Safety Reports Series

No.106

Ageing Management and Long Term Operation of Nuclear Power Plants: Data Management, Scope Setting, Plant Programmes and Documentation

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AGEING MANAGEMENT AND LONG TERM OPERATION OF NUCLEAR POWER PLANTS: DATA MANAGEMENT, SCOPE SETTING, PLANT PROGRAMMES AND DOCUMENTATION

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SAFETY REPORTS SERIES No. 106

AGEING MANAGEMENT AND LONG TERM OPERATION OF NUCLEAR POWER PLANTS: DATA MANAGEMENT, SCOPE SETTING, PLANT PROGRAMMES AND DOCUMENTATION

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FOREWORD

Out of the total number of nuclear power plants currently operating in the world, approximately 25% have been in operation for more than 40 years, and about 68% for more than 30 years. However, in line with economic and energy supply growth and environmental quality factors, a number of IAEA Member States have over the past decade started to consider long term operation of their nuclear power plants beyond the time frame originally anticipated.

This Safety Report complements IAEA Safety Standards Series Nos SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation, and SSG-48, Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants. It provides information on selected topics from SSG-48. Specifically, it addresses data collection and record keeping, scope setting for structures, systems and components, plant programmes, corrective action programmes, and documentation of ageing management and long term operation assessment.

This report focuses on nuclear power plants throughout their lifetime, including operation beyond the time frame originally established for their operation and decommissioning, while considering the different reactor designs that exist around the world. It is also relevant for facilities for spent fuel storage and radioactive waste management at nuclear power plants. It may also be used as a basis for managing the ageing of other nuclear installations and for radioactive waste management facilities. This Safety Report is intended to provide information for operating organizations but may be also used by regulatory bodies.

The IAEA is grateful for the contributions of all those who were involved in the drafting and review of this report. The IAEA officers responsible for this publication were R. Krivanek and G. Petofi of the Division of Nuclear Installation Safety.

EDITORIAL NOTE

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

Paragraph 5.51 of IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design [1], states:

> "The design for a nuclear power plant shall take due account of ageing and wear out effects in all operational states for which a component is credited, including testing, maintenance, maintenance outages, plant states during a postulated initiating event and plant states following a postulated initiating event."

In addition, Requirement 14 of IAEA Safety Standards Series No. SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation [2], states:

> "The operating organization shall ensure that an effective ageing management programme is implemented to ensure that required safety functions of systems, structures and components are fulfilled over the entire operating lifetime of the plant."

Data on the operating experience of nuclear power plants (NPPs) are collected and retained for use as input for the management of plant ageing [2, 3].

Effective management ensures that the effects of ageing will not prevent structures, systems and components (SSCs) from being able to fulfil their required safety functions throughout the lifetime of the plant (including decommissioning), taking into account the changes that occur with time and use. This requires addressing both the effects of the physical ageing of SSCs, resulting in degradation of their performance characteristics, and the non-physical ageing (obsolescence) of SSCs (i.e. becoming out of date in comparison with current knowledge, codes, standards and regulations, and technology) [3]. Effective ageing management throughout the service life of SSCs requires the use of a systematic approach, providing a framework for coordination of all programmes and activities related to the understanding, prevention, detection, monitoring and mitigation of ageing effects of the plant structures and components. This approach comprises maintenance, in-service inspection, testing and surveillance, as well as operations, technical support programmes (including analysis of any ageing effects and degradation mechanisms) and external programmes such as R&D [4, 5].

The IAEA prepared publications on the safety aspects of ageing management in the 1990s (e.g. Ref. [6]). Subsequently, a number of reports on the subject were published, including general methodological publications[1] [7], as well as publications on selected major structures and components, such as reactor vessels, reactor internals, piping, steam generators and the containment [8–18].

In recent decades, the number of IAEA Member States planning to continue the operation of NPPs beyond the time frame originally anticipated (typically 30–40 years) and into a period of long term operation (LTO) has steadily increased. Recognizing the need to assist Member States in dealing with the unique challenges associated with LTO, the IAEA conducted the Extrabudgetary Programme on Safety Aspects of Long Term Operation of Water Moderated Reactors from 2003 to 2006 [19]. This was followed by the IAEA Extrabudgetary Programme on International Generic Ageing Lessons Learned (IGALL) from 2010 to 2013, resulting in the preparation of a Safety Report on IGALL [20]. That publication provided a common, internationally agreed basis on what constitutes an acceptable ageing management programme (AMP), as well as a knowledge base on ageing management for the design of new NPPs, design reviews and safety reviews.

General recommendations and guidance on methodology, key elements and implementation of effective AMPs for SSCs important to safety at NPPs are provided in IAEA Safety Standards Series No. SSG-48, Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants [3]. In parallel with these safety related publications, the IAEA also published reports on the engineering as well as technological and scientific aspects of ageing management [21–23].

User feedback and the results of IAEA Safety Aspects of Long Term Operation (SALTO) missions indicate that additional information is needed in the following areas of SSG-48 [3]:

— Section 4, on relevant plant documentation and programmes;
— Parts of section 5, on data collection and record keeping, scope setting for SSCs and documentation of ageing management;
— Parts of section 7, on development of a programme for LTO, scope setting for SSCs for LTO, review of plant programmes and AMPs for LTO, documentation in support of LTO, and implementation of the programme for LTO.

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Implementation and Review of a Nuclear Power Plant Ageing Management Programme, Safety Reports Series No. 15, IAEA, Vienna (1999) (superseded by SSG-48 [3]).

1.2. OBJECTIVE

The objective of this publication is to provide supplementary information to support the implementation of the recommendations and guidance in SSG-48 [3] relating to ageing management and preparation for safe LTO of NPPs. Specifically, it addresses the following:

- Data collection and record keeping for ageing management and LTO assessment;
- Scope setting for SSCs for ageing management and LTO assessment;
- Review and improvement of plant programmes relevant to ageing management and LTO, including corrective action programmes (CAPs);
- Documentation of ageing management and LTO.

It also includes selected good practices collected from Member States and ensures consistency with the terminology used in SSR-2/2 (Rev. 1) [2], SSG-48 [3] and the Safety Report on IGALL [20]. The information provided in this publication represents expert opinion but does not constitute recommendations made on the basis of a consensus of Member States.

