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Einreichung des Berichtes "Topical Peer Review 2017" des KKB
Technische Mitteilung TM-014-M 17059, Rev. 0

Sehr geehrte Damen und Herren

Mit Ihrem Schreiben vom 14.03.2017 [1] haben Sie vom KKB die Einreichung des anlagespezifischen Berichtes "Ageing Management of Nuclear Power Plants" bis zum 31.08.2017 verfügt.

Gemäss Vereinbarung (Email vom 02.11.2017) haben wir die vom ENSI gelieferte Übersetzung der technischen Mitteilung TM-014-M 17045 [2] geprüft und leicht überarbeitet.

Anbei erhalten Sie den englischen Bericht in Form der technischen Mitteilung TM-014-M 17059, Rev. 0, Topical Peer Review 2017, "Ageing Management of Nuclear Power Plants".

Bei Fragen steht Ihnen unser [redacted] gerne zur Verfügung.

Mit freundlichen Grüssen
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Referenzen:

[1] ENSI-Schreiben vom 14.03.2017 (AZ.: [redacted] - 10KEX.TPR2017), Rechtliches Gehör, Verfügung: Teilnahme an Topical Peer Review 2017 "Ageing Management of Nuclear Power Plants"

[2] Technische Mitteilung TM-014-M 17045, Rev. 0, Topical Peer Review 2017 "Aging Management of Nuclear Power Plants", 22.08.2017

Beilagen (nicht öffentlich): erwähnt [redacted]

Technical Note

TM-014-M 17059

Title	: **Topical Peer Review 2017** **Aging Management of Nuclear Power Plants**	Unit	:	1+2
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For changes, see revision index on the following page

REVISIONS

The last revision signed by the competent office is valid.

Date	Rev.	Correction/supplement	Pages	Initials
07.12.2017	0	• Initial version • Version 0 in English. Content same as in the German version of technical note TM-014-M 17045, version 0, sent to ENSI by letter dated 30.08.2017 • The English version is a translation of the original in German. In case of a discrepancy, the German original will prevail.	all	[redacted]

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1 General Information

Switzerland is participating in the Topical Peer Review (TPR), adopted by the Council of the European Union in 2017, focusing on the "Ageing Management of Nuclear Power Plants". The European Nuclear Safety Regulators Group (ENSREG) is coordinating the TPR 2017. The objectives of the TPR 2017 include, in particular, ensuring that the participating countries review the provisions put in place so far in the context of the ageing management of operational nuclear installations, identifying good practices and areas of improvement from them and exchanging operating experience at European level.

As part of this, in phase 1 of the TPR the Swiss Federal Nuclear Safety Inspectorate (ENSI) is called upon to publish a national assessment report on the current status of ageing management in Switzerland by the end of 2017. Consequently, all Swiss licensees of nuclear installations with a power of ≥ 1 MW, which will also continue operation beyond 2017, are requested in the form of a directive [1], to prepare a plant report by the end of 31 August 2017. This will provide the essential contents for the national assessment report.

In creating the plant reports, the requirements of the corresponding specification [2], drawn up by the Western Nuclear Regulators Association (WENRA), need to be considered.

This document presents the plant report for TPR 2017 for units 1 and 2 of the Beznau NPP of Axpo Power AG.

2 Overall ageing management program requirements and implementation

2.1 National regulatory framework

To understand the overall ageing management programs (AMP) applied in Switzerland, it is necessary to describe the development of the AMP in Switzerland. This will therefore be looked at first. We will refer back to this content in subsequent subsections wherever necessary.

At the end of 1991, the Swiss NPPs were requested by the Swiss supervisory authority, ENSI, to introduce an ageing management program for safety-relevant structures, systems and components (SSCs) and to maintain it up until the end of the period of operation. Consequently, it was decided within the framework of the Group of Swiss NPP Managers (GSKL), to authorize a new working group "Ageing management in Swiss NPPs (CH-KKW)" with creating joint interpretative documents for surveying the ageing process.

Its purpose is to ensure that the ageing management in all Swiss nuclear power plants is performed according to the same requirements and with the same quality. The procedure for implementing ageing management within the Swiss NPPs was carried out gradually:

- The GSKL program for checking the ageing management measures builds on many years of applied maintenance concepts of the Swiss NPPs, references the legal requirements and forms the basis for ageing management of the Swiss NPPs. The document describes the physical ageing phenomena occurring in the NPPs in general and presents a procedure for the early detection and control of these phenomena.

- Ageing management is implemented in the individual departments of the Swiss NPPs. In addition, an independent GSKL expert team was set up for each department making it possible to monitor ageing with the necessary technical competence. As a result of dividing ageing management over the three departments, electrical, civil and mechanical engineering, it was necessary to create a GSKL interface document which lists and clearly allocates interface and liaison points between the individual departments in the handling of equipment.
- In terms of ageing management of civil engineering, the GSKL guide for the creation of fact sheets contains a listing and an assignment of ageing mechanisms relevant for the various construction materials.
- In the ageing management of electrical engineering and I&C, Part 1 of the fact sheets contains a listing of the most important function-impairing and qualification-influencing descriptions for the specified component with a link to the corresponding references. Part 2 of the fact sheets contains possible diagnostics and testing methods, as well as characteristics by which the ageing progress can be identified.
- The GSKL catalogue of ageing mechanisms for mechanical equipment (KATAM) identifies, classifies and describes in detail the ageing mechanisms relevant for light water reactors. After it was revised in 2011, this document was recognized by the regulator as an essential foundation for ageing management in the Swiss NPPs.
- GSKL guides for the creation of fact sheets for civil, electrical and mechanical engineering provide guidance for the practical implementation of ageing management and documenting the results of the assessment of mechanical and electrical components and the civil engineering structures.
- Departments in the individual plants implemented the AMP in detail based on the specifications of the GSKL working group. The ageing assessments of civil engineering structures and/or SSCs are summarized in the plant-specific fact sheets.

2.1.1 Scope of the overall ageing management programs

Section 6.3.1 of the ENSI-B10 [3] guideline defines specific requirements for technical and scientific staff in the plants who are involved in ageing management. The licensee appoints this staff in accordance with ENSI-B10. Persons who are responsible for ageing management must be qualified to degree level in a scientific or technical subject and also have additional knowledge of methods for ageing management and sufficient experience in the relevant subject (electrical, civil or mechanical engineering).

As already mentioned in Section 2.1, the GSKL expert teams, whose representatives are responsible for the AMP of their plants or who contribute to the area, do not only work to ensure the reliable implementation of the GSKL foundations in their plants, but also ensure that information is fed back from the GSKL Working Group (AG) "CM in Swiss NPPs" and their specialist teams.

The ageing management process is regulated in detail in the KKB integrated Management System (iMS) of the corresponding process. Ageing management provides evidence that known material ageing mechanisms are adequately considered in the maintenance system for all safety-relevant plant parts (SSCs) and that measures for closing any omissions are taken. The overall ageing management process is subdivided into three main areas (mechanical, electrical and civil engineering). The interfaces between the individual departments are defined in the interface document, the power-plant-specific implementation of the GSKL interface document, so that there are no omissions in the area of the department intersections. Special directives, guidelines, process instructions and work instructions in the individual departments clearly define the organization, workflows and responsibilities of the ageing management process.

In accordance with Article 35 of the nuclear energy regulation KEV, the licensee must perform systematic ageing management based on the AMP for all equipment and civil engineering structures whose function and integrity are important for safety and security. Ageing management requirements are specified in the guideline ENSI-B01 [4].

The scope of the systems, structures and components (SSCs) to be considered within the AMP primarily depends on the classification of the SSCs in accordance with guideline ENSI-G01 [5] and the relevant specifications of guideline ENSI-B01. Mechanical and electrical equipment which, in accordance with the guideline ENSI-A06 [6], is relevant for safety based on the probabilistic safety analysis (PSA) must be identified as such and incorporated in the mechanical engineering and electrical engineering AMP. In accordance with the guideline ENSI-G01, essential data relating to electrical and mechanical engineering safety classified components are to be periodically recorded or recorded in component lists and/or component type lists, when plant changes occur. These lists are to be made available to ENSI. All SSCs are recorded with this relevant metadata using SAP enterprise software, permitting automated identification and checks.

Civil engineering

Based on Section 5 of ENSI-B01 [4], ageing management is to include all civil engineering structures classified according to ENSI-G01 [5]. In line with their significance for nuclear safety and radiation protection, civil engineering structures are assigned to two nuclear structure classifications, BK1 and BK2.

Civil engineering structures and substructures are complete buildings or large parts of buildings. Civil engineering systems are groups of civil engineering components which fulfil a common function, such as steel platforms or seals or fire protection elements. In turn, civil engineering systems comprise civil engineering components such as anchor plates or fire protection doors.

Each classified building is assessed separately within the scope of ageing management. The fact sheets concern individual buildings or parts thereof.

Mechanical engineering

The systematic ageing management for all vessels and pipelines assigned to safety classes SK1-SK3 based on guideline ENSI-G01 [1], including their supports and pressurized equipments (pumps, valves, safety valves etc.), must be documented according to ENSI-B01 [4] for their use in Swiss nuclear installations. Exceptions to this include small pipes with nominal diameters DN ≤ 25 for SK 1 and DN ≤ 50 for SK2 & SK3. The ageing condition of the mechanical engineering equipments not covered by the systematic ageing management in accordance with ENSI-B01 is tracked as part of the scheduled maintenance, so that early action can be taken to prevent possible damage.

The guideline ENSI-B01 and the results of the PSA are taken into account when identifying structures to be included in the AMP. All active and passive components are assessed.

The guideline ENSI B-01 specifies the SSCs which may be grouped together for assessment. Components that belong to safety classes SK1 and SK2 are not grouped. In general, components of the same or similar construction, that are exposed to the same or similar conditions and which exhibit a similar ageing behavior are grouped together. The groupings must be identified in the fact sheet in a transparent manner. It is not necessary to provide a detailed listing of the components and component parts.

Electrical engineering

According to Section 6 of ENSI-B01 [4], the AMP is valid for all electrical and I&C equipments classified as 1E in ENSI-G01 [5] and for all safety-relevant electrical equipments classified as 0E.

According to ENSI-B01, fact sheets must be created for 1E components, whereas for 0E classified components ageing dossiers must be created. Plant-specific inputs are used to identify the components to be incorporated in the AMP.

As established in electrical engineering ageing management, similar component groups are assessed. Relevant ageing mechanisms and possible diagnostic methods for identifying the ageing of electrical components (grouped by operational type such as cables, switches, transmitters, motors, etc.) were elaborated in Parts 1 and 2 of the fact sheet by the GSKL expert team for electrical engineering ageing management. The generic fact sheets contain manufacturer and plant-independent foundations for the plant-specific AMP Part 3. The plant-specific fact sheets (Part 3) are drawn up in the individual plants. Here, grouping of components (by nature, type, manufacturer or combined) is left to the plants.

Cross-department

In keeping with the early development of AMPs in Switzerland, no specific AMPs have been used: these were only introduced in the USA at national level in 2001 by way of the Generic Ageing Lessons Learned (GALL) report (NUREG-1801). In contrast, the AMP was introduced in Switzerland 10 years earlier. At international level, IGALL adopts the GALL methodology (and consequently also the AMPs). IGALL came into existence about 20 years later than the Swiss AMP.

As already presented in Section 2.1, the methods and requirements of the AMP have been set out in the interpretive documents of the GSKL. Moreover, the GSKL guides for the creation of fact sheets for civil, electrical and mechanical engineering are guides for the practical implementation of ageing management and for documenting the results of the assessment of mechanical and electrical components as well as of civil engineering structures. On the basis of the specifications of the GSKL working group in KKB, the AMP was implemented in detail according to the specifications provided by the departments in the integrated Management System (iMS). The ageing assessments of civil engineering structures and/or SSCs are summarized in the plant-specific fact sheets. The ageing mechanisms relevant for particular plant parts are identified by the ageing management. On this basis, existing programs, especially maintenance for example, are checked as to whether ageing-induced damage can be avoided or detected at an early stage. Any omissions revealed by the check are closed in a documented fashion. Embedding this in the national and international activities of GSKL's working group "AMP in Swiss NPPs" ensures that the state-of-the-art of science and technology in the fields of materials and structural ageing as well as their analysis and diagnostic technology will continue to be considered in future.

Drawing on the trends and findings from maintenance undertaken, the effectiveness of ageing management and the additional measures resulting from it are evaluated annually in accordance with the state-of-the-art of science and technology on the basis of guideline ENSI-B02 [8].

Relevant ageing mechanisms are determined on the basis of internal and external experience, and essential elements assigned for the components being assessed. All ageing mechanisms relevant for the individual component parts are listed in tabular form in the fact sheets. The AMP relevant test programs (e.g. in-service inspection programs, maintenance programs, etc.) are determined and the significance of the individual programs evaluated.

