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Contribution to the National Assessment Report, Topical Peer Review 2017

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Abbreviations

AMP	Ageing Management Programme
BE	Fuel element
BHB	Operating manual Chemical
CIS	Chemical Information System
CODAP	Degradation and Ageing Programme
DP	Pressure test
PWR	Pressurised water reactor
EOL	End of Life
ET	Eddy current testing
EPRI	Electric Power Research Institute
EQDB	Equipment Data Bank
EROSKO	Wall thickness measurement programme
FD	Fresh steam
FDU	Fresh steam diversion
GSKL	Group of Swiss NPP Managers
HD	High pressure
HKML	Reactor coolant loop
HKMP	Reactor coolant pump
HSK	Main department for the safety of nuclear installations
IGALL	International Generic Ageing Lessons Learned
IHP	Maintenance programme
ISA	Internal safety committee
KATAM	Catalogue of Ageing Mechanisms for Mechanical Equipment
KKG	Gösgen-Däniken Nuclear Power Plant
KO	Core grid plate top
KU	Core grid plate bottom
KÜS	Structure borne sound monitoring system
LF	Load case
LSC	Laser scanning device
LT	Leak rate test
MT	Magnetic particle testing
NDT	Nil-Ductility Transition (Temperature)
NCC	Natural Circulation Cooldown
NW (DN)	Nominal width
OBE	Operating base earthquake
OKG	Upper internals
OR	Surface crack testing (non-destructive testing)
PISA	Primary safety valve replacement
PR	Power Ratio
PSI	Paul Scherrer Institut
PSU	Periodic Safety Review
PT	Dye penetrant test
PTS	Pressurised Thermal Shock
PWSCC	Primary Water Stress Corrosion Cracking
RDB	Reactor pressure vessel
RESA	Scram Reactor cooling system
RKS	Reactor cooling system
RN	Circumferential weld
RTNDT	Reference temperature for nil-ductility transition

SIKL	Safety class weld
SN	Weld
SSC/SSK	Systems, structures and components
SSE	Design base earthquake
SÜS	Vibration monitoring system
SVTI	Schweizerischer Verein für technische Inspektionen (Swiss Association for Technical Inspections [previously SVDB])
TÜV	Technischer Überwachungsverein (Technical Inspection Association)
TSpRK	Transgranular stress corrosion cracking
UKG	Lower internals
UP	Submerged arc welding
UT	Programme Ultrasonic testing
VGB	Verein der Grosskraftwerks Betreiber
VOL	(Association of large power plant operators)
VT	Volumetric testing (NDT) Visual testing
WANO	World Association of Nuclear
WKP	Operators Periodic testing
WPS	Warm Prestress (Effect)
NDT	Non-destructive testing

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Abstract

This report fulfils the directive ‘Topical Peer Review 2017 Ageing Management of Nuclear Power Plants’, [1] and is KKG's contribution to the Swiss National Assessment Report as part of the WENRA Topical Peer Review.

The objectives of the Topical Peer Review 2017 are, in particular, to ensure that the participating countries review the provisions put in place so far within the context of the ageing management of operational nuclear installations, identify good practices and areas of improvement from them and exchange operating experience at the European level.

The scope and layout of the Swiss National Assessment Report as a contribution to the WENRA Topical Peer Review is explained in directive [1] Para. 1.2.

‘1.2 Scope of TPR 2017 and layout of the Swiss National Assessment Report’. The scope of nuclear installations and systems, structures and components (SSC) to be dealt with as part of TPR 2017 plus the layout of the national assessment reports is specified in detail by the Western Nuclear Regulators Association (WENRA) in [2] .

According to this, NPPs and research reactors with a thermal output of greater than or equal to 1 MW are to be incorporated in TPR 2017. As there are no research reactors operating in Switzerland with this level of output, only the ageing management programmes developed and implemented by the Swiss NPPs form the subject of the Swiss National Assessment Report. Moreover, in terms of the NPP types operating in Switzerland, the ageing management programmes for the following components and structures in the Swiss National Assessment Report are applicable: electrical cables, concealed pipework, reactor pressure vessels and concrete containment structures.

Based on this specified scope, the Swiss National Assessment Report is laid out as follows taking into consideration the specifications in [2] :

Section 1: General information

Section 2: Overall ageing management programme requirements and implementation

Section 3: Electrical cables

Section 4: Concealed pipework

Section 5: Reactor pressure vessel

Section 6: Concrete containment structures

Section 7: Overall assessment and general conclusions

Section 8: References

The sub-sections of the Swiss National Assessment Report and their expected contents are specified in detail in the WENRA specification [2]. Accordingly, in each of the above mentioned Sections 2 to 5 first the overall or the SSC-specific AMP is to be presented and then these programmes are to be checked by the licensees and evaluated by the regulators. Starting from the previously presented layout of the Swiss National Assessment Report and the table of contents to be applied from Annex 1 of the WENRA specification [2], the reports of the licensees of the Swiss NPPs must include the following sections:

Section 2: Sub-section 2.3 to 2.5

Section 3: Sub-section 3.1 and 3.2

Section 4: Sub-section 4.1 and 4.2

Section 5: Sub-section 5.1 and 5.2

Section 6: Sub-section 6.1 and 6.2

Sub-sections 2.3 and 3.1 to 6.1 must be further sub-divided according to specifications in the WENRA specification [2]. The overall conclusions reached from the reviews must be detailed in a concluding section.

The contributions of the Swiss NPP licensees to the NAR in the present report on the Gösgen NPP are consequently limited to the following ageing management topics:

- Electrical cables → corresponds to Section 3 in this report
- Concealed pipework → corresponds to Section 4 in this report
- Reactor pressure vessel → corresponds to Section 5 in this report
- Concrete containment structures → corresponds to Section 6 in this report

In the opinion of KKG, the result of the present review is positive. KKG is always up-to-date in its implementation of ageing management. Consequently, ageing management at KKG forms a sound basis for safe long-term operation according to ENSI A03/d [3].

1 Introduction

The present report fulfils the directive ‘Participation in the Topical Peer Review 2017 "Ageing Management of Nuclear Power Plants’, [1] .

The objectives of the Topical Peer Review 2017 are, in particular, to ensure that the participating countries review the provisions put in place so far within the context of the ageing management of operational nuclear installations, identify good practices and areas of improvement from them and exchange operating experience at the European level.

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Section 7 contains the summarising assessment of the review of the AMP from the viewpoint of the licensee.

2 Overall ageing management programme requirements and implementation

2.1 (ENSI contribution)

2.2 (ENSI contribution)

2.3 Description of the overall ageing management programme

To understand the overall ageing management programme (AMP) applied in Switzerland, the description of the development of the AMP in Switzerland is necessary. Therefore this will be looked at first. Where necessary in the following subsections, we shall refer back to this content.

At the end of 1991, the Swiss NPPs were requested by the Swiss regulator, ENSI, to introduce an ageing management programme (AMP) 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 charge a new working group ‘Ageing Monitoring in Swiss NPPs (CH-KKW)’ with preparing joint interpretative documents for surveying the ageing process. This should therefore 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 a step-by-step one:

- The GSKL programme 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 the ageing management of the Swiss NPPs. The GSKL programme 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 the ageing management of the Swiss NPPs.

- The ageing management is implemented in the individual departments of the Swiss NPPs. In addition, an independent GSKL team of experts was set up for each department, making it possible to monitor ageing with the necessary technical competence. By dividing the ageing management into three departments, electrical, civil and mechanical engineering, it was necessary to create a GSKL interface document that lists and clearly allocates interface and liaison points of the individual departments in the treatment of equipment.

- In terms of the ageing management of the civil engineering, the GSKL guide for the creation of ageing reports 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 ageing reports contains a listing of the most important function-impairing and qualification-influencing ageing mechanisms for the specified component with a link to the corresponding references. Part 2 of the ageing reports 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 its revision in 2011, this document was, recognised by the regulator as an essential foundation for ageing management in the Swiss NPPs.

- The GSKL guides for the creation of ageing reports for civil, electrical and mechanical engineering provide guidance for the practical implementation of ageing management and for the documenting of the results of the assessment of the mechanical and electrical components as well as 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 summarised in the plant-specific ageing reports.

2.3.1 Scope of the overall AMP

The ISO 9001:2015 certified management system of KKG organises the overall ageing management in the maintenance/replacement process which is subdivided into the areas mechanical engineering and electrical engineering. The processes define both the responsibilities as well as the higher-level and applicable documents (guidelines, procedure instructions, work instructions). The interfaces and/or responsibilities of the electrical, civil and mechanical engineering divisions are defined in the ‘Interface document’ co-authored by GSKL.

Section 6.3.1 of the ENSI-B10 [4] guideline defines specific requirements for technical and scientific staff in the plants who are involved in ageing management. This staff is appointed by ENSI, provided the relevant job holder has the necessary knowledge and capabilities.

As already mentioned in Section 2.3, the GSKL teams of experts, 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 the feedback of information from the GSKL Working Group and their specialist teams.

<u>Identification of the SSC as part of ageing management</u>

In accordance with Article 35 of the nuclear energy regulation KEV (SR 732.11), 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 [5] (see Section 2.1).

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 (‘Safety classification for existing NPPs’) [6] and the relevant specifications of guideline ENSI- B01. Mechanical and electrical equipment which, in accordance with guideline ENSI-A06 (‘Probabilistic Safety Analysis’) [7], is relevant for safety based on the PSA, must be identified as such and incorporated in the mechanical engineering and electrical engineering AMP. Essential data relating to electrical and mechanical engineering safety classified components are to be periodically recorded or recorded when plant changes occur, in component lists and/or component type lists in accordance with guideline ENSI-G01. These lists are to be made available to ENSI. All SSCs are recorded with this relevant metadata in the database of the integrated plant information system (IPIS), which permits automated identification and checking.

Civil engineering

In accordance with ENSI-B01 [5], Section 5, all civil engineering structures classified according to ENSI-G01 [6] are to be included in the ageing management. In line with their significance for nuclear safety and radiation protection, civil engineering structures are assigned to two nuclear structure classifications, BKI and BKII. 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. The classified civil engineering structures are indicated in the safety report.

Mechanical engineering

The systematic ageing management for all vessels and pipelines assigned to safety classes 1-3 based on guideline ENSI-G01 [6], including their supports and pressurised equipment (pumps, valves, safety valves), must be documented according to ENSI-B01 [5] for its use in Swiss nuclear installations. Excepted from this are small pipes. The ageing condition of the mechanical engineering equipment 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.

Component lists are used for identification of the structures to be recorded. All active and passive components are assessed. Here the term ‘active’ is used in the sense of the US American ‘Maintenance Rule’, i.e. active components need not necessarily be active in the sense of ENSI-G11 [8].

Electrical engineering

According to Section 6 of ENSI-B01 [5], the AMP is valid for all electrical and I&C equipment classified as 1E in ENSI-G01 [6] and for all safety-relevant electrical equipment classified as 0E. According to ENSI-B01, ageing reports must be created for 1E components, whereas for 0E classified components ageing dossiers must be created. The scope of the AMP for electrical engineering extends beyond the safety-classified components to a large number of not-1E classified components. The reason for this may be logistical, i.e. the 1E-classified and not 1E-classified components are treated absolutely identically in respect of the maintenance activities (test cycle, test scope, inspections, checks). Typical examples are batteries, radiation detectors, transducers, circuit breakers, rectifiers, inverters and cable supporting structures.

<u>Grouping methods for SSCs in the selection process</u>

Civil engineering - grouping

Each classified building is assessed separately within the scope of ageing management. The ageing reports consider individual buildings or parts thereof.

Electrical engineering - grouping

As established internationally in electrical engineering ageing management [9], similar component groups are assessed. The specifications are contained in the corresponding GSKL documents and in the corresponding KKG documents that are available to ENSI.

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 ageing report by the GSKL team of experts for electrical engineering ageing management. The generic ageing reports (total 41) contain manufacturer and plant-independent foundations for the plant-specific AMP Part 3.

The plant-specific ageing reports (Part 3) are drawn up in the individual plants. Here the grouping of components (by nature, type, manufacturer or combined) is left to the plants.

Mechanical engineering - grouping

In accordance with guideline ENSI-B01 [5], components of safety class 1 and 2 are not grouped. Guideline ENSI B-01 specifies the SSCs for which a grouped consideration is permitted. In general, components of the same or similar construction that are exposed to the same or similar conditions and which exhibit a similar ageing behaviour are grouped together. The grouping must correspond to the GSKL guides and must be transparently identified in the ageing report. In doing so, a detailed listing of the components and component parts is not necessary.

<u>Methodology and requirements for evaluating the existing maintenance practice and development of ageing management programmes, that are suitable for identification of the known ageing mechanisms.</u>

In fitting with the early development of the AMPs in Switzerland no specific AMPs are used, because these were only introduced in the USA at a national level in 2001 through GALL (NUREG-1801 [10]). By contrast, the AMP was introduced in Switzerland 10 years earlier. At the international level, IGALL [11] adopts the GALL methodology (and consequently also the AMPs). The IGALL came into existence about 20 years later than the Swiss AMP.

As already presented in Section 2.3, the methods and requirements of the AMP were set out in the interpretive documents of the GSKL and the GSKL guides for the creation of ageing reports for civil, electrical and mechanical engineering provide guidance for the practical implementation of ageing management and for the documenting of the results of the assessment of the mechanical and electrical components as well as the civil engineering structures. On the basis of the specifications of the GSKL working group in KKG, the AMP was implemented in detail according to the specifications by the departments (see Section 2.3). The ageing assessments of civil engineering structures and/or SSCs are summarised in the plant-specific ageing reports. The ageing mechanisms relevant for particular plant parts are identified by the ageing management and on this basis, the existing programmes, such as in particular the maintenance, are checked as to whether ageing induced damage can be avoided or detected at an early stage. Omissions revealed by the check are closed in a documented manner. By embedding this within the national and international activities of the GSKL working group 'AMP in Swiss NPPs' it is ensured 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 continue to be considered in future.

<u>Quality assurance within the AMP with reference to data management and the trending of information from the maintenance program</u>

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 using trends and findings from maintenance.