1.3. SCOPE

This publication provides information on several topics from SSG-48 [3] to support ageing management and preparation for safe LTO. It complements the Safety Report on IGALL [20]. It is applicable to NPPs throughout their lifetime, including operation beyond the time frame originally established for their operation, LTO and decommissioning. It takes into account the different reactor designs worldwide. In addition to operating reactors, this publication may also be relevant to facilities for spent fuel storage and radioactive waste management at NPPs. While intended to provide information for operating organizations, this publication may also be used by regulatory bodies.

1.4. STRUCTURE

This publication is divided into six sections. Section 1 provides the background, objective and scope of the publication. Section 2 provides information and good practices for data collection and record keeping. Section 3 provides information and good practices for scope setting for SSCs for ageing management and LTO assessment. Section 4 provides information and good practices for review and improvement of plant programmes relevant to ageing management and LTO. Section 5 provides information and good practices for a CAP. Section 6 provides information and good practices for documentation of ageing management and LTO assessment.

Four annexes are included: Annex I provides an overview of data required for AMP and LTO assessment and examples of relevant data management in Member States. Annex II provides examples of approaches to the review and improvement of plant programmes relevant to ageing management and LTO, including CAPs in Member States. Annex III provides an example of a CAP. Annex IV provides examples of commodity groups for each technical area.

2. DATA COLLECTION AND RECORD KEEPING

2.1. GENERAL CONSIDERATIONS

A data collection and record keeping system supports the development and implementation of effective ageing management and LTO in compliance with paras 5.9–5.13 of SSG-48 [3]. Such a system for ageing management contains plant related information which is systematically collected and managed through the lifetime of the plant. This includes the rules to define the information collected, storage requirements and correlations that exist within the data.

The use of available industry wide or generic data on ageing effects and degradation mechanisms is typically considered a starting point for ageing management and LTO. These generic data are further supplemented with plant specific data and operating experience. The examples of data collection and record keeping systems in Annex I have been derived from proven practices in Member States.

2.2. DATA COLLECTION AND RECORD KEEPING SYSTEM

A data collection and record keeping system is necessary to support effective plant ageing management activities. A general expectation related to data management is to have a complete and detailed master list of plant SSCs. Each SSC is identified with a unique code which is traceable throughout the lifetime of the plant.

The information linked to each SSC is plant specific and usually includes the following attributes:

- The unique identifier;
- The technical area of the SSC (e.g. mechanical, electrical, instrumentation and control (I&C), civil structures);
- The type of structure or component (e.g. pump, valve, relay, breaker, building, beam);
- The system, building or room where it is located.

A master list of plant SSCs is typically developed during the design and construction phases and is further developed during the implementation of plant specific AMPs. The level of detail of the SSC master list varies from plant to plant and defines its usability for ageing management. In some cases, pipelines are uniquely identified with a single code for each section, whereas in other cases a pipeline belongs to the component to which it is linked. Similarly, in some plants certain supports have their own code, while in other plants they belong to the component they support or have no specific identification. In the latter case, the implementation of AMPs provides opportunities to continuously improve the quality and completeness of the master list.

It is good practice to use the unique identifier in the master list throughout the plant when referring to a given SSC. For a given unique identifier, it is possible to identify all the available information related to design, commissioning, operation, maintenance, surveillance, inspections and ageing management activities (see Section 2.3). From a programmatic perspective, the scope, planning and outputs of each plant programme can be associated with the group of unique identifiers covered by the relevant programme.

If the plant does not have unique identifiers for SSCs, two approaches can be followed. Either a new unique identifier can be assigned and added to the master list, or generic groups (such as for supports, cables, cable trays) can be defined and registered with a single unique identifier. If the latter approach is followed, SSCs can be grouped on the basis of material, design, operational conditions, and environment. This could be used as a basis for commodity grouping, as described in Section 3.4.

An effective data collection and record keeping system contains relevant data for ageing management and LTO. Lists of information typically included are provided in Section 2.3 and include manufacturers, fabrication and operational data, maintenance, and surveillance and inspection data. These data are then linked to each unique identifier. The scope, scheduling and records of each plant programme can also be associated with a single unique identifier or group of unique identifiers for SSCs.

The data collection and record keeping system for ageing management is typically established at the early stages of the NPP's life and meets the following objectives:

- Ageing management related information is maintained throughout the lifetime of the plant.
- Ageing management related information is up to date and represents the current plant configuration and physical condition of the SSCs.
- The database structure considers the various characteristics of different types of SSC.
- Ageing management related information is auditable and traceable to demonstrate consistency.
- Links to relevant information sources are identified.
- Administrative controls according to the plant management system are applied to ensure the integrity of stored data (such as procedures and data validation).
- Relevant information about the SSCs of the plant is provided, including baseline information, and operation and maintenance history data, as described in Section 2.3.
- Reliable information storage and retrieval over the required lifetime of the database are maintained.
- Information retrieval is sufficiently timely (the 'timeliness' requirement can vary according to the use of the information) for ageing management evaluations such as ageing management review (AMR) and the effectiveness of AMPs.
- Tools for data analysis, trending, graphical display and the production of reports are provided.
- The system is accessible to all relevant personnel working within ageing management.

If the plant manages the data collection and record keeping in different databases, the consistency and link between these databases is ensured (such as by doing cross-checks or regular reviews, or using automatic data linking).

Various data collection and record keeping systems can satisfy those objectives. Examples of systems that have met some of the above objectives include Asset Suite, Sygma, EAM/SDIN, the SAP system and the IFS, Darwin and DACAAM databases. Figure 1 shows a representative high level data model of an integrated data collection and record keeping system.

