, 2006, when the Borssele covenant [11] between the owners and the government was made. This agreement will make it possible for KCB to realize Long-Term Operation (LTO) for an additional period of 20 years.

For LTO the following conditions have to be complied with:

- Safe operation has to be demonstrated;
- A license change will have to be issued for operation after 2013.

In order to meet these requirements EPZ has started the assessment project LTO "bewijsvoering" (LTO "Justification"). This project provides the justification and documentation needed for the license application for LTO in 2011. This includes recommendations and implementation of commitments that may result from the assessments.

The basis for the project LTO "bewijsvoering" is formed by the IAEA guidelines on LTO. To evaluate the project, the Dutch regulator (KFD) will make use of external specialists GRS in Germany and IAEA SALTO peer reviews. As a result of comments in the first IAEA SALTO peer review in 2009, the scope of the project was extended with the assessment of active components. Additional requests have also been made by the Dutch regulator with respect to non-technical requirements. These non-technical requirements (organisation & administration and human factors) are dealt with in the PSR project 10EVA13 [toetsingskader 10EVA13] and will not be dealt with in this conceptual document. The license change application will be done in a separate project and is based on the outcome of LTO "bewijsvoering" and specific parts of 10EVA13 which fill in the additional requests of the regulator.
The goal of this conceptual document is to describe the contents and coherence of the different parts in the project and how these respond to the IAEA guidelines on LTO.

The conceptual document is structured as follows. In chapter 1 the framework for LTO "bewijsvoering" is given, presenting the overall structure and its background together. In chapter 2 the phase prior to LTO assessment is described. The subsequent description of LTO assessment is given in chapter 3. The active components are then described in chapter 4. Chapter 5 describes the documentation needed to provide the basis for LTO. The phase LTO approval and implementation is provided in chapter 6 and conclusions are drawn in chapter 7.

1 Framework LTO “Bewijsvoering”

1.1 Regulatory Framework

1.1.1 Introduction

In the Netherlands, the nuclear regulatory requirements are contained in the Nuclear Energy Act (Kernenergie wet, Kew). 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, resorting under the Department for Nuclear Safety Security and Safeguards, reporting to the Dutch Ministry Economic affairs, Agriculture and Innovation, ELI.

1.1.2 IAEA Guidelines

The existing set of NVRs does not provide guidance on Long Term Operation (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” (LTOB) project [5], [6] and [7]. The regulatory framework for the LTO “bewijsvoering” project of KCB is accordingly defined by:

- IAEA Safety Report No. 57, Safe Long Term Operation of Nuclear Power Plants (SR57) [1];
- IAEA Safety Guide No. NS-G-2.12, Ageing Management for Nuclear Power Plants [2].

EPZ reviewed and compared the IAEA guidelines [1] and [2] in order to establish the basis and structure for the LTO “bewijsvoering” project. The IAEA Safety Guide NS-G-2.12 [2] describes general ageing management for nuclear power plants. The specific LTO recommendations are given in chapter 6 of [2] (“Review of Ageing Management for Long Term Operation”). An in-depth review of ageing management is described in table 2 of [2], which corresponds to section 5.3 in SR57 [1]. Other aspects in [2] are screening, the Ageing Management Review (AMR) and revalidation of Time Limited Ageing Analyses (TLAAs), which are covered in [1] as well. It can be concluded that SR57 [1] covers NS G-2.12 [2] with respect to LTO.

A representative overview from the IAEA Safety Report 57 [1] is shown in Figure 1. This overview is used as the basis for the project LTO “bewijsvoering”.

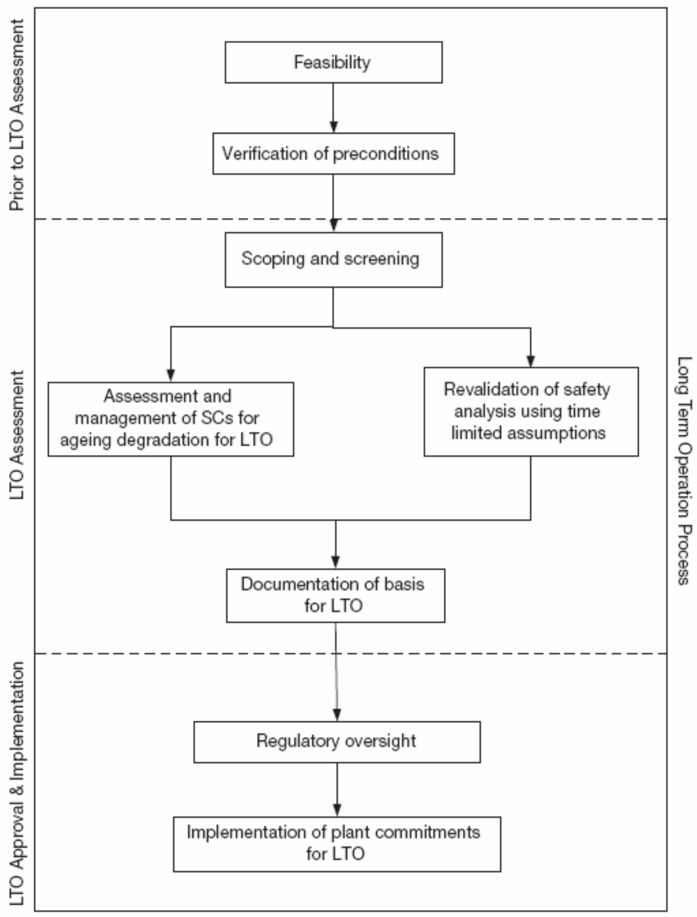

Figure 1 Overview of activities for LTO assessment; figure taken from SR57 [1]

1.1.3 Additional Requirements

The preparatory work for the LTO assessment at KCB was reviewed in 2009 by a SALTO peer review team [8], on request of the KFD. The peer review mission had a limited scope restricted to the LTO assessment part of Safety Report 57 [1]. Based on the comments of this SALTO peer review, the project LTO "bewijsvoering" was extended by the inclusion of the assessment of active safety and safety relevant components. Furthermore, non-technical requirements from the KFD, i.e. the safety factors 10 (organisation and administration) and 12 (human factor) from the IAEA PSR Safety Guide [3] will be taken into account in the Periodic Safety Review (project 10EVA13) and are not addressed further in this conceptual document.

1.1.4 Summary

The regulatory framework that forms the basis for project LTO "bewijsvoering", as discussed in the previous sections, is summarized as:

- IAEA Safety Report 57 [1] (covers IAEA Safety guide NS-G-2.12 [2] for LTO aspects);
- Assessment of active safety and safety relevant components identified in the screening process;

1.2 Overall Structure of LTO "Bewijsvoering" at KCB

The structure of the project LTO "bewijsvoering" is based on IAEA Safety Report 57 [1]. A representative overview from SR57 is shown in Figure 1. This figure shows that the LTO process consists of three phases:

- Phase prior to LTO assessment;
- Phase LTO assessment;
- Phase LTO approval and implementation.

For the KCB project LTO "bewijsvoering" an additional part, review of active components is added.

The overall structure of the LTO "Bewijsvoering" is given in Figure 2. The figure gives a general overview of the elements in LTO "Bewijsvoering", which will be discussed in more detail in the remainder of this conceptual document. The same three phases as identified in SR57 [1] are used in project LTO "bewijsvoering". The numbers used in Figure 2 refer to the chapter numbers in SR57.

The different steps in Figure 2 are briefly described below.

- Regulatory requirements by KFD, which are formulated in IAEA Safety Report 57 [1] and chapter 6 of the IAEA Safety Guide NS-G-2.12 [2], as discussed in section 1.1;
- The phase prior to LTO assessment (as given in figure 1 of SR 57 [1]) consists of feasibility and verification of pre-conditions;
- The phase LTO assessment (as given in figure 1 of SR 57 [1]) consists of the following steps:
    - Scoping identifies the safety and safety relevant systems, structures and components (SSC) on system level that are applicable to LTO assessment;
    - During screening further detailing of the different SSCs on structure and component level is performed. Screening also distinguishes between passive on the one hand and active components on the other hand, in order to be able to verify safe long term operation of all safety and safety relevant components;

- Passive components are assessed in Ageing Management Reviews (AMR) on mechanical (A and B), electrical and civil/structural structures and components (SC);
    - Time Limited Ageing Analyses (TLAAs) are assessed in further detail for the Reactor Pressure Vessel (RPV), Fatigue, Leak Before Break (LBB), and Qualification of design base accident resistant electrical Equipment (EQDBA);
        - For the project EQDBA relations exist with electrical AMR and electrical active SSCs, shown by the dashed lines in Figure 2;
        - In the other TLAAs relations exist with mechanical A and B components in AMR, shown by the dashed lines in Figure 2.
    - Documentation of the basis for LTO, where the documents generated in the previous steps are assembled in order to form the basis for LTO.
- The assessment of active safety and safety relevant components will also form part of the LTO assessment at KCB, as discussed in section 1.1. Mechanical, civil/structural and electrical parts will be checked against existing plant programmes and operating procedures;
- The phase approval and implementation (as given in figure 1 of SR 57 [1]) consists of:
    - Regulatory oversight, review of documentation by the regulator;
    - Implementation of plant commitments for LTO, where and when the recommendations are followed-up.