The ageing management process is incorporated in the KKG management system, which is certified according to ISO 9001, and is regularly audited. All data relevant to the SSCs including the maintenance history are recorded in the IPIS. All AMP-relevant reports (especially ageing reports) are saved in the electronic content management (ECM) system, which ensures correct processing of these documents from testing through to archiving. In addition, essential testing and maintenance work is documented in the monthly, audit and annual reports.

Operating measurement quantities such as flow, pressure and temperature recording or closely-meshed water chemistry examination findings are likewise saved in their own databases.

The effectiveness of the AMP can be assessed and quantified based on various measures. In internal instructions and regulations, steps and measures for checking results and sequences within the maintenance/replacement processes, mechanical engineering and other necessary measures are specified, insofar as inadequate results are available or improvement potential has been identified. Specifically, NDT results, function tests after maintenance measures, the results of test runs and function checks are evaluated, documented (e.g. based on an anomaly report) and are incorporated in the process as feedback from experience.

<u>Indicators for ensuring the effectiveness of the programme</u>

As indicators with direct reference to the AMP, KKG evaluates production outages as a result of the non-availability of SSCs and NDT results.

2.3.2 Ageing assessment

The GSKL programme 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 the 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.

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 ageing reports for civil, electrical and mechanical engineering provide guidance 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. The component or group-specific assessment takes account of all relevant design and manufacturing documents (especially specifications, bills of material, material certificates, manufacturing and prototyping testing certificates).

The ageing assessments of civil engineering structures and/or SSCs are summarised in the plant-specific ageing reports.

<u>Key elements of ageing management</u>

The key elements for effective ageing management are, as also recorded in the guideline ENSI-A03 [3], listed in the following table. The basis in this respect is the IAEA report, NSG-2-12, AGEING MANAGEMENT FOR NUCLEAR POWER PLANTS [9]. Documentation of ageing management is provided within the framework of the periodic safety review.

Tabelle 2 1 Key elements AMP

No	Attribute NSG-2-12
1	Scope of the AMP based on the understanding of the ageing phenomena
2	Preventative actions to minimize and monitoring the ageing degradation
3	Detection of ageing effects
4	Monitoring and trending of ageing effects
5	Mitigation of ageing effects
6	Acceptance criteria
7	Corrective actions
8	Operating experience feedback from research and development
9	Quality management

<u>Processes and procedures for systematic identification of ageing mechanisms and possible resulting consequences</u>

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

Civil engineering

All ageing mechanisms relevant for civil engineering are specified in Annex 1 of the guide for civil engineering ageing reports. In the case of inspections likewise defined in the guide, the 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 also how to interpret and evaluate possibly occurring, unexpected anomalies. When working within the framework of the AMP, the support of a specialist planner/engineer and, if necessary, a special expert when using special diagnostic methods, is essential. The resources for this are provided as part of the KKG budget planning. The results of the inspections are recorded in the ageing reports of the individual building structures and any actions defined.

Electrical engineering

The completeness and evaluation of the known ageing mechanisms taking into consideration the latest developments in science and technology and the world-wide experience in NPPs is evaluated and documented as part of the activities of the GSKL team of mechanical engineering ageing management experts. Necessary adjustments and developments are permanently implemented. So that the state-of-the-art of science and technology is ensured in the plant-specific ageing reports including in the years after the ageing report has been created, the generic ageing reports Part 1 and Part 2 ('basis documentation') are continually checked by the GSKL-AMP electrical engineering team, in any event no later than every ten years within the framework of the periodic safety review (PSR), and updated as necessary.

Mechanical engineering

The completeness and evaluation of the known ageing mechanisms taking into consideration the latest developments in science and technology and the world-wide experience in NPPs is evaluated and documented as part of the activities of the GSKL team of mechanical engineering ageing management experts. Here in particular it is necassary mentioning the 'Catalogue of Ageing Mechanisms of Mechanical Equipment' (KATAM), which acts as an essential, ENSI-recognised reference for assessing the relevance of ageing mechanisms.

In the creation of system ageing reports, the following aspects are systematically treated 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 ageing reports 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 ageing reports (Part 3) in the individual plants.

<u>Overall acceptance criteria</u>

In Switzerland there are also overall criteria specified by the Federal Department of the Environment, Transport, Energy and Communications (DETEC) in an ordinance [12] for the temporary shut-down of NPPs, which are closely associated with the physical ageing of the 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. Thus ENSI can monitor adherence to defined acceptance criteria.

Civil engineering acceptance and evaluation criteria

Criteria for a condition assessment based on a five-level scale are listed in Annex 3 of the GSKL guide. All civil engineering structures within the scope of consideration are assessed according to it and assigned to the condition levels:

1) Very good condition

2) Good condition

3) Adequate condition

4) Inadequate condition

5) Poor condition

Evaluation criteria within electrical engineering

Due to the diversity of electrical and I&C 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. Acceptance criteria are specified by the manufacturers or the departments. This also takes account of operating experience. Acceptance criteria are checked in the respective departments. Adherence to acceptance criteria is periodically checked and evaluated by the respective departments. The responsibilities are clearly regulated via the organisational structure.

Evaluation criteria within mechanical engineering

The acceptance criteria for the mechanical engineering passive components are module or component specific. Acceptance criteria for the reactor pressure vessel are defined separately in the RPV section. 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 [5]. Regularly performed function tests of active components use specific acceptance values or threshold values. If these values are exceeded, a fault indication is triggered, which then leads to maintenance and/or repair actions, so that the correct design condition of the component is recreated.

Use of the R&D programme

Dependent on the design, all Swiss nuclear power plants participate, fully or partially, in on-going research and development programmes via the following institutions:

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

Currently, research activities are taking place in the following areas:

- **EPRI/BWRVIP (Boiling Water Reactor Vessel and Internals Program):** This is an internationally recognised research project. On the basis of the findings, EPRI prepares inspection projects for RPV internals of boiling water plants (austenite and Ni-based alloys) which are applied both in Switzerland and many other countries.
- **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 behaviour 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 guided-wave technology on complex geometries:** to make use of the possibilities of non-destructive condition assessment of containment shells encased in concrete, programmes 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 [13]:

- **SAFE-II (Safe long term operation in the context of environmental effects on fracture, fatigue and environmentally assisted cracking):** The SAFE-II project deals with materials problems, especially in respect of crack corrosion and fatigue in the structural materials of light-water reactors. This internationally-recognised project supports and promotes the acquisition of know-how in environment-induced crack propagation, an area which is important for the operation of NPPs.

- **NORA-II (Noble metal deposition behaviour in BWRs):** Nobel metal deposition is used in both Swiss BWRs to prevent or delay the occurrence of stress corrosion cracking in the RPV internals. The project primarily investigates the platinum coating of test samples stored in the primary water of KKL. Based on the investigation results, the protective effect of the Pt-injection in both Swiss BWRs was improved.

- **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.

<u>Use of internal and external experience communications</u>

New findings based on external sources and bodies such as EPRI, TÜV, work groups of the VGB, WANO, CODAP, IGALL, suppliers, EQDB etc. or from conferences and seminars as well as new, recognised diagnostic methods and models are discussed and evaluated in the GSKL AMP team and decisions made about their application in the Swiss AMP. 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’).

In the analysis of external experience communications and the decision about actions to be taken, factors taken into account in KKG are internal operating experience, the evaluation of the actual circumstances in conjunction with the plant-specific system characteristics and also the findings from the plant PSA. KKG assesses the findings according to the systematic approach defined in the internal instruction for the evaluation of incidents. The results are presented for evaluation to the internal safety committee (ISA). This committee decides in a multidisciplinary manner about the necessity for corrective measures and checks their implementation.

Civil engineering

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

As it has been possible to repeatedly demonstrate the qualitatively good state of construction of the Swiss NPPs since 1996, the assessment of the concealed components also takes account of the following:

– Existing experience in our own plant

– Existing experience from other Swiss plants

– Considerations as to whether the currently applicable external and internal ambient conditions have changed, in particular whether they have worsened or whether new conditions have come into play.

– Considerations as to whether the existing effectively occurring stresses/strains have changed in respect of the ageing mechanisms.

– Considerations and checks of whether the image from the previous visual inspection in the context of the concealed component has significantly changed.

Electrical engineering

Within the context of the repeating checking of plant-specific ageing reports, new internal/external experience is discussed and evaluated by the internal work team for ageing management and electrical engineering maintenance based on internal sources such as maintenance documents and histories, and on external sources such as EPRI, TÜV, work groups of the VGB, WANO, suppliers, EQDB etc., or from conferences and seminars, so that a decision can then be made about its introduction. On the basis of these evaluations, work-specific documents (ageing reports Part 3, maintenance documents) are adjusted as necessary. If worthwhile and useful for the other Swiss NPPs, the generic AMP basic documents (GSKL ageing reports Part 1 and 2) are adjusted, or the application/proposal is submitted to the GSKL electrical engineering team of experts.

Mechanical engineering

The Catalogue of Ageing Mechanisms of Mechanical Equipment (KATAM) represents the current state-of-the-art of science and technology where the ageing mechanisms of light water reactors are concerned and is used in 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. The results of this review are presented in summary in the annual reports of the individual power plants.

The KKG mechanical engineering department has defined the internal and external evaluation of experience as an input to the maintenance/change process. Based on the example of the RPV, Section 5.3 of this report illustrates the detailed evaluation of internal and external experience for mechanical engineering.

2.3.3 Monitoring, testing, sampling and inspection activities

Essential components of ageing management measures for monitoring the technical equipment and for controlling the relevant damage mechanisms are:

- Operational monitoring
- Preventive maintenance
- Periodic testing including function tests

For example, the following programmes have been set up in the individual departments, 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 programmes (‘EROSKO’)
- Cable removal programmes and inspection programmes System and component walkdowns
- 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 crack widths are performed. Further materials tests on civil engineering structures and laboratory analyses are listed in the guide and are applied as necessary.

Inspection programmes

For mechanical components of SK 1 to 4 subject to nuclear acceptance testing, in-service inspection programmes have been established according to specification NE-14 [14]. These include non-destructive testing, system and component walkdowns, pressure tests and function tests on safety valves and snubbers. Relevant criteria such as the selection of suitable test methods and test parameters plus classification and finding-dependent test intervals are defined in NE-14 [14]. These programmes 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.

Civil engineering

In the PSR experience report for the civil engineering AMP, KKG delivers a systematic and meaningful summary of the inspection programme, the existing findings and the repair measures. From the condition investigations contained in the ageing reports of the civil engineering AMP, it is apparent that all civil engineering structures are in a good to very good condition. Impairment of the structural safety of the civil engineering structures as a consequence of ageing events is effectively prevented using the applied AMP.

In accordance with VBRK [15], preventive maintenance must be performed for all systems and components of SC 1-4. The preventive maintenance strategy is also used for civil engineering structures of structure classification 1. This can also be applied for civil engineering classification II and unclassified.

Mechanical engineering

Preventative and in-service inspection tests going beyond this draw on the SVTI specification, NE-14, ‘Repeat tests on mechanical components subject to nuclear acceptance testing of safety classes 1 to 4’ and guideline ENSI-B06 ‘Maintenance of safety classified vessels and pipelines’. The regulations specify the framework for inspections.

The requirements of specification NE-14 and ENSI-B06 are implemented with the aid of component test schedules. They contain all information necessary for the tests. Where it seems appropriate to KKG, the test items derived from them are supplemented by other test items referred to as operator tests.

Electrical engineering

Guideline ENSI-B14 requires the creation of maintenance programmes. The maintenance programme is the means for preventive maintenance. The term includes

- the planning of periodic maintenance work and
- the test instructions/test protocols that describe the procedure for performing the tests.

Repeat function tests and maintenance work are carried out as part of the maintenance programme. The regular function checks demonstrate that the components and systems remain functional under the specified operating and fault conditions.

The function tests fulfil the nuclear safety success criteria and conform with the information in the safety status analysis. See also the definitions of the safety functions in Table 2-1 of the safety status analysis.

For equipment classified as 1E and 0E, ENSI-B14 generally requires the performance of repeat tests. For non-classified components, the person responsible for the system/component decides whether periodic tests are performed: where non-classified components are only of minor importance for nuclear safety or where a possible failure would not affect availability at all (e.g. because of redundancy), then a reactive repair regime applies.
I.e. no tests or maintenance work is carried out.

Individual components, e.g. selected motors and transformers, are equipped with monitoring systems. This permits condition-oriented maintenance. Consequently, maintenance work is performed dependent on monitored wear aspects.

<u>Maintenance programmes</u>

Operational monitoring of technical facilities is performed through the automatic or direct evaluation of physical, chemical and biological parameters using the operating instrumentation, sampling or if necessary with the help of task-specific special instrumentation in respect of the maintaining of target values (e.g. pressure, temperature, transients, vibrations). Various levels are effective in operational monitoring:

- Monitoring by the shift and specialist personnel
- Integrated automatic monitoring
- Independent automatic monitoring

The shift and specialist personnel, continuously monitor the operating and plant data. Measuring data and findings from operations are recorded and evaluated by the shift and specialist personnel. Moreover walkdowns and visual inspections take place. In this way, age-related changes to the quality required to meet the needs of the plant and its technical facilities are detected at an early stage by comparison with the operating characteristics, and based on plant experience.

Integrated automatic monitoring is carried out by automatic monitoring systems (especially true for the electrical engineering and I&C) that are designed to be self-monitoring. This monitoring is incorporated in the plant reporting concept. Reports indicate early deviations before impermissible changes to the quality of the systems occur.

Independent automatic monitoring takes place with the aid of independent monitoring facilities and monitoring results are systematically evaluated. These facilities are largely incorporated in the plant reporting concept and indicate deviations from the operating characteristics in the control room. Typical examples include:

- Long-term monitoring systems (e.g. FAMOSi)
- Structure-borne sound monitoring system of the reactor pressure vessel (KÜS)
- Vibration monitoring of the primary circuit (SÜS)
- Vibration monitoring of the main coolant pump shafts (VIBROCAM 5000)
- Leak monitoring system (LÜS)
- Valve condition monitoring with ADAM-SIPLUG

Additional investigations to identify unexpected ageing mechanisms

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

- Shift walkdowns
- Anomalies during function tests
- Raising the awareness of maintenance personnel so that they monitor the general state of individual parts during maintenance.
- Daily discussion of anomalies in operating parameters
- Water-chemistry monitoring. Changes in the chemical parameters can indicate leaks.
- Special tests if a suspected problem exists

2.3.4 Preventive and remedial actions

The AMP of the Swiss NPPs is designed so that the relevant ageing mechanisms and the resulting ageing effects are detected at an early stage. This is the basis for identifying and implementing any necessary preventive and remedial actions. For damage mechanisms applicable to multiple plants, the GSKL has developed multi-licensee concepts for their management. This applies to electrical engineering and I&C, mechanical engineering and civil engineering.