If omissions are identified, measures will be defined to correct them. All defined measures are specified in the fact sheets in a list of outstanding actions. Periodic checks assess the implementation of these measures, and their completion is recorded in documents (e.g. logs, reports, maintenance reports, etc.) and fact sheets. All AMP-relevant reports are recorded in SAP, which ensures that the documents are securely archived. Test reports and non-conformance reports are saved in a separate database.

2.1.2 Ageing assessment

2.1.2.1 Identification and evaluation

The GSKL programs for checking ageing management measures build on many years of applied maintenance concepts of the Swiss NPPs, reference the legal requirements and form the basis for the ageing management of Swiss NPPs.

The document describes the physical ageing phenomena occurring in the NPPs in general and presents a procedure for the early detection and control of these phenomena.

The division of the AMP into three areas, civil engineering, electrical engineering and mechanical engineering is defined in the GSKL interface document. The GSKL guides for the creation of fact sheets for civil, electrical and mechanical engineering provide specifications for the practical implementation of ageing management and for documenting the results of the assessment of mechanical and electrical components as well as of the civil engineering structures. The component or group-specific assessment takes account of all relevant design and manufacturing documents (especially specifications, lists of material, material certificates, manufacturing and prototyping testing certificates etc.).

As also specified in the guideline ENSI-A03 [9], the key elements for effective ageing management are listed in the following table. The basis here is the IAEA Safety Guide for Ageing Management [10]. The documentation of ageing management is provided within the framework of the periodic safety review.

No.	Attribute from [10]
1	Scope of the AMP based on the understanding of ageing
2	Preventive actions to minimize and control ageing degradation
3	Detection of ageing effects
4	Monitoring and trending of ageing effects
5	Mitigating ageing effects
6	Acceptance criteria
7	Corrective actions
8	Operating experience feedback and feedback of research and development results
9	Quality management

The systematic identification of ageing mechanisms occurs differently in the three departments.

Civil engineering

All ageing mechanisms relevant to civil engineering are specified in Annex 1 of the guide for civil engineering fact sheets. In the case of inspections also defined in the guide, civil engineering structures are inspected at least every ten years for the relevant ageing mechanisms. The inspections may only be carried out by qualified and experienced persons who know how to interpret and evaluate any unexpected anomalies that might occur.

When working within the framework of the AMP, support of a specialist planner / engineer and, if necessary, a special expert is essential when using special diagnostic methods. The results of inspections are recorded in the fact sheets for the individual buildings, and any actions are defined.

Electrical engineering

The GSKL team of electrical engineering ageing management experts inspects, evaluates and documents the completeness and assessment of known ageing mechanisms, taking into consideration the state-of-the-art of science and technology and the world-wide experience in NPPs. Necessary adjustments and developments are permanently implemented. In order to ensure the state-of-the-art of science and technology in the plant-specific fact sheets including in the years after fact sheet creation, the generic fact sheets Part 1 and Part 2 ("Basis Documentation") are continually checked by the GSKL AMP electrical engineering team at least every ten years and updated as necessary.

Mechanical engineering

The GSKL team of mechanical engineering ageing management experts inspects, evaluates and documents the completeness and assessment of known ageing mechanisms taking into consideration the state-of-the-art of science and technology available and world-wide experience in NPPs. This includes, in particular, the "Catalogue of Ageing Mechanisms of Mechanical Equipment" (KATAM), an essential, ENSI-recognized reference for assessing the relevance of ageing mechanisms.

In creating the system fact sheets, the following aspects are systematically dealt with and documented:

- General information about the system and its components
- Influencing variables (media, operating conditions, material data)
- Identification of relevant ageing mechanisms
- Internal and external operating experience
- Existing monitoring

Supplementary measures:

A special case is the ageing management of emergency diesel generators. Due to the very similar design in all Swiss plants, generic fact sheets were created here (as is normal in the electrical engineering department) for the identification of the relevant ageing mechanisms (Part 1) and possible diagnostics methods (Part 2) by the GSKL specialist team, which are then only supplemented by generator-specific fact sheets (Part 3) in the individual plants.

2.1.2.2 Acceptance criteria

Implementing ageing management actions ensures that a structure or component maintains its functionality under all design conditions at least until the next inspection cycle.

Civil engineering

The GSKL guide specifies condition levels 1 to 5 for the civil engineering fact sheets. All components subject to assessment are evaluated according to these condition levels as part of the regularly performed inspections. Level 1 means "very good condition", level 5 means "poor condition". For levels 4 and 5 short-notice or immediate repair is necessary.

Electrical engineering

Due to the diversity of electrical and process control equipment there are no standardised acceptance criteria. These must be derived from methodically analysed predictions (accelerated ageing tests in a test environment; inspection of removed components with known conditions of use; cable or component storage in the containment under extreme ambient conditions such as temperature, humidity, radiation, etc.) and the plant-specific ambient conditions.

Mechanical engineering

The acceptance criteria for passive mechanical components are assembly or component specific. In Section 5, which relates to the reactor pressure vessel (RPV), the defined acceptance criteria for this component are looked at in more detail. Where RPV embrittlement and fatigue monitoring are concerned, ENSI defined precise specifications in Appendices 5 and 6 of the revision of the regulatory guideline on ageing management ENSI-B01 [4]. Regularly performed function tests of active components use specific acceptance values or threshold values. If these values are exceeded, a fault message is triggered, which then leads to maintenance and/or repair actions, so that the correct design condition of the component is recreated.

2.1.2.3 External findings

In Switzerland there are also higher-level criteria specified by the Federal Department of the Environment, Transport, Energy and Communications (DETEC) in an ordinance [11] for the temporary shut-down of NPPs. These relate to the embrittlement of RPVs, reductions in wall thickness and cracks in primary circuits, wall thickness reductions of steel containment structures of the primary containment and cracks and spalling of the containment concrete shell.

The licensee is legally obliged to perform corresponding tests or analyses. This enables ENSI to monitor compliance with defined acceptance criteria.

All Swiss nuclear power plants participate fully or partially, dependent on the design, in on-going research and development programs via the following institutions:

- Electric Power Research Institute (EPRI) Boiling Water Reactor Vessel Internals Program (BWRVIP)
- EPRI Pressurized Water Reactor Materials Reliability Program (MRP)
- Verband Grosskraftwerksbetreiber (VGB) Power Tech e.V.
- swissnuclear (sn), Begleitgruppe Material (BGM)
- Paul Scherrer Institut PSI

Currently KKB is pursuing research activities in the following areas:

- EPRI/MRP (Pressurized Water Reactor Materials Reliability Program): The MRP program is an international research project for pressurised water reactors, which is concerned with the specific influences of the PWR on the materials (in particular for example, Inconel 600) of the primary systems (pressure vessel, internals, nozzles, main cooling lines).

  The MRP areas are subdivided by subject into ageing and wear mechanisms and are treated in separate groups, where EPRI takes over the coordination and control. The participating plants are able to collaborate on a basic program and on specific detailed programs. However, they are also capable of incorporating this know-how in their AMPs by searching existing and published reports and obtaining the relevant knowledge by consulting specialist companies and drawing upon their relevant expertise.
- PLIM (Plant Life Management: Thermo-Mechanical and Multiaxial Fatigue caused by Cyclic Thermal Shocks): This project covers crack formation due to thermal fatigue in components made of austenitic steel. This project analysed a pipe configuration (hot/cold feed) of a Swiss NPP for example.

- Investigation of the creep-crack behavior in the copper alloy CuNi2Si: even if generators are not safety-relevant units, investigations are currently being carried out into crack propagation in generator wedges made of copper alloys, due to their important operational significance for the plant. These activities are coordinated by the VGB Component Integrity Study Group.
- UT (ultrasonic) guided-wave technology on complex geometries: to make use of the possibilities of non-destructive condition assessment of containment shells encased in concrete, programs were started in some Swiss NPPs to make it possible to also use UT guided-wave technology on geometries that are more complex than those associated with piping.

In addition, licensees have access to the results of the following regulator-financed projects [12]:

- SAFE-II (Safe long term operation in the context of environmental effects on fracture, fatigue and environmental assisted cracking): The SAFE-II project deals with materials problems, especially with respect to corrosion cracking and fatigue in the structural materials of light-water reactors. This internationally-recognized project supports and promotes the acquisition of know-how in environment-induced crack propagation, an area which is important for the operation of NPPs
- CODAP database: For ENSI and the Swiss NPPs, this data collection and background information represents a direct and current source of international experience relating to damage cases occurring on classified mechanical equipment, which can be used directly for ageing assessments.

New findings based on external sources and bodies such as EPRI, TÜV (Technical Inspection Agency), work groups of the VGB, WANO (World Association of Nuclear Operators), CODAP (Code de Construction des Appareils à Pression non soumis à la flamme), IGALL, suppliers, EQDB (equipment database) etc. as well as from conferences and seminars and new, recognized diagnostic methods and models are discussed and evaluated in the GSKL AMP specialist teams and decisions made about their application in the Swiss ageing management programs. Operation-induced damage cases occurring in the individual Swiss NPPs are also presented to the GSKL AMP specialist teams and then discussed in respect of their relevance for the AMP ("operating experience exchange").

Civil engineering

New findings such as methods or testing techniques for materials used in civil engineering such as concrete and steel, plastics or coating materials are discussed in the GSKL AMP civil engineering group and evaluated in respect of their application in ageing management. Participation in courses and seminars ensures that knowledge of the latest state of the art is kept up to date.

Electrical engineering

New findings from internal and external operating experience are presented and discussed within the framework of the GSKL working group "Electrical Engineering Ageing Management" and if necessary followed up and integrated in the AMP. In the context of checking and updating of fact sheets and ageing dossiers, the existing sources/references are scrutinized and current information identified which could be used to update the fact sheets.

Mechanical engineering

The Catalogue of Ageing Mechanisms of Mechanical Equipment (KATAM) represents the current state-of-the-art of science and technology concerning the ageing mechanisms of light water reactors. This is used in the power plants as a basic document for the implementation of mechanical engineering ageing management. Under the aegis of the mechanical engineering specialist team within GSKL's ageing management working group, this catalogue is checked regularly to determine whether new findings are available that require the KATAM to be adapted. To do so, relevant publications, conference proceedings, codes and standards are systematically studied and evaluated. A summary of the results of this review is presented in the annual reports of the individual power plants.

2.1.2.4 Internal operating experience

The collection and treatment of internal, cross-department operating experience in KKB is regulated by a guideline. The operating experience feedback process in KKB is classified at three levels, i) reportable incident, ii) non-reportable incident and (iii) deviation from expectations. When analysing events, the equipment itself and also human and organisational factors are taken into account. The results of the event treatment are stored in a database in the form of the WANO base coding. The findings derived from the evaluation of internal operating experience are implemented as corrective actions. Prioritization of the corrective actions means the actions can be scheduled based on importance and urgency.

The recording and analysis of operating experience from external sources (e.g. from external NPPs, authorities, plant and component suppliers, etc.) is likewise governed by a guideline within KKB. The aim of this process is to use the targeted evaluation of experience reports and the consistent implementation of findings relevant to KKB to maintain or improve the safety, availability and environmental compatibility of the plant. Within KKB the following quantities are used to measure the effectiveness of the process:

- Number of completed actions
- Number of defined actions
- Number of KKB-relevant reports.

2.1.3 Monitoring, testing, sampling and inspection activities

The essential components of the ageing management actions for monitoring the technical equipment and controlling the relevant ageing mechanisms are:

- Operational monitoring
- Preventive maintenance
- Periodic inspections (WKP) including functional tests

For example, the following programs are set up in the individual specialist areas, which the plant-specific AMP accesses:

- Water-chemistry analyses based on internationally valid guidelines and specifications
- Regular checking of operating resources, such as lubricants etc.
- Wall thickness measurement programs ("EROSKO")
- Cable swapping programs and inspection programs
- System and component walk-downs
- Crane tests

Special inspections are performed in addition to the inspection plan. These include the visual inspection or material sampling of various potential areas of damage which can contribute to the ageing degradation of structures. In addition, electronic measurements of the relative air humidity and temperature as well as electronic and manual measurements of any changes in cracks are performed.

Further materials tests on civil engineering structures and laboratory analyses are listed in the guideline and are applied as necessary.

In KKB inspection programs such as:

- Diagnostic measurements on actuators (MOV)
- Diagnostic measurements on solenoid valves
- Diagnostic measurements on the stator windings of motors
- Measurements of the dielectric loss factor on medium-voltage (MV) cable runs
- Cable disposal in the containment for 1E-LOCA cable
- ECAD diagnostic measurements on low-voltage (Lv0 cables)
- Capacity measurements on emergency power batteries
- On-going qualification of newly qualified components (accelerated ageing test) in the heat box

have proven themselves and yield authoritative results on the ageing state of individual components.