The different steps and phases briefly described above are further presented in detail in the rest of this conceptual document.

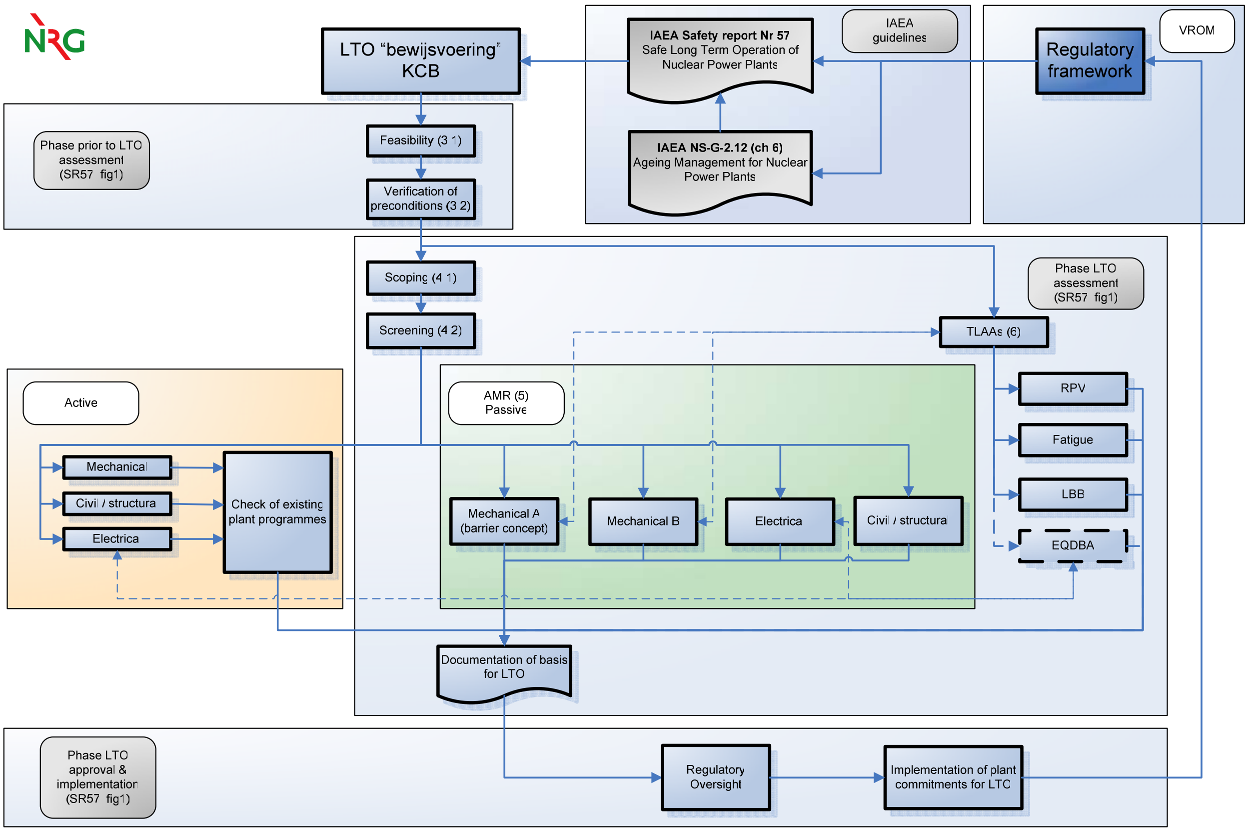

Figure 2 Overview of LTO “bewijsvoering” project (numbers as in SR57 [1])

2 Phase Prior to LTO Assessment

The first phase of the LTO activities in SR57 [1] is “prior to LTO assessment”. This phase consists of LTO feasibility and verification of preconditions, as can be seen in Figure 2. A more detailed overview of this phase is given in Figure 3. The numbers used in Figure 3 relate to the chapter and paragraph numbers in SR57. The details of the different blocks are discussed in this chapter.

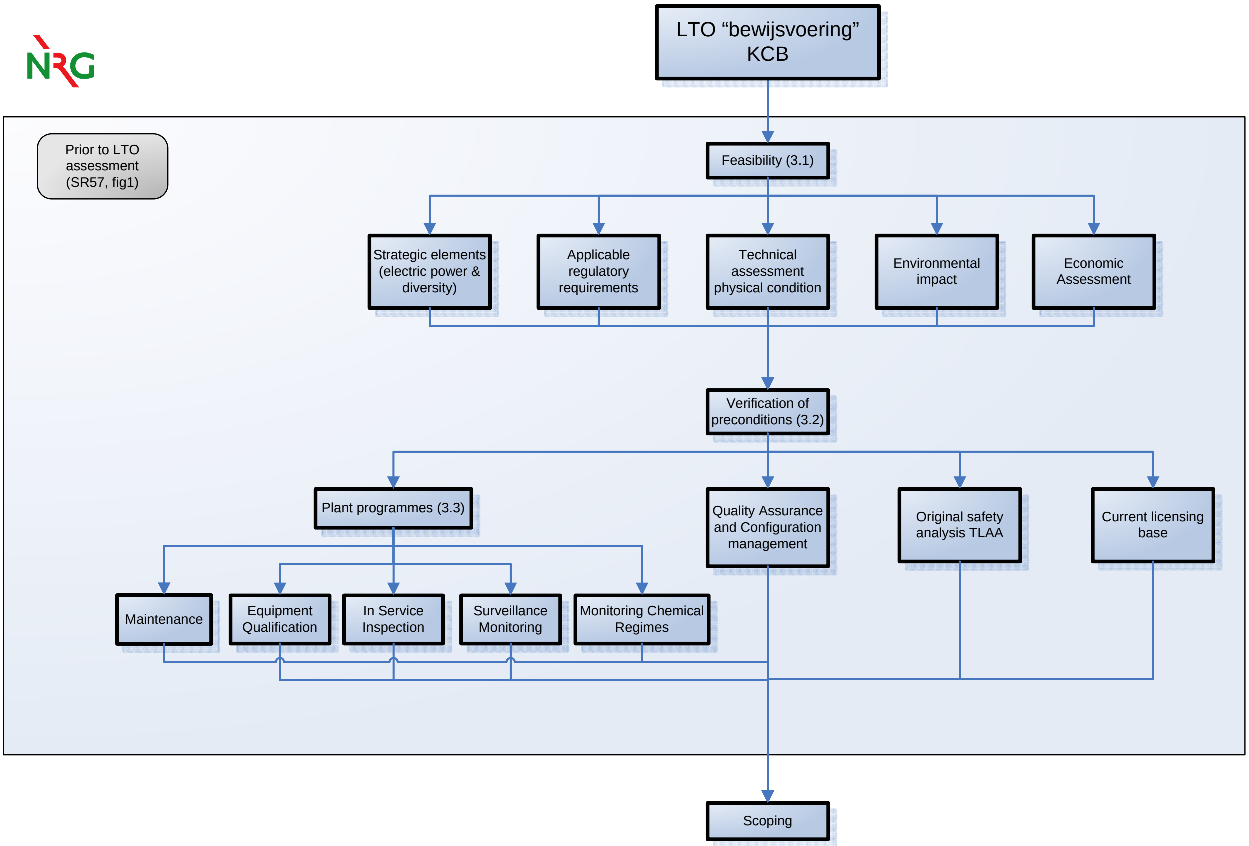

Figure 3 Overview of the phase: Prior to LTO assessment (numbers as in SR57 [1])

2.1 Feasibility

2.1.1 Strategic Elements

Strategic elements are defined in SR57 [1] as elements such as the need for electric power and issues concerning supply diversity. These strategic elements are addressed in the letter of the Ministry of Housing, Spatial Planning and Environment (VROM, in 2010 changed to Ministry of Infrastructure and Environment) to the Dutch Parliament [9] about decision making for KCB Long Term Operation. Details of the strategic elements are addressed in the annex to this letter [10] on consequences of closing KCB after 2013. The conclusions on the strategic elements from [10] are briefly summarized in [9] as the existence of minimal differences between the considered options (closure or not) in terms of supply security of electric power.