For I&C components, discontinued safety modules can be repaired by German certified workshops. However, in most cases they are repaired on site, because KKG has the necessary module documentation. Experience and repair reports are exchanged via the VGB. Frequently the experience reports from the VGB frequently result in comprehensive remedial actions.

Manufacturer warning values are adopted for electrical engineering components. This ensures that components are replaced or reconditioned prior to ageing-induced failure. An example for this are the chemical values in the oil samples of oil cooled transformers.

Implementation takes place in the relevant departments based on various quality management programmes, such as in the maintenance programme or plant change for example.

A few large-scale mechanical engineering actions are presented below by way of example.

Transgranular stress corrosion cracking (TGSCC) occurred on various occasions primarily in the area of small austenitic pipes and was identified as ‘chloride-induced TGSCC’. Due to the verifiably chloride-free coolant circulation, findings did not occur in pipes with a significant flow, rather only at those points where a concentration build-up is possible. Preconditions for the mechanism may be chloride containing plastic mounting elements, for example, or plastic adhesive tapes used form marking and fastening or chloride containing spiral asbestos gaskets. Therefore alongside the introduction of low-chloride adhesive tapes, chloride-containing gaskets in contact with the medium were extensively replaced. Moreover, certain areas were converted to high alloy steels to provide better corrosion protection.

As part of fatigue analyses on components of the pressure boundary, existing analyses were recently revised based on results obtained in Swiss and foreign plants since the analyses were initially carried out. In some system areas, fluid layers with different temperatures as well as intermittent plug-flows were found to be present that are confirmed to contribute to fatigue processes. These were not originally incorporated in the design. To measure these additional loads, thermocouples were attached over the circumference in a distributed manner in the affected or possibly affected piping sections of the German series light water reactors. This arrangement made it possible to measure the transient changes in temperature for all relevant load cases and to document the results in transient reports. In conjunction with the load case frequencies defined in the load specification, they form the basis for the revision of the fatigue analyses. In addition, strain gauges attached temporarily in a scattered manner are used to check the stress level and whether or not local deformations are harmless. The revision of the fatigue analyses led to some licensees replacing certain system sections, partially in conjunction with a retrospective, redesigned higher output that occurred as early as during plant commissioning. At the same time, design optimisation was undertaken with the aim of achieving as low as possible stresses. As a further consequence of the temperature measurements the establishment of a more preservative operating mode for reduction of the fatigue-related stresses is also worth mentioning.

For components subject to relevant ageing mechanisms and which cannot be inspected or renovated using standard methods (e.g. primary containment), ENSI requires a maintenance concept (generally as a PSR requirement). Here, the specific ageing situations are considered in depth and a holistic concept for maintaining integrity developed.

The optimisation of the primary water chemistry for reduction of stress corrosion cracking of adjoining components while simultaneously avoiding higher dose rates in the area of the fresh steam lines is incorporated in the Swiss PWRs at programme level and is also associated with corresponding research actions. This programme can be linked with a maintenance concept, for example.

A further example are cross-system exchange programmes 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 ageing reports.

2.4 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 specialist groups 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 specialist groups.

The working group coordination team 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 specialist groups for use in the individual plants. The tasks of the specialist groups 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.

In the following subsections 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 Monitoring in Swiss NPPs (CH-KKW)’ described above.

Implementation of the experience from audits and inspections

When AMP ageing reports are revised, the in-service inspection programme is 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 [14] governs scope and the involvement of ENSI and SVTI. The 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. The completion of these activities is documented in IPIS and the AMP tracking folder of the SSC in question so that this information can be considered in the next revision of the ageing reports.

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 organisation units of the licensee shall derive an action plan with clear tasks, responsibilities and deadlines. In general with audits and reviews, ‘follow-ups’ are normally performed a few months later in which the auditors check the effectiveness of the implemented measures.

Evaluation of power plant-specific and other experience messages

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 organisational units. In addition, all plants receive prompt AMP-relevant messages from international operating experience via memberships and contacts in a wide range of organisations and working groups.

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 (‘Periodic reporting of nuclear installations’), the ‘Ageing management annual overview’ section of the ‘Safety Annual Report’, informs ENSI at least annually for each power plant of the external events that have been evaluated and of the respective results.

Likewise, when revising AMP ageing reports, all external messages from the previous year are collected, evaluated and clearly documented for all of the SSCs being assessed.

Evaluation power plant-specific system changes that influence the overall AMP

The ageing management guideline ENSI-B01 which came into force in 2011, involved a revision of the 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.

An exception is KKM which in 2017 had already started to prepare an ageing management concept for the post shut-down phase from 2020. However the focus of TPR 2017, is not on the ageing management of NPPs which have been finally shut down and therefore this is not discussed further at this point.

The influence of smaller plant modifications (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.

Effectiveness of the AMP

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 ‘unavailability’ per year in percent, which 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. Additionally, the occurring plant-specific operating events are evaluated in respect of the occurrence of ageing mechanisms, which provides indirect statements about the effectiveness of the AMP. In connection with the implementation of guideline ENSI-G08, KKG has introduced a comprehensive programme for the safety assessment of all fault indications. The repeating occurrence of faults likewise gives indications for assessing the effectiveness of the AMP.

Evaluation of time-limited ageing analyses (TLAA)

Examples of possibly relevant TLAAs from IGALL are:

- TLAA 303 “Cumulative Fatigue Damage of Containment Liners and Penetrations"
- TLAA 304 “Foundation Settlement due to Soil Movement”
- TLAA 305 "Internal Pressure Capacity Evaluation of Containment Structure"

The systematic approach to creation of AMP ageing reports ensures that ageing mechanisms which result in a time-limited deployment of SSCs (e.g. embrittlement, fatigue, reduction in wall thickness) do not remain unconsidered. Moreover, by means of an annually updated fatigue assessment, KKG checks the current degree of fatigue of important SSCs that are subject to fatigue.

Consideration of changes to the regulatory framework within the AMP

ENSI granted a five-year transitional period for the full implementation of the AMP in accordance with the new guideline. Due to activities resulting from the Fukushima reactor disaster that were more pressing for both the regulator and the plants, this term was extended by two years. 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.

Identification of the research requirement

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 in various bodies with the VGB, EPRI.

Strategy for periodic review of the AMP taking into consideration possible interfaces to the periodic safety review

The cycle of no more than 10 years defined in ENSI-A03 (Periodic safety review of nuclear power plants) between PSRs defines a reasonable upper time limit for reviewing the AMP. 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 acted upon.

In accordance with guideline ENSI-B02 (‘Periodic reporting of nuclear installations’) [16] the section ‘Ageing management annual overview’ 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.

Likewise, an evaluation of the effectiveness of the AMP takes place as part of the annual systematic safety review according to Article 33 of the nuclear energy regulation KEV (SR 732.11) and under guideline ENSI-G08.

Consideration of unexpected or new topics in the AMP

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 KKG, the non-conformance reports process (see Section 2.4) 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 programmes
- Annual maintenance of the KATAM
- Periodic processing of the external experience with each update of the AMP ageing reports

Important 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. cracks outside the heat affected zones on core shrouds (experience from the Hatch NPP 2014), unexpected findings in the RPV base material (experience from the Doel NPP 2012) are always closely tracked and monitored by ENSI.

<u>Use of the results of monitoring, tests and inspections for revising the AMP</u>

Since the new ageing management guideline ENSI-B01 came into force in 2011, findings of monitoring, testing and inspection programmes have not resulted in significant omissions being detected in the methodology nor that 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.

<u>Periodic evaluation and measurement of the effectiveness of the AMP</u>

The periodic evaluation and revision of the AMP based on performance indicators was examined in the first part of Section 2.4.

The effectiveness of the AMP can be measured in individual plants based on annual determined performance indicators, especially if long-term trends are to be evaluated.

2.5 Licensee's experience of application of the overall AMP

The ageing management guideline ENSI-B01 which came into force in 2011, involved a revision of the ageing management in the areas of civil, electrical and mechanical engineering in all Swiss NPPs. Within just a few years, the close interaction between the plants and ENSI led to a comprehensive, effective and yet still practical implementation of ageing management with a recognisable positive influence on plant availability.

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 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 introduced in 2011 with the new guideline ENSI-B01 and large number of ageing reports to be revised led to a later bottleneck in respect of the available technical resources on the side of the authority, which made it difficult for ENSI to comment on the submitted documents within a reasonable time-scale.

The continual exchange of experience and the systematic processing of external events are essential instruments for the effective optimisation and/or expansion of individual AMPs and for the competent staff to develop their know-how. Adaptations and improvements in ageing management were not triggered by this. In this respect, the periodic reviews performed by WANO and the IAEA prove effective measures for identifying systematic improvement potential in ageing management. E.g. awareness of the necessity of the AMP was improved via the internal training provision for the operating and maintenance personnel.

Swiss NPP licensees assess their experience in application of the AMP as useful and largely positive.

3 Electrical cables

3.1 Description of ageing management programmes for electrical cables

The ageing management programme was harmonised in Switzerland within the GSKL AMP. Ageing reports were created for selected components, here for the cables. Three different applicable basic ageing reports were created for cables for all the Swiss NPPs:

Tabelle 3 2 Ageing reports valid for cable

Group	Definition	GSKL Ageing report [Part 1 & 2]	Comment
G1	1 klack / > 1.5 kVdc	Ageing report 'Medium Voltage Cables'	WENRA: High Voltage Cables, from 3 kV
G2	Low voltage power cable 50 V - 1000 Vac / 1500 Vdc	Ageing report 'Cables'	WENRA: MediumVoltage Cables 380V to 3 kV
G3	Instrumentation cable < 50 V	Ageing report 'Cables'	
G4	Special cables (e.g. mineral-insulated, etc.)	Ageing report 'MI cable'	WENRA: Focus on cables for neutron flux measurement

The basis for the subdivision of cables is, on the one hand, the standards applicable in Switzerland and on the other the WENRA-Specification 'Topical Peer Review 2017, Ageing Management, Technical Specification for the National Assessment Reports', which stipulates different voltage level subdivisions to the standard Swiss divisions. The column Comment refers to the different voltage levels.

3.1.1 Scope of ageing management for electrical cables

Each ageing report comprises three parts: Parts 1 and 2 were created together for all Swiss NPPs, while Part 3 corresponds to plant-specific implementation and is consequently different for the various power plants.

The ageing report Part 1s list the ageing mechanisms for cables and were jointly created for all Swiss NPPs. Component-specific ageing mechanisms are determined through the study of relevant technical articles/technical literature. Part 1 is updated to the state-of-the-art of science and technology by tracking the relevant technical publications and evaluation of external and internal operating experience.

The ageing report Part 2s list possible diagnostics methods that can detect the ageing mechanisms mentioned in Part 1. They were jointly created for all Swiss NPPs. Component-specified diagnostics options are determined through the study of relevant technical articles/technical literature. Part 2s are updated to the state-of-the-art of science and technology by following the relevant technical literature.

Plant-specific implementation takes place in the Part 3s of the ageing reports. There are different ageing report Part 3s for different cables. The diagnostic methods used in the plant are described and any omissions are identified in each ageing report Part 3. If not already included, these methods and findings are incorporated into the maintenance program. They are included in the applicable test instructions for the periodic tests. This closes the circle from ageing management to maintenance.

The ageing reports are revised every 5 to 10 years (at the latest). New findings from science and technology, from internal operating experience and from external experience communications are thus regularly incorporated in ageing management and in the maintenance programme. If plant changes (change projects) affect ageing report Part 3s, they are adapted within the scope of the project.

3.1.1.1 Medium voltage cable (group G1, > 1kVac / > 1.5 kVdc)

The medium voltage cable component group includes the thermoplastic insulated cables and their connections in the voltage range from 1 kV up to 30 kV. Ageing management includes not just the cables themselves but also the cable fittings (sleeves, terminations).

In KKG there are two medium voltage levels, 10 kV for the standard network and 6 kV for the emergency network. Since 2011 when the medium voltage cable replacement project was completed, both networks have used halogen-free, flame-retardant cross-linked polyethylene cables.

Based on the purposes of the two medium voltage networks, the 10 kV cables are not classified and the 6 kV cables are class 1E.

This component group has its own set of ageing report Part 1s, 2s and 3s.

6 kV cables:
No 6 kV cables are fitted inside the containment. The cables are part of the emergency power network and are not exposed to any hostile ambient conditions.

10 kV cables:
The 10 kV cables are not electrically classified. The cables are part of the normal network not exposed to any hostile ambient conditions.

The relevant ageing mechanisms of the medium voltage cables are listed in ageing report Part 1 ‘Medium voltage cables’ while the corresponding diagnostics options are listed in ageing report Part 2 ‘Medium voltage cables’. The power plant-specific implementation is systematically recorded in the corresponding ageing report Part 3s and Section 3.1.2.1.

According to the ageing report, the medium voltage cable is subdivided into the following ageing relevant component parts. Moreover, the table also lists the ageing mechanisms for each component part based on the material used as well as the diagnostic methods to be used for detection.