For the mechanical components of safety classes SK1 to SK4 subject to nuclear acceptance testing, in-service inspection programs are established according to specification NE-14 [13] and guideline ENSI-B06 [14]. These include non-destructive testing (NDT), system and component walkdowns, pressure tests, function tests on safety valves and snubbers, and pressure tests. Relevant criteria such as the selection of suitable test methods and test parameters as well as classification and finding-dependent test intervals are also specified in NE-14 and guideline ENSI-B06. These programs are checked and approved by ENSI and/or its technical experts, the SVTI Nuclear Inspectorate (Swiss Association for Technical Inspections).

Periodic tests on safety systems and components are defined in the technical specifications of the licensee and generally include function and leak tests at defined intervals.

In accordance with guideline ENSI-B01 [4] surveillance programs to detect embrittlement of the RPV material and fatigue-relevant components of SK1 to SK3 are necessary. These two surveillance programs are continuously performed so that the condition of the components mentioned can be continuously gauged and an extrapolation made to determine the expected service life.

In addition, further provisions and routines are established, which provide information about whether ageing-induced damage is present in the SSC of interest:

- Walkdowns by the operating personnel
- Anomalies in function tests (see repeat tests in the technical specifications)
- Raising the awareness of maintenance personnel so that they monitor the general state of individual parts during maintenance
- Weekday discussion of anomalies in operating parameters

- Water-chemistry monitoring. (Among other things, the change in the chemical parameters implies internal leaks are occurring)
- Special tests if a suspected problem exists
- Vibration monitoring
- Monitoring for structure-borne sound

2.1.4 Preventive and remedial actions

The AMP of the Swiss NPPs is designed so that the relevant ageing mechanisms and the resulting ageing effects are, as far as possible, detected at an early stage. This is the basis for identifying and implementing any necessary preventive and remedial actions. Implementation takes place in the relevant departments based on various quality management programs, such as in the maintenance programs or plant change for example. Examples include:

Plant modification programs

"Modification" here corresponds to: a) modifications in the plant and b) process changes. Processes for the initialization, design, implementation planning, performance and commissioning as well as final documentation and conclusion of modifications are specified in a guideline. Each employee, irrespective of their function and organisational unit is authorized to submit a change application and consequently fulfil the role of modification applicant. The "Modification Committee" is responsible for ensuring that the processing of requested changes can take place in a way that is coordinated in a cross-department/business unit manner, targeted, prioritized, provided with the necessary resources and that fulfils the regulatory requirements and guidelines.

In KKB all modifications are usually implemented as a project. Applicants compile a modification application and hand it to their supervisors for review. The "Modification Committee" decides whether the request is to be further processed or rejected. If the amendment is adopted, the committee checks the form of implementation, defines the priority and scheduling and approves the financial and human resources. Budget and resource planning are taken into consideration. After the modification request has been approved and financial resources and contractual relationship with the suppliers have been arranged, implementation planning is carried out. This includes the final definition of the implementation and creation of all necessary planning documents. The actual modification is implemented in the process "Implementation and commissioning", and, where applicable, scheduled in the shut-down plan. The modification dossier is then archived in paper form in the KKB archive and in electronic form in SAP.

Maintenance

Maintenance work in KKB is subdivided into the three main areas, civil, electrical and mechanical engineering. In the overall corporate target setting, maintenance forms a package of measures that keeps the plant in a safe and functional condition while simultaneously optimizing costs. To ensure the safe and reliable operation of both units with a high level of availability, maintenance tasks and the associated quality assurance are performed using modern methods and equipments. This takes account of the following aspects:

- Energy economic goals of the company and power plant regulations
- The legal prescriptions, the regulatory requirements and the applicable safety regulations
- Optimum power plant availability

- The radiological dose for the deployed personnel is kept as low as possible (ALARA principle)
- Experience from the planning and implementation of maintenance measures in other NPPs or from the original component suppliers

The respective departments in KKB are responsible for maintenance and creating the necessary applications, programs, regulations, instructions and specifications. After maintenance work has been completed, the responsible department evaluates the findings and, if necessary, the future scope of work is adapted. Long-term planning of human resources in the responsible departments are aligned with maintaining the technical competence for carrying out maintenance.

ENSI requires a special concept for components subject to relevant ageing mechanisms and which cannot be inspected or renovated with standard methods (e.g. inaccessible areas of the containment). Here, the specific ageing situations are considered in depth and a holistic concept for maintaining integrity is developed.

Further example are cross-system exchange programs, which are initiated as soon as a systematic defect or a strongly time-limited applicability has been identified within the AMP for a particular group of components (e.g. cables).

On the structural side, progressive carbonation is effectively prevented by thermal insulation measures, by sealing and in particular by the application of surface protection systems.

The respective measures are systematically recorded in the fact sheets (see Section 2.1.2).

2.2 Review and update of the overall AMP

The cross-plant contribution to checking and updating of ageing management is carried out in the GSKL working group "Ageing Management in Swiss NPPs (CH-KKW)". Managers of the expert teams of civil, electrical and mechanical engineering make up the coordination team of the working group. All parties responsible for the AMP in the individual plants are represented in the expert teams.

The coordination team of the working group discusses overriding aspects of ageing, updates the common overriding documents and defines joint measures and procedures in Switzerland. The common subject-specific specifications and principles for carrying out the ageing management are compiled or updated by the expert teams for use in the individual plants. The tasks of the expert teams include the active participation in specialist events, national and international exchange of experience and the joint monitoring of the state-of-the-art of science and technology, which is documented in joint subject-specific documents and made available to the individual power plants to implement ageing management.

Below, overall ageing management is considered at the level of the individual power plants. If necessary, reference is made to the tasks of the GSKL working group "Ageing management in Swiss NPPs (CH-KKW)", described above.

When AMP fact sheets are revised, in-service inspection programs are checked in respect of its effectiveness, adapted as necessary and in rare cases special tests are scheduled. In implementing the tests, if the criteria defined in the test instruction are not adhered to, non-conformance reports are prepared. The anomalies must be dealt with inside a defined period, where NE-14 [13] governs the scope and the involvement of ENSI and SVTI. Treatment of the non-conformance reports can be implemented in the form of alternative NDT tests, computational analyses and surveys, maintenance work or component replacement. Completion of these activities is documented in SAP and the AMP tracking folder or in the fact sheets of the SSC in question as described in Section 2.1.4 "Preventive and remedial actions", so that this information can be considered in the next revision of the fact sheets.

Deviations and areas for improvement in the AMP process detected in audits, inspections and reviews (e.g. by ENSI, WANO, IAEA) are documented in the final report of the tests in question. Unless specified by the supervising entity, the responsible organization units of the licensee shall derive an action plan with clear tasks, responsibilities and deadlines. With audits and reviews, "follow-ups" are normally performed a few months later in which auditors check the effectiveness of measures implemented.

Specialist departments are established in the plants for operational evaluation, which continuously carry out systematic screening of external events and forward the potentially relevant messages to the relevant maintenance and AMP organizational units. In addition, all plants receive prompt AMP-relevant messages from international operating experience via memberships and contacts in a wide range of organizations and working groups (see Section 2.1.2).

In general, these messages are analysed promptly in respect of the transferability and relevance for the home plant and documented, e.g. in the form of an "external event evaluation". In accordance with guideline ENSI-B02 [8], the "Ageing management annual overview" section of the "Safety Annual Report" provides ENSI with information for each power plant, providing details on which external events have been evaluated and on the respective result.

Likewise, when revising AMP fact sheets in electrical and mechanical engineering, all external messages from the previous year are collected, evaluated and clearly documented for all of the SSCs being assessed.

The ageing management guideline ENSI-B01 [4], which came into force in 2011, involved a revision of ageing management in the areas of civil, electrical and mechanical engineering in all Swiss NPPs. Since 2011 no fundamental changes have taken place in any of the plants (e.g. an increase in power output or a significant change in the primary water chemistry) with relevance for overall ageing management. The influence of smaller changes (e.g. changing of the type or material of individual components or system sections) on the AMP is (if actually relevant) addressed in the approval process with ENSI.

The effectiveness of ageing management can only be indirectly and inaccurately quantified. A concise key performance indicator (KPI), which is largely, but not exclusively, dependent on ageing management, is "unplanned unavailability" per year. This is expressed as a percent and is broken down in all Swiss plants in more or less detail from the entire plant to individual systems or system groups (e.g. emergency cooling systems or emergency power systems). A further indicator, which is also to some extent dependent on ageing management induced influencing values, is the number of scrams per year.

The systematic approach to creation of AMP fact sheets ensures that ageing mechanisms which result in a time-limited deployment of SSCs (e.g. embrittlement, fatigue, reduction in wall thickness) are considered.

Corresponding programs are initiated for the fatigue and embrittlement of key components (see Section 2.1.3).

If necessary, wall thickness measurement programs are extended so that trends can be defined.

ENSI continuously monitors the changes and measures in the AMP area and evaluates the overall ageing management at least every ten years in its PSR statement.

The requirement for additional research is discussed and if necessary initiated several times a year within the scope of the GSKL AMP specialist team meetings, swissnuclear's support team "Material", and with various organisations such as VGB and EPRI.

The period of maximum 10 years between PSRs, stipulated in ENSI-A03 [9] defines a reasonable upper threshold for reviewing ageing management. In addition, all plants undertake that they will undergo periodic reviews more frequently than every 10 years (e.g. WANO, OSART) in the area of AMP, so that basic areas for improvement are reliably detected and can be quickly acted upon.

In accordance with guideline ENSI-B02 [8], ENSI is informed annually about essential activities and events in the AMP of each plant. This is used as an additional tool for closely checking the implementation of ageing management.

Unexpected ageing mechanisms or new ageing-relevant aspects can be incorporated in the AMP in various ways. In the event of findings or damage within KKB, the non-conformance reports process (see Section 2.2) ensures that not only do short-term measures take place, but also that the results of these are transferred into the AMP.

External operating experience and findings from research and development continually flow into the AMP of the potentially affected SSCs via the following channels:

- Feedback of experience from working groups, conferences and participating research programs (see Section 2.1.2)
- Annual maintenance of the KATAM (see Section 2.1.2)
- Periodic processing of the external experience with each update of the AMP Fact sheets

New aspects that are safety-relevant are always treated very quickly by way of special tests and/or in-depth analyses of the influencing variables (manufacturer documentation, operational measurement data). These topics (e.g. unexpected findings in the RPV base material (Doel 2012)) are always closely followed and monitored by ENSI.

Since the new ageing management guideline ENSI-B01 came into force in 2011, neither the monitoring, testing and inspection programs have resulted in significant omissions being detected in the methodology nor the overall ageing management had to be adapted.

This confirms the good and close monitoring of the implementation of ageing management in Switzerland as an accompanying measure to the defence in depth safety concept.

The periodic evaluation and revision of ageing management as well as its measurable effectiveness (with certain limitations) based on performance indicators were already alluded to at the start of Section 2.2.

Licensee's experience of application of the overall AMPThe ageing management guideline ENSI-B01 [4] which came into force in 2011, involved a revision of ageing management in the areas of civil, electrical and mechanical engineering in all Swiss NPPs. The close interaction between the plants and ENSI led, within just a few years to a comprehensive, effective and yet still practical implementation of ageing management.

With the introduction of the new ENSI-B01 guideline, personnel requirements in the plants have increased significantly. Given the broad level of expertise required and the only indirectly positive effect of the AMP, it is somewhat difficult to recruit suitable personnel and then to motivate them in the long term.

The more stringent requirements of the new guideline ENSI-B01 introduced in 2011 and the corresponding large number of fact sheets to be revised led to a bottleneck in respect of technical capacity at the side of the regulator. This has made it difficult for ENSI to comment on the documents submitted within a reasonable time-scale.

The continual exchange of experience and the systematic processing of external events are essential instruments for the effective optimization and/or expansion of individual AMPs and for the competent staff to develop their know-how.

Adaptations and improvements in the ageing management were not triggered by this. In this respect, the periodic reviews performed by WANO and the IAEA prove to be effective measures for identifying the systematic improvement potential in ageing management.

For example, system health reviews (condition assessment of components and systems) in the KKB mechanical engineering division have incorporated AMP knowledge, in-house maintenance findings and maintenance knowledge, while on the other hand there has been feedback to the AMP documents (fact sheets).

3 Electrical cables

3.1 Description of the ageing management program for electrical cables

3.1.1 Scope of ageing management for electrical cables

As part of the AMP for electrical engineering and I&C safety classified equipment, age-induced damage mechanisms, which could lead to faults/impairment of SSCs are identified and monitored. In this respect, cables which connect the corresponding SSCs and/or supply them with power are particularly important individual components.

The plant-specific scope of the AMP for cables is defined by means of internal iMS (integrated management system) processes as well as existing ageing management programs and the plant-specific fact sheets for cables. Here, in accordance with ENSI guideline ENSI-G01/d [5], all 1E classified (including accident-proof 1E-LOCA) cables are subject to the AMP without fail.