The strategic elements as discussed in [9] and [10] have been taken into account in the preparation of the covenant [11] about the continuation of operation of KCB until 2034.

2.1.2 Applicable Regulatory Requirements

The applicable regulatory requirements, deduced from the conditions in [9] are:

- Demonstration of technical safety after 2013 by means of PSR (10EVA13);
- Safety relevant decisions based on current license (Kernenergiewet vergunning);
- KCB has to belong to the 25% safest western NPPs (confirmed by benchmark commission);
- Direct decommissioning after end of operation in 2034.

Additional discussions between EPZ and KFD have led to a regulatory framework for Long Term Operation based on IAEA guidelines on LTO. The requirements are summarized in section 1.1 and repeated here for completeness:

- IAEA Safety Report 57 [1] (covers IAEA Safety guide NS-G-2.12 [2] for LTO aspects);
- Review of active safety and safety relevant components identified in the screening process.

These requirements form the basis for the project LTO “bewijsvoering”.

As mentioned in 1.1 KFD has also non-technical requirements on organisation & administration and human factors. These requirements will be dealt in the PSR project, 10EVA13.

2.1.3 Technical Assessment

The technical assessment of the Long Term Operation was investigated by EPZ and AREVA by means of a technical feasibility study. A summary of the public results of this feasibility study is given in a conference paper [12]. It is concluded that the major components of the primary circuit are well designed and maintained in such a condition that 60 years operation is possible without major replacement activities. Recommendations are made for smaller replacements of specific SSCs. Major uncertainties are mainly to be seen in the field of electrical and I&C components, not because of deteriorated condition but rather concerning the availability of spare parts and technological advances of product lines during the extended service life. However, this is not seen as a viability issue for LTO, since this issue can be handled within the scope of specific studies which should be initiated early enough to establish a cost-effective replacement strategy. The feasibility study shows that LTO of KCB until 2034 is technically feasible.

In preparation of the covenant [11], a letter was written by VROM to the Dutch parliament [9], where LTO was considered technically feasible. Reference was made to the results of the last PSR, where the good technical state of KCB was underlined by the latest insights. This shows that the most important components will easily meet the safety criteria in 2013. Besides this, the results of the PSR show that the system of ageing management applied at KCB is appropriate to timely detect degradation of safety relevant components and take necessary measures. These conclusions are in line with the conclusions from the EPZ/AREVA feasibility study [12].

2.1.4 Environmental Impact

The environmental impact of the continued operation of the Borssele Nuclear Power Plant has also been discussed in the letter of the Ministry of VROM to the Dutch Parliament [9] about decision making for KCB Long Term Operation. Details of the environmental impact are investigated more extensively in the annex to this letter [10] on consequences of closing the Borssele Nuclear Power Plant after 2013. The environmental impact results from [10] are briefly summarized in [9] as the existence of minimal differences between the considered options (closure or not) in terms of environmental impact.

2.1.5 Economic Assessment

An economic assessment was also addressed in the feasibility study on lifetime extension for KCB. The conclusions of the feasibility study with respect to technical assessment are already discussed in section 2.1.3. The economic assessment in the study demonstrated that lifetime extension to 60 years operation is economically viable.

2.2 Verification of Preconditions

In this section the existing plant programmes and documentation will be described. The structure of verification of preconditions is shown in Figure 3.

2.2.1 Plant Programmes

Plant programmes are a planned series of events or a set of related long term measures or activities that are performed and conducted in a certain order or manner to achieve the purpose for which the plant was constructed.

For the assessment of the plant programmes, five areas are considered as preconditions for LTO by SR57 [1]. These five plant programme areas are described at KCB using the nine elements as defined in SR57 [1]. Therefore documents are written which describe the specific programmes. Below, references to the documents are given together with a description of the requirements from SR57 [1].

- Maintenance:
  - Described for KCB in [16];
  - Nine elements of section 5.3 in SR57 [1].
- Equipment Qualification:
  - Described for KCB in [17];
  - Intended safety functions under environmental conditions.
- In Service Inspection:
  - Described for KCB in [18];
  - Technical basis of demonstration of adequate detection of ageing phenomena;
  - Methodology, equipment and personnel qualified in accordance with national standards;
  - ISI results correctly documented;
  - Database developed to support the findings and conclusions for LTO.
- Surveillance monitoring:
  - Described for KCB in [19];
  - Three aspects stressed: integrity of barriers, availability of safety systems, and availability of items whose failure could adversely affect safety.
- Monitoring chemical regimes:
  - Described for KCB in [20];
  - Nine elements of section 5.3 in SR57 [1] are addressed.

2.2.2 Quality Assurance and Configuration Management

A management system that addresses quality assurance and configuration management will be described according to SR57 [1]. Quality assurance and configuration management address quality control, design basis management, and the means to control and track the quality of the material, structure, component or system to predetermined requirements.

The references made in [1] for these subjects are:

- IAEA Safety Standards Series No. GS-R-3, The Management System for Facilities and Activities [28];
- IAEA Safety Standard Series No. GS-G-3.1, Application of the Management System for Facilities and Activities [29].

These two documents are the basis to assess the Quality Assurance and Configuration Management systems at KCB.

2.2.3 Original Safety Analysis TLAA

Original Safety analyses which contain Time Limited Ageing Analyses (TLAAs) are to be revalidated for LTO. Safety analyses to be revalidated are those that:

(a) Involve SSCs within the scope of LTO;

(b) Consider the effects of ageing degradation;

(c) Involve time limited assumptions defined by the current operating term;

(d) Were determined to be relevant in making safety determinations as required by national regulations;

(e) Involve conclusions or provide the basis for conclusions related to the capability of the SSC to perform its intended functions;

(f) Are contained or incorporated by reference in the Current Licensing Basis (CLB).

These criteria were used to identify TLAAs at KCB resulting in the following three topics:

- Reactor Pressure Vessel (RPV);
- Fatigue;
- Leak Before Break (LBB).

KCB added a fourth category, Qualification of design base accident resistant electrical Equipment (EQDBA). Although this is not formally a TLAA according to the definition, it is treated as one in the project LTO “bewijsvoering” due to the time related aspects.

The LTO assessment of these four categories is discussed in more detail in section (3.4).

2.2.4 Current Licensing Basis Documents

The current licensing basis of KCB is described in the Veiligheidsrapport [21] in combination with the Technical Information Package (TIP) [22].

3 Phase LTO Assessment

3.1 Scoping

The scope of the LTO assessment is determined on the basis of IAEA Safety Report 57 [1]. According to this document the Systems Structures and Components (SSCs) within the scope of LTO assessment are the following:

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.

Based on these criteria, the SSCs in the LTO scope were identified and reported in a scoping report [23] in close cooperation between KCB and AREVA. The safety functions of these SSCs were identified in detail, and subsequently they were categorized in three different "safety categories":

- Safety category 1, This category contains components of the reactor coolant system whose postulated catastrophic failure is not enveloped by accident analyses. In the event of postulated catastrophic failure (for example circumferential break at a weld) of the main components of the reactor coolant pressure boundary an event sequence is to be expected for which accident control has not been verified. For this reason, these components are assigned to category S1.
- Safety category 2, Other SSCs important to safety, including
    - High-energy SSCs inside the containment whose postulated failure may lead to cross-redundancy consequential damage, or
    - whose failure initiates a design-basis accident with immediate adverse impact on heat removal from the reactor core;
    - SSCs for the control of design-basis accidents (safety functions), for which no alternative measures are available promptly or in an adequate time frame;
    - SSCs with auxiliary/supply functions whose failure will lead to loss of safety functions required for accident control;
    - Supports as well as supporting structures for category 1 components.

- Safety category 3, SSCs, whose failure may impact upon the safety functions specified in categories 1 and 2.

The SSCs in the LTO scope are provided in tabular format in the scoping report [23] where all SSCs are classified according to the categories mentioned, as described above. The scoping results are limited to system level.