Tabelle 3 3 Medium voltage cable – ageing mechanisms and diagnostics methods

Component parts	Ageing mechanisms [from Ageing report Part 1]	Diagnostic methods/Comments [from Ageing report Part 2]
Jacket insulation	Oxidation (embrittlement) Cracking Discolouration	Visual inspection Visual inspection Infrared measurement
Wire screen Aluminium screen	Corrosion (laid in the ground/damp)	Resistance test (Unreliable process)
Semiconductor	Cracking Embrittlement	-
Conductor	Oxidation (embrittlement) Diffusing out of cross-linked polymer products	When using modern VPE cable no diagnostics necessary, as life at least 40 years
Conductor and connection	Corrosion Loosening of the connection	Visual check IR measurement
Cable fittings	Oxidation Discolouration Cracking	Visual inspection IR measurement TE measurement

3.1.1.2 Low voltage power cables (group G2, 50 V - 1000 Vac/ 1500 Vdc) and instrumentation cable (group G3, < 50 V)

The low voltage component group includes the thermoplastic insulated cables with a voltages up to 1000 Vac or 1500 Vdc and their connections in the small and low voltage range. This also includes ageing relevant device-internal wiring.

This cable group has its own set of ageing report Part 1s, 2s and 3s.

a) LOCA accident-resistant cable fitted inside the containment

   Both the electrically classified cables and also the cables that are not classified as LOCA-resistant are fully recorded in the AMP.

Between 2003 and 2008 Halar cables of this cable category were systematically replaced.

b) LOCA accident-resistant cable not fitted inside the containment

The ageing relevant safety classified special cables for radiation detectors are recorded in the AMP.

Highly thermally and radiologically loaded class 1E high current and I&C cables are recorded in the AMP.

c) Cables not fitted in the containment

Both electrically classified and also unclassified cables for which an ageing relevance exists, are recorded in the AMP.

This includes amongst others, special cables for radiation detectors fitted outside the containment and the signal cables for actuation criteria for cooling water protection logic.

Various connecting cables (so-called cable conduits) for components in the fresh steam and feedwater valve chamber form part of the AMP. This includes connection cables

- for the inductive linear position sensors on miscellaneous fresh steam valves that count as part of the accident instrumentation and
- for the inductive quasi-binary position sensors on the fresh steam isolation valves and on the fresh steam blowoff isolating valves that count as part of the accident instrumentation.

The relevant ageing mechanisms of low voltage cables are listed, based on the materials used, in ageing report Part 1 ‘Cables’ and the corresponding diagnostics options in ageing report Part 2 ‘Cables’. The power plant-specific implementation is systematically recorded in the corresponding ageing report Part 3s and explained in Section 3.1.2.2.

According to the ageing report, the low voltage cable is subdivided into the following ageing relevant component parts. Moreover, the table also lists the ageing mechanisms for each component part based on the material used as well as the diagnostic methods to be used for detection.

Tabelle 3 4 Low voltage cable – ageing mechanisms and diagnostics methods

Component parts	Ageing mechanisms [from Ageing report Part 1]	Diagnostic methods/comments [from Ageing report Part 2]
Jacket insulation	Oxidation Embrittlement Discolouration Dielectric change Cracking Friction Blistering	Visual inspection Infrared measurement Visual inspection Cable pre-ageing area Visual inspection Visual inspection Visual inspection
Conductor insulation	Embrittlement Discolouration Dielectric change Cracking	Cable pre-ageing area Visual inspection Voltage test Cable pre-ageing area
Conductor and connection	Corrosion Loosening of the connection	Magnetic pulse Visual inspection Infrared measurement
Protective coating elec. connections	Corrosion of the under-lying metals	Visual inspection
Option: Plug with connection	[Ageing report Part 1 'Connectors']	[Ageing report Part 2 'Connectors']

3.1.1.3 Special cables, e.g. neutron flux instrumentation (group G4)

The special cables include mineral-insulated cables (MI cables) which include amongst others the neutron flux measurements. In accordance with the WENRA specifications, the following sections deal solely with these neutron flux measurements. In KKG, two cables form part of the measuring circuit for the above mentioned neutron flux measurements: The first cable is a mineral-insulated cable (MI cable) which runs from the detector to a LOCA-resistant subdistribution board on the circular platform. The signal goes from the subdistribution board to a further cable run in insulated copper tube to the measuring cabinets.

a) MI cable for neutron flux measurement (cable between detector and the subdistribution board)

The relevant ageing mechanisms of the MI cable are listed in ageing report Part 1 ‘MI cable’ while the corresponding diagnostics options are listed in ageing report Part 2 ‘MI cable’. The power plant-specific implementation is systematically recorded in the corresponding ageing report Part 3 and Section 3.1.2.3.

The MI cable of the neutron flux instrumentation is subdivided according to ageing report MI cable into the following ageing-relevant component parts. Moreover, the table also lists the ageing mechanisms for each component part based on the material used as well as the diagnostic methods to be used for detection.

Tabelle 3 5 MI-cable for neutron flux instrumentation – ageing mechanisms and diagnostic options

Component parts	Ageing mechanisms [from ageing report Part 1]	Diagnostic methods/Comments [from ageing report Part 2]
Outer tube	Corrosion Cracking	Visual inspection
Conductor	Corrosion	
Insulation	Leakage current increase Change in insulation	Insulation measurement
Termination	Cracking	Visual inspection
- Fitting	Corrosion Leakage	
- Spacer	Cracking	
- Potting compound	Cracking Embrittlement Leak-tightness	
Electrical connection	Corrosion Cracking Loosening	Visual inspection TDR method (reflection method)
Heat shrink tube fittings	[Ageing report Part 1 ‘Heat shrink tube fittings’]	[Ageing report Part 2 ‘Heat shrink tube fittings’]
Option: Connection with plug	[Ageing report Part 1 ‘Connectors’]	[Ageing report Part 2 ‘Connectors’]

b) Special cable for neutron flux measurement (cable between subdistribution board and measuring cabinet)

The relevant ageing mechanisms of the special cable for neutron flux measurements between the subdistribution board and the measuring cabinets are listed in ageing report Part 1 ‘Special cable for medium range neutron flux’ while the corresponding diagnostics options are listed in ageing report Part 2 ‘Special cable for medium range neutron flux’. The power plant-specific implementation is systematically recorded in the corresponding ageing report Part 3s and Section 3.1.2.3. To prevent electromagnetic interference, the cable is routed throughout through insulated copper tube and consequently largely protected against mechanical influences and inaccessible.

According to the ageing report, the special cable of neutron flux instrumentation is subdivided into the following ageing-relevant component parts. Moreover, the table also lists the ageing mechanisms for each component part based on the material used as well as the diagnostic methods to be used for detection.

Tabelle 3 6 Neutron flux instrumentation special cable - ageing mechanisms and diagnostic options

Component parts	Ageing mechanisms [from Ageing report Part 1]	Diagnostic methods/Comments [from Ageing report Part 2]
Jacket insulation	Oxidation Embrittlement Discolouration Dielectric change Cracking Abrasion Blistering	Visual inspection Visual inspection Visual inspection Cable pre-ageing area Visual inspection Visual inspection
Wire harness wrapping	Embrittlement Discolouration	Cable pre-ageing area Cable pre-ageing area
Conductor insulation	Embrittlement Discolouration Dielectric change Cracking	Cable pre-ageing area Cable pre-ageing area Voltage test Capacitance measurement Insulation resistance Cable pre-ageing area
Conductor and connection	Corrosion Loosening of the connection	Magnetic pulse Visual inspection Infrared measurement Visual inspection Magnetic pulse
Protective sleeve on electrical connections	Corrosion of the underlying material	Visual inspection
Junction boxes	Corrosion	Visual inspection
Option: Connection with plug	[Ageing report Part 1 'Connectors']	[Ageing report Part 2 'Connectors']

3.1.2 Ageing assessment of electrical cables

The following sections describe plant-specific implementation (ageing reports Part 3). The ageing mechanisms are assessed for their significance and the diagnostics methods applied in KKG are described.

3.1.2.1 Implementation of the AMP for medium voltage cables (group G1, > 1 kVac / > 1.5 kVdc)

The implementation in the power plant is documented in the Medium Voltage Cable Ageing report Part 3. In doing so, the diagnostics options specified in the ageing report Part 2 are documented for the various ageing mechanisms. The diagnostics options from ageing report Part 2 are compared with the already applied maintenance instructions (test instructions). Checks are made to assess whether known diagnostics options from the technical literature are covered by the already institutionalised checks. If certain diagnostics methods are not applied, then this is either justified or the identification is recorded in ageing report Part 3 as an omission. Subsequently, the omission is closed by supplementing the maintenance instruction and this finally documented in the Medium Voltage Cable Ageing report Part 3.

Tabelle 3 7 Implementation of the AMP for medium voltage cable

Component parts	Ageing mechanisms [from Ageing report Part 1]	Diagnostic methods/Comments [from Ageing report Part 2]	Application diagnostics in KKG
Jacket insulation	Oxidation (embrittlement) Cracking Discolouration	Visual inspection Visual inspection IR measurement	Yes Yes No 1)
Wire screen Aluminium screen	Corrosion (laid in the ground/damp)	Resistance test (Unreliable process)	No 2)
Semiconductor source tape	Cracking Embrittlement	-	-
Conductor insulation	Oxidation (embrittlement) Diffusing out of cross-linked polymer fission products	When using modern VPE cable, no diagnostics necessary, as service life at least 40 years	-
Conductor and connection	Corrosion Loosening of the connection	Visual inspection IR measurement	Yes No 1)
Cable fittings	Oxidation Discolouration	Visual inspection IR measurement	Yes No 1)
	Cracking	TE measurement	No 3)

1) The infrared measurement to detect embrittlement is not used. Compensation: on the periodic walkdowns the cables are visually checked and manually qualitatively checked by feeling with the hand to test for heat formation and brittleness. KKG participates in the VGB programme ‘Operational demonstration of cable ageing of medium voltage cables’.

2) In KKG the relevant medium voltage cables are routed in the dry, hence corrosion as an ageing effect in the wire/tape screen is not significant.

3) Partial discharge measurements and loss factor measurements are not comprehensively carried out. Compensation: All medium voltage cables were systematically replaced (project completion 2011) so that now these cables are practically new. The manufacturer indicates a service life of at least 40 years. Nevertheless, periodically a loss factor measurement is carried out on a specified random sample. This measurement was carried out when new (fingerprint for the basis of comparisons).

3.1.2.2 Implementation of the ageing management programme for low voltage power cables (group G2, 50 V — 1000 Vac) and instrumentation cables (group G3, < 50 V)

Implementation in the power plant is documented in the Cables ageing report Part 3. In doing so, the diagnostics options specified in the ageing report Part 2 are documented for the various ageing mechanisms. The diagnostics options from ageing report Part 2 are compared with the already applied maintenance instructions (test instructions). Checks are made to assess whether known diagnostics options from the technical literature are covered by already institutionalised checks. If certain diagnostics methods are not applied, then this is either justified or the identification is recorded in ageing report Part 3 as an omission. Subsequently, the omission is closed by supplementing the maintenance instruction and this finally documented in the Cables ageing report Part 3.

Tabelle 3 8 Implementation of the AMP for medium voltage cable

Component parts	Ageing mechanisms [from ageing report Part 1]	Diagnostic methods/Comments [from ageing report Part 2]	Application diagnostics in KKG
Jacket insulation	Oxidation Embrittlement Discolouration Dielectric change Cracking Friction Blistering	Visual inspection IR measurement Visual inspection Cable pre-ageing area Visual inspection Visual inspection Visual inspection	Yes No 1) Yes Yes Yes Yes Yes
Conductor insulation	Embrittlement Discolouration Dielectric change Cracking	Cable pre-ageing area Visual inspection Voltage test Cable pre-ageing area LIRA measurement	Yes Yes No 2) No 3) Yes
Conductor and connection	Corrosion Loosening of the connection	Magnetic pulse Visual inspection Infrared measurement	No 4) Yes No 1)
Protective coating on electrical connections	Corrosion of the underlying metal	Visual inspection	Yes
Junction box	Corrosion	Visual inspection	Yes
Option: Plug with connection	[Ageing report ‘Connectors’]	See ageing report ‘Connectors’	-

1) There is no programme to test all cables for embrittlement by infrared measurement or to check the connections for looseness. However, infrared measurements are performed as necessary.

2) Installed cables are not systematically checked for dielectric changes by means of a voltage test. As compensation, a random sample of about 50 highly loaded cables is periodically measured using LIRA (line resonance analysis), for a detailed explanation see Section 3.1.3, and ageing progress (change in the electrical parameters) assessed.

3) KKG does not currently manage its own high stress test area for cable pre-ageing, rather use can be made of the central high stress test area for cable pre-ageing as part of the VGB programme ‘Operational verification of the LOCA-resistance of electrical engineering and I&C components’.

4) There is no comprehensive programme for testing cables using the magnetic pules method (or similar). Instead, KKG uses the LIRA method to periodically measure a random sample of about 50 highly loaded cables and assesses the ageing progress (change in the electrical parameters).

3.1.2.3 Implementation of the AMP for special cable, e.g. neutron flux instrumentation (group G4)

As described in Section 3.1.1.3, in KKG, 2 cables form part of the measuring circuit for neutron flux measurement. The implementation in the power plant is therefore documented in the MI cables for neutron flux measurement ageing report Part 3 as well as Special cables for neutron flux measurement Part 3. In doing so, the diagnostics options specified in the ageing report Part 2 are documented for the various ageing mechanisms. The diagnostics options from ageing report Part 2 are compared with the already applied maintenance instructions (test instructions). Checks are made to assess whether known diagnostics options from the technical literature are covered by the already institutionalised checks. If certain diagnostics methods are not applied, then this is either justified or the identification is recorded in ageing report Part 3 as an omission. Subsequently the omission is closed by supplementing the maintenance instruction and this finally documented in the corresponding ageing report Part 3.

a) MI cable for neutron flux measurement (cable between detector and the subdistribution board)

Tabelle 3 9 Implementation of the AMP for MI cable

Component parts	Ageing mechanisms [from ageing report Part 1]	Diagnostic methods/Comments [from ageing report Part 2]	Application diagnostics in KKG
Outer tube	Corrosion Cracking	Visual inspection	No 1)
Conductor	Corrosion		No 1)
Insulation	Leakage current increase Change in insulation	Insulation measurement	Yes
Termination - Fitting	Cracking Corrosion Leakage	Visual inspection	No 1)
- Spacer	Cracking		No 2)
- Potting compound	Cracking Embrittlement Leak-tightness		No 1)
Electrical connection	Corrosion Cracking Loosening	Visual inspection TDR method (reflection method)	No 1)
Heat shrink tube fittings	[Ageing report Part 1 'Heat shrink tube fittings']	[Ageing report Part 2 'Heat shrink tube fittings']	No 3)
Option: Connection with plug	[Ageing report Part 1 'Connectors']	[Ageing report Part 2 'Connectors']	No 4)

1) The MI cables of the neutron flux external instrumentation are not accessible. Compensation: the insulation resistance values, the saturation characteristics of the ionisation chambers and the signal transmission behaviour of the measuring circuits are checked within the scope of the periodic tests recommended by the manufacturer and continually improved upon over the years. Ageing induced errors are detected based on these integral tests.