The aim of the established AMP for electrical cables is to ensure the long-term functioning of cables under normal operating conditions as well as under the design-case accidents (e.g. LOCA).

The electrical cable AMP includes a systematic approach which should uncover omissions in preventive and condition-based maintenance as well as in the diagnostics. The observations resulted in adapted and optimized maintenance programs (e.g. in-service inspection programs) which are then correspondingly adapted or optimized.

The relevant ageing mechanisms and the possible diagnostic methods for cables are defined in so-called, "generic fact sheets", which have been created for all Swiss NPPs as base documents. The following fact sheets have been created by the GSKL electrical engineering specialist team for KKB cables (accident-proof and not accident-proof):

- B015 "Medium-voltage cables"
- G001 "Thermoplastic, plastic insulated cables and their connectors" (up to 1 kV)
- B011 "Mineral-insulated cables"

The cables subject to the AMP are subdivided into the following groups (categories) for the TPR:

Group G1: Medium voltage power cable (6 kV), classified 1E

Type (manufacturer):

GKG (Kabelwerke AG), NoFlamm (Cossonay), GKN (Kabelwerke AG), XDME-Mono (Leoni-Studer)

Group G2: Low voltage power cable (0.4 kV), classified 1E and 1E-LOCA

Type (manufacturer):

Noflamm (Cossonay), Radox (Huber+Suhner), Pyrofil (Dätwyler), Comp. 702 GG-B2 (Studer), NU-EHXHX (Eupen)

Insulation material:

EPDM (ethylene polyethylene diene monomer rubber) and EPR (ethylene propylene rubber)

Group G3: Instrumentation cable (I&C), classified 1E and 1E-LOCA

Type (manufacturer):

Noflamm (Cossonay), Radox (Huber+Suhner), Pyrofil (Dätwyler), Comp. 702 GG-B2 (Studer), NU-THXCHX (Eupen)

Insulation material:

EPDM (ethylene polyethylene diene monomer rubber) and EPR (ethylene propylene rubber)

Group G4: Special cables (neutron flux, MI-cable), classified 1E and 1E-LOCA

Type (manufacturer):

Mineral-insulated cable (combustion engineering)

Insulation material:

Magnesium, aluminum or silicon oxide

3.1.2 Ageing assessment of electrical cables

In accordance with ENSI-B01/d [4], safety-relevant aspects of the material ageing of mechanical and electrical equipment as well as of civil engineering structures must be assessed. At the same time, material ageing aspects in accordance with IAEA Safety Guide NS-G-2.12 [10] must be fulfilled. This also includes electrical cables.

In the course of their service life in the radiation field and under high room temperatures, the cables, in particular their plastic insulation material, suffer changes to the strength values due to oxygen diffusion (dependent on time and temperature). In KKB, suitable tests on batch samples from the cable storage enable changes in strength values properties to be monitored as part of the operation accompanying AMP.

The effectiveness of the cable AMP can be checked using the international specification of the IAEA for ageing management, in that the nine attributes from Table 2 of the IAEA Safety Guide, which specify the characteristics of effective ageing management, are compared with the implementation of the AMP for cables in KKB. This is shown as summary in the following table.

No.	Attribute from NS-G-2.12 [10]	Evaluation of the implementation in KKB
1	Scope of the AMP based on the understanding of ageing	• Coverage according to the requirements of ENSI-B01 is guaranteed. • The scope of 1E classified cable is specified in the 1E cable lists. • The ageing mechanisms and their diagnostics methods are specified in the generic GSKL fact sheets Part 1 and Part 2. • The creation and maintainance of the base documentation (fact sheets) and periodic tracking takes place within the framework of ENSI-B02. • KKB uses models or analyses for prediction of ageing. Examples are cable storage in the containment, temperature measurement series etc..
2	Preventive actions to minimize and control ageing degradation	• Planned diagnostics or cable condition measurements • Evaluation of the inspection/test results from maintenance by the departmental heads KBE-I/ KBE-S with support from the KBE-Q department • Preventive replacement of cables • Targeted temperature measurement series for selected cables
3	Detection of ageing effects	• Diagnostic measurements of ageing mechanisms in accordance with Part 2 of the GSKL AMP cable fact sheets • Feedback from periodic tests • Feedback from walk-downs with specified check-lists

No.	Attribute from NS-G-2.12 [10]	Evaluation of the implementation in KKB
4	Monitoring and trends of ageing effects	• GSKL methods: Operation accompanying AMP for cables • Evaluation of measurement results via performed measurements, e.g. evaluation of measurement results MV Cable Report by the company GASENZER, cable diagnostic measurements on selected 1E classified, accident-proof LV/I&C cables using the ECAD method
5	Mitigating ageing effects	• Reduction of influences from the ambient conditions, e.g. removal of hot-spots identified by means of temperature measurement series, displacement of components into more environments
6	Acceptance criteria	• Acceptance criteria are specified in maintenance regulations by means of target values that include the necessary tolerances • Target values based on manufacturer specifications and own experience
7	Corrective actions	• Analysis of failures (single fault condition or systematic component fault conditions) • e.g. displacement of components and their cables to locations with moderate ambient conditions (temperature, radiation)
8	Operating experience feedback and findings of research and development results	• Recording and evaluation of internal operating experience • Evaluation and analysis of external events for transferability to the KKB plant in accordance with the iMS process 2-P321-1 'Evaluation of events in third-party plants" • Participation in conferences, congresses and seminars • Feedback from the EQDB database • Messages from suppliers/manufacturers • Periodic exchange of experience GSKL • Working Group AMP Electrical Engineering and I&C
9	Quality management	• Annual AMP review according to the iMS process "Age Management Programs AMP" based on the AMP management file • Review of the practical implementation of AMP fact sheets Part 3 Electrical dept. (Section X: Check-list Periodic Testing) • Periodic check of AMP implementation in maintenance via work team E-89-04 IH+AMP • Annual submission of the plant-specific fact sheets Part 3 to ENSI

The relevant ageing mechanisms and their diagnostic methods applied in KKB for cables are listed in detail in the following plant-specific fact sheets.

Cable group	Plant specific fact sheets
Group G1: Medium voltage power cables (6 kV), classified 1E	Fact sheet "Medium voltage cable"
Group G2: Low voltage power cable (0.4 kV), classified 1E and 1E-LOCA	Fact sheet "Cable EUPEN inside the containment (low voltage)" Fact sheet "Power cable (low voltage)" Fact sheet "Studer cables outside containment (low voltage)"
Group G3: Instrumentation cable (I&C), classified 1E and 1E-LOCA	Fact sheet "Cable EUPEN inside the containment (low voltage)" Fact sheet "Studer cables outside containment (low voltage)"
Group G4: Special cable (neutron flux, MI-cable), classified 1E and 1E-LOCA	Fact sheet "MI cable for TC-Incore"

Cable group G1 component parts	Ageing mechanisms (from fact sheet Part 1)	Diagnostic methods in KKB / *Comment* (from fact sheet Part 2)
EPR jacket	***Ground/damp installation:*** water absorption oxidation (embrittlement) discoloration	Visual inspection
	Dry installation: Oxidation (embrittlement) Discoloration Crack formation	Visual inspection Infrared measurement (*Hot-spot locating)* Visual check
Diffusion barrier	***Ground/damp installation:***	
	Corrosion	(Resistance test) *Unreliable process*
Wire shielding	***Ground/damp installation:***	
Strip shielding	Corrosion	(Resistance test) *Unreliable process*
EPR conductor insulation	***Ground/damp installation:***	
	Water cabling harnesses	tan δ (1&2xU_0, 0.1 Hz) IRC-Analyze *Limit values present* *Comparison values not present*
	Dielectric change	If nec. R_{iso} measurement *Megger DC; 1 kV(5 kV) limit values not present*
	Dry installation:	
	Oxidation (embrittlement)	Measurement tan δ
	Diffusion out of cross-linked polymer fission products	(1x, 1.5x, 2xU_0, 0.1 Hz) after 25 years

Conductor + connection	Corrosion	Visual inspection
	Loosening of the connection	Infrared measurement *Hot-spot locating*

Cable group G2 + G3 component parts	**Ageing mechanisms (from fact sheet Part 1)**	**Diagnostic methods in KKB / *Comment* (from fact sheet Part 2)**
Sheath insulation	Oxidation	Visual inspection
	Embrittlement	Visual inspection

Cable group G2 + G3 Component parts	**Ageing mechanisms (from fact sheet Part 1)**	**Diagnostic methods in KKB / *Comment* (from fact sheet Part2)**
	Discoloration	
	Diel. change	Cable sample/storage
	Crack formation	Visual inspection
	Friction	Visual inspection
	Blistering	Visual inspection
		TDR measurement
Harness wrapping	Embrittlement	Cable sample/storage
	Discoloration	Cable sample/storage
Conductor insulation	Embrittlement	Cable sample/storage
	Discoloration	Cable sample/storage
	Diel. change	Voltage test
		Capacity measurement
		Insulation resistance
	Crack formation	Cable sample/storage
		TDR measurement
Transition points + connections	Corrosion	Magnetic pulse
		Visual inspection
		Infrared measurement
	Loosening of the connection	Visual inspection
		Magnetic pulse
Protective coating on electrical connections	Corrosion of the underlying metal	Visual inspection of the transition points

Cable group G4 component parts	**Ageing mechanisms (from fact sheet Part 1)**	**Diagnostic methods in KKB / *Comment* (from fact sheet Part2)**
Outer tube	Corrosion Cracking	Visual inspection
Conductor	Corrosion	
Insulation	Leakage current increase Change in insulation	Insulation measurement *in conjunction with the component*
Termination - fitting	Cracking Corrosion Leaks	Visual inspection
Electrical connection	Corrosion Cracking Loosening	Visual inspection TDR method *ECAD* (reflection method)

3.1.3 Monitoring, testing, sample selection and inspection activities for electrical cables

The electrical cables installed in Beznau Nuclear Power Plant are always monitored by periodic visual inspections and diagnostic measurements to detect any ageing. The visual inspections form part of various operational walk-downs and take place according to the in-service inspection programs. During periodic inspections of cable supporting structure, for example, simultaneous visual checking of the outer condition (discoloration, cracking, mechanical damage, etc.) of the cable supported on the structure is performed and the results are recorded in checklists.

Likewise, visual checks of connecting cables are made as part of component tests (e.g. motors). Diagnostic measurements of installed cables are performed using non-destructive methods.

Group G1: Medium voltage power cable (6 kV), classified 1E

The test programs such as:

- Measurements of the dielectric loss factor "tan δ" on MV cable runs have proved to be effective and yield authoritative results on the ageing condition of the individual cables. Measurements are repeated every 10 years on selected cables.

Existing programs for ageing management:

The proven method for measuring the dielectric loss factor "tan δ" (TD) using sinusoidal 0.1 Hz VLF AC voltage is used on the medium voltage cables of KKB. The TD measurement is a relatively simple and effective method for determining the ageing condition of MV cables. The TD measurement is performed at the cable nominal voltage U0 and then at twice the nominal voltage 2xU0. Then the measured values are compared with the baseline measurement (mainly the commissioning measurement) and correspondingly classified or assessed (new, significantly aged, defective). A significant increase in "tan δ" with increasing measurement voltage is an indication of a significant ageing. Dependent on the completed condition classification, necessary maintenance measures can be planned at an early stage (e.g. repair, replacement).

The TD measurement is described in many of the current testing standards across the world (DIN VDE 0276, IEEE 400.2, CENELEC HD620 S, etc.).

Group G2: Low voltage power cable (0.4 kV), classified 1E and 1E-LOCA, as well as Group G3: Instrumentation cables (I&C), classified 1E and 1E-LOCA

The test programs such as:

- Resistance (DC) and impedance (AC) measurements
- Insulation resistance (IR) measurements
- Cable storage in the containment for 1E-LOCA cables
- Diagnostic measurements (time domain reflectometry) on LV cables

have proven themselves and yield authoritative results on the ageing state of individual cables. The TDR measurements are repeated every 12 years on selected cables.

Existing programs for ageing management:

- Cable surveillance programs 1E LOCA (cable storage in the unit 2 containment).

  Since 1996, 1E LOCA reserve cables and pre-fabricated sample pieces have been exposed over a long period in a targeted manner to an environment with high room temperature and high radiation (behind steam generators) to determine the exact significant influence of radiation and temperature on ageing.

  As part of the procurement of 1E-LOCA qualified cables from a new supplier (EUPEN) in 1999, the high stress test area for cable pre-aging was expanded with reserve cables and prefabricated sample pieces from this supplier. With periodic evaluations every 5 years and further tests, the KKB-specific service time can be realistically determined and this in advance of the cables installed in the plant.

  Actual measurements and evaluations are contained in the respective cable fact sheets and are continuously updated.

  First evaluations of the samples were performed by the Paul Scherrer Institut in 1998 and 2003, with further evaluations performed by Sulzer Innotec in 2008/09, 2011 and by Qualitech AG in 2016.