3.2 Screening

In the screening phase further detailing of the different SSCs on structure and component level is performed and active and passive SCs are identified (see Figure 2). The passive SCs identified in the screening step are subject to AMR (section 3.3). The active SCs are subject to a review of existing plant programmes in the active components assessment (chapter 4).

- Passive SCs are structures, components or subcomponents whose functioning does not depend on an external input such as actuation, mechanical movement or supply of power;
- Active SCs are defined as structures, components or subcomponents that are not passive.

These two different groups are directed towards different follow-up processes in the LTO assessment, as can be seen in Figure 2.

The passive SSCs from screening for KCB are classified into four main groups in order to facilitate AMR. These four groups are:

- Mechanical A structures and components;
- Mechanical B systems, structures and components;
- Electrical and I&C commodities;
- Civil/ structural commodities.

Two types of mechanical SCs are identified in the screening process: mechanical A and mechanical B. The mechanical A SCs are identified based on the barrier concept. The barrier concept was established to limit the potential for radiological release to the environment through assurance of the continued integrity of structures and components composing the Main Coolant Pressure Boundary (MCPB) and Containment. The specific components classified as mechanical A are listed in Figure 5.

The remaining mechanical SSCs from the screening process are handled in the frame of mechanical B AMR. The list of mechanical B categories is shown in Figure 5. As a large number of category B systems are subject to an Ageing Management Review, they are grouped for AMR report preparation to simplify the handling of the amount of individual components and make it more effective.

Commodity groups are identified in the screening report in order to facilitate the AMR. The US nuclear industry guidance for screening NEI-95-10 [25], which is one of the basis documents for SR57 [1], recommends the establishment of commodity groups of similar structures or components to carry out AMR. Commodity groups are determined based on characteristics such as similar design, similar materials of construction, similar ageing management practices and similar environments.

3.3 Ageing Management Review

The next step of the review sequence involves detailed technical evaluation of in-scope passive components (e.g. piping) and passive subcomponents of active SCs (e.g. pump casing) to demonstrate that the effects of ageing will be adequately managed, (i.e. the intended function(s) will remain consistent with the NPP licensing basis during Long-Term Operation).

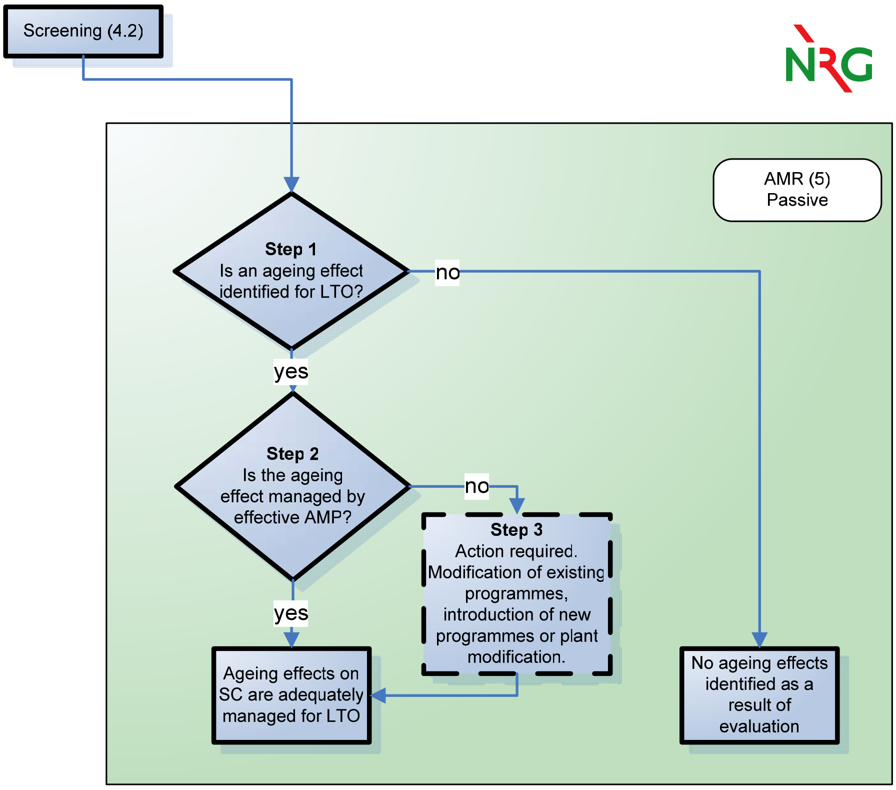

Figure 4 Overview of Ageing Management Review (AMR) process according to SR57 [1]

The AMR process for passive subcomponents is described in Figure 4 in correspondence with SR57 [1]. The three steps in the figure are described as follows:

- **Step 1**: The ageing mechanisms and/or effects that require management are first identified. In this step the possible ageing mechanisms are identified for three sub-groups (Mechanical, electrical and civil/structural);
- **Step 2**: Subsequently the ageing effect is evaluated for in-scope SCs. The environmental and operating conditions could cause ageing degradation of each in-scope SC during the service life of the plant. Therefore, each review considers the environmental and operating conditions to which each SC is subjected, including system pressure, temperature and water chemistry. These

conditions are then evaluated with respect to their effect on applicable ageing mechanisms for each in-scope component;

- **Step 3**: Once this ageing mechanism evaluation is completed, the necessity for any specific ageing management actions is identified. Effective ageing management may be accomplished by coordinating existing programs and activities, including maintenance, In-Service Inspection (ISI) and surveillance, as well as operations, technical support programs (including analysis of any ageing mechanisms) and external programs, such as research and development. Effective ageing management serves to manage the effects of ageing during operation, such that the intended functions of SCs can be maintained consistent with the current licensing basis. Existing plant programs and documents are reviewed and evaluated during this step to determine where existing programs are adequate without modification, as well as whether existing programs should be augmented for Long-Term Operation. Recommendations will be made regarding the specific areas in which KCB plant practices and policies should be augmented to substantiate LTO.

The AMR is reported according to the document structure shown in Figure 5. The general methodology is described in the AMR methodology report [26].