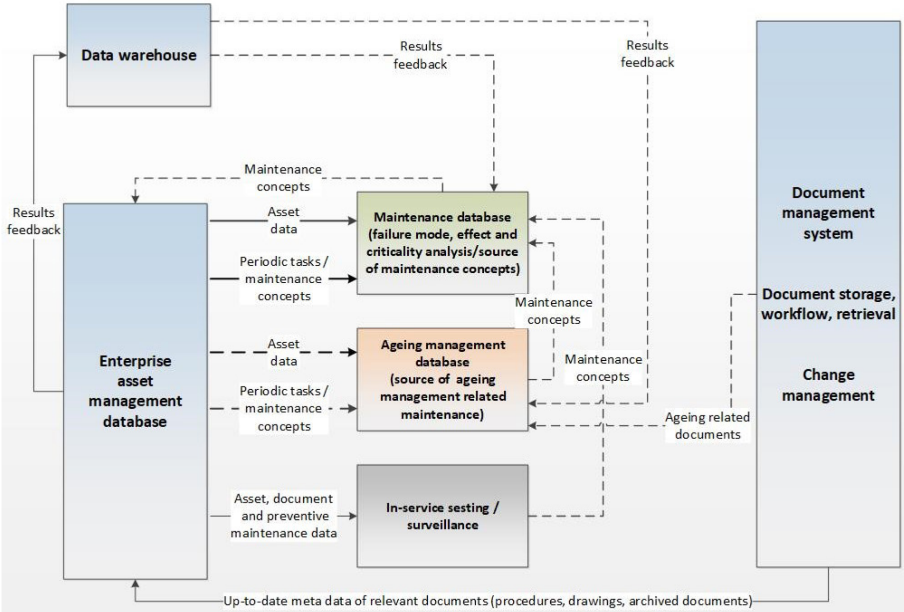

FIG. 1. Representative data collection and record keeping system.

Effective ageing management relies on the proper use of available information. Plant organizations typically share the relevant information for ageing management by using a data collection and record keeping system. This is regulated by plant specific procedures. Typically, information stored in the system includes the following:

— Manufacturer’s specifications;
— Commissioning test results;
— Maintenance results;
— In-service inspection (ISI) and functional testing results;
— Water chemistry results;
— Plant configuration changes;
— Operation parameters;
— Surveillance results;
— System and component health information;
— Repair and replacement information;
— Obsolescence information;
— R&D results;
— Internal and external operating experience;
— AMR results;

— AMP results;
— Time limited ageing analysis (TLAA) revalidation results;
— Information from periodic safety review (PSR) and other relevant licensing documents.

2.3. DATA FOR AGEING MANAGEMENT AND LONG TERM OPERATION

Not all data listed in this section are necessary for each structure or component. The level of detail depends on the type, safety significance and technical area of the structure or component, and the required level of understanding of significant ageing effects and degradation mechanisms. For each component type, the careful specification of the data required to support ageing management and LTO ensures that only the relevant data are collected, with the required accuracy.

The data relevant for SSCs are grouped into five main categories:

(1) *Baseline information.* These data provide essential information for developing effective AMPs and for the identification and revalidation of TLAAs for LTO. In general, NPP baseline information exists, but it is usually dispersed in numerous reports or databases. To ensure the completeness of baseline information, contact with the original designer or vendor is usually required. It is important to ensure that structure and component baseline data are updated when the configuration is changed according to the management system and configuration management programme.

(2) *Operating history data.* These data describe the actual service conditions under which a component operates, including data on process conditions, chemistry, the ambient environment and transients (such as pressure–temperature transients for pressure retaining components) and the component's availability, testing and failure data.

(3) *Maintenance and ISI history data.* These data consist of condition monitoring data, repair history and modification history. They may be used in conjunction with appropriate system health reports to predict the future rate of material and functional degradation, and to decide on the timing and the most appropriate type of corrective measures (i.e. repair, refurbishment or replacement, or evaluation).

(4) *Results of ageing management activities.* These include all data created during the development and implementation of the AMP (e.g. the results of scope setting, of the AMR, AMPs and TLAA revalidation). Also, all data

necessary for monitoring AMP effectiveness and updates are collected and stored.

(5) *External operating experience data.* Event reports, operating experience databases, and topical reports incorporated into relevant AMPs and considered in TLAA calculations.

Typical information sources for ageing management and LTO are as follows:

(a) Baseline information:
- — Master list of all SSCs.
- — Unique identifier of structure or component.
- — General arrangement of the facility and structural outline drawings.
- — Description and technical specification of the structures and components.
- — Safety classification of SSCs.
- — Functions of SSCs under both normal and accident conditions.
- — Design specifications (including design service conditions and design loads).
- — Design, construction, manufacturing and procurement documentation for SSCs, including design drawing documentation, material specifications.
- — Relevant fabrication records (e.g. heat treatment history, certified reports on material tests).
- — Pre-service or baseline inspection results.
- — Type and location of structures and components.
- — Quality classification (e.g. safety, seismic, pressure classification) of the structures and components.
- — Equipment qualification records (for external and internal events belonging to the facility design basis).
- — Commissioning data (e.g. data on the startup tests and on baseline vibrations, the date of component installation, mappings of environmental conditions).
- — Information on design modifications implemented.
- — Information on construction modifications.
- — Process and instrumentation diagrams (P&IDs).
- — AMRs identifying potential ageing effects and degradation mechanisms.
- — AMPs identifying actions implemented to manage ageing effects.
- — Ageing analyses that have time limited assumptions (i.e. TLAAs).
- — Safety related reports (e.g. safety analysis report; PSR; level 1 and level 2 probabilistic safety assessment).

— Plant operating instruction and other plant procedures and programmes.

(b) Operating history data:

— History of the service conditions of structures and components.
— Unique identifier of structures or components.
— Environmental conditions of building structures (e.g. outer and inner pressure, temperature, humidity).
— System process conditions (e.g. temperature, flow, pressure).
— Chemistry data.
— Radioactivity data.
— Vibration data.
— Noise data (e.g. neutron, audio, electrical).
— System transient data: dates and profiles of system loading, cycling or startup (e.g. pressure–temperature records, chemistry records).
— Mode of operation (i.e. continuous, standby or intermittent).
— Information on major changes in system operation.
— Information on conditions and practices that prevent or minimize ageing.
— Relevant records from the CAP.
— Functional testing data:
  - Unique identifier of structure or component;
  - Test description (including test frequency);
  - Date of test;
  - Test result (success or failure);
  - Repeated tests (in the case of failed tests);
  - Results of the maintenance effectiveness monitoring programme.
— Failure data:
  - Unique identifier of structure or component.
  - Date of failure.
  - Failure time (hours or cycles of operation before failure).
  - Method of failure discovery.
  - Inspection report of the failure, including failure mode and description, deviation sheets.
  - Failure cause: (a) perceived; (b) root (at failure mechanism level).
  - Failed parts (if the component can be divided into subcomponents).
  - Relevant system conditions (e.g. unusual loading, power or signal conditions).
  - Relevant environmental conditions.