  Comparing the baseline measurement and the current measurement, it is apparent that the residual elongation at break is still above the required 50%.

  If there are significant changes in test values, the test intervals are correspondingly shortened.

- TDR diagnostic measurements on LV cables

  The Time Domain Reflectometry (TDR) test involves sending an electrical signal pulse through a cable and measuring its reflection to identify the location of any impedance change in the cable and/or end device. The signal pulse is reflected when it encounters a change in impedance or discontinuity (fault) in the cable, connector or end device. This method provides diagnostic information about the cable insulation and connections in the circuit. It can also provide diagnostics about a device at the end of the cable, such as the inductance of a motor or solenoid. The test methodology is significantly enhanced when baseline data is available or when data on a similar circuit is available for comparison.

  The TDR signal is actually a wave of energy guided between the conductors of the cable, passing through the insulation. The time that it takes for the TDR signal to travel down the cable under test and for a reflection to return is affected both by the physical dimensions of the cable (length and cross-sectional area of the conductor) and the insulation properties.

  Based on the cable properties, the measured time of the reflections can readily be converted to distance.

Group G4: Special cables (neutron flux, MI-cable), classified 1E and 1E-LOCA

The materials are not subject to any ageing-relevant material change under the ambient conditions prevailing in KKB.

The existing test programs (visual inspection, insulation measurement) have proven to be effective.

3.1.4 Preventive and remedial actions for electrical cables

Group G1: Medium voltage power cables (6 kV), 1E classified

Cable surveillance programs (MV cables, up to 10 kV):

Ageing tests have been performed on MV cables at EUPEN in Belgium together with cables from Leibstadt NPP. The same cable types from the same manufacturer are used in both plants KKL/KKB. Diagnostic measurements have been performed by GASENZER in the plant on various MV cables. The results were evaluated in the plant-specific Medium Voltage Fact Sheet and maintenance measures specified.

Within the scope of a range of projects (e.g. AUTANOVE, new autonomous emergency power supply) various MV cables were replaced in a preventive manner by new XDME-mono cable (Leoni Studer).

Group G2: Low voltage power cables (0.4 kV), classified 1E and 1E-LOCA, as well as Group G3: Instrumentation cables (I&C), classified 1E and 1E-LOCA

During the course of their service life in the radiation field, the cables, in particular their plastic insulation material, suffer changes to the mechanical strength values due to oxygen diffusion (time and temperature dependent). In KKB, suitable tests on batch samples from the cable storage enable changes in strength values properties to be monitored as part of the operation accompanying AMP.

The results of the evaluations demonstrate that the specified scope or the interval of 5 years for the removal of test samples is suitable for following the cable ageing process in advance.

In the 1980s, all partially accident-resistant or non-accident-resistant cables inside the containment were replaced with LOCA-resistant cables (blue jacket).

Group G4: Special cable (neutron flux, MI-cable), classified 1E and 1E-LOCA

The materials are not subject to any ageing-relevant material change under the ambient conditions prevailing in KKB.

3.2 Licensee's experience of the application of AMPs for electrical cables

The GSKL team of electrical engineering ageing management experts inspects, evaluates and documents the completeness and assessment of known ageing mechanisms, taking into consideration the state-of-the-art of science and technology and the world-wide experience in NPPs. Necessary adjustments and developments are permanently implemented. In order to ensure the state-of-the-art of science and technology in the plant-specific fact sheets including in the years after fact sheet creation, the generic fact sheets Part 1 and Part 2 ("Basis Documentation") are continually checked by the GSKL AMP electrical engineering team at least every ten years and updated as necessary.

New findings based on external sources and bodies such as EPRI, TÜV, work groups of the VGB, WANO, suppliers, EQDB, etc. as well as from conferences and seminars and new, recognized diagnostic methods and models are discussed and evaluated in the GSKL AMP specialist team and decisions made about their introduction.

Based on these evaluations, the generic basic documents of the AMP (Fact Sheets Part 1 and 2 Cables) and the plant-specific documents (Fact Sheet Part 3 Cable, maintenance documents) are adjusted as necessary.

Group G1: Medium voltage power cable (6 kV), classified 1E

Fact sheet "Medium voltage cable":

No new ageing relevant findings are known. The existing maintenance concept (periodic inspection and measurements according to the in-service inspection programs WP) has proven itself.

Group G2: Low voltage power cable (0.4 kV), classified 1E and 1E- LOCA

Group G3: Instrumentation cable (I&C), classified 1E and 1E-LOCA

Fact Sheet "EUPEN cables inside the containment (low voltage)":

No new ageing relevant findings are known. The existing maintenance concept has proven itself. Elongation at break measurements were performed in 2010 and 2011 on KKB samples released from stock taken from the 1999/2003/2010/2016 series. From the comparison between the baseline measurement and the current measurement, it is apparent that the test values are significantly above the required 50%. Therefore there is no need for any action.

Fact Sheet "Power Cable (Low Voltage)":

No new ageing relevant findings are known. The existing maintenance concept (periodic inspection according to the in-service inspection programs WP) has proven itself. In 2016 periodic elongation at break measurements were performed on KKB samples from the 1998 series. Comparing the baseline measurement and the current measurement, it is apparent that the test values are still above the required 50%.

Group G4: Special cable (neutron flux, MI-cable), classified 1E and 1E-LOCA

The materials are not subject to any ageing-relevant material change under the ambient conditions prevailing in KKB.

4 Concealed pipework

4.1 Description of ageing management programs for concealed pipework

4.1.1 Scope of ageing management for concealed pipework

On the site of KKB, the following classified systems are assessed, for which based on the system schematics and local walk-downs it has been specifically clarified to what extent they contain concealed pipework sections (buried in the ground, embedded in concrete, below inaccessible shafts):

- PRW: Primary Service Water System (1x per unit)
- PRN: Secondary Service Water System (1x per unit)
- PKZ: Secondary component cooling water system (1x per unit)
- LNB: Emergency well water system (for unit 1&2)
- LBW: Well water system (for unit 1&2)
- LSE: Emergency feedwater system - tank makeup (unit 1&2)

On the one hand, the feed to the PRW (primary service water) system takes place via a non-classified shut-off portion of piping and, on the other hand, through a classified part of the emergency cooling water piping via very short (< 1m) pipe sections embedded in concrete. The only inaccessible areas in the PRW system are six parallel and straight piping sections made of stainless steel without welds, which run over a length of about 3m in hollow tubes set in concrete (without any contact with these). Due to the benign atmospheric conditions inside the machine house (dry, constant temperatures), the inaccessible areas of the PRW are not considered further.

The pumps and the adjoining suction-side pipe sections of the LNB (bunkered well water) and LBW (well water) systems are located in accessible shafts and can be fully pulled out and inspected. The discharge side routing of the systems is accessible throughout. Consequently, no pipe sections of the LNB and LBW are assessed in this section. The LSE tank makeup pump is likewise in the accessible shaft of the emergency well water pumps. Consequently, the whole LSE is
accessible.

The PRN (secondary service water) system itself is not classified, however it draws water from the classified part of the PRW and uses the classified PKZ (secondary component cooling water) to supply other classified systems with cooling water. The PKZ and downstream systems are accessible in all parts and therefore will not be addressed further.

Moreover, a comparison with the system schematics confirms that no inaccessibly routed oil, fuel or control air pipes are present that are significant for safety.

Concrete-embedded classified piping sections are not further considered here, because the inaccessible sections are very short (e.g. at building penetrations) and the external surfaces are not subject to relevant ageing mechanisms. Hence, within the scope of the AMP nothing other than the accessible areas of the system concerned need to be dealt with.

The zone concept also ensures that unclassified, concealed pipes cannot carry any radioactive inventory. The potential emission paths are documented in specific technical reports for each unit.

4.1.2 Ageing assessment of concealed pipework

As set out in Section 4.1.1, no classified pipe sections come within the scope of this Section 4.

4.1.3 Monitoring, testing, sampling and inspection activities for the concealed pipework

As set out in Section 4.1.1, no classified pipe sections come within the scope of this Section 4. Consequently, no activities in the areas of monitoring, testing, sampling and inspections are necessary on concealed pipework.

4.1.4 Preventive and remedial actions for concealed pipework

As set out in Section 4.1.1, no classified pipe sections come within the scope of this Section 4. Consequently, no preventive and remedial actions on concealed pipework are necessary.

4.2 Licensee's experience of the application of AMPs for concealed pipework

As set out in Section 4.1.1, no classified pipe sections come within the scope of this Section 4. Operating experience confirms that for short concrete-embedded sections (e.g. wall penetrations) no special ageing management measures are necessary.

5 Reactor pressure vessels

5.1 Description of ageing management programs for RPVs

5.1.1 Scope of ageing management for RPVs

Beznau Nuclear Power Plant (KKB) comprises two units, Beznau 1 and Beznau 2. Both have the same thermal and electrical performance. Structurally there are many similarities between them. Many components were procured for both units simultaneously with practically an identical design, although unit 2 was brought online approximately two years after unit 1 (1969 and 1971). Consequently, both RPVs (reactor pressure vessels) are practically identical, the two new RPV heads procured and installed in 2015 are identical with the exception of a leak
monitoring system on the inner RPV seal that is specific to KKB-1.

System	Nuclear steam generator
Plant identifier (technical location)	Unit 1: 10JRC 0001-A (Reactor pressure vessel) 10JRC 0001-B (Reactor pressure vessel head) Unit 2: 20JRC 0001-A (Reactor pressure vessel), 20JRC 0001-B (Reactor pressure vessel head)
Reactor type	Pressurised water reactor
Thermal rated power	2 x 1130 MW
Electrical gross power	2 x 380 MW
Electrical net power	2 x 360 MW
Material	Reactor pressure vessel: Creusot Acier 1, 2 MD07 boiler steel for forged cylindrical parts, RPV flange, RPV head, inlet and outlet nozzles, external suspension lugs. Reactor pressure vessel head: Monoblock, forged SA- 508 Gr. 3 Cl. 1; Suspension lugs: SA-533 Type B, Cl. 2
Safety class	SK1
Seismic category	EK I
As built design specification	ASME 3A / 3B IIIA / IIIB
Target design specification	ASME NG III NB
Supplier	Reactor pressure vessel: Westinghouse / Société des Forges et Ateliers du Creusot Reactor pressure vessel head: Westinghouse / JSW / ENSA

System	Nuclear steam generator
Operating / design temperature	279 - 315 / 343°C
Operating pressure / design pressure	154 / 171 bar
Medium	Reactor water
Internal height	9987 mm
Internal diameter	3327.4 mm (131")
Wall thickness (without cladding)	108 to 180 mm
RT_{NDT}-Initial temperature of the base metal	max. 4.4°C
Cladding material	RPV: Strip weld cladding from austenitic steel welded with an E308 electrode (AISI 304) RPV head: E308L- / E309L electrode
Thickness of the cladding	5 mm
Commercial commissioning	Unit 1: 1969, Unit 2: 1971

The reactor cooling circuit (also referred to as the primary system or pressure boundary) comprises the RPV including the head, the outlet pipes (hot legs), the steam generators, the connecting pipes from the steam generators to the reactor coolant pumps (closure legs), the inlet pipes (cold legs), each for circuit A and B, as well as the pressure equalization pipe and pressurizer (connected to circuit B). Moreover, the pressurizer relief lines up to the safety valves (Sebim), which protect the reactor cooling system against overpressure and the blow off isolation valves of steam generator B as a normal heat sink, form part of the pressure boundary. Lastly, the latter includes the connection lines up to the second isolating valve (SK1 sections) of the safety feed system and residual heat system.

The validity range of age management as defined in the in-service inspection programs encompasses the reactor pressure vessel as such, including the nozzle-safe-end welds, plus the welds on the inside of the RPV and the RPV cladding. RPV internals and the control rod drive mechanism are given special consideration within the framework of the AMP.

The RPV is a safety-classified vessel of safety class 1, as are all components of the pressure boundary of the reactor cooling system up to and including the second connection valve [5]. Consequently, it belongs to category A according to the ageing management guideline for Swiss nuclear installations ENSI-B01 and must be treated in detail and not grouped with other components [4].

The scope and concept of the ageing management are subdivided for each unit, and by RPV and RPV head in the AMP mechanical engineering fact sheets. In addition, the RPV head fact sheets include the pressure boundary of the control rod drives.

As in Section 2.1.2, the Mechanical Engineering Department carries out the procedure for identifying the relevant ageing mechanisms.

5.1.2 Ageing assessment of RPVs

The components are subject to ageing management based on their function in respect of pressure containment (see Section 5.1.1). The reactor cooling circuit, SK1, is checked every ten years by a pressure test at the design pressure of 171 bar to check the leak-tightness.

Each component is assessed for ageing due to damage that has occurred based on the materials used in manufacture, the operating conditions and the contact medium.