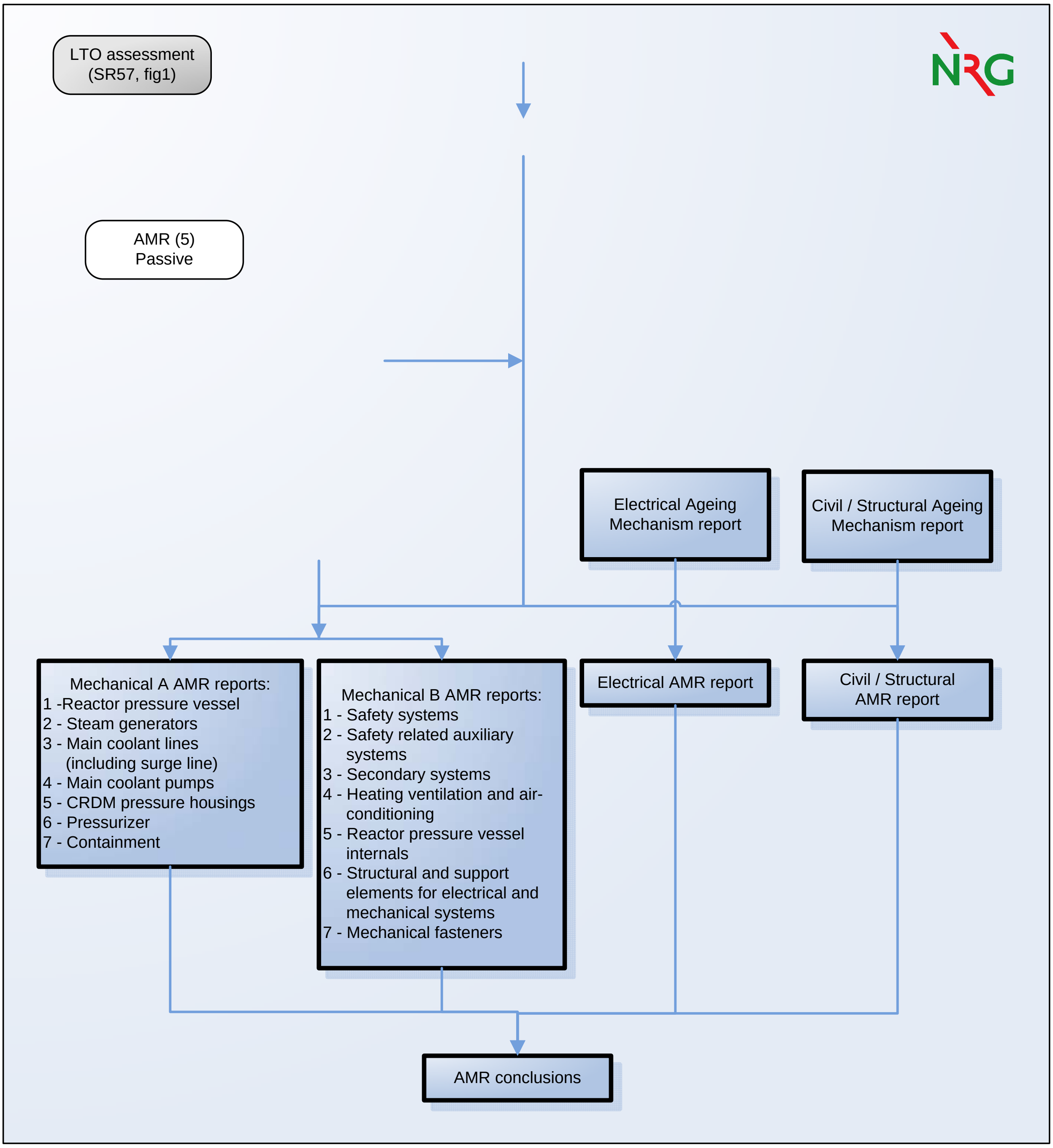

Figure 5 Overview of document structure for AMR

3.4 Time Limited Ageing Analyses (TLAAs)

These TLAAs at KCB identified as TLAA in section 2.2.3 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.

3.4.1 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 described in the RPV safety analysis report [13].

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 [13]. 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 objective of the RPV safety assessment report [13] is to prove the integrity of the KCB RPV for an operating term of up to 60 years. Therefore, the structural integrity of the RPV with respect to operation, irradiation surveillance and Pressurized Thermal Shock (PTS) analysis is assessed. 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 and by a general benchmark of the KCB results with RPV safety assessment data worldwide.

The RPV safety assessment report [13] for the KCB RPV is an overview of the prepared underlying reports, see Figure 6. In this figure the sequence of underlying reports is shown in clockwise direction.

- First, the status report is written to give an overview of the status of the RPV assessments before starting the LTO assessment;
- Then fluence calculations are performed in order to determine the fluence in the surveillance specimen and the RPV;
- These calculations are performed for MOX fuel loading as well.
- The fluence calculations have been verified independently by NRG by means of shadow calculations amongst others;

- Since the original surveillance program (SOP 0, SOP 1 and SOP 2) does not cover 60 years of operation an additional surveillance program is being carried out. Therefore, additional surveillance specimen and capsules (SOP 0a, SOP 3 and SOP 4) were manufactured;.
- The testing of the unirradiated specimen in SOP 0a has subsequently been carried out.
- The PTS report describes the PTS calculations where the safety margins with respect to Pressurized Thermal Shock are assessed;
- Underlying thermal hydraulics calculations are carried out to determine the thermal loading which occurs during PTS;
- These underlying thermal hydraulics calculations are reviewed independently by TüV;
- The results from the PTS report concerning RT_{NDT} at 55 EFPY are used for a re-evaluation of the pressure-temperature limits.

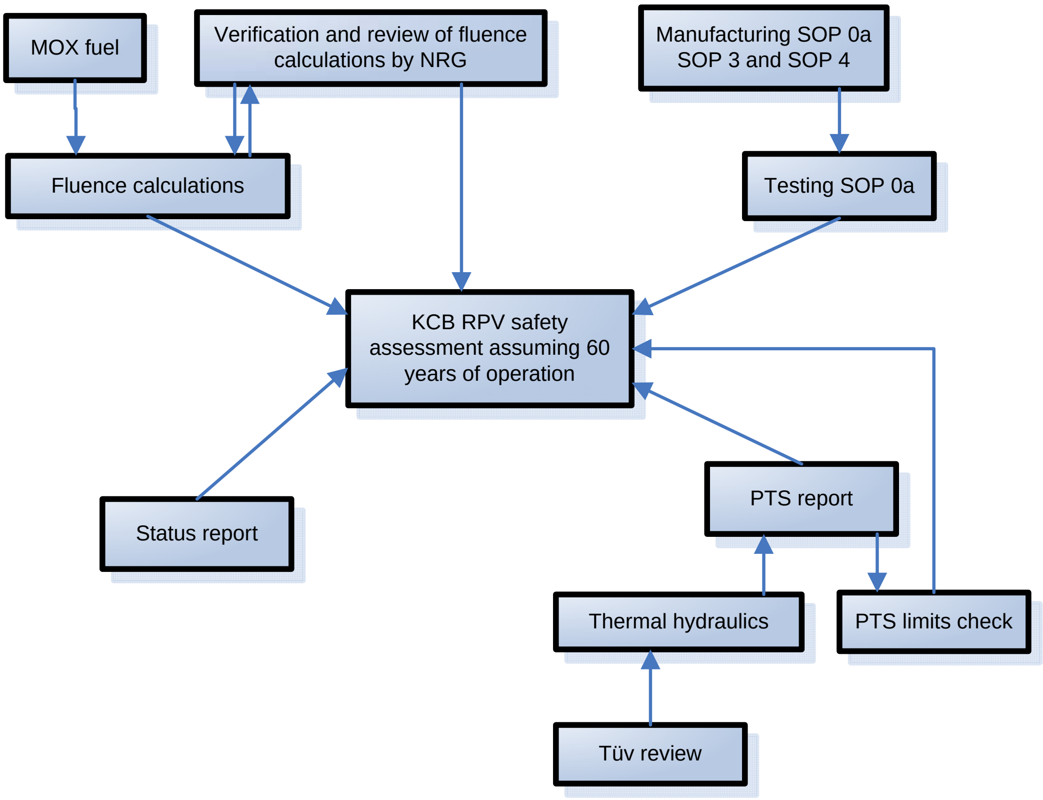

Figure 6 Overview of underlying reports for RPV safety assessment report [13]

In addition to [13] scraping samples are taken from the RPV and analysed as verification of the fluence calculations.

3.4.2 Fatigue

The fatigue TLAA in LTO "bewijsvoering" is described in [32] and underlying documents. The approach is described in the current paragraph.

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.

The goal of the fatigue project is to demonstrate that for all components important to safety adequate safety margins against crack initiation by fatigue are in place at every moment during operation until 2034, taking into consideration the possible influence of environmental effects.

In order to achieve this goal, a number of activities is carried out. The project with its activities and a timeline is shown in Figure 7 and described below:

Thermal Load monitoring / load specification

As mentioned above the calculated cumulative usage factors (CUF) in the original analyses are based on conservative assumptions on numbers of load cycles and stress ranges of transients. As a first step the load catalogue is updated for operation until 2034. However 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 AREVA 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 3 to 5 cycles.

Scoping TLAA Fatigue

Although NPP Borssele has a set of existing Fatigue TLAAs it was decided for LTO to perform an independent scoping survey to determine for which component locations fatigue assessments should be necessary. This survey was based on international practice and engineering judgement. The scope for which revalidation is foreseen consists of the newly determined component locations complemented with the component locations for which fatigue TLAAs were available.

Demonstration on safety margins for LTO

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 CUF_{2034} is calculated for every in-scope component location. Environmental fatigue is addressed by following the newly proposed 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.

For all component locations for which a CUF_{2034} below 1.0 cannot be delivered with this assessment (based on the original analyses) or for which the usage factor is above the KTA environmental fatigue threshold values, short term assessments are proposed to prove the safety margins on fatigue crack initiation for these locations. These further assessments must be delivered before the end of 2013.

In the assessment also the management of high cycle thermal fatigue is studied. Worldwide some NPPs experienced fatigue cracks because of high cycle thermal fatigue. Those events are evaluated at NPP Borssele and in this assessment an overview is given. The applicability of the new fatigue design curve for austenitic stainless steels (ASME Boiler and Pressure Vessel Code 2009b Addenda) is discussed. The impact of the new ASME design fatigue curve on the stainless steels in NPP Borssele is investigated.