2) No spacers are used.

3) No heat shrink tube fittings are used in this area.

4) No connectors are used in this area.

b) Special cable for neutron flux measurement (cable between subdistribution board and measuring cabinet)

Tabelle 3 10 Implementation of the AMP for special cable for neutron flux measurement

Component parts	Ageing mechanisms [from ageing report Part 1]	Diagnostic methods/Comments [from ageing report Part 2]	Application diagnostics in KKG
Jacket insulation	Oxidation Embrittlement Discolouration Dielectric change Cracking Abrasion Blistering	Visual inspection Visual inspection Visual inspection Cable pre-ageing area Visual inspection Visual inspection Visual inspection	Yes No[1)] No[1)] No[1)] Yes Yes Yes
Harness wrapping	Embrittlement, Discolouration	Cable pre-ageing areas	No[1)]
Conductor insulation	Embrittlement, discolouration Dielectric change Cracking	Cable pre-ageing area Voltage test Capacity measurement Insulation resistance Cable pre-ageing area	No[1)] Yes No[1)] Yes No[1)]
Conductor and connection	Corrosion Loosening of the connection	Magnetic pulse Visual inspection Infrared measurement Visual inspection Magnetic pulse	No[1)] Yes No[1)] No[1)]
Protective coating on electrical connections	Corrosion of the underlying material	Visual inspection	No[2)]
Junction box	Corrosion	Visual inspection	No[3)]
Option: Connection with plug	[Ageing report Part 1 'Connectors']	[Ageing report Part 2 'Connectors']	No[4)]

1) The special cables of the radiation measuring points carry currents in the range from 1E-14 A to a maximum 1E-1 A. There is practically no heat development, even with covered contact resistances. For this reason, various diagnostics methods listed in the ageing report which are relevant for power cables are not applicable for the special cables of radiation measuring. To prevent electromagnetic interference, the cables are routed throughout through insulated copper tube and thus also largely protected against mechanical effects and they are *not* accessible. Ageing-induced changes are detected within the scope of the periodically performed integral function tests. Amongst other things the function check includes the measurement of the

insulation resistance, checking of the limits and the signalling. KKG participates in the VGB programme 'Operational verification of the LOCA-resistance of electrical engineering and I&C components' which amongst other things covers cable ageing. For this purpose a central high stress test area for cable pre-ageing is maintained in a German NPP and ageing systematically monitored.

2) No protective coatings are used or they are not accessible

3) High-quality connections are used, junction boxes (subdistribution boards) are not used.

4) No connectors are used.

3.1.3 Monitoring, testing, sampling and inspection activities for electrical cables

<u>Operational ageing management for cables</u>

Operational ageing management for cables is an extension of the qualification tests performed originally. Operational ageing management methods are based on the monitoring of the change in the strain at break of cable sample materials. KKG decided to exploit the use of synergies by making used of NPPs appropriately equipped in Germany and participate in the research and development projects of the VGB in the area of demonstration of LOCA-resistance. Within the framework of this programme, verification procedures for the LOCA-resistance of the heavy current and I&C components, including for cables, are developed during operation. VGB operates a High stress test area for cable pre-ageing in the German NPP at Neckarwestheim. Samples of the accident-resistant cable types used in KKG are stored in the preageing area (cable depot). Ambient conditions prevailing in the high stress test area for cable pre-ageing (temperature, radiation) are measured. Periodic elongation at break tests are performed, specifically before and after a LOCA test. These investigations make it possible to determine service life curves for the stored cable types. The service life curve indicates the possible service life for a cable dependent on the local dose rate, up to which no further recurring verifications of the accident resistance are necessary.

<u>Calculation of remaining service life</u>

For special long-term LOCA-resistant cables, a remaining life calculation is performed in the ageing report. The basis for this is the data from the original qualification test. The prevailing ambient conditions at the place of installation in normal operation and accident states are used to determine the thermal and the radiological cable ageing. Both thermal and radiological ageing limit the service life at the installation location to an equal extent. Each aspect of ageing type which shortens the remaining service life defines when the cable is to be replaced.

<u>LIRA measurements for I&C and low voltage power cables</u>

The LIRA measuring method is considered as a supplement to the above-mentioned operational ageing management, which is used in the field of I&C and low voltage power cables. It has the

advantage that you can not only make generic, cable-type related statements but also through non-destructive measurements make statements about the status of individual cables fitted in KKG.
The LIRA method is based on transmission line theory, i.e. the theory of the transmission behaviour of electrical cables. The analysis of the transmission behaviour when feeding a white noise signal into one end of the cable allows general statements to be made about possible damage and the ageing condition of the cable.

LIRA can be used to make measurements over several cable sections, i.e. across subdistribution boards and cable penetrations. These connection points are also visible in the measurements because reflections are caused at them due to changes in impedance. Local cable degradation, e.g. due to mechanical damage, thermal or radiological effects, can also be reliably detected based on one-off measurements, i.e. without trend monitoring. However, the evaluation of such cable degradation points requires a lot of experience in using the measurement method and can only be carried out by experts.

For a more significant evaluation of the general ageing condition of a cable, a reference measurement of the cable when new must be available or at least a series of measurements over a long time period so that a trend can be derived. As no such reference measurements exist for cables older than 35 years, it is only possible to set up an appropriate measuring cycle if the general ageing condition is to be determined.

In KKG, some 50 highly loaded cable runs are included in the LIRA measurement programme. The first 10 cable runs were measured in 2012. Each additional year a further 10 cables were measured and in 2017 the cables first measured in 2012 were remeasured, so that for the first time it was possible to determine the change in cable parameters over 5 years.

Loss factor measurement on medium voltage cables

As part of ageing management, the preventive, systematic replacement of all medium voltage cables was decided upon and completed by 2011. This was based, on the one hand, on experience in other NPPs and on the other hand, on investigations into the ageing condition commissioned by KKG at cable suppliers'.
After replacement, measurements of the initial loss factor were performed for representative new medium voltage cables, which will serve as reference values for future measurements. In terms of the ageing management or condition monitoring of the medium voltage cable, new loss factor measurements are to be made every 6 to 8 years, so that the measurement intervals can be shortened for suspicious changes. The measurements are performed by external specialists.

Inclusion of cables in integral periodic tests

The cables concerned are included in nearly all periodic tests of systems, subsystems or functions. With certain periodic tests, detailed measurements are performed which allow direct conclusions to be drawn about the cable quality: For example in the neutron flux measurement circuits, the insulation resistance and the signal transmission behaviour is periodically measured (see Section 3.1.2.3).

Visual inspection during periodic walkdowns

The operating department performs institutionalised, periodic walkdowns through all buildings, rooms and channels. During them cable cellars, cable rooms and cable channels are systematically inspected. Attention is primarily paid to the general state of the cables, but the ambient conditions (moisture, water ingress, leaks, etc.) are also checked.

3.1.4 Preventive and remedial actions for electrical cables

For a number of years, the cabling has also been renewed during any plant changes. The old cables are not left on the supporting structures, rather are fully removed. This approach prevents ageing effects, reduces the load of the cable supports, maintains constant fire loads and reduces the risk of increased temperatures along the cable runs.

From 2009 to 2011, all 6 kV cables of the emergency power supply were replaced. Therefore no ageing effects are to be expected for these cables over the next 40 years.

2011 also saw the completion of the replacement of all 10 kV cables. Therefore no ageing effects are to be expected for these cables over the next 40 years.

During 2003 – 2008 Halar cables with a LOCA-requirement were systematically renewed as part of a replacement programme.

Mechanically damaged cables are detected within the course of walkdowns and are replaced or repaired as necessary.

In the coming years the cable supports will be replaced in redundancies 1 and 3. If, in association with this, there are any findings on the cables (e.g. damage), the cables will be replaced or repaired.

Brittle cables were identified during the course of changes to the control panels in the control room. Consequently cables were checked on similar locations. This led to replacement of the I&C cables at the control panels in the control room.

If there are any findings as a result of the LIRA measurements, the cables are replaced. If there are any findings as a result of the periodic testing of medium voltage cables, the cables are replaced.

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

KKG is planning a 60 years' service life. The most appropriate measure in respect of the ageing management of cables is systematic preventive replacement of cables as and when plant changes occur.

The systematic replacement of 10 kV and 6 kV cables has proven its worth. Periodically, a loss factor measurement is performed on a random sample.

The participation in the VGB research project with regular evaluation of cables that are subject to accelerated ageing in a test area yields valuable information on cable ageing effects throughout the NPP fleet associated with the VGB.

The use of the LIRA-measuring programme has proven its worth. In June 2017, cables are being measured for the first time that were already measured 5 years ago. For the first time, possible ageing-induced changes will be apparent.

KKG rates the integration of cables in the AMP as adequate.

4 Concealed pipework

The ageing management of concealed pipework is more closely considered as part of the WENRA TECHNICAL PEER REVIEW 2017. The scope includes safety-relevant pipes that are buried in the ground or routed in non-accessible channels.

4.1 Description of ageing management programmes for concealed pipework

In KKG, pipes are laid in the ground or inaccessible channels in the following systems.

Service water intake system VA (safety class 3*)

Nuclear service water system VE (safety class 3*)

*According to ENSI regulations

Neither the auxiliary cooling water nor the nuclear auxiliary cooling water system is exposed to tritium or any other radioactive medium. Both systems solely contain river or ground water. The pipes of the operational water supply are buried either in the ground or in inaccessible concrete ducts.

Maintenance inspections comply with regulation SVTI-NE14 Rev. 6, [14]

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

In general operating experience in respect of buried pipework is positive. This is based on the results of the operational inspections and periodic system tests.

The following maintenance measures were implemented in the safety-relevant water supply systems:

- 2004-2005: Coating of the inner surfaces of various buried pipework sections with an epoxy resin coating

- 2008: Replacement of a buried pipe section of ferritic tubes with tubes made of austenitic, stainless steel

- 2008-2009: Coating of the inner surface of various buried pipes with a PE-Inliner

5 Reactor pressure vessel

5.1 Scope of ageing management for RPV

The scope of the mechanical engineering AMP (AMP-M) is defined by ENSI-B01 [5].

According to the GSKL guides for the compiling of ageing reports for mechanical engineering, all components in SK 1 must be evaluated with a comprehensive ageing report. According to the guide:

All SK 1 components with a nominal diameter > 25 mm must be considered both in detail and to the full extent.

5.1.1 Pressure boundary

The pressure boundary of the RPV, see figure 1, essentially comprises:

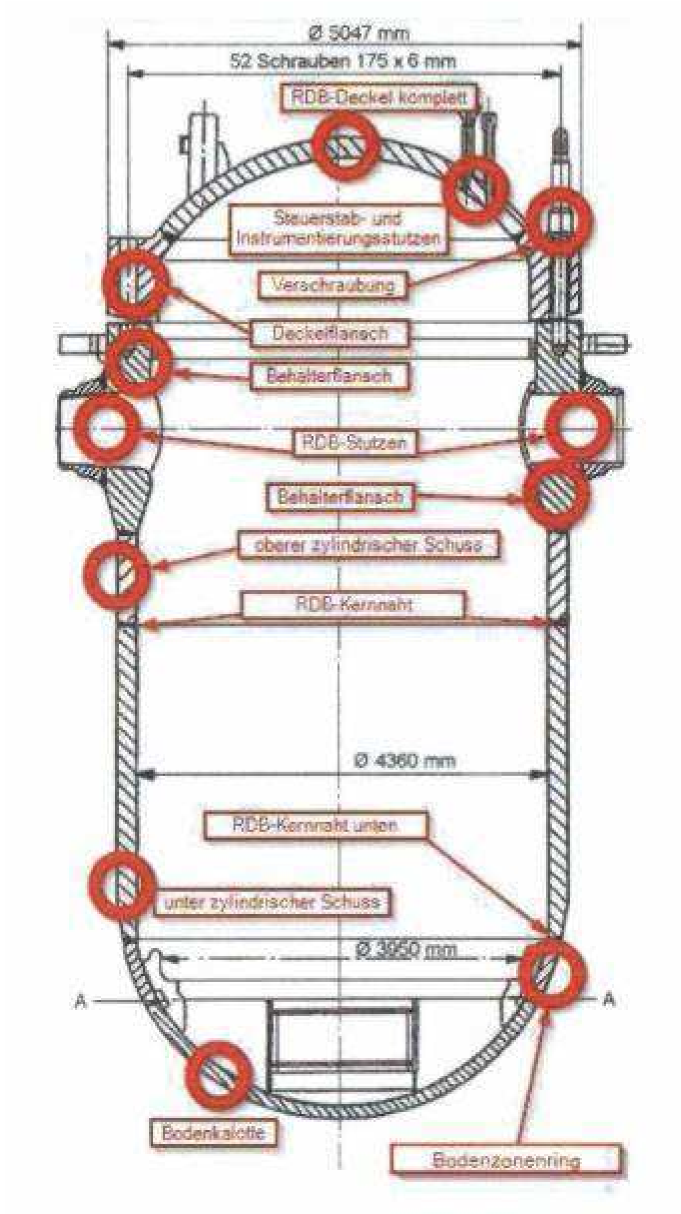

Abbildung 5 1 Schematic diagram of the RPV of the Gösgen NPP

- Bottom zone ring
- Bottom calotte
- Lower cylindrical shell
- RPV lower core weld
- RPV core weld

- Upper cylindrical shell
- Vessel flange
- RPV Nozzles
- Vessel flange
- Head flange
- Fitting
- Control rod and instrumentation nozzles
- RPV head assembly

5.1.2 Processes/procedures for the identification of ageing mechanisms for the different materials and components of the RPV

The GSKL guide for the creation of ageing reports for the ageing management of mechanical engineering components is used in general for the compilation of ageing reports. The guide also applies in detail to the RPV ageing report. The table of contents of the RPV contains the following sections:

1) Component information
2) Component specific ageing mechanisms
3) Transients
4) Peculiarities from the component/system history
5) Component specific ageing management
6) Overall evaluation and supplementary measures
7) References
8) Drawings
9) Abbreviations and material designations

5.1.2.1 Definitions

The definitions correspond to those of the GSKL guide for the creation of ageing reports for the ageing management of mechanical engineering components and the internal maintenance instructions.