All components within the scope of consideration have been evaluated taking into account operating parameters acting on them, the medium in contact with them and their sensitivity to potential damage mechanisms. In this respect, the following relevant ageing mechanisms have been identified:

- Surface corrosion
- Intergranular corrosion
- Acid corrosion
- Stress corrosion cracking
- Crevice corrosion
- Fatigue as a result of operating transients
- Embrittlement due to neutron irradiation
- Abrasive sliding wear
- Adhesive wear, microscopic bonding, seizure, galling
- Plastic deformation as a consequence of high loading

The basic acceptance criteria for RPV are explained in Section 2.1.2.

Moreover in Switzerland, criteria for the temporary shut-down of NPPs are defined by the UVEK guideline [11]. Embrittlement of the RPV: The licensee must immediately temporarily shut down the NPP if:

a) the current adjusted brittle fracture reference temperature of the inner wall at a depth of one quarter of the wall thickness reaches 93°C

   or

b) the actual upper shelf energy from the Charpy impact test falls below 68 J.

If through-wall cracks appear in the primary circuit then, with the exception of piping with ND ≤ 25 mm, the licensee must immediately provisionally shut the NPP down. No leaks are allowed. If the wall thickness falls below the calculated minimum wall thickness of the primary circuit, with the exception of piping with ND ≤ 25 mm, (without thickness additions, safety factor equal to 1.0) the licensee must likewise immediately provisionally shut the NPP down.

For ultrasonic crack testing of the welds, permissible crack sizes for the welds are determined by computation. The relevant influencing factors for these calculations are the local embrittlement condition and the local stress condition under design conditions. The calculations for the KKB RPV were carried out in accordance with ASME XI IWB 3600 using linear elastic fracture mechanics. In addition, checking for ductile fracture according to ASME XI Division 1 C-5322 and C-5410 is performed.

These specific acceptance criteria were checked and approved by ENSI and its technical experts.

In line with the standards the following documents are available in KKB, which contribute to the precise identification of the relevant ageing mechanisms and the establishment of appropriate measures:

- Manufacturing drawings for all components
- Manufacturing documentation (material certificates, proof of heat treatment)
- Manufacturing test results
- Checking of the manufacturer documentation about the RPV material in respect of the susceptibility to hydrogen flakes (2013): "A Review of the Fabrication Records of the Beznau Reactor Vessels, and the Potential for Indications such as those found in the Recent Doel 3/Tihange 2 Inspections".

Investigations in 2013 revealed that indications based on hydrogen flakes in the base material, as were detected at Doel 3 /Tihange 2, were found to be safe based on the ultrasonic testing (UT) specified during manufacture for Beznau 1 and 2. The UT tests on the base material during manufacture were performed under the supervision of an authorized expert (APAV, Veritas-Alpave). In contrast to the base metal in Doel, the base metal in Beznau was forged immediately, without first cooling it to room temperature. After forging, a "precautionary" heat treatment at 650°C, followed by slow cooling to 350°C was carried out. The temperature control and quenching at 200°C were selected to prevent hydrogen flaking. It can be concluded that the probability of hydrogen flakes in the Beznau base metal is much less than that at Doel. According to the report, definitive exclusion of hydrogen flake formation cannot take place based on the manufacturing documentation alone.

Subsequently, in January 2013, ENSI requested an opinion on the quality of the base material of the KKB RPV. The extensive manufacturing quality documentation of the KKB RPVs was inspected and evaluated by Westinghouse. As a result it was recognized that, based on the manufacturing processes and the quality assurance measures performed at the time, the presence of hydrogen flakes in the KKB RPV is unlikely. These documents were submitted to ENSI on time on 14 October 2013.

As a consequence of the detection of indications in the base material of the reactor pressure vessels of the Belgian plants Doel 3 and Tihange 2, ENSI requested that additional inspection measures be implemented by the Swiss NPPs. KKB carried out an analysis of the manufacturing documents and a qualified test on the base material of the RPV during the 2015 outage. In accordance with working hypotheses within the framework of the root cause analysis, the indications found in unit 1 are highly likely to be non-metallic inclusions from the manufacturing process in 1965. There is no evidence that the indications are as a result of operation.

In mid-November 2016, Axpo submitted the unit 1 RPV safety proof to ENSI. Axpo expects to bring the plant back on line after clarification of the still-open ENSI comments raised after the submission.

Within the scope of the unit 1 BEDAM project, RPV irradiation programs, the last surveillance specimen capsule T was removed from the RPV in 2010. Within the scope of the unit 2 BEDAM project, RPV irradiation programs, the penultimate surveillance specimen capsule P was removed from the RPV in the same year. Both samples were placed in the fuel element store for their radiation level to decrease.

The radiation reaction of the test specimens in the T irradiation test corresponds to the condition after an operating time of significantly greater than 60 years on the RPV inner wall. Each of the test specimens in the P irradiation test corresponds to the condition after an operating time of significantly greater than 70 years on the RPV inner wall. Both specimens in the T irradiation and the P radiation test were evaluated in 2011.

The toughness data from the radiation programs was evaluated using the reference temperature concept in accordance with the US Regulatory Guide 1.99, Rev. 2 and the master curve concept.

The adjusted reference temperature for brittle fracture under irradiated condition RT_{ref}, ART is determined according to ENSI-B01 [4]. The values apply for the safety proof of the structural integrity of the RPV and the specification of the operating start-up and shut-down limits as well as the determination of the minimum temperature of the repeated pressure tests of the reactor cooling system.

The most important damage mechanism from the point of view of service life and safety of light water reactors is neutron embrittlement of the pressure bearing wall close to the core and its welds.

Work is under way on the INTEGER research project in the Nuclear Materials Laboratory of the Nuclear Energy and Safety Research Division at the Paul Scherrer Institute (PSI). This research project, jointly financed by the regulator ENSI and swissnuclear is subdivided into three subprojects:

- Ageing of materials: Characterisation and mechanisms: environmentally assisted cracking, thermal fatigue, embrittlement due to neutron irradiation
- Structural integrity: modelling and evaluation: RPV integrity and safety, thermal fatigue
- Diagnostics: early detection, monitoring: Embrittlement due to neutron irradiation, stress corrosion cracking

Project SAFE-II (Safe Long-Term Operation in the Context of Environmental Effects on Fracture, Fatigue and Environmentally Assisted Cracking), financially supported by the regulator ENSI:

RPV embrittlement behavior.

Investigations into the influence of hydrogen from 2 to 5 ppm on the fracture behavior of low alloy RPVs have allowed the following conclusions to be reached for the RPV and reactor water: Based on the PSI research results, the hydrogen dissolved in the reactor water (2 - 5 ppm) does not cause any risk of hardening of the RPV steel at 25 C or softening at an operating temperature of 288°C (measured at the elastic limit) or embrittlement of the base material or the heat affected zone (measured at the breaking elongation).

High temperature water influence on the fracture behavior of low alloy RPV steels.

If the A 508 Cl. 2 steel used for the KKB RPV is exposed to primary coolant at an operating temperature (PWR) of 150 and 288°C, there is no reduction in the initial ductility or the tearing resistance.

Project PROBAB, financially supported by the regulator ENSI. TP-II: probabilistic and deterministic fracture mechanics analyses of the RPV taking into consideration the neutron embrittlement and material inhomogeneities under pressurised thermal shock (PTS) loading and during start-up and shut-down transients.

New in PROBAB: Probabilistic fracture mechanics analyses of nozzles and pipes under consideration of active damage mechanisms such as fatigue, corrosion, stress corrosion cracking, etc.

Internal operating experience

Indications that are not permitted or must be assessed require further clarification as to whether the affected component can be repaired or replaced so that it can once again contribute to the structural integrity of the system. If the findings have suddenly worsened and exhibit unforeseeable accelerated ageing, an increase in inspection intensity can be initiated and/or the intervals between inspections shortened down to a minimum one year. Use of a second test method is conceivable to enable more precise estimation of the identified wear. If testing activity is to be expanded or the frequency increased as a long-term measure, the corresponding in-service inspection programs will be adjusted.

External operating experience

- Evaluation of the CODAP database to detect clusters of RPV events (Component Operational Experience, Degradation and Ageing Programs Project Database): Clusters of damage due to the mechanisms ECSCC (external chloride stress corrosion cracking), PWSCC (primary water stress corrosion cracking) and TGSCC (transgranular stress corrosion cracking), which were identified in the corresponding AMP fact sheets as not relevant for the KKB RPVs, require a more detailed look at the individual entries. Here, it is apparent that all damage associated with boric acid containing reactor water of components (e.g. control rod drives, measuring or drainage pipes) outside the scope of the fact sheet needed to be recorded.
- Reports from the manufacturer (Westinghouse)
- Reports from WANO (World Association of Nuclear Operators):
- Reports about events derived from external operating experience in plants of widely varying origin from across the globe are prepared.
- IGALL database (International Generic Ageing Lessons Learned (IAEA Project): The IGALL database is also searched. The assessment serves to determine if any other so far unknown events have been recorded that convey additional new findings about relevant ageing mechanisms in PWR reactor pressure vessels.

5.1.3 Monitoring, testing, sampling and inspection activities for RPVs

Maintenance programs, repair and service

No special maintenance programs exist for the RPV. If maintenance or repair becomes necessary as a result of the in-service inspection programs, this would be planned and implemented based on the findings (e.g. overlay welding).

General monitoring actions

- Temperature recordings: to check the method of operating or to check temperature gradients, pipes to the RPV (e.g. surge line) are equipped with thermocouples.
- Irradiation specimens: the analysis of the specimen sets for monitoring of RPV material embrittlement reveals no limitation of the service life of at least 60 operating years (54 years of full power operation).

In-service inspection programs

Periodic tests take place on the RPV over the entire service life of the vessel. They have been carried out and evaluated according to the SVTI specification NE-14 [13] or guideline ENSI-B06 [14] since commissioning. Essentially they include the following listed areas, which must be performed by qualified, volumetric and visual tests according to fixed in-service inspection programs. A couple of examples are mentioned below:

- Ultrasonic (UT) and eddy current testing (ET) of the RPV annular welds, nozzle welds and safe ends
- Indirect visual inspection of selected cladding areas, the nozzles and instrumentation nozzles in the floor area
- RPV head studs by visual inspection and ET
- RPV, threaded blind holes by ET
- Visual inspection of the screw nuts and washers
- Visual inspections during leak and pressure tests.
- Pressure test at the design pressure of the primary system (JRC system) every ten years

The following list depicts the components in groups with assignment of the relevant and therefore monitored for damage mechanisms:

Assignment of the relevant damage mechanisms and their testing to the age monitored component groups dependent on their material type.

Component group	Material	Relevant ageing mechanism	Remarks
Cylindrical part of the pressure vessel			
RPV flange A, Sealing surface Vessel flange Threaded blind holes 1.1	Low alloy steel	Surface corrosion Adhesion	Maintenance VT, ET, DP
Base metal close to the core ('beltline') 1.2-1.4	Low alloy steel	Embrittlement due to neutron irradiation	Irradiation programs PTS study UT, DP
Weld metal close to the core ("beltline") 2.3-2.5			
Radial bearing 1.14 incl. welds and buttering, 2.17-2.19	Nickel-based alloy	Stress corrosion cracking Fatigue as a result of operating transients	Transient monitoring ALMA Phase 2, VT
Wedges on the radial bearing 1.15	Nickel-based + cobalt-based alloy	Abrasive sliding wear	VT
Bolting Radial bearing 1.16	Austenitic steel	Plastic deformation as a result of high loading	VT
Support lugs 1.19 including weld 2.20	Low alloy steel	Fatigue as a result of operating transients	Transient monitoring ALMA Phase 2, UT
Incore guide tubes 1.21	Austenitic steel	Abrasive sliding wear	ET, BG
RPV fittings: bolts, nuts, 3.1, 3.2	Low alloy steel	Acid corrosion Stress corrosion cracking Fatigue as a result of operating transients (bolts only) Adhesion	UT, VT, MT UT, MT Transient monitoring ALMA Phase 2, ET, VT, DP
RPV fittings: nuts, washers, 3.3	Low alloy steel	Acid corrosion	VT

Component group	Material	Relevant ageing mechanism	Remarks
Pressure vessel nozzles			
Inlet nozzles Outlet nozzles 1.8 1.9, including welds 2.8, 2.9	Low alloy steel	Fatigue as a result of operating transients	Transient monitoring REQUA-stress analyses ALMA Phase 2, UT, ET, VT, DP
Dissimilar metal welds on RPV inlet and outlet nozzles, 2.23-2.28	Austenitic steel	Fatigue as a result of operating transients	UT, ET, VT, PT, DP
SE nozzles 1.11, incl. weld, 2.14	Nickel-based alloy	Stress corrosion cracking Fatigue as a result of operating transients	ALMA Phase 2, UT ET, DP REQUA-stress analyses ALMA Phase 2, UT, VT, DP
Incore guide tubes 1.12, incl. welds bottom, safe-end, 2.10, 2.12	Nickel-based alloy	Stress corrosion cracking	ALMA Phase 2, VT, DP, UT, ET
RPV head			
RPV head (mono block), outer, head support lugs, fastening elements, shroud support ring flange/ring shell, bearing bracket, fastening elements, bearing elements, reinforcement, "flux ring half"	Low alloy steel	Acid corrosion	BG, VT, DP, PT
CRDM and CETNA through nozzles, Vent line welds (MN, "J- Groove", buffering), extension tube (CRDM), safety wire	Nickel based alloy	-	VT
Leak monitoring inner seal, CRDM ratchet housing, CETNA housing adapter, cladding (overlay welding), extension tube, guide funnels	Austenitic steel		VT

Table of abbreviations

ALMA Project ageing management
MT Magnetic particle Testing
BG System and component walk-down
PT Penetrant Testing
DP Pressure Testing
UT Ultrasonic Testing
ET Eddy Current Testing
VT Visual Testing

The tests defined in the in-service inspection programs are performed according to the KKB technical specification. The test intervals in the existing in-service inspection programs are defined individually for all test items and can be adjusted should a finding behave other than expected. Acceptance criteria are documented in a separate calculation report and approved by ENSI (see Section 5.1.2).