Demonstration including environmental fatigue and fatigue monitoring during LTO

After 3 to 5 cycles of measuring new load specifications come available for thermal transients. Based on the new load specifications it is foreseen to perform new fatigue calculations including environmental effects, if applicable. About the influence of the water environment discussion is ongoing. Different approaches can be seen to account for environmental fatigue. Due to the fact that NPP Borssele is a German Siemens/KWU plant it was decided to join a VGB working group research project which aims to deliver a specific basis and approach for German and Swiss NPPs and NPP Borssele, regarding environmental fatigue. The first results of this project are expected in 2012. These results will be taken into account for further investigation of environmental fatigue.

After the determination of best estimate usage factors (including environmental effects) all relevant locations will be continuously monitored for the period of LTO by FAMOS. For all locations in the scope a yearly update of the fatigue usage will be provided. In some cases it might be possible to modify existing operation procedures to lower the fatigue loads if this is desirable based on FAMOS monitoring.

With the aforementioned approach a sound basis is given for the prevention of crack initiation by fatigue for the period of LTO.

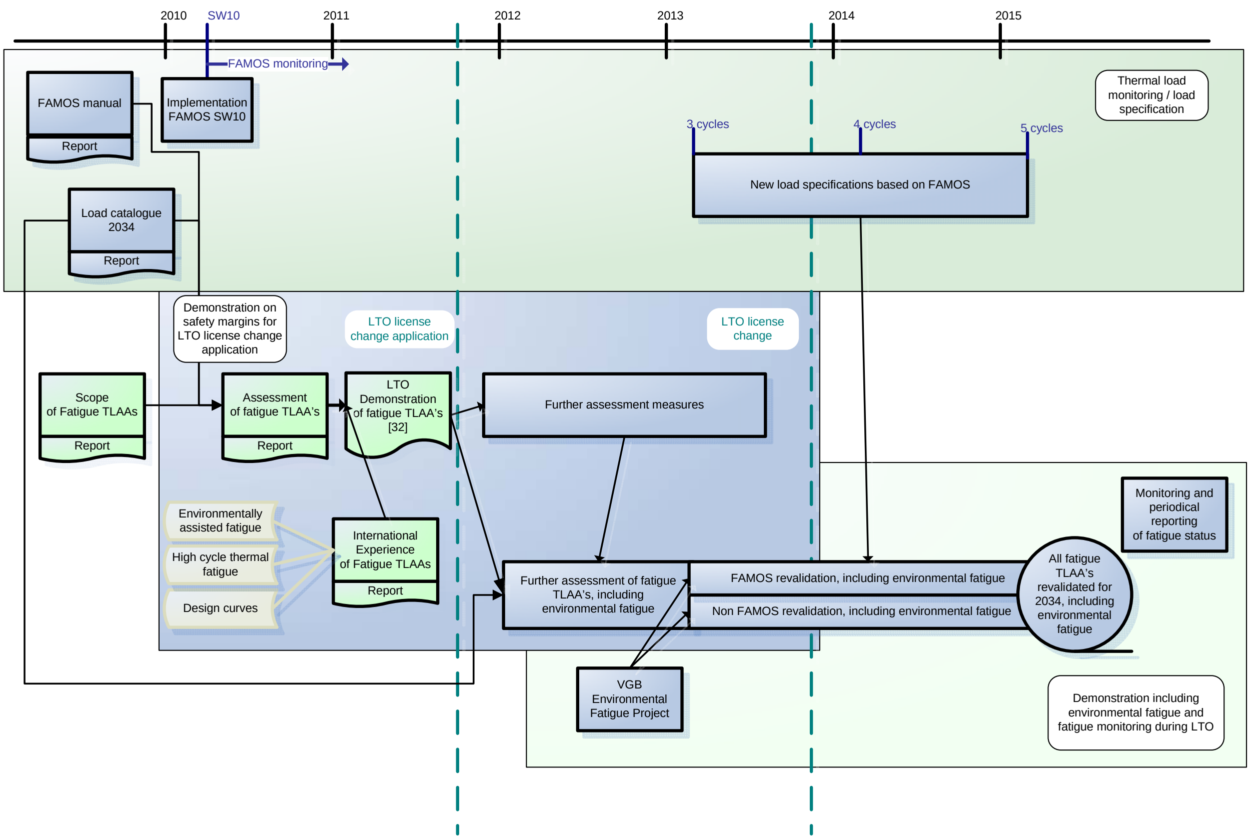

Figure 7 LTO demonstration and projects in the framework of fatigue at NPP Borssele

3.4.3 Leak Before Break

Leak before break 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 review of existing literature at EPZ in terms of time dependency in Break Preclusion is discussed in the LBB report [27].

The scope for Break Preclusion in [27] for LBB is given below:

- Main coolant lines (YA) .
- Surge line (YP) .
- Main steam lines (RA) within the secondary containment (reactor building 02).
- Main feedwater lines (RL) within the secondary containment (reactor building 02)
- Emergency feedwater lines (RL) between the first non-return valve at the steam generator and main feedwater line.
- Lines of the secondary reserve feedwater system (RS) between the first non-return valve at the steam generator and main feedwater line.

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

The goal of the review [27] is the answer to the question:
Is the concept Break Preclusion (Bruchausschluß) as entered in 1997 still valid in case of plant life extension to 2034?
And: If the answer to the question is no, what measures will have to be taken in order to apply the concept for plant life extension.

The status of KCB towards the Break Preclusion concept is assessed based on the available literature as referred to in the TIP-03-04 document "Bestendigheid tegen invloeden van binnenuit" [14].

3.4.4 Qualification of Design Base Accident resistant electrical Equipment (EQDBA)

In this section information is provided about the project EQDBA, Qualification of Design Base Accident resistant electrical Equipment (harsh environment qualification), where the preservation of the environmental qualification has to be demonstrated. This section describes the different phases in the subproject and gives background information about the history of the components qualified for design base accident conditions and description of the scope of the project EQDBA.

Background and Scope

The first equipment qualification project at NPP Borssele was performed in the mid-'80s of the twentieth century. Due to the Harrisburg accident it was realized that the electrical components didn't have a qualification for harsh environment conditions. The project "Ongevalsbestendige Apparatuur" (in English: accident resistant components) was worked out in cooperation with Siemens-Erlangen (now AREVA). In this project the approach of the German NPPs was adopted. Based on design base accident scenarios and required safety functions a list of electrical equipment needed to manage the various accidents was developed. The selected components, the requirements and the criteria were listed in the so called "Störfallmatrix" (in English: accident matrix).

The selected hardware was qualified in conformity with the German KTA standards. As follow-up of the first PSR (1992) an update of the "Störfallmatrix" was made in 1994. Also some hardware updates were performed as a result of this PSR.

EQDBA within LTO "bewijsvoering"

Goal of the EQDBA project is the implementation of a method to establish the qualified life of each component with a harsh environment qualification for LTO. The project LTO "bewijsvoering" deals with this issue as a TLAA-like issue, as discussed in section 2.2.3.

The AUREST-Database (Areva) is used as a tool to calculate and present the qualified life of the components. Areva developed this database in close cooperation with the German NPPs, within the VGB working group "Betriebsbegleitende Nachweise der KMV-Störfallfestigkeit" (this group handles proof of qualified life). EPZ participates in this VGB working group to ensure information about developments with respect to the concerned equipment.

The EQDBA process is carried out in a number of steps, which are schematically shown in Figure 8. The scope of the project is given by the components in the Störfallmatrix. The steps in the EQDBA process are described below:

- **Step 1** consists of an environment condition monitoring program which has been performed over the period 2007-2009. The goal of this program was to determine the service conditions for each concerned single component resulting in data for the accident resistant components at KCB;
- **Step 2** consists of the verification if the design base accident resistant electric components are in the standard component library of the AUREST database. If the component is within the library,

step 3 is taken. Otherwise, the component is forwarded to the KCB specific component library, which is forwarded to step 6;

- **Step 3** consists of editing the qualification data of equipment installed at KCB into a form suitable for the AUREST-database. Subsequently the actual qualified life calculations are performed using AUREST;
- **Step 4** consists of a check of the residual lifetime of the component. If the allowable residual lifetime allows for use beyond 2034, the preservation of environmental qualification is successfully passed. Otherwise action is required in step 5;
- **Step 5** is the development of a program to requalify or to replace the components of which the residual lifetime is insufficient;
- **Step 6** consists of treatment of the components with a lack of useful qualification data, with respect to the needed information for the AUREST-database. These components are distinguished after step 2.