(c) Maintenance and ISI history data:
   — Structure and component condition monitoring data:
      • Unique identifier of structure or component;
      • Parameters to be monitored or tracked (e.g. vibration, temperature, chemistry);
      • Component condition indicator data (e.g. acceptance criteria, functional test results, ISI and surveillance results, including incipient failures, their dates and operational time or cycles);
      • Information on changes in condition monitoring, including ISI and functional testing history records;
      • System health reports, including equipment reliability data;
      • Corrective measures decided (i.e. repair, further analyses and their evaluation reports).
   — Maintenance data:
      • Unique identifier of structure or component;
      • Reason for maintenance action (including the decision criteria);
      • Type of maintenance (i.e. corrective or preventive);
      • Date and duration of maintenance;
      • Description of maintenance work (e.g. repair, refurbishment, replacement);
      • Information on changes in maintenance methods and intervals.
(d) Results of ageing management activities:
   — Scope setting results, including marked-up P&IDs, if the scope of the structure or component has been determined in the plant's ageing management or LTO programmes, or the list of structures and components for ageing management and LTO;
   — AMR results;
   — AMP results;
   — TLAA results.
(e) External operating experience data:
   — Joint IAEA–OECD Nuclear Energy Agency (OECD/NEA) International Reporting System for Operating Experience (IRS) database event reports;
   — IRS topical reports;
   — World Association of Nuclear Operators (WANO) operating experience database;
   — Operating experience databases of various user groups (e.g. Boiling Water Reactor (BWR) Owners' Group, Pressurized Water Reactor (PWR) Owners Group, Canada Deuterium–Uranium (CANDU) Owners Group).

3. SCOPE SETTING

The objective of this section is to provide additional recommendations for paras 5.14–5.21 of SSG-48 [3]. The scope setting documentation at the plant typically comprises the following:

— A scope setting methodology document providing detailed guidance;
— Scope setting results for each technical area (mechanical, electrical, I&C and civil SSCs).

Prior to starting the detailed scope setting process, a pilot scoping analysis can be performed on selected systems or groups of components. The data and information required to accomplish this are described in Section 2.2. The documentation of the methodology and results is described in Section 6.5.

3.1. INTERPRETATION OF SCOPE SETTING CRITERIA

Paragraph 5.16 of SSG-48 [3] provides the basis for defining whether or not an SSC is included in the scope of ageing management. This section further elaborates the criteria provided in items (a), (b) and (c) of para. 5.16. For ease of use in this report, the criteria in those items are hereafter referred to as 'criterion A', 'criterion B' and 'criterion C', respectively.

3.1.1. Criterion A

Criterion A applies to "items important to safety that are necessary to fulfil the fundamental safety functions". Requirement 4 of IAEA Safety Standards Series No. SSR-2/1 (Rev. 1) [1] states:

> "**Fulfilment of the following fundamental safety functions for a nuclear power plant shall be ensured for all plant states: (i) control of reactivity; (ii) removal of heat from the reactor and from the fuel store; and (iii) confinement of radioactive material, shielding against radiation and control of planned radioactive releases, as well as limitation of accidental radioactive releases**".

Implementation of criterion A requires an understanding of the term 'items important to safety'. Such items are either safety related or part of safety systems or safety features (for design extension conditions), according to the definition of the term in the IAEA Safety Glossary [24]. Further details are provided in Refs [1, 3, 24].

The IAEA Safety Glossary [24] defines a 'safety system' as one that is "important to safety, provided to ensure the safe shutdown of the reactor or the residual heat removal from the reactor core, or to limit the consequences of anticipated operational occurrences and design basis accidents". It also defines a 'safety related system' as "a system important to safety that is not part of a safety system" [24]. Systems important to safety, as defined in criterion A, include both safety systems and safety related systems. The definition of safety system in Member States can differ from that of the IAEA. The definition of safety related items in the IAEA Safety Glossary [24] may cover the gap between these definitions.

Another publication, IAEA Safety Standards Series No. SSG-30, Safety Classification of Structures, Systems and Components in Nuclear Power Plants [25], provides recommendations for the identification of SSCs important to safety and for their classification on the basis of their function and safety significance.

To ensure consistency and coherence across the technical areas for criterion A, the following aspects may be considered:

— Mechanical, electrical, I&C and civil SSCs fulfilling a fundamental safety function are in the scope.
— If a mechanical component is in the scope for its active function, the connected electrical and I&C equipment ensuring the active function (see Section 3.2.4) also needs to be in the scope under criterion A, through the following steps:
    - Identify the components in the scope that include the electrical control equipment;
    - Identify the associated equipment power sources and switchboards which supply the electrical control equipment (including the connecting electrical equipment: cables, junction boxes);
    - Identify the components associated to the control and power supply of the switchboard.
— Civil structures (e.g. foundations, concrete bases, supports, cable trays) that support mechanical or electrical and I&C SSCs under criterion A are in the scope. Structures that are required to ensure the functions of in-scope mechanical, electrical and I&C structures and components are also covered by criterion A (e.g. snubbers, leaktight doors, penetrations).

3.1.2. Criterion B

Criterion B applies to other SSCs whose failure may prevent SSCs important to safety from fulfilling their intended functions. Paragraph 5.16 of SSG-48 [3] provides a list of examples of potential failures that might cause an SSC not important to safety to be included in the scope. The scope setting process (see Section 3.2.5) provides relevant information, including a list of failures to be considered.

The development of this list may be based on a (deterministic or probabilistic) hazard analysis performed within a PSR (safety factor 7: hazard analysis in IAEA Safety Standards Series No. SSG-25, Periodic Safety Review for Nuclear Power Plants [5]), or specifically for the scoping process. Depending on the hazard, single and multiple failures may be assumed.

Some Member States have found it helpful to provide examples of the types of interaction that would result in an item not important to safety being brought within the scope under criterion B. These Member States have also found it useful to identify these interactions on the basis of the technical areas (i.e. mechanical, electrical, I&C or civil structures) that are being considered, as described below.