Additionally, the following surveillance programs are set up:

- Fatigue monitoring in primary circuit: Monitoring of fatigue on the guiding RPV nozzles of the safety injection system has been carried out since the beginning of 2002 using the On Line Monitoring (OLM) System WESTEMS™ provided by Westinghouse. In this way the partial degrees of fatigue resulting from the operating transients is determined using conservative models based on the defining physical quantities from the ANIS process information system.

  The current overall degree of fatigue grade is determined together with the partial degrees of fatigue from before 2001 (baseline), which were determined based on the design calculation methodology.
- In addition to the fatigue monitoring, the number of primary transients is recorded in the primary transient accounting, updated annually. The number of effectively occurring transients is significantly below the number of design transients.
- Irradiation surveillance specimen capsule programs: The increase in embrittlement in the RPV steel can be determined with the help of the evaluation of the irradiation surveillance specimen capsule records. It is proven that the structural integrity of both RPVs allows a service life of at least 60 years.

The following measures can also provide information if unexpected degradation in the RPV should become apparent:

- Water-chemistry monitoring: changes in the chemical parameters can indicate internal leaks
- Daily discussions in the 08:00 meeting about any anomalies in the operating parameters based on recordings in the MCR
- Reactor building sump level monitoring
- Temperature, relative humidity and pressure monitoring in the safety building
- Temperature monitoring, head flange seal (space between the seals)
- Walkdowns in the primary containment, with inspection of specific components

5.1.4 Preventive and remedial actions for RPVs

Temperature monitoring during the cooling and heating of the primary circuit ensures that no inadmissible transients occur during operator actions that could impair the RPV integrity.

The 2015 replacement of the RPV heads ensures that primary water stress corrosion cracking (PWSCC) on the head penetrations can be ruled out with a very high probability. The material Inconel 600 was used in the original heads and this was much more sensitive to ageing mechanisms. Alongside a series of smaller improvements in line with the current state of the art, the new RPV heads have eliminated a major weak point in the form of through-welding of the head. Moreover, Inconel 600, which is susceptible to PWSCC, was replaced by Inconel 690, which is resistant to PWSCC.

5.2 Licensee's experience of the application of AMPs for RPVs

The condition of the reactor pressure vessel and its internals is safeguarded by the established preventive maintenance measures and the programs for protection of the core internals against stress corrosion cracking as well as the implemented ageing management and the recording and evaluation of transients. This is confirmed by the results of the implemented function tests and repeat tests. Replacing both welded RPV heads with monoblock forged parts and optimized material selection, Inconel 690 for the penetration tubes and Inconel 52 for the welds and dissimilar material welds, means that damage due to stress corrosion cracking and fatigue can be completely excluded.

The existing results of the RPV embrittlement monitoring for RT_{ref} at a depth of 1/4 of the wall thickness measured from the inner wall show that at the limit of the temporary shutdown guideline [11| (V2- Weld RT_{ref} 1/4 wall < 93 C), considerable safety margins exist for a service life of 60 operating years. These results confirm that in respect of the brittle fracture safety of the RPV, there are sufficient safety margins for long-term operation.

The test results of the specimen sets T, unit 1 and P, unit 2, the safety assessment carried out by a deterministic PTS analysis, the designated additional margins in the material characteristics and the large overall margins or small contributions to the PSA from the probabilistic PTS analysis all cover the safety influence of the RPV neutron embrittlement for a duration of at least 60 years for both units.

The results show that for both the units, brittle fracture for all investigated areas of the RPV can safely be excluded for 60 years' operation. The limits of the DETEC guideline are complied with and continuously monitored by the annual tracking of the fluence increases.

For unit 1 which has been shut down since March 2015, Axpo submitted the RPV safety proof to ENSI on 14.11.2016. Based on the review comments of the regulator and their responses, it has not yet been possible to start the unit up again.

The licensee assumes that, after successful approval for the restarting of unit 1, it will be possible to operate both the units of the power plant safely and reliably in the coming years.

6 Calandria/pressure tubes (CANDU)

The subject of pressure tubes in CANDU reactors is not relevant for Swiss reactors and therefore requires no further elaboration (see [1])

7 Concrete containment structures

7.1 Description of ageing management programs for concrete structures

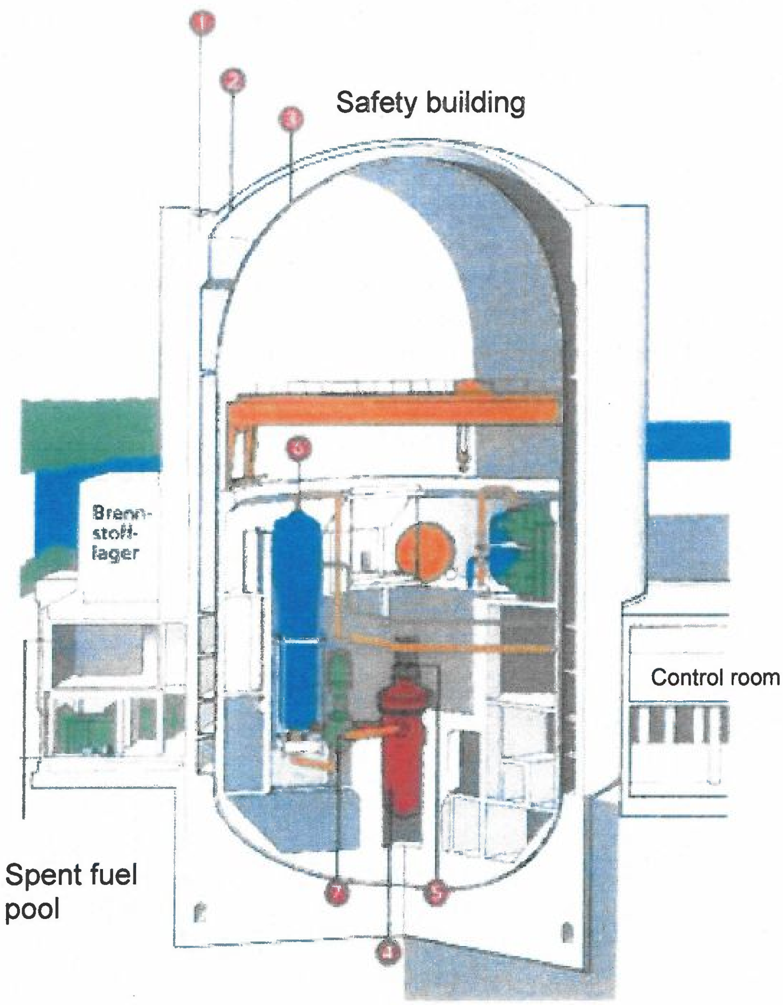
7.1.1 Scope of ageing management for concrete structures

With reference to the Topical Peer Review specification [2], Section 7, the following components of the concrete containment are taken into account:

- Concrete cylinder with inner steel plate cladding (steel liner) as outer containment of the reactor shielding building
- Reinforced concrete foundation slab
- Pre-stressed concrete ring at the top of the concrete cylinder as a tensile belt to absorb horizontal dome loads

The outer concrete containment forms the outer structure of the reactor shielding building. It comprises a reinforced concrete circular foundation slab with a thickness of 2.45 m to 5.45 m, the 46 m high concrete cylinder of wall thickness 90 cm and internal diameter 36 m and the spherically shaped dome of 75 cm thickness.

The top of the dome is elevated by 6.20 m and comprises a steel frame with reinforced concrete infill and reinforced overlay. The foundation slab acts as a support for the outer concrete containment and the steel containment with the internal structure. The annular space between the steel containment and the outer concrete containment is 1.5m wide. The inside of the concrete structure is lined with a 6 mm thick steel liner, which acts as a sealing skin. This was directly embedded in concrete and is anchored with angular sections and head studs.



1 Concrete jacket
2 Steel liner
3 Steel containment
4 Reactor pressure vessel
5 Control rod drive
6 Steam generator
7 Reactor coolant pump

Figure 1: General view of the reactor safety building

The auxiliary buildings and the emergency building are arranged around the outer concrete containment as independent buildings, separated with dilatation joints both from each other and the containment building. The exhaust air stack is arranged on the eastern side of the safety building and integrated in the structure of the safety building envelope.

The outer concrete containment protects all internal structures against external influences and provides radiation shielding for the environment.

Known civil engineering ageing mechanisms for the relevant building materials are listed in all guidelines for GSKL civil engineering fact sheets, valid and updated for all Swiss NPPs. Using this as a basis, the following building structures and components of the concrete containment are periodically reviewed and assessed:

- Outer concrete structures, weathered
- Inner concrete structures Reinforcement steel/pre-stressing
- Dome sealing/ground water sealing
- Steel liner

The ageing mechanisms are identified in the mentioned guidelines for these structures and components (partially listed below).

Extracts from the guideline for civil engineering fact sheets

Ageing mechanisms for concrete and reinforced concrete

Influence and phenomena	Ageing mechanism	Consequences
Temperature	Constraint stresses and deformation in the presence of temperature differences, which promote crack formation	Cracks and spalling due to excess stresses E.g. if expansion joints are incorrectly configured Deformations are reversible
Moisture, water	Moisture plays an important role in all physical effects	On its own, moisture does not cause any damage
Frost	This effect is the underlying cause of complex microscopic and macroscopic interactions. The pore fluid of concrete contains a large number of dissociated ions, which reduce the freezing point. Moreover, the freezing point of the pore water falls even further with a reduction in pore size.	The phase transition from water to ice is associated with a 9 % increase in volume, which results in a hydraulic pressure in the concrete joints. The consequence is spalling of components due to volume expansion
Thawing agent	Both carbon dioxide and chloride react with the calcium hydroxide of the cement stone; chloride however primarily with the aluminate phases to form Friedel's salt. Through the stable binding of calcium hydroxide in calcite and aragonite, carbonation reduces the chloride binding capacity of the concrete. Additionally, the carbonation of the concrete destroys the protective passive layer on the steel surfaces so that even very low concentrations of chloride attack the steel. Therefore for carbonated concrete, the corrosion triggering chloride content must lie below the limits specified for the non-carbonated concrete	Criteria for corrosion risk are carbonation, chloride loading and the relative pore humidity of the concrete.

Influence and phenomena	Ageing mechanism	Consequences
Shrinkage, swelling	Cement based materials are deformed by changes in the moisture content in the pores. Drying out is referred to as early shrinkage or also, in the absence of after-treatment, as plastic shrinkage and the supply of moisture as swelling. The change in moisture content can take place as a result of capillary water transport or diffusion	Cracks, deformation, partially reversible with moisture changes
Load, static	The overall change in shape of concrete under external load can be subdivided into immediately occurring (elastic) and delayed (elastic and plastic) parts. The sum of the changes in shape is referred to as elastic if it is reversible, and largely as plastic when it is irreversible. Concrete only behaves in an approximately elastic manner. If the load is removed after just a short application, there will still be permanent strain	Deformation and/or crack formation, decrease in Young's modulus
Load, dynamic	Material fatigue, promoting cracking	Reduced load bearing capacity and cracking possible
Settlement	Deformations and load shifting	Cracking, local overloading
Carbon dioxide (CO_2)	Carbonation refers to the chemical reaction of alkaline components of the cement with carbon dioxide to form carbonates. The reactions only take place in the presence of sufficient moisture. The pH value of the concrete pore water falls from an original value of > 12.5 to values between 6 and 9 (depending on the CO_2 content). As a result the corrosion protection of the reinforcement is lost	These reactions change the structure and essential properties of the concrete. Particular hazard points for the carbonate induced reinforcement corrosion are corners, edges, water courses, dripping areas of components and severe cracking but also components of small size and components with a high level of reinforcement
Fouling	Moisture penetration and root penetration in porous areas and cracks	Scaling possible

Ageing mechanisms for reinforcement steel and prestressing steel

Influence and phenomena	Ageing mechanism	Consequences
Oxygen corrosion	Approximately neutral, conducting and oxygen-containing water (electrolyte) acts on the metal The rate of corrosion is dependent on the oxygen supply	Loss of load bearing capacity
Pitting/seam corrosion	Dry periods: oxide layer formation Damp periods: oxygen corrosion	Corrosion in pits
Contact corrosion (electro-chemical series)	Different metals connected in a conducting manner in the same electrolyte form an electro-chemical element if potential differences are at least 250 mV	The more noble metal is protected against corrosion, the least noble is dissolved.
Load, dynamic Load change	Fatigue and high actual load proportion relative to the total load has an unfavorable effect on steel. Fatigue strength decreases	Fatigue fracture at areas of peak stress and changes in the material geometry (screw holes, welded seams)

7.1.2 Ageing assessment of concrete structures

The components of the outer concrete containment protect all internal structures against external influences and provide radiation shielding for the environment. Based on guideline ENSI-G01 [5] the structures are assigned to building class BK1 and consequently evaluated in detail in respect of ageing (see Section 7.1.3).