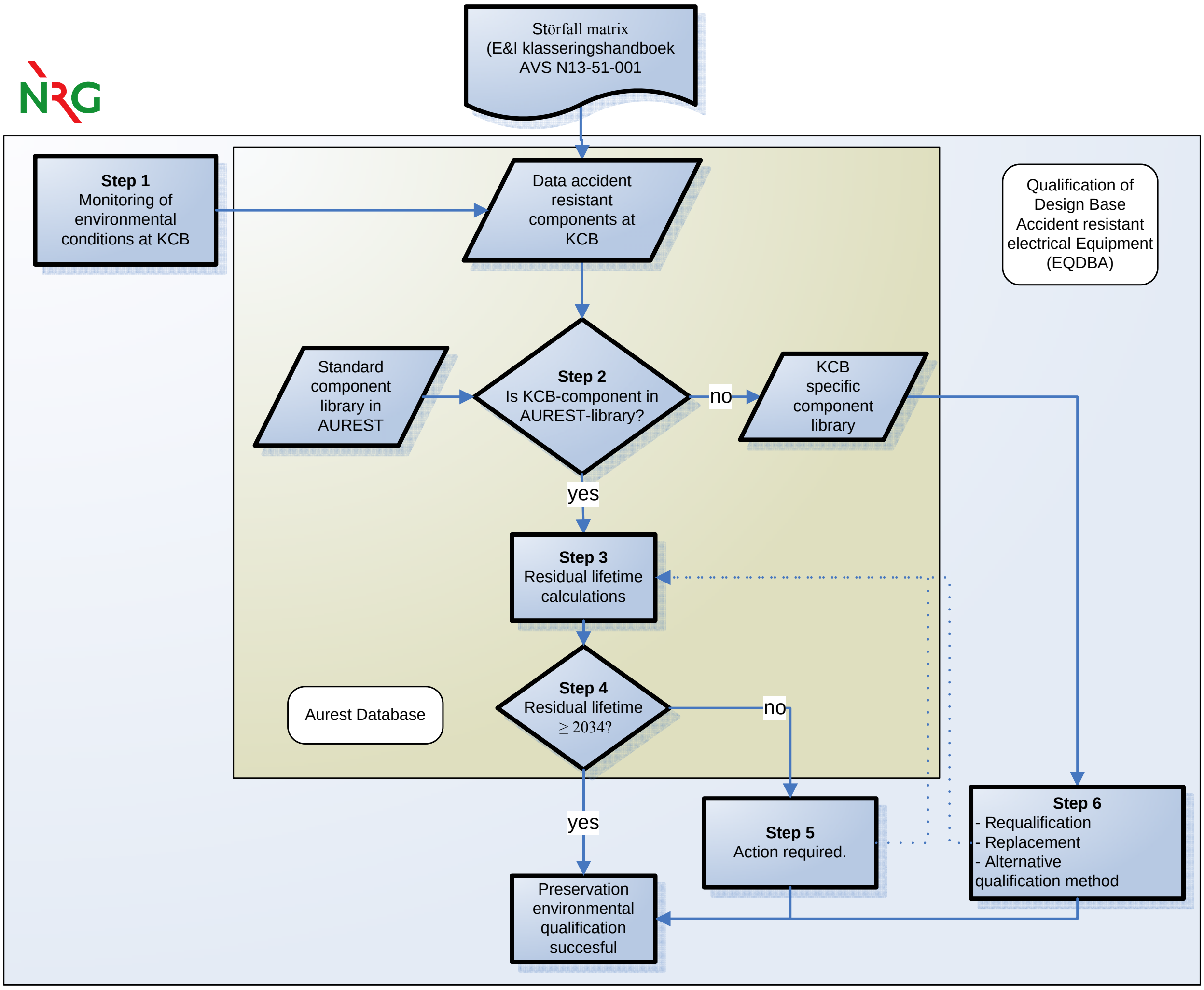

Figure 8 Overview of EQDBA process

4 Assessment of Active Components

4.1 Background

The preparatory work for the LTO assessment at KCB was reviewed on request of KFD in 2009 by a SALTO peer review team [8]. The peer review mission had a limited scope, restricted to the part LTO assessment of Safety Report 57 [1]. Based on the comments of this SALTO peer review, the project LTO "bewijsvoering" was extended by inclusion of the assessment of active safety, and safety relevant 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) [30]. This rule requires that the utility monitors the performance or condition of relevant SSC, or applies a preventative maintenance programme. 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. Therefore, evaluation of active components is included in the project LTO "bewijsvoering" in line with the Maintenance Rule (10 CFR 50.65) [30].

4.2 Active Components in LTO "Bewijsvoering"

Although application of the Maintenance Rule is not mandatory in the Netherlands, KCB does have a comprehensive programme for life-cycle management of the KCB plant in place. The purpose of this life-cycle management programme is to ensure that all activities have been established and applied, necessary to maintain the KCB plant compliant with design and applicable regulatory requirements [31].

The review process for the active components is schematically shown in Figure 9. The active components are identified in the screening process, which is described in section 3.2. The active components are classified into three groups:

- Mechanical;
- Civil/structural;
- Electrical.

The components of these three groups are subsequently processed in six steps. These six steps are shown in the figure and are described as follows:

- **Step 1**: First, a check is performed if the component is addressed in a preventive maintenance programme. Preventive maintenance at KCB forms part of the life-cycle management programme described above. Preventive maintenance aspects of the programme are described in the documents, which are produced during the verification of preconditions phase, see section 2.2.1. Preventive maintenance programmes are:
    - Maintenance [16]
    - Equipment qualification [17]
- **Step 2**: Subsequent to step 1, the appropriate preventive maintenance programme is evaluated in terms of adequately addressing the ageing of active components. According to 10CFR50.65 [30], the capability of performing the intended (safety) function is to be evaluated.
- **Step 3**: Once the preventive maintenance programmes are evaluated for the active component, the need for action is identified. If the ageing of the active component is not adequately addressed in the preventive maintenance programme, modification of existing programmes, introduction of new programmes or plant modification may be required.
- **Step 4**: When the active component is not addressed in a preventive maintenance programme, as identified in step 1, the check is made to establish that the performance or condition of the component is monitored to ensure its capability of fulfilling its intended function. Monitoring of the performance or condition also forms part of the life-cycle management programme and is provided in the surveillance monitoring programme as described in [19]. Description of the testing procedure applied, is provided in Step 6.
- **Step 5**: When no performance or condition monitoring is performed according to the criteria in step 4, action is required. Like in step 3, modification of existing programmes, introduction of new programmes or plant modification may be required.
- **Step 6**: A description and reference to the programme or procedure where the component is tested is to be provided.