Ageing mechanism: Time-dependent process which leads to a change of the physical and/or chemical properties of a material.

Ageing mechanisms, potential: All possible ageing mechanisms for components of light water reactor plants from a materials science point of view. An up-to-date overview can be found in the KATAM catalogue of ageing mechanisms of mechanical equipment.

Ageing mechanisms, relevant: Ageing mechanisms that cannot be excluded for KKG and could lead to damage.

Maintenance:

Maintenance refers to the sum of planned and systematic actions that are necessary for maintaining and restoring operability, the reliability and availability of the power plant as well as for preventing the failure of individual systems. Maintenance is based on the underlying measures of service, inspection/testing, repair and enhancement.

Ageing report:

Contains the most important component data and gives, in a comprehensible evaluation, information about which ageing mechanisms are relevant for which points or materials, and which ageing mechanisms could have a decisive influence on the safety-relevant function of a component. In addition, the ageing report indicates with which procedure these can be monitored and/or countered. The ageing reports are documents which accompany maintenance planning.

5.1.2.2 Determination of ageing mechanisms relevant for the KKG RPV

The ageing mechanisms to be considered are defined in the KATAM. In a first step, theoretically possible ageing mechanisms are assigned to the components under consideration based on internal and external experience plus the KATAM.

The internal experience is derived from:

1) The plant documentation, comprising:

- The layout
- The existing designs, materials and manufacturing methods

- Peculiarities occurring during component manufacturing
- The results of all trials and tests during the construction phase
- All component calculations
- All plant modifications carried out during the operating phase

2) The mechanical engineering maintenance activities, comprising:

- Component histories
- Results of tests performed
- Special events

3) The measurement and evaluation of transients within KKG. Significant here is the subdivision into specified and non-specified load cases.

- Specified load cases:

In the creation and/or revision of the ageing report, load cases relevant for the considered components are listed and the number of transients that has occurred is compared with the number of specified transients. Those points at which the ageing mechanism fatigue could occur are specified by considering the design calculations. The corresponding level of fatigue usage is also specified.

- Non-specified load cases:

If corresponding results or data are available for a component, these are presented in the ageing report.

The external experience is derived from:

1) Generally accessible literature, comprising:

- Textbooks
- Technical publications
- Conference proceedings

2) Information provided by plant and component manufacturers

3) Experience reports from other NPPs, comprising:

- AREVA / Siemens / KWU
- VGB
- WANO
- Direct exchange of experience with other NPPs
- CODAP database
- IAEA IGALL list

All ageing mechanisms theoretically possible for KKG are presented in a table in the ageing report together with a source reference. Likewise, the results of transient monitoring and the peculiarities from the component history are entered in the respective ageing report.

5.1.2.3 Comparison with the existing monitoring measures

Existing monitoring measures are assigned to the essential components of the considered systems and components in the ageing report and set against the theoretically possible ageing mechanisms. Typical monitoring measures include (non-comprehensive list):

- Periodic tests
- Function tests
- Preventive maintenance
- Transient monitoring/evaluation of FAMOSi data

5.1.2.4 Relevant ageing mechanisms

The ageing mechanisms theoretically possible for the KKG RPV are checked for relevance. This is done by evaluating the information from internal and external experience as well as the KATAM. Where ageing mechanisms are assessed as relevant, an evaluation is undertaken to decide if the existing monitoring measures are suitable for monitoring them.

5.1.2.5 Supplementary measures

Where omissions are identified, the AMP-M coordinator, in consultation with the system manager, formulates measures to remedy the situation. The measures can be of different kinds:

One-off measures:

- If, within the framework of the work for the AMP-M, there are knowledge/skill deficits or gaps/omissions in the documentation for the home plant, if there are ambiguities about the relevance of an ageing mechanism or if weaknesses are detected in the components inspected, then one-off measures can be defined. These may be checks conducted by mechanical engineering quality assurance or inspections/tests, calculations, maintenance, etc. to be performed by the mechanical engineering personnel. Depending on the outcome of these measures other measures may be required.

Repeated measures:

- If, within the framework of the work for the AMP-M, omissions are identified between the relevant ageing mechanisms and the existing ageing management, then providing it is both sensible and possible, periodic monitoring measures must be specified. These may be periodic tests as defined in the SVTI specification ‘Repeat tests on mechanical components subject to nuclear acceptance testing of safety classes 1 to 4’ SVTI Specification NE-14, [14] or ENSI B06 [17], or inspections, tests and servicing to be performed by the mechanical engineering personnel. These measures are specified in a list of outstanding actions contained in Section 6 of the ageing reports. The implementation of these measures is periodically checked and their completion is also documented in the ageing report in addition to standard KKG forms (e.g. log, report, work proposal).

5.1.2.6 Tracking of science and technology

The tracking of science and technology in the area of ageing management is assigned to the GSKL AMP mechanical engineering team of experts. Activities are coordinated by the team of experts. The periodic revision of the catalogue of ageing mechanisms of mechanical equipment (KATAM) ensures that the KATAM remains up to date. New findings are reviewed by the team of experts and rated according to their relevance for Swiss NPPs. New relevant findings are considered and documented for the next revision of the KATAM.

5.1.3 Tasks

The responsibilities of the system managers and the basic tasks resulting from them are specified within KKG in regulations governing responsibilities. The regulations for the AMP are specified in the AMP-M. The following tasks are of special importance for the AMP-M:

5.1.3.1 AMP-M coordinator

The AMP-M coordinator has the following tasks:

- Creating and updating of the AMP-M documentation
- Instigating measures to remedy identified omissions
- Checking the completion of AMP-M outstanding actions

5.1.3.2 System managers

The system managers have the following tasks:

- Maintaining a component history
- Supporting the AMP-M coordinator in the evaluation of AMP-M relevant findings.

5.1.4 Documentation

5.1.4.1 Documentation composition

The AMP-M documentation comprises:

- Ageing report: Ageing reports are created according to the specifications in the ageing report guides for monitoring mechanical engineering components. They form part of the plant documentation.
- Reference documentation: Reference documentation is created for each ageing report. It contains copies of all documents mentioned in the ageing report 'References' section.
- Ageing report working documents: a folder is maintained with working documents for each ageing report.

5.1.4.2 Storage of documentation

For ageing reports created in accordance with guideline ENSI-B01 [5] a copy of the ageing report is submitted to ENSI. The ageing reports are treated in accordance with the instructions for the creation and handling of KKG documentation. The ageing reports are stored in the electronic document management system on the KKG servers provided for this purpose. A printed working copy is available in the responsible department.

5.1.4.3 Revision

The ageing report for a system or component must be revised after essential system changes or if essential new findings exist or at the request of the regulator (see ENSI-B01), but in any case no later than 10 years after its creation.

5.2 Description of ageing management programmes for RPV

The technical implementation of the mechanical engineering AMP takes place at the plant level. The GSKL guide serves as a template. When creating documentation for ageing management, the results of the performed ageing assessments are summarised in the form of ageing reports, whereby in general the components of one system are assessed in one corresponding ageing report.

All pressurised components of SK 1 with DN > 25 mm form part of the mechanical engineering AMP.

In respect of the requirements for a system or component, a distinction is made between the terms ‘Integrity’ and ‘Function’. Integrity requires that the pressure boundary must be guaranteed; function requires a component to remain functional even after an accident.

Ageing reports of safety class 1 and 2 primarily govern the main components, the remaining ageing reports relate to the system as a whole. The RPV ageing report is structured in accordance with the SK 1 requirements.

5.2.1 Scope of ageing management for the KKG RPV

The basis for the ageing management is guideline ENSI-B01 [5]. The areas defined in ENSI-B01 [5] are submitted to the regulator (ENSI) in the form of ageing reports. For RPV ageing management, a separate ageing report must be constantly updated.

The implementation of ENSI-B01 is regulated internally within KKG by the mechanical engineering AMP.

5.3 Ageing Assessment of RPVs

The scope and principles for the implementation of the AMP-M are defined in the KATAM catalogue of ageing mechanisms for mechanical equipment, in ENSI-B01 [5], and in the KKG mechanical engineering AMP. Figure 5-2 provides an overview of the workflow of KKG AMP-M also in relation to the RPV.

The delimitation of the systems and components considered in AMP-M relative to AMP-E and AMP-B takes place according to an internal instruction in respect of the responsibility for components of the electrical engineering, mechanical engineering and chemistry/radiation safety departments. The same applies to the RPV.

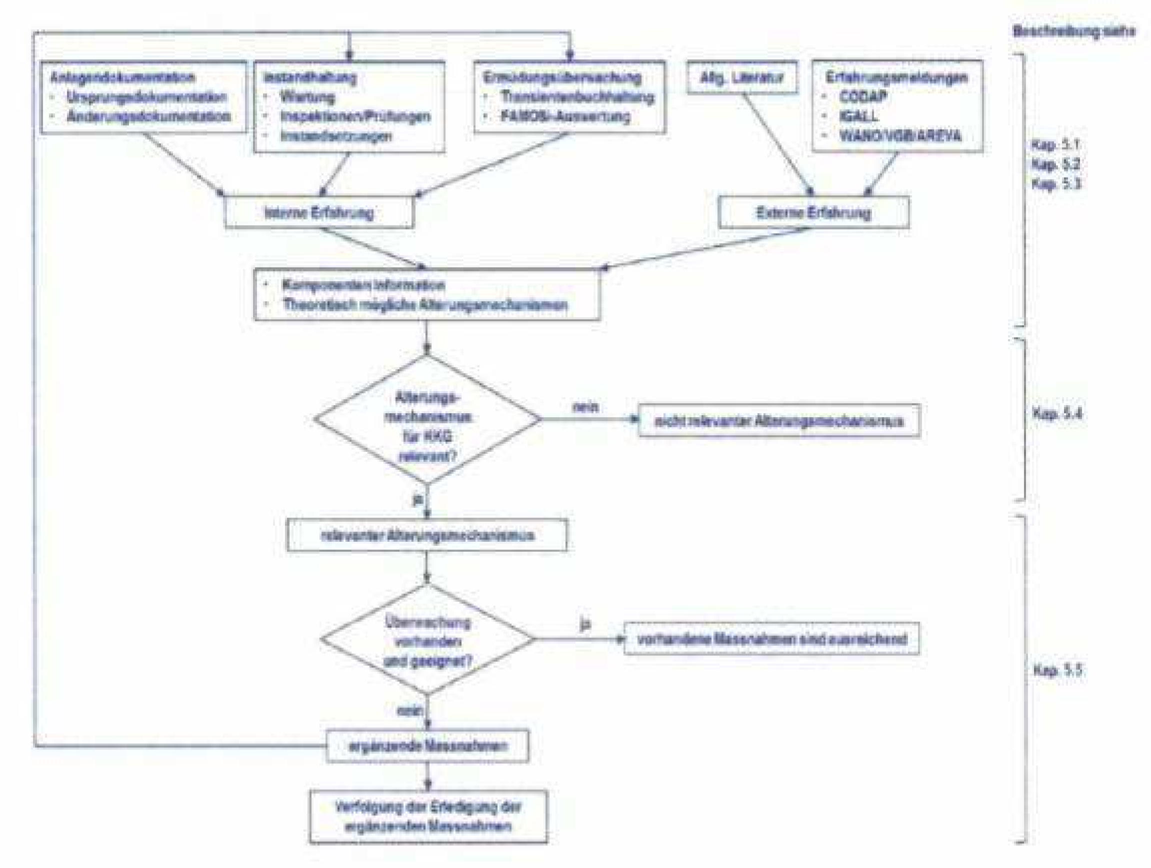

Abbildung 5 2 Sequences in the identification of relevant ageing mechanisms according to [8] and [18]

5.3.1 Component information

The manner in which the most important component data, defined according to the guide for creating ageing reports to monitor mechanical engineering components with reference to detailed descriptions, is presented, is contained in Section 1 of the RPV ageing report. Additionally, the RPV ageing report contains the drawings and schematic diagrams necessary to understand the components dealt with in the ageing report.

System	Reactor pressure vessel
Components	Reactor pressure vessel
Plant identifier	YC10B001
Safety class	1
Seismic category	1
Safety requirement	Integrity
Comments	
Building code:	ASME III NB
Specification:	RE-L798, Rev. d
Manufacturer:	Sulzer AG, Winterthur

Tabelle 5 11 Presentation of the most important component data in ageing reports

System components	**Temperature [°C]** Operating temperature (Design temperature)	**Pressure [bar]** Operating pressure (Design pressure)	Medium
Reactor pressure vessel	326 (350)	161 (175)	Primary coolant

5.3.2 Assessment of the ageing mechanisms

Existing ageing management through periodic tests arises primarily from requirements according to [14] and [17]. Essentially, tests performed to date, have not revealed any change relative to the baseline test. In the period up to 2017, further RPV tests were performed according to the in-service inspection programme, which confirmed the results from the earlier years. Visual inspections up until 2017 did not reveal any change relative to earlier inspections. The UT performed in 2015-17 showed that there were no crack-type indications.

According to [19], the most significant ageing mechanisms for the RPV are fatigue and radiation-embrittlement. According to the latest version of the IAEA investigations [20], only radiation-embrittlement in the core zone and acid corrosion of the outer surface are relevant for the KKG RPV. The RPV fatigue usage is classed as not relevant by the IAEA because worldwide, as also at KKG, it is far below the design values.