For mechanical components, the scope setting methodology could identify which aspects or criteria are considered to include components that are not in the scope for criterion A on the basis of their (potential) connection or interaction with SSCs that are in the scope for criterion A. Some examples of connections are provided below:

— *Functional connection.* Other SSCs supporting the fulfilment of a safety function or safety related function in the scope (for criterion A).
— *Physical connection.* Other SSCs directly connected to or providing structural support for SSCs in the scope.
— *Potential spatial interaction.* Other SSCs not mechanically connected to SSCs in the scope for criterion A, but with a potential for spatial interaction with in-scope SSCs. This spatial interaction may include structural interaction, high energy interaction, fluid and steam interaction, flooding and spraying caused by rupture of piping or tanks. These types of interaction criterion usually necessitate a walkdown (discussed in Section 3.2.6) to assess the potential for this type of interaction.
— *Protective equipment.* Other SSCs considered as mitigative or protective items for in-scope mechanical, electrical and I&C SSCs.

For electrical and I&C SSCs, the scope setting methodology could identify which aspects are considered for components not in the scope for criterion A, on the basis of their (potential) connection or interaction with SSCs important to safety:

— Electrical and I&C systems and components required to ensure the function of the in-scope mechanical components based on a functional and protective connection. This can be associated with an active or a passive function (e.g. I&C components which are not in the scope, associated with high energy lines that are in the scope under criterion B).
— Setting the scope in this case could be influenced by the design criteria being applied for the independence of systems and components. Independence refers to physical separation and electrical isolation. Associated systems and components may be set in the scope for criterion B, as these might not be physically separated or electrically isolated from systems in the scope for criterion A by structures that are important to safety, barriers, isolation devices or acceptable separation distances. Electrical and I&C components not in the scope under criterion A can be set in the scope under criterion B based on their protective function.
— Apart from the independence of systems in the scope for criterion A, it is recommended to define the types of spatial interaction considered in the scope of electrical and I&C components for criterion B. Examples include the following:
  - Proximity of cables in the scope and not in the scope in cable trays, eventually in combination with overload of cable trays;
  - Presence of high energy electrical equipment, such as transformers, creating a risk for explosion and potential source of missiles, potentially endangering in-scope systems and components.
— Electrical equipment not in the scope that generates electromagnetic fields that interfere with the function of in-scope components.

For civil structures, the scope setting methodology could identify which aspects or criteria are considered for structures that are not in the scope for criterion A, on the basis of their relationship with SSCs that are within the scope. Such structures include the following:

— Mechanical, electrical and I&C supporting structures required to ensure the supporting function of systems and components in the scope for criterion A.
— Structures not important to safety used as mitigative measures to protect mechanical, electrical and I&C systems and components important to safety from different types of spatial interaction. Examples include the following:
  - Structures not in the scope that protect systems and components in the scope for criterion A from missiles;

- Whip restraints, jet impingement shields and blow-out panels not important to safety that are designed and installed to protect systems and components important to safety from the effects of high energy line breaks;
- Other features that provide flood or spray barriers to systems and components in the scope for criterion A.

— Structures not in the scope with a potential interaction with SSCs in the scope for criterion A that are not protected from the effects of a failure of these structures (e.g. the overhead load handling systems (cranes) from which a load drop could cause damage to an in-scope structure or component based on criterion A).

— Civil structures that are not in the scope for criterion A and that are located so that their failure could result in an in-scope structure or component failing to perform its intended safety function.

— Civil structures not important to safety whose failure could impact a safety function (e.g. a building not important to safety containing SSCs that are in the scope).

3.1.3. Criterion C

Criterion C applies to other SSCs that are credited in the safety analysis as performing the function of coping with certain types of internal event, external hazard and specified regulated event, and with design extension conditions, or to mitigate the consequences of severe accidents. This criterion includes in-scope SSCs that are important to safety (e.g. safety features for design extension conditions [24]) as well as SSCs that are not important to safety but are credited in existing safety analyses of the plant.

The following examples of internal and external events and hazards could be considered:

— Internal events:
- Internal fire;
- Internal explosion;
- Missiles;
- Collapse of structures and falling objects;
- Pipe breaks (e.g. pipe failures and their consequences, including pipe whip and jet effects, steam release);
- Internal floods;
- Release of hazardous substances (e.g. asphyxiant and toxic gases, corrosive and radioactive fluids);
- Electromagnetic interference.

— External events:
  - Earthquake;
  - Volcanism;
  - External floods (including tsunami);
  - Extreme winds (including tornadoes and tropical cyclones);
  - Other meteorological hazards (including lightning strikes and extreme temperatures);
  - Biological phenomena;
  - Collisions of floating bodies with water intakes and ultimate heat sink components;
  - Electromagnetic interference (including solar storms);
  - External fire;
  - External explosion (including missiles and shockwaves);
  - Accidental aircraft crash;
  - Release of hazardous substances (e.g. asphyxiant and toxic gases, corrosive and radioactive fluids).

The following types of regulated event could be considered on the basis of national regulatory requirements:

— Pressurized thermal shock;
— Anticipated transient without scram;
— Station blackout.

The following events related to design extension conditions or to the mitigation of the consequences of severe accidents could be considered:

— Review level earthquake;
— External flooding;
— Complete station blackout;
— Loss of ultimate heat sink;
— Other events leading to design extension conditions.

The examples cited above can be considered to expand the list of events provided in para. 5.16 of SSG-48 [3], in addition to the specific requirements of Member States on the subject.

If a PSR has been completed, other events, hazards and conditions analysed in accordance with safety factors 5–7 (deterministic safety analysis, probabilistic safety assessment, hazard analysis) of SSG-25 [5], can be considered in the LTO analysis for criterion C.