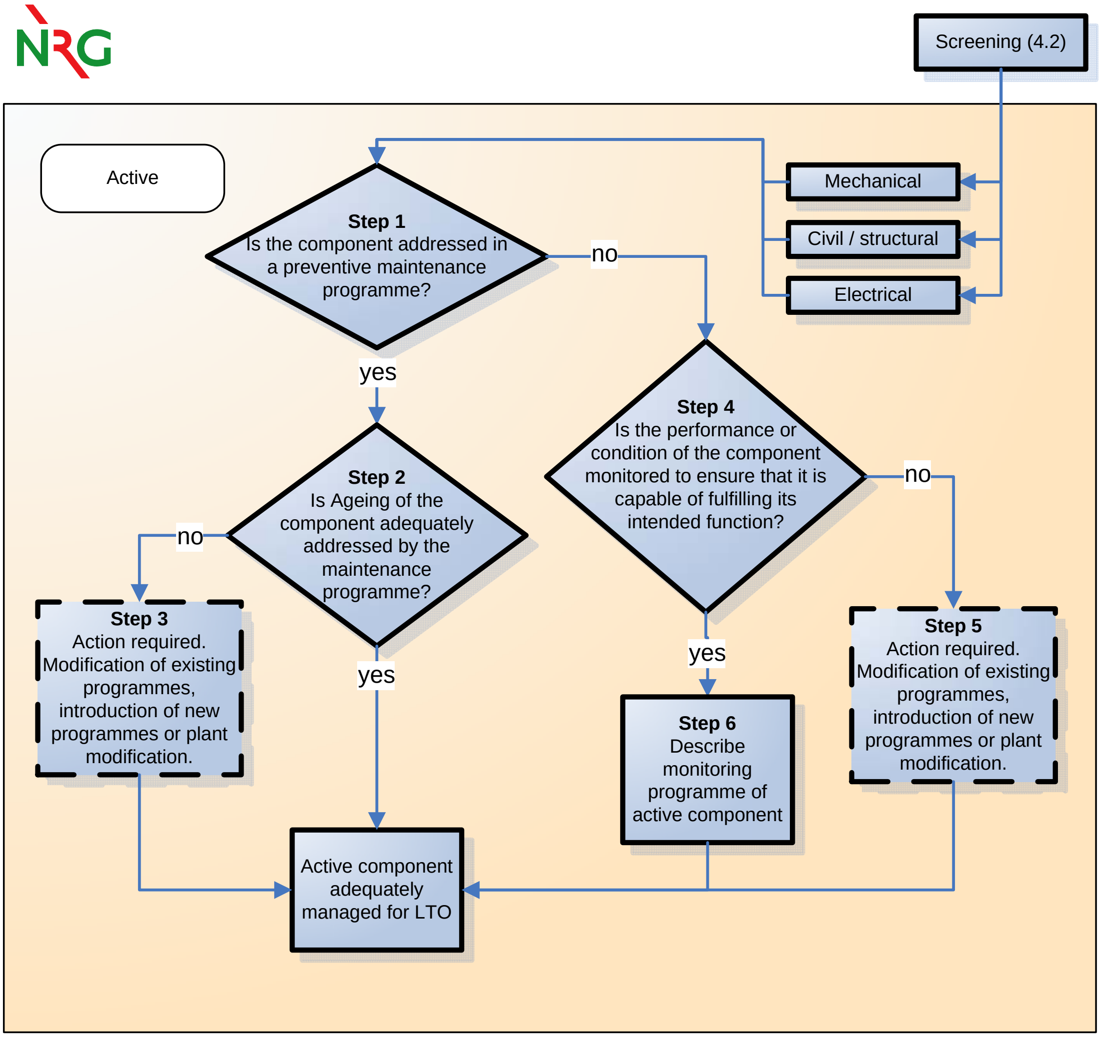

Figure 9 Overview of active components review process

5 Documentation for LTO Basis

The documentation which forms the basis for LTO consists of all documents resulting from the project LTO “bewijsvoering”. This documentation should cover the entire project, as schematically shown in Figure 2.

The Dutch regulator (KFD) will make use of external specialists of GRS in Germany and IAEA SALTO peer reviews to evaluate the results of the project LTO “bewijsvoering”. External specialists from GRS will review the documents which will be delivered by EPZ to the regulator. In the project discussions between the regulator and EPZ, a document list is used for planning of the project and review of all documents.

Document lists based on the LTO “bewijsvoering” project structure are given in this section. In sections 5.1.1 (phase prior to LTO assessment), 5.1.2 (phase LTO assessment) and 5.1.3 (active components) document lists are presented, ordered according to the project overview in Figure 2.

5.1.1 Phase Prior to LTO Assessment

The documentation of the phase prior to LTO assessment consists of:

- Feasibility phase assessment, which is given in the current document in section 2.1.
- Verification of preconditions:
  - The assessment of the five plant programmes from the verification of preconditions is discussed in five separate EPZ documents: [16], [17], [18], [19] and [20].
  - Quality Assurance and Configuration Management;
  - Original safety analyses TLAA, given in section 2.2.3 of the current document;
  - Current licensing basis, given in section 2.2.4 of the current document.

This documentation is also given in more detail in Table 2.

Table 2 Document list for Phase prior to LTO assessment

Para.	Phase	Part	Subject	Document or location
2.1	Prior to LTO assessment	Feasibility	-	Section 2.1
2.2.1	Prior to LTO assessment	Verification of preconditions	Plant programmes	Maintenance [16]
				Equipment Qualification [17]
				In service inspections [18]
				Surveillance monitoring [19]
				Monitoring chemical regimes [20]
2.2.2	Prior to LTO assessment	Verification of preconditions	QA and config. management	Quality Assurance and configuration management
2.2.3	Prior to LTO assessment	Verification of preconditions	Original safety analyses TLAA	2.2.3
2.2.4	Prior to LTO assessment	Verification of preconditions	CLB	2.2.4

5.1.2 Phase LTO Assessment

The documentation of the phase LTO assessment consists of:

- Scoping report [23];
- Screening report [24];
- AMR documentation as shown in Figure 5;
- TLAAs:
    - RPV documentation as shown in Figure 6 ([13] including underlying documents);
    - Fatigue: strategy report and load catalogue;
    - Leak Before Break: strategy report [27];
    - Equipment Qualification: strategy report.

This documentation is also given in more detail in Table 3 and Table 4.

Table 3 Document list for Phase LTO assessment (scoping, screening & AMR)

Para.	Phase	Part	Subject	Document or location
3.1	LTO assessment	Scoping	-	Scoping [23]
3.2	LTO assessment	Screening	-	Screening [24]
3.3	LTO assessment	AMR	-	AMR methodology report
				Mechanical ageing mechanisms report
				Electrical ageing mechanisms report
				Civil/structural ageing mechanisms report
				AMR Mech A RPV report
				AMR Mech A SG report
				AMR Mech A MCL report
				AMR Mech A MCP report
				AMR Mech A CRDM pressure housings report
				AMR Mech A PZR report
				AMR Mech A Containment report
				AMR Mech B Safety systems
				AMR Mech B Safety related auxiliary systems
				AMR Mech B Secondary systems
				AMR Mech B Heating ventilation and air-conditioning
				AMR Mech B RPV internals
				AMR Mech B Structural and support elements for electrical and mechanical systems
				AMR Mech B Mechanical fasteners
				Electrical AMR report
				Civil/Structural AMR report
				AMR conclusions report

Table 4 Document list for Phase LTO assessment (TLAA)

Para.	Phase	Part	Subject	Document or location
3.4.1	LTO assessment	TLAA	RPV	RPV safety assessment report [13]
				RPV status report [15]
				Fluence calculations report
				MOX fuel report
				Verification fluence calculations by NRG report
				Manufacturing of SOP0a, SOP3 and SOP4 report
				Testing SOP0a report
				PTS report
				Thermal hydraulics report
				TUV review report
				PTS limits check report
				Kernkraftwerk Borssele Entnahme und Auswertung van Kratzproben aus der RDB-Plattierung
3.4.2	LTO assessment	TLAA	Fatigue	LTO Demonstration of Fatigue TLAAs [32]
				Scope of Fatigue TLAAs
				Assessment of Fatigue TLAAs
				International Experience of Fatigue TLAAs
				Load catalogue
3.4.3	LTO assessment	TLAA	LBB	Strategy report LBB
3.4.4	LTO assessment	TLAA	EQDBA	Strategy report EQDBA

5.1.3 Active Components

The documentation of the active components consists of:

- Active components: report describing assessment results.

This documentation is also given in more detail in Table 5.

Table 5 Document list for active components

Para.	Phase	Part	Subject	Document or location
4	Active components	-	-	Active components document

6 Phase LTO Approval and Implementation

6.1 Regulatory Oversight

According to SR57 [1] the regulatory review verifies that the operating organization (EPZ) carries out a comprehensive evaluation and implements appropriate corrective actions and/or safety improvements within the agreed time, in accordance with the regulatory framework as discussed in section 1.1. A main part of this task is the assessment of document submissions by EPZ, as summarized in chapter 5, in order to demonstrate that SSCs will perform their intended functions in accordance with their licensing and design basis until 2034. To evaluate the project LTO “bewijsvoering”, the Dutch regulator (KFD) will make use of external specialists of GRS in Germany and IAEA SALTO peer reviews.

6.2 Implementation of Plant Commitments for LTO

The commitments to be implemented from the documents mentioned in section 5 will have to be taken into account in the LTO “bewijsvoering”. The implementation of commitments for LTO will be determined in consultation with the regulator.

7 Conclusions

KCB conducts 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. The outline of the project is based on IAEA safety guide 57 "Safe Long Term Operation of Nuclear Power Plants".

This conceptual document described the contents and coherence of the following parts in the project:

- Feasibility and verification of preconditions in the phase prior to LTO assessment;
- Scoping, screening and Ageing Management Reviews;
- Revalidation of the following TLAAs:
  - Reactor Pressure Vessel (RPV);
  - Fatigue;
  - Leak Before Break;
  - Qualification of Design Base Accident resistant electrical Equipment.
- Assessment of active components;
- Documentation for LTO basis;
- Regulatory oversight and the KCB implementation of plant commitments for LTO.

The outcome of the project LTO "bewijsvoering" will be used for a license change application and this will be submitted to the Dutch regulator KFD for approval of prolonged operation of KCB after 2013.

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