Here, measurement and evaluation of the condition depends on the possible ageing mechanisms per material. The most important ageing mechanisms, by material, (those to which particular attention has been paid) are listed below.

Reinforced concrete

Frost: on porous outer surfaces and on areas re-profiled during maintenance or mended areas, damage caused by penetrating and freezing water is possible. This damage is visually identifiable, occurs only locally and can be repaired with little effort. The risk of compromising of the building structure is low.

Carbonation: The loss of alkalinity and with it the passivation of the reinforcement is the most significant ageing mechanism. The buildings in the Beznau NPP have shadow gaps. Particular attention must be paid to the extent of carbonation in these gaps. If action is taken promptly, the effects of carbonation can be overcome without any risk of damage to the reinforcement. The risk of compromising of the building structure is then low.

Alkali-Aggregate-Reaction (AAR): Damage caused by AAR does not often occur in concretes with additives from the Swiss plateau (Mittelland) and it therefore plays a relatively minor role in comparison with other damage mechanisms. Nevertheless, the occurrence of AAR on weathered concrete components in the presence of potentially reactive aggregates cannot be excluded. The risk for the building structure is low because the occurrence can be quickly recognized and if necessary a repair is easily implemented.

Reinforcement/pre-stressing steel

Oxygen corrosion and pitting/seam corrosion: These types of corrosion occur in carbonated outer areas, because here there is a loss of passivity and a high moisture level. If action is taken promptly, the danger to the building structure is low, because the corrosion is superficial and no pitting/localized corrosion occurs.

Dome seal

Embrittlement: The dome seal comprises a detachably positioned plastic film. Over time, direct sunlight leads to a loss of plasticizer and ultimately to embrittlement of the seal. The danger to the underlying concrete structure is low because leak points can be quickly detected and rain water is low in contaminants. However, soft water that ingresses can leach out calcium hydroxide.

Steel liner

Oxygen corrosion and pitting/seam corrosion: As the cupola roof is not thermally insulated, low outside temperatures can cause condensation on the steel liner surface and result in surface corrosion. The danger for the steel liner is low because any damage is clearly visible and allows prompt action to be taken.

Internal and external operating experience, events and changes in the state of the art plus papers in specialist journals dealing with ageing problems are collected by the licensee and discussed in the GSKL AMP civil engineering group and its relevance in respect of ageing is evaluated. The new findings are recorded and included in the ageing management. Moreover, a summary of the evaluated findings is given in the annual safety report of the individual licensees.

7.1.3 Monitoring, testing, sampling and inspection activities for concrete structures

The basis for the ageing management programs of the Swiss NPPs is the guideline of the GSKL civil engineering group. The general inspection plan for civil engineering structures is defined in the guideline. The structure-specific inspection plan is specified in the fact sheets. The base inspection is the first main inspection and takes place at the beginning of a civil engineering structure surveillance program. In Beznau Nuclear Power Plant, the periodic monitoring of the civil engineering structure of the outer concrete containment was started in 1996 with the base inspection. A main inspection then takes place at least every ten years, the findings of which are entered in the fact sheet. In the middle of this interval, the relevant findings since the last main inspection are summarized as interim inspections and likewise added to the fact sheet. A special inspection can be carried out at any time for a given reason.

The focus of the inspections is to determine the current condition of the civil engineering structures and components. The aim of the investigations is to determine the current state in respect of nuclear safety plus to be able to assess the fitness for purpose and to make possible a comparison with the target state and the results from earlier inspections ("trending").

The possible detection methods for the different materials are described in the guideline along with the aims of the investigations. The selection of the detection method is dependent on the type, scope and aim of the inspection and is defined by qualified specialist personnel.

The key to the inspections is a visual check of the concrete structure. In the visual condition analysis, a check is performed to see whether cracks, spalling, inhomogeneous surfaces, efflorescence or discoloration are present. Crack widths are determined using a crack width comparison standard. The position of the findings are entered on drawings and summarized in tables in the findings inventory. The most striking points are photographed and documented. Moreover, to assess the risk of corrosion, the covering of the reinforcement is measured and compared with the carbonation depth determined from drilled cores. Further laboratory tests are carried out on the drilled cores, such as determination of the concrete density, the compressive and tensile strength and, metallographic study analysis, determination of the microstructure quality etc.. If active reinforcement corrosion is suspected and to be investigated, potential measurements and potential field measurements are taken on both untensioned and pre-tensioning reinforcement. Samples are cut from the plastic film of the cupola seal and subjected to tensile and folding endurance tests in the laboratory and the content of plasticizers are determined. This allows the expected remaining service life to be estimated.

The steam generators of units 1 and 2 were replaced in 1993 and 1999, respectively; while the reactor pressure vessel heads were replaced in 2015. In both cases the outer concrete containment and the steel liner were broken over large surface areas. As part of such interventions, information is always collected to aid in ageing management, for example information about the state of concrete, reinforcement and in the actual case also about the steel liner and its anchoring.

Acceptance criteria: For assessment of the condition, the following defined condition levels are applied. Condition level 2 is defined as the target state, the state under which nuclear safety is still guaranteed.

Assessment	Description
1: Very good condition	Fatigue and high actual load proportion relative to the total load has an unfavorable effect on steel. Fatigue strength decreases.
2: Good condition	The defect/damage may prejudice the service life and/or the structural integrity of the component in the long-term. Nuclear safety is ensured. Repairs are required in the long-term.
3: Adequate condition	The defect/damage prejudices the service life and/or the structural integrity of the civil engineering structure/component, the nuclear safety may be prejudiced. Repairs are required in the medium-term, may also be needed in the short-term to prevent the damage from spreading.
4: Inadequate condition	The defect/damage will prejudice the service life and/or the structural integrity of the civil engineering structure/component. The deviations in component condition, material quality or component dimensions have reached the tolerance limits. Nuclear safety may be prejudiced. Repairs must be performed at short notice.
5: Poor condition	The defect/damage will considerably prejudice the service life of the civil engineering structure/component. The deviations in component condition, material quality or component dimensions have exceeded the tolerance limits. Nuclear safety may be prejudiced. Repairs must be performed immediately.

The GSKL guide also contains condition tables with direct reference to the assessed materials, such as concrete or steel.

Alongside the periodic inspections, plant walk-downs are performed both by plant staff and also by the authorized civil engineering experts. The civil engineering plant walk-downs are planned so that all buildings and rooms are surveyed at least once every year. Visual findings arising from these plant walk-downs are, if relevant, likewise recorded in the ageing management assessment.

7.1.4 Preventive and remedial measures for concrete structures

Findings from the inspections or the plant walk-downs are evaluated by civil engineering. These can in principle be incorporated in the maintenance plan, if it is assumed that within an inspection interval degradation will lead to a condition that is worse than the target condition. Minor damage such as local concrete spalling, efflorescence, corrosion points etc. are however, frequently repaired on an ongoing basis because, in general, the degradation increases exponentially and waiting would not be economical.

As a preventive measure, a protective coating was applied to the shadow gap of all other concrete containment structures. This measure has prevented the ingress of water, humidity and CO_2 into the shadow gap area to reduce the advance of carbonation and the risk of corrosion of the reinforcement. As a kind of preventative measure, a concept was applied to all nuclear classified buildings in 2016 that identified steps as to how reinforcement corrosion can be prevented in the long-term, in particular in the shadow gap area.

7.2 Licensee's experience of the application of AMPs for concrete structures

The new guideline for ageing management ENSI-B01 [4], which came into force in 2011, resulted in the revision and updating of ageing management in the civil engineering area. Thanks to the close cooperation between the plants and ENSI, the guidelines for the civil engineering fact sheets were revised within just a few years, and updated in terms of the latest state of the art of science and technology (concluded end of 2015). The new ageing management guideline ENSI-B01 and the new guideline for the civil engineering fact sheets have neither resulted in any significant omissions being detected in the methodology nor in the overall ageing management having to be adapted.

The ageing management, as it has been applied with periodic inspections in KKB for nearly 30 years, has not thus far revealed any unexpected findings due to ageing that would require an adaptation of the AMP or the investigation methods.

As part of the collaborative work in the GSKL civil engineering group, experience in ageing management, ageing mechanisms and investigation methods and knowledge about the state of the art is exchanged. The exchange in this platform likewise confirms that the applied methodology is successful. According to this exchange, no unexpected ageing events have arisen at any other Swiss plant.

The inspections certify all civil engineering structures and the components being evaluated in KKB as either of condition 1 or 2. In a few cases, local condition 3 is attested, which generally also triggers a repair. This good to very good quality of the civil engineering structures and components is a result of the good design of the plant but also of appropriate and effective ageing management as an important accompanying measure in the defence in depth safety concept.

8 Pre-stressed concrete pressure vessels (AGR)

The subject of pre-stressed concrete pressure vessels is not relevant for Swiss reactors and therefore requires no further elaboration (see [1])

9 Overall assessment and general conclusions

Within the scope of the Topical Peer Review 2017 on ageing management in nuclear installations, this present plant report for units 1 and 2 of the Beznau nuclear power plant highlights the current status in respect of the following key points for:

- Requirements on the overall AMP and its implementation
- Electrical cables
- Concealed pipework
- Reactor pressure vessel
- Concrete containment structures

The overall AMP has been developed over the last thirty years in all the main areas in cooperation with the other Swiss plants by the GSKL AMP Working Group under intense consultation with ENSI. In this way it was ensured that the requirements of the national regulatory framework and international (in particular standards specified by the IAEA and WENRA) standards are considered. These include the scope of consideration and the methods involved in ageing management, preventive measures and overhauls, the implementation, testing and updating of the corresponding process content in the KKB management system, as well as the operating experience with the processes applied as part of the ageing management.

For the four example areas that are relevant for KKB drawn from electrical, civil and mechanical engineering ageing management, the above named aspects were presented in depth and the actual implementation was described. Two other systems and structures monitored within the context of the overall TPR 2017 are not present in KKB and were therefore not considered.

Overall it can be stated for all areas that the implementation of the AMP in KKB meets very high international standards, in which respect no known procedural omissions or defects have been found.

10 References

[1] ENSI, Directive: Participation in the Topical Peer Review 2017 "Ageing Management of Nuclear Power Plants", 14.03.2017, THK/VOB - 10KEX.TPR2017

[2] WENRA-RHWG, Report Topical Peer Review 2017, Ageing Management, Technical Specification for the National Assessment Reports, 21.12.2016

[3] Guideline ENSI-B10: Vocational training, recurrent training and continuing education of personnel, October 2010

[4] Guideline ENSI-B01: Ageing management, August 2011

[5] Guideline ENSI-G01: Safety classification for existing nuclear power plants, January 2011

[6] Guideline ENSI-A06: Probabilistic Safety Analysis (PSA): Applications, November 2015

[7] Guideline ENSI-G11 Rev. 2: Safety classified vessels and pipework: Planning, production and assembly, June 2013

[8] Guideline ENSI-B02 Rev. 5: Periodic reporting of nuclear installations, June 2015

[9] Guideline ENSI-A03: Periodic safety review of nuclear power plants, October 2014 (under revision)

[10] IAEA Safety Guide NS-G-2.12: Ageing Management for Nuclear Power Plants, 2009

[11] UVEK SR 732.114.5: DETEC ordinance on the methodology and boundary conditions for checking the criteria for the temporary shut-down of NPPs

[12] ENSI, Research and Experience Report 2015, Developments in the area of the foundations of nuclear supervision, June 2016

[13] SVTI Specification NE-14: Repeat tests on mechanical components subject to nuclear acceptance testing of safety classes 1 to 4, Rev. 6, January 2005

[14] Guideline ENSI-B06 Rev.2: Safety classified vessels and pipework: Maintenance