Setting the scope for criterion C has to be performed consistently across the different technical areas. The following aspects are taken into consideration for the application of criterion C in the different technical areas:

- *Mechanical systems and components.* The mechanical systems and components that are not important to safety but are credited in the safety analyses.
- *Electrical and I&C SSCs.* The following structures and components are set in the scope for criterion C, if they have not already been set for criterion A (and probably non-nuclear classified):
  - Structures and components required to fulfil the intended (active) function of mechanical structures and components in the scope for criterion C;
  - Structures and components required to ensure the structural and pressure retaining boundary function of the mechanical structures and components in the scope for criterion C;
  - Structures and components required to fulfil the intended function in the scope for criterion C.
- *Civil structures.* The following civil structures are set in the scope for criterion C:
  - Structures and components supporting the mechanical, electrical and I&C structures and components set in the scope for criterion C;
  - Structures and components required to fulfil a structural intended function in the scope for criterion C (e.g. fire barriers and controlled leakage doors).

3.2. APPLICATION OF SCOPE SETTING CRITERIA

3.2.1. Team creation

For systematic scope setting, a suitable team with expertise in different disciplines and with extensive knowledge of existing SSCs in the plant is established to review available documentation and to assess whether an SSC is to be included in the scope for ageing management and LTO. The team comprises the necessary expertise in maintenance, engineering, design, operations and knowledge of nuclear safety codes and standards, regulatory specifics for understanding the system, and application of the scoping criteria within the different technical areas relevant to ageing management and LTO:

— Mechanical;
— Electrical and I&C;
— Civil structures.

There are various types of structure in the plant. It is necessary to clearly identify which technical area team is responsible for including a given structure in the scope, to avoid gaps in the scope setting results.

3.2.2. Use of safety classification

The scope setting methodology can include the requirement to use an existing safety classification methodology (e.g. SSG-30 [25]) as a basis for determining which SSCs are important to safety and which are in the scope according to criterion B or C. Such an approach could include a classification methodology for SSCs such as the one described in. SSG-30 [25], where SSCs important to safety are assigned to three safety classes (1, 2 or 3), or a classification methodology for civil structures using seismic categories. Simultaneous consideration of the safety classification of a structure or component as well as its function may be beneficial in reaching a scope determination, especially for electrical and I&C SSCs.

The adequacy of the safety classification of SSCs may need to be verified using deterministic safety analysis, which may be complemented by insights from probabilistic safety assessments. It is recommended that a function based scope setting analysis, which takes into consideration the scope setting criteria of para. 5.16 of SSG-48 [3], be used to confirm whether an SCC is in the scope or out of the scope on the basis of the safety classification. Alternatively, a gap analysis can be performed to justify the use of the safety classification, demonstrating that the plant specific interpretation and application of the scoping criteria covers the objectives related to the scoping criteria of para. 5.16 of SSG-48 [3].

3.2.3. Boundaries

A boundary can be defined as the line that marks the limits of a specific item or area. Typically, boundaries are set as follows:

— At the NPP or unit level;
— For a technical area for ageing management (e.g. for mechanical, electrical, I&C and civil structures and components);
— At the system level;
— At the structure or component level;
— At the safety class level.

Before the process of scope setting begins, clear boundaries need to be defined for SSCs and for the technical areas.

3.2.3.1. Boundaries between technical areas

In a list or database of all SSCs of the NPP (see para. 5.15 of SSG-48 [3]), it is a common practice to define boundaries between technical areas for ageing management. The objective is to clarify in which technical area structures and components will be included for the AMR after the scope setting process is finalized. For this purpose, a list of structures and components included in each technical area is usually provided.

For some SSCs, such as pipelines (mechanical), cables (electrical and I&C) and containment (civil structures), it is relatively straightforward to assign the SSCs to the technical area to which they belong. However, other SSCs are more difficult to categorize. For example, anchors, expanders and anchor plates are usually considered to belong to the building construction itself and are managed within the technical area for civil structures. Welds and bolting that attach process systems to embedded anchor plates are usually not included in the technical area for civil structures but in the area for mechanical components.

Certain structures and components can be broken down into different subcomponents, which in turn can be managed by different technical areas. For instance, a valve housing is a typical subcomponent of a valve that is managed as a mechanical component while the motor of the same valve is usually managed within the technical area for electrical components. The use of boundaries can be also relevant when making commodity groups (see Section 3.4).

3.2.3.2. Boundaries between SSCs within the scope which are directly connected to SSCs out of the scope

Clear definition of boundaries between SSCs within the scope which are directly connected to SSCs out of the scope (see para. 5.18 of SSG-48 [3]) is also important. Some typical cases are as follows:

— Pipelines not important to safety that are connected to SSCs important to safety are typically included up to the first isolation valve, including valve connection welds. The definition of what is considered an isolation valve could be the following:
  - For boundaries between quality classes, open valves (manual or motor operated valves) are also used as isolation valves.
  - For control valves, this applies if the valve closes upon failure to meet the criterion ‘first isolation valve’.

  - Check valves in the right direction, so as to protect the function of higher safety classified structures and components in case of leakage in the lower safety classified structures and components.
- For electrical components not important to safety that are fed from trains that also feed components important to safety, components of the part not important to safety are normally included up to the first switch.
- For I&C systems not important to safety that are connected by small bore pipes to mechanical pressure retaining components important to safety, components up to the first isolation valve are included in the scope. Components behind the first isolation valve are excluded.

In order to make boundaries between different technical areas visible, a common practice is to highlight them in P&IDs during the scope setting process (see Section 6.5). It is important to understand that there is no single best approach. Many combinations of the aforementioned tools and considerations are used in different Member States to clearly define what is in the scope and what is out of the scope. For this reason, it is important to explicitly state the criteria used while defining the overall scope setting strategy to be applied.

3.2.4. Defining active and passive functions

Active functions are those which are fulfilled by means of moving parts or are subject to a change in phase or shape while fulfilling the function. Passive functions are those not active. Typical passive functions include structural integrity, pressure boundary, thermal and electrical insulation, and heat exchange. Typical active functions include adequate flow rate, pressure control, and actuation.

Structures and components are evaluated for scoping purposes on the basis of their function (active or passive). Passive structures and components are in the scope only for their passive function. Active structures and components can be in the scope for passive as well as active functions.

In some Member States, the distinction between active and passive structures and components is important in determining how they are evaluated for ageing management, especially for mechanical systems and components. The scope setting methodology may provide guidance concerning how active and passive structures and components are distinguished. Setting a mechanical component in the scope as active has several consequences:

- The moving items of the component need to be included in the scope.
- The actuation and supply (electricity, air, etc.) items permitting actuation need to be included in the scope.

— The instrumentation to control the active function needs to be included in the scope.

For each structure or component in the scope, its passive and active intended functions are identified as inputs for the AMR.

3.2.5. Scope setting process

The scope setting methodology provides guidance to the reviewers on how to effectively perform or update the scope of SSCs for ageing management and LTO assessment. This guidance may focus on whether SSCs are reviewed individually or as part of systems or groups, utilizing information on which technical area an SSC belongs to (i.e. mechanical, electrical, I&C or civil), and in what order to evaluate the SSCs against the criteria for inclusion into the scope. The review may be organized using several of these approaches. The methodology could distinguish possible phases in which system based scoping is performed and followed by component based scoping. This is also a way of demonstrating completeness of the scope setting, at the system level and the component level.

Given the importance of the scope setting process and the significant amount of information involved, management of this information is necessary. These issues are addressed in Sections 3.2.5.1 and 3.2.5.2.

There is substantial variation among Member States as to how information is managed in the scope setting process. The following approaches (and their combination) have been successfully applied:

— *System based approach.* In this approach, whole systems are assessed against criteria A to C (as described above). If the system meets the criteria, the entire system is in the scope. Structures and components belonging to systems that are not in the scope are then evaluated individually to determine whether they are in the scope. This approach may be applied to different types of system (e.g. mechanical, electrical, I&C) and would normally begin with a master list of plant systems. This needs to be complemented with scope setting for structures that cannot be directly connected with the system approach (e.g. fire barriers, hatches). Additionally, structures and components that are a part of in-scope systems may be excluded from the scope if they do not support the system's intended functions.

— *Structure or component based approach.* In this approach, the scope of structures and components is set individually if they meet the criteria. A precondition for this method is a high level of assurance that the master list of structures and components is complete. The structure or component is individually identified in the master list as a functional location or as (physical) equipment. While they may be reviewed in conjunction with other items in a given system, inclusion of a structure or component is based solely on the structure or component itself, not on the system in which they are located. The scope setting methodology may include additional details on the review of individual structures and components.

The plant's scope setting methodology specifies the order in which SSCs are assessed against criteria A to C. Criterion A is used first for scope setting for SSCs and is typically followed by criterion C and criterion B.

In general, experience with scope setting has shown that conducting reviews of mechanical components first is efficient in that criteria A to C can be most readily interpreted for mechanical components. Electrical, I&C and civil structures and components can then be partially reviewed on the basis of their association with in-scope mechanical components as well as their own intended function.

For mechanical components, the use of marked-up P&IDs, in combination with the recording of the components in a scoping database, is a typical approach. Marking up P&IDs with different colours related to the different scoping criteria and subcriteria can be useful for the following reasons:

— In combination with the overall reporting and the established ageing management database, it can support the completeness of the scope setting process. Mechanical scope setting determines the core of the overall process, as this will support scope setting in other technical areas.
— It supports the identification of structures and components not important to safety that could adversely affect the ability of a component important to safety for each failure identified.
— It supports scope setting in a practical way for discussion of in-scope structures and components.
— It supports the boundary definition at site level for shared systems, as well as at the system and subsystem levels for definition of the criterion.
— It supports interaction with other technical areas such as scope setting for I&C equipment (e.g. measure devices for pressure, temperature, flow and instrumentation tubing).
— It supports the management of the interaction between mechanical systems or between the portions of systems in the scope and out of the scope.

3.2.5.1. System based approach

The main steps of the system based approach are listed below, together with some important characteristics of each step:

(1) Identify systems in the scope and out of the scope for criteria A and C.
(2) Collect data and review documentation, as described in the previous sections.
(3) Define a freeze date (the date after which modifications to the NPP are not considered for scope setting).
(4) List the intended functions of the in-scope systems — report the reason for being in the scope for the different scoping criteria (e.g. criterion A).
(5) Define the evaluation boundary and marking up of the P&ID, according to the agreed colour scheme for criteria A and C systems:
   - The portions of the systems in the scope for criteria A and C are marked up.
   - If possible, identify the outside perimeter of the areas containing the portions of systems in the scope for criteria A and C, which coincide with specific building structures or rooms within buildings, and mark up this perimeter as a boundary on the P&IDs of the criteria A and C systems.
   - Structures and components in the system that do not support criteria A or C functions of the system can be marked as being out of the scope. These structures and components are considered for criterion B.
(6) Consider structures and components not in criteria A and C systems and identify the structures and components that meet criterion A or C — marking up the drawings for A and C structures and components not in A or C systems.
(7) Consider structures and components not previously identified as in the scope for criterion A or C, using criterion B:
   - Plant walkdowns or existing documentation can be used to clearly identify the structures and components in the scope for criterion B (see Section 3.2.6);
   - Mark up the drawings for criterion B structures and components;
   - Structures and components in the system that do not support criterion B can be marked out of the scope.
(8) Establish the list of structures and components in the scope for LTO for mechanical systems, assigning the applicable scoping criteria to each structure or component and the intended functions of each structure or component in the scope.
(9) Maintain the scoping database (creating the scoping master list of mechanical systems and components in the scope). The data in the scoping

database can identify which structures and components are in the scope, for example owing to an active function or the type of actuation, to master the consistency with the electrical and I&C systems and components in the scope.

(10) Update the scoping database to reflect modifications of the NPP after the freeze date. This can be done either periodically or continuously as part of a modification management process.

The approach to identifying structures and components in the scope for criterion B can vary among Member States. Some Member States conservatively consider that all structures and components not in the scope for criterion A or C will meet criterion B if they are located in the same room or building in which a structure or component important to safety is located. In a more refined approach, the consideration of spatial interactions is confirmed by plant walkdowns. This method allows the distance (either physical or functional) between the in-scope structure or component for criterion A and the component under consideration to be accurately assessed. In this case, a justification is provided to demonstrate that spatial interactions between the structure or component under consideration will not adversely affect the function of a criterion A structure or component.