Summary of the evaluation:

Thus, for the components considered, the following ageing mechanisms of those already mentioned should be regarded as relevant:

Tabelle 5 12 Relevant ageing mechanisms

Components	Ageing mechanisms	Comments
• Vessel flange • Vessel bolts • Nuts • Washers	Pitting and surface corrosion	Relevant because of old findings
Centring block and weld Dissimilar metal welds	Stress corrosion cracking	
Core barrel support ring	Fretting corrosion	Since improvement of mounting conditions (1989), no change in state
Vessel bolts	Fatigue as a result of operating transients	Assessed as relevant because classed as leading component in respect of fatigue.
Bottom zone ring • Lower cylindrical shell • Upper cylindrical shell RN: • Bottom zone ring/Bottom calotte • Bottom zone ring / lower cylindrical shell • Lower cylindrical shell / Upper cylindrical shell Upper cylindrical shell/Vessel flange	Embrittlement due to neutron irradiation	Uncritical for KKG according to PTS analysis
• Core barrel support ring • Head flange	Abrasive sliding wear	Since improvement of mounting conditions (1989), no change in state At the sealing surface in the area of the holding down bolts

All other areas of the KKG RPV are adequately monitored under the KKG AMP.

5.3.3 Supplementary measures

No supplementary measures arise from an evaluation of the KKG ageing report. Established ageing management measures relating to operational monitoring, repeat tests and maintenance are considered satisfactory.

5.4 Monitoring, testing, sampling and inspection activities for RPVs

This part of the report lists the RPV component parts covered by ageing management. The relevant ageing mechanisms are assigned to component parts as described in the previous section. Moreover, measures are listed to exclude damage due to possibly relevant ageing mechanisms.

5.4.1 Component specific ageing management

The inspections required according to Swiss regulations are covered in Section 4.4.4. Moreover, the following monitoring methods are used:

1) Neutron flux measurement external instrumentation (system YX)

   Used to monitor the neutron flux (continuous monitoring).

2) Structure-borne sound monitoring system (System YG10)

   Used to detect loose parts with a weight > 100 g (continuous monitoring)

3) Vibration monitoring system SÜS (System YG20)

   Used to monitor the RPV vibration. The system detects even small changes in the RPV vibration during plant operation. Vibration measurement is implemented using 4 transducers on the RPV head. Measured value acquisition and evaluation takes place every 3 weeks.

4) Visual inspections

   Inspection of the RPV flange sealing surfaces (from 1999 also integrated in the component test plan) and RPV bolted joints by the maintenance personnel after each lifting of the head.

5) Continuous leak monitoring (system XQ21/22)

   Continuous monitoring in the RPV head area by the leak detection system XQ21 and in the area of the RPV lower part by leak detection system XQ22.

6) RPV head seal monitoring (system TY15)

Continuous monitoring for small leaks from the inner sealing ring by monitoring levels in the leak collection tank TY15B001. Additional continuous monitoring for large leaks by measuring the pressure between the two seals (measuring point TY05P001).

5.4.2 RPV irradiation program

The irradiation programme is used to detect changes in RPV material properties due to neutron irradiation. Three sample sets inserted at core height are evaluated. The gradient capsules were removed in the 2006 overhaul. To confirm the trend of the neutron flux density, a third scratch sample set was removed at the same time. The latest status of the irradiation programme is presented in various documents in conjunction with the test results of the Gösgen-Däniken material samples tested under the Carina programme. All documents are classified as confidential.

The part of the RPV affected by neutron embrittlement is derived from the axial distribution of the neutron fluence. According to the KATAM, with fluences greater than 10^{17}n/cm^2 (E > 1 MeV) lattice defects such as local empty spaces and sessile dislocation rings can arise. This ageing mechanism is relevant for all positions with a fluence integrated over 32 full load years according to the plant design. According to the design, the maximum fluence on the inside of the RPV for 32 full load years (40 operating years) is 1.8 x 10^{19}n/cm^2.

5.4.2.1 Material condition of the RPV, current condition and forecast

The actual neutron fluence that has occurred can be determined based on scratch samples taken from the inner surface of the RPV. Based on these data, the neutron fluence at the maximum loaded point of the RPV was calculated after 54 full load years (60 operating years). According to the calculation the neutron fluence after 60 years would be 1.4 x 10^{19}n/cm^2 and thus after 60 years still below the original design value. The material properties following the manufacture of all the component parts used for the RPV are recorded in the original documentation. Additionally, 3 irradiation sample sets were incorporated in the RPV and removed from the RPV after various irradiation times. The irradiated samples were investigated under three different fluences ~5.44 x 10^{18}n/cm^2, ~1.2 x 10^{19}n/cm^2 and ~3.28 x 10^{19}n/cm^2 (E > 1 MeV). The results of the investigations on the irradiation samples as well as the results of the PTS analysis performed on the results are summarised in the ageing report provided for this purpose.

5.4.2.2 Neutron fluence calculation

In the reactor pressure vessel (RPV) of the Gösgen-Däniken NPP, three different irradiation programmes were carried out during operating cycles 1 - 8. Accordingly, the corresponding sample sets were irradiated at different times and in different irradiation positions. The corresponding irradiation channels are located at the azimuth angles of 93°, 210° and 330°, the distance between capsule and core middle is 164 cm, see Figure 5-3.

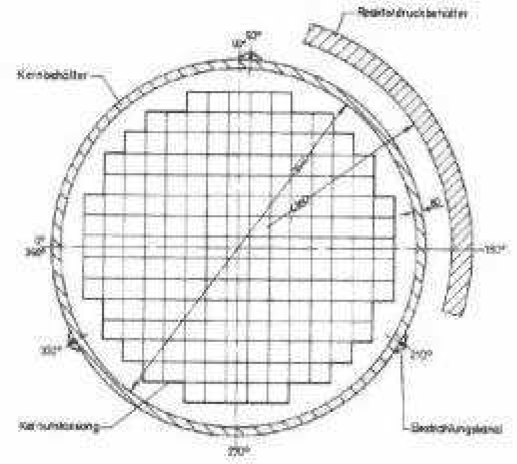

Abbildung 5 3 Position of the irradiation channels in the RPV

The first probe set was irradiated for the duration of the first operating cycle (304 full load days (FLD)). The second probe set was irradiated for 587 FLD (second and third operating cycles) and removed at the end of the third cycle. The third probe set was inserted at the beginning of the fourth operating cycle and removed after 1605 FLD at the end of the eighth operating cycle. From the measured ^{54}Mn and ^{93m}Nb activities of the fluence monitors also irradiated in the sample capsules, the experimental neutron fluences for E > 1 MeV are determined taking into consideration the irradiation histories and spectra of the irradiating neutrons. Additionally, neutron transport calculations are performed to determine the theoretical neutron fluences for the irradiation capsules and for the individual material groups. The experimental fluence values derived from the measurements are compared with the theoretical fluences. All measurement are performed according to Regulatory Guide 1.190 [21].

5.4.2.3 Brittle fracture safety proof

Based on the PTS analysis it was possible to demonstrate that a brittle fracture in the RPV can be excluded, even after a loss of coolant. This is confirmed by a statement made by ENSI.

5.4.2.4 Nil-ductility transition

Temperature Core seam area

The core seam area, which because of the material is classed as the most important item in the safety assessment, was evaluated in pressurised thermal shock analyses for Gösgen NPP using finite element calculations and fracture mechanics analytic methods. The results achieved for the core seam area and the postulated 10 mm deep semi-elliptical sub-clad cracks are summarised in Figure 5-4 for the point in the base metal. The permissible reference temperatures resulting from this for the maximum load point (WPS effect according to [18]) and the very conservative tangent point are:

$RT_{ref,ARTpermissible}$ 98°C at the maximum point

$RT_{ref,ARTpermissible}$ = 74°C at the tangent point.

The most important leakage value is the transient caused by a 200 cm^2 leak with the designation 200h_1HDk_1NKP_1DSPk-3DSPh.

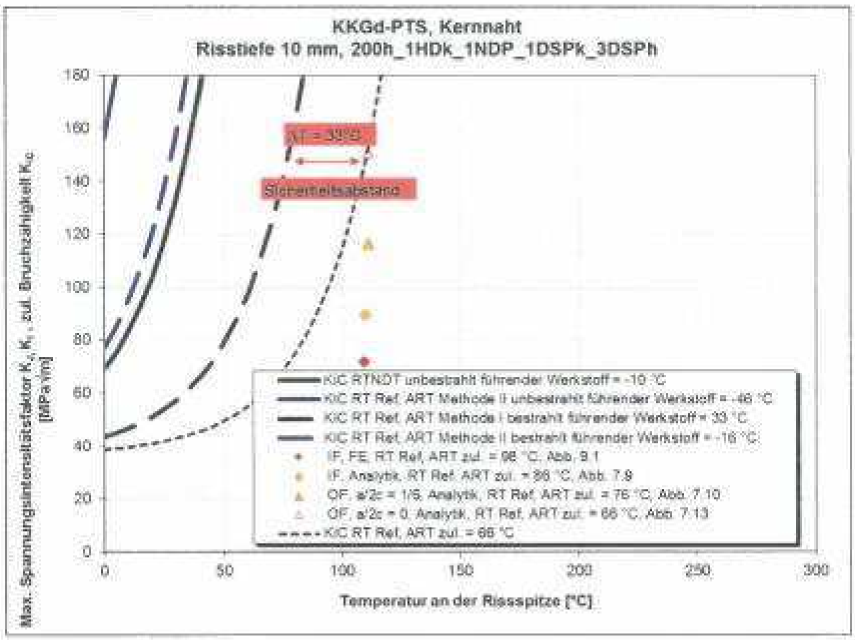

Abbildung 5 4 Results of the PTS analyses for the area close to core welds

The calculated permissible reference temperatures based on fracture mechanics finite element results are compared with the relevant material characteristic values. An approach is taken to exclude brittle fracture initiators in accordance with KTA Rules [18]. In the core area, as the base metal in its irradiated state is considered ahead of the weld metal based on the RT_{NDT} concept, the $RT_{ref,ART}$ corresponding to the base metal based on RT_{NDT} is used. The covering defined determined RT_{NDT} is used for the nozzles. It is shown that brittle crack initiation can be excluded for the design fluence (corresponding to an operating life of 60 years) for all investigated areas. In line with the rules, the lowest point in the base metal is safeguarded against ductile crack initiation. To do so, all load paths calculated using finite elements are compared with the values for ductile crack initiation according to Section 3. It is demonstrated that for all transients and all areas ductile crack initiation in the base metal is excluded.

5.4.3 Charpy-V upper shelf energy

The evaluation of the lowering of the upper shelf of the impact energy for the materials of the KKG/D irradiation sample sets 1 to 3 is performed according to the Reg. Guide 1.99 Rev. 2 [22] in that the measured values are compared with those of the fluence and the Cu-content dependent reduction factors of the Reg. Guide 1.99 Rev. 2. Here the fluence-dependent curve of the high shelf reduction for 0.1% (SG) or 0.05 % (GW) Cu according to Figure 2 of the Reg. Guide 1.99 Rev. 2 is used based on the chemical composition of the three monitored RPV materials. The results of the evaluation are listed in detail in respect of the DETEC criteria in the evaluation of the RPV standard irradiation sample sets of the Gösgen NPP. The conservative Charpy upper shelf energies contained in Table 5-3 are obtained after 54 full load years with a fluence of 1.4E+19 cm^{-2} (E >1 MeV) for the monitored materials GW I, GW II and SG of the KKG/D RPV based on the evaluations of the RPV standard irradiation samples of the Gösgen NPP. The high shelf energy values specified in Table 5-3 are covered by all measured values of the KKG standard irradiation programme. The lowest high shelf value specified in Table 5-3 is reached by GW II at 118 J and is significantly above the criterion of a high shelf energy ≥ 68 J required by DETEC.

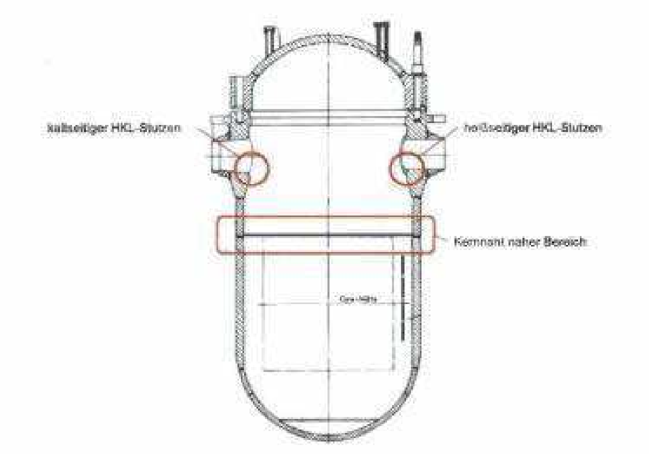

Abbildung 5 5 Schematic diagram of the KKG RPV with the area close to core welds

Tabelle 5 13 Evaluation of the Charpy upper shelf energies of KKG/D RPV materials defined according to Reg. Guide 1.99 Rev. 2 after 54 full load years for their compliance with the DETEC criterion.

Material	Upper shelf energy [J]	Compliance with the DETEC criterion Upper shelf energy >=68J
GW I	119	Yes
GW II	118	Yes
SG	138	Yes

5.4.4 Inspections

Inspections are performed according to a component test plan, which is checked by SVTI-N and approved by ENSI. In general the test interval is 10 years.

The criteria for the recording or evaluation limits are recorded in the testing instructions that have been accepted by the Schweiz QSt (NDT), or SVTI approval body.

5.4.4.1 Principles

Principles for carrying out the inspections:

SVTI Specification NE-14, Revision 6 of 01.01.2005, ‘Repeat tests on mechanical components subject to nuclear acceptance testing of safety classes 1 to 4’, [14]

Guideline ENSI-B06, Issue April 2009, Revision 2 of 01 June 2013, ‘Maintenance of safety classified vessels and pipelines’, [17]

5.4.4.2 Components subject to testing according to SVTI Specification NE-14

Cat. 1B 1 (Pressurised full-penetration vessel welds)

Testing obligation: 100% volumetric testing of all category 1B 1 welds.

Test: All category 1B 1 welds are volumetrically tested. Additionally the head circumferential weld and the weld of the head misdrill are also subject to surface crack testing.