For criterion C, the scope setting methodology is influenced by the requirements of the regulatory body. To correctly identify all structures and components applicable to events defined by the regulator, the following actions can be considered:

— Identify and perform analyses related to in-scope events, hazards and conditions, in order to determine which SSCs are required to effectively respond to hazards or to mitigate them. This may include both deterministic and probabilistic analyses.
— Consider, in the case of multi-unit sites, the effects of the presence of multiple units on the ability of the site to respond.
— Use probabilistic safety assessments for placing SSCs in or out of the scope for criterion C. Existing probabilistic safety assessments may be examined and components significantly contributing to risk be identified. These components may be added to the scope.

For electrical and I&C SSCs, the scope setting approach can include the following steps:

— Identify and list the component types for setting the scope of the components. The component types can be the basis for commodity grouping and the AMR.

- Collect data. Review the documentation used, as described in previous sections.
- Define a freeze date (the date after which modifications to the NPP are not considered for the scope setting).
- List electrical and I&C SSCs in and out of the scope based on their own intended functions and on their connection with mechanical components.
- List electrical and I&C SSCs out of the scope.
- Set electrical and I&C components in the scope according to the listed component types.
- Apply a commodity grouping, or critical part based, approach for the components in the scope.
- Verify the completeness of the list of component types and commodity groups. To this end, electrical and I&C schematics can be used to illustrate the typical interconnections of electrical and I&C components. Such typical schematics can be associated with air operated valves and registers, motor operated valves, logic contacts of switches (e.g. level, temperature, pressure), and pumps, fans, compressors and heaters. These schematics can be used to check the database of in-scope SSCs.
- Maintain the scoping database (create the scoping master list of in-scope electrical and I&C components).
- Update the scoping database to reflect modifications of the NPP after the freeze date. This can be done either periodically or continuously as part of a modification management process.

A similar approach can be applied to civil structures and components.

To ensure completeness of the scoping process, consideration needs to be given to include the SSCs which support the intended function of an in-scope structure or component. For the example of an in-scope active pump, consideration is needed to include the motor, wiring and control systems in the scope to support the active function.

It is possible to exclude some portions of an in-scope structure or component if this portion does not support the intended function of the structure or component. For the example of an in-scope pump included owing to passive function only, solely those portions that support the passive function need to be included in the scope. Some SSCs that meet criterion A, B or C can be excluded from the scope, as described in Section 3.2.7.

3.2.5.2. Structure or component based approach

The scope setting methodology for the structure or component based approach provides a detailed series of steps to ensure that all in-scope structures and components are appropriately identified. Using a complete master list of structures and components, each structure or component is evaluated solely on the basis of the characteristics of the structure or component — not on the system in which it is located — to determine whether it meets the criteria to be in the scope.

3.2.6. Walkdowns to ensure completeness

The objective of this section is to clarify the application of para. 5.19 of SSG-48 [3] during the scope setting for SSCs. During the systematic scope setting process, P&IDs and other sources, such as deterministic or probabilistic hazard analyses included in safety related reports (see Section 2.3), are typically used for the identification of SSCs to be included in the scope of the LTO assessment. Sometimes these sources do not include all the information necessary for the scope setting process. In such cases, dedicated walkdowns may be required to identify additional structures and components and to ensure the completeness of the scope.

It may be impractical to determine the spatial and functional interactions of SSCs solely based on plant documentation. In that case, a walkdown is typically conducted to decide whether scoping criteria B and C in para. 5.16 of SSG-48 [3] are met. Walkdowns are used for the following purposes:

- To improve the understanding of the geometry, size and location of structures and components and their subcomponents, since documentation might not be sufficient;
- To identify structures and components that are not properly documented in the documentation used for the scope setting process, but are included in the scope according to the criteria in para. 5.16 of SSG-48 [3];
- To verify that the breakdown of structures and components and corresponding commodity grouping has been done correctly;
- To determine whether there are other SSCs whose failure may prevent criterion A SSCs from fulfilling their intended functions according to criterion B in para. 5.16 of SSG-48 [3], based on spatial and functional interactions;
- To identify other SSCs considered as mitigative or protective items for criterion A SSCs (see criterion B in Section 3.1);
- To complement information used in safety analyses which are typically required by national regulations, based on criterion C in para. 5.16 of SSG-48 [3].

The methodology for the walkdowns can be developed on the basis of operating experience, probabilistic safety assessments and internationally applied practices for certain types of event. They can be conducted for a room or system, depending on the purpose of the walkdown and whether spatial or functional interactions (including mitigative or protective functions) are assessed.

Walkdowns are normally conducted by a multidisciplinary group of experts from different departments (operation, maintenance, technical support and projects) to avail of broad expertise. Because the identification of criterion B components might rely heavily on the judgement and experience of the group members, the methodology and criteria used for walkdowns are established in advance. In some cases, further evaluation is needed. This might include the review of P&IDs and specifications to confirm materials, load and flooding paths, anchorage types and medium to enhance the decisions made for individual SSCs.

Drawings and photographs are usually provided in the documentation of walkdowns to capture the essential features of each item reviewed. Such documented judgement is normally needed because it is important that the reasons to include or exclude a certain structure or component in the LTO scope are described. The documentation can even contain the list of items under evaluation and the result.

The identification of spatial interaction between SSCs is not limited to seismic events but involves aspects included in criterion B in para. 5.16 of SSG-48 [3], such as missile impact from rotating machines, failures of lifting equipment, flooding, high energy line break and leakage of liquids. A seismic assessment with the use of seismic margin walkdowns is a typical case where spatial interaction is considered. This type of walkdown is used to identify structures and components which are more potentially vulnerable to earthquake loading, and are therefore considered not to be criterion A structures, and components affecting criterion A structures and components. In general, seismic walkdowns focus on the seismic ruggedness of the component itself, the component anchorage, mounting of internal devices, and potential interaction concerns with other adjacent spatial systems. The aim is to identify structures and components whose structural failure may have an impact on criterion A structures or components and prevent them from fulfilling their intended safety functions owing to seismic interactions.

Indirect effects are usually considered in walkdowns where seismic interactions are assessed, and these are normally based on the following postulated pipe failure induced conditions, which are part of criterion B in para. 5.16 of SSG-48 [3]:

— Flooding;
— Water spray;

— Pipe whip;
— Jet impingement;
— High environmental temperatures (e.g. steam line break).

Flooding and water spray are usually evaluated