Cat. 1B 2.1 (Full-penetration nozzle welds in vessels ≥ DN100)

Testing obligation: 100% volumetric testing of all category 1B 2.1 welds.

Test: All category 1B 2.1 welds are volumetrically tested. Within the scope of these tests, the nozzle inner edges of cat. 1B 3, which are also subject to testing, are likewise tested.

Cat. 1B 2.2 (miscellaneous welded seams)

Testing obligation 1: Seal welds > DN 25: 100% VT-2

Test: There are a total of 60 seal welds (SS and KI nozzles).

The testing of all 60 seal welds W27 (Drawing 0-103.082.674 Bl.2 on the SS and KI nozzles) is carried out and documented in connection with the cladding test of the RPV head, cat. 1B 8 - test number 0016.

Testing obligation 2: Welds on support structures or mountings of core internals. VT-1

Test: The welds subject to testing are VT-1 tested. A voluntary licensee test (VT-3) of the drum screen welds is also carried out.

Testing obligation 3: Circumferential welds of control rod and instrumentation tubes (including dissimilar metal joints) on preferably peripheral tubes. (Drawing 0-103.081.976, Annex 9)

> DN 25: 10 % OR or 10 % VOL.

≥ DN 100: 10 % VOL.

Test: In total, there are 60 circumferential welds (25 < DN < 100) on control rod and instrumentation tubes. Of these 10 % (6 circumferential welds) are OR and VOL tested.

Cat. 1B 3 (nozzle inner edges)

Testing obligation: 100 % volumetric for radial cracks

Test: The testing of the nozzle inner edges is performed in connection with the cat. 1B 2.1 tests and documented on the same report.

Cat. 1B 4 (dissimilar metal joints on vessel nozzles)

The vessel nozzles of the reactor pressure vessel YC10B001 have no dissimilar metal joints.

Cat. 1B 5 (selected base metal areas of the RDB)

Testing obligation: Threading in the flange: 25% ET or 25 % VOL for surface cracks

Other areas: Repeat tests as necessary

Test: All 52 M175 threads in the flange (for the stud bolts) are ET-tested.

Additionally, other selected areas are subjected to VT-3 testing.

Cat. 1B 6 (bolts, nuts, sealing surfaces)

Testing obligation: Bolts, nuts with thread dia. > 25 mm, washers, sealing surfaces of flanges: 100 % VT-1

Bolts with thread dia. > 50 mm: 100 % OR or 100 % VOL

Test: All cat. 1B 6 components subject to testing are tested.

The 52 stud bolts (M175X6) are VT-1 tested (voluntary licensee test) prior to ET testing.

Cat. 1B 7 (outer supports, mountings, support structures)

Testing obligation: Integral welds with pressure-bearing walls: 100 % OR or 100 % VOL

Structural parts: 100 % VT-3

Test: All cat. 1B 7 components subject to testing are tested

Cat. 1B 8 (stainless weld overlay)

Testing obligation: VT-1: Selected areas

Test: Selected areas (where damage is most expected) are tested. In the course of the head cladding testing, VT-2 tests of the cat. 1B 2.2 SS+KI seal welds are also performed:

The testing of the cladding on the outlet nozzles also includes the area of the ‘collar’. The attachment weld of the collar cannot be visually tested because it is covered by the cladding.

Cat. 1R 1 (pipework welds)

The pipe connection welds of the main coolant line at the RPV essentially form part of the testing scope of the main coolant line. However, in the testing context (automated ultrasonic testing) they are included in the RPV component test plan.

5.4.4.3 ENSI-B06, Rev.2, Section 6.3 (System and component walkdowns)

Testing obligation: For BRK of safety class 1, the system and component walkdowns must be performed when restarting the plant after every fuel element change. After other shut-downs, the regulator's ordinance must be followed.

Test: The inspectable area of the reactor pressure vessel (head) is inspected annually during the system walkdown under ‘hot no-load’ conditions. As an additional voluntary licensee test, the RPV cover is removed and stored alongside the reactor pool where it is inspected by maintenance personnel. This voluntary licensee test is performed now because in this state and at this time optimum conditions for testing the RPV head exist.

5.4.4.4 ENSI-B06, Rev.2 Section 6.4 (Pressure testing the reactor cooling system)

Testing obligation: The licensee must perform a periodic pressure test of the reactor cooling system at 10-year intervals.

Test: The periodic pressure test of the reactor pressure vessel is performed in association with the pressure test of the reactor cooling system at intervals of 10 years at the design pressure.

5.4.5 Further investigations

Further investigations are not necessary within the scope of the AMP.

5.5 Preventive and remedial actions for RPVs

The ageing behaviour of the materials was considered from the start during the layout, design and manufacture of the German PWR RPV. Precautions to ensure uninterrupted operation of the RPV up until the end of service life have been taken by selecting appropriate materials, through extensive quality assurance measures during production and the extensive surveillance concept for the causes and consequences of operational degradation mechanisms, as well as by the continuous evaluation of the experience of other nuclear power plants and the monitoring of the state-of-the-art of science and technology in the context of the German ageing management concept for the RPV. This is confirmed by the existing operating experience of the German PWRs so that no additional preventive measures or repairs have been necessary for the pressurised wall of the RPV.

5.6 Licensee’s experience of the application of AMPs for RPVs

The experience in the application of ageing management to KKG RPV is completely positive. KKG does not consider it necessary to expand of the scope of ageing management.

6 Concrete Containment Structures

This section presents the civil engineering Amp in accordance with the WENRA requirements for topical Peer Review 2107.

6.1 Outer building envelope of the containment

6.1.1 Description of ageing management for the concrete structure

The civil engineering structures specified in the safety report and classified as BKI and BKII in accordance with guideline ENSI-B01 [5] are considered for the civil engineering AMP.

6.1.1.1 Scope of ageing management for concrete structures

The reactor building comprises a spherical steel envelope with an inside diameter of 52.0 m that is surrounded by a concrete shell, the concrete containment.

The concrete containment comprises a cylindrical concrete shell with an outer diameter of 63.6 m and a wall thickness of 1.6 m. The upper closure of the containment comprises a 1.2 m thick hemispherical concrete dome. The total height of the containment is 56.8 m, the floor slab has a thickness of 2.6 m.

The foundation slab, including the outer cylindrical reinforced concrete shell up to ground level is surrounded by an isolating coating that is resistant to pressurised water.

The outer concrete shell serves as the secondary containment, the purpose of which, following a reactor accident, is to reduce radiation exposure in the surrounding area to a permissible level. It also provides protection against aircraft impact, explosion pressure waves and earthquakes.

As part of the reactor building, the concrete containment and the floor slab surround the reactor cooling system and have the following tasks:

- Supporting the building load
- Protecting the reactor cooling system and the connected systems against external influences Retaining radioactive substances
- Shielding the environment against radiation
- Keeping the groundwater out

All known ageing mechanisms for particular construction materials are listed in the corresponding GKSL document. 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
- Tensioning system (not pre-stressed)

The corresponding ageing mechanisms are included in the civil engineering-specific ageing reports.

The performance of ageing management takes place based on ENSI guideline B01: and is documented according to the regulations of the GSKL civil engineering working group.

6.1.1.2 Ageing assessment of concrete structures

The basis for the implementation of the ageing management programme AMP in the Swiss NPPs is the GSKL civil engineering guide. This was last revised in 2015 by the GSKL civil engineering group. It contains amongst other things the most important basic documents for ageing management and, moreover, defines the layout of a ageing report and the scope of the AMP.

The influences, the ageing mechanisms and the consequences resulting from them for the concrete containment structures, that is for the concrete, reinforcement steel and the prestressing steel, are likewise described in the GSKL civil engineering working group guide.

Tabelle 6 14 Ageing mechanisms for concrete and reinforced concrete, extract from the guide

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 reduces the freezing point. Moreover the freezing point of the pore water falls even further, the smaller the pores	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. The operational demands reach from low level frost in front plates of concrete to high level demands on driven concrete infrastructure.
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. This ageing mechanism can mainly be found in traffic struuctures and nearly never in NPPs.
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 of cracking	Reduced high load bearing capacity and cracking possible
Settlement	Deformations and load shifting	Cracking, local overloading
Carbon dioxide (CO2)	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 CO2 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. (e.g supports)
Fouling	Moisture penetration and root penetration in porous areas and cracks.	Spalling possible.

Tabelle 6 15 Ageing mechanisms for reinforcement steel and prestressing steel, extract from the guide

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 (electrochemical 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 Alternating stress below strength at rupture	Fatigue and high actual load proportion relative to the total load has an unfavourable effect on steel. Fatigue strength decreases.	Fatigue fracture at areas of peak stress and changes in the material geometry (screw holes, welded seams)

Moreover, the GSKL civil engineering working group guide defines the condition levels of the individual construction materials. These are the parameters that must be drawn upon for evaluating the acceptance criteria. The evaluation takes place by assigning the civil engineering structure to one of the five condition levels.

Tabelle 6 16 Condition levels of construction materials according to the GSKL civil engineering guide

Assessment	Description
1: Very good condition	The defect/damage has no influence on the durability, structural integrity and nuclear safety of the component/civil engineering structure. No measures are needed for damage remediation
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 carried out immediately.

The relevant materials and the corresponding ageing mechanisms are listed in the civil engineering ageing ageing reports. Moreover, the target condition levels for the civil engineering parts are defined in it. The relevant plans, structural analysis and reports are recorded in the section ‘List of documents’.

Internal and external operating experience is discussed in the GSKL civil engineering group and classified according to its relevance for the AMP. The new results of the AMP relevant findings are specified in writing. A summary of the evaluated results is presented in the annual report.

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

The basis for the ageing management programme of Swiss NPPs is the guide of the GSKL civil engineering group.

The guide defines the individual inspection plan for civil engineering structures. The baseline inspection is the first main inspection and takes place at the beginning of a civil engineering structure surveillance programme. The intermediate and main inspections take place alternately at ten-year intervals. A special inspection can be carried out at any time for a given reason.

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

The parameters drawn upon for evaluation of the acceptance criteria are the target condition levels. The assignment of the target condition levels of the individual materials is also regulated in the guide.

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 of the components in respect of safety plus to be able to assess the fitness for purpose.

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 discolouration are present. Crack widths are determined using a crack width comparison standard. The position of the findings are entered in the corresponding drawings and summarised in tables in the findings inventory. The most striking points are photographed and documented. To support the visual inspections, reinforcement overlaps are measured, compression strength measurements made using a rebound hammer or sample drilling cores taken for laboratory tests. Amongst other things, the carbonation depths, water absorption, overall porosity and the drilling core strengths are checked.

The results of the AMP, i.e. the results of the local visual inspections of the components and materials testing, are recorded in inspection reports. Summaries of the results are documented in the ageing reports.

6.1.1.4 Preventive and remedial measures for concrete structures

The results of the ageing management inspections are fully documented in the inspection reports. Here, checks assess whether the type and scope of the inspections are suitable for monitoring the ageing condition of the individual structures and components. If necessary, additional inspections are carried out or a special inspection arranged.

Findings from the inspections or the plant walkdowns are recorded in the maintenance plan, even if they are statistically irrelevant and no significant changes would be expected in the next 10 years.

KKG civil engineering operates a preventive maintenance programme, which means that maintenance is implemented when measures can be implemented for a proportionately optimised expense.

In the coming years, the surface coating of the reactor dome will be replaced. In this way, water and moisture will be consistently and permanently deflected from the surface and penetration into the support structure prevented. This will significantly extend the service life of the structure.

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

The procedure according to the rules of the GSKL civil engineering working group guide, which is based on the regulator's specifications in the guidelines ENSI-G01 [6] and ENSI-B01 [5], ensures that the AMP of the Swiss NPPs is complete, up-to-date and correct.

Experience from the AMP has not yet revealed any unexpected findings that would require an adjustment of the AMP or the investigation methods.

The cooperation in the GSKL civil engineering group additionally ensures that any alterations are quickly incorporated in the civil engineering ageing management.

From the current perspective, with the same AMP and unchanged maintenance of the civil engineering structures, no significant changes in condition are to be expected.

KKG assesses ageing management as satisfactory in respect of the buildings.

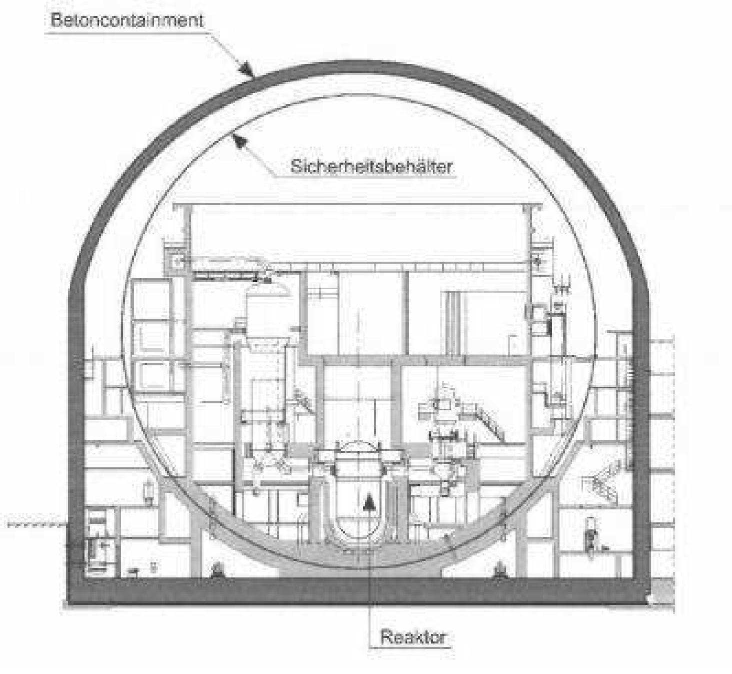

Abbildung 6 6 Reactor building schematic sectional view

7 Overall assessment and general conclusions

The result of the undertaken review is positive in the opinion of KKG. KKG is always up-to-date in its implementation of ageing management. Consequently, ageing management in KKG forms a sound basis for safe long-term operation according to ENSI A03/d [3] .

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9 List of revisions

Rev.	Seite	Beschreibung der Änderung
v1		Translation of the German original document BER-S-92631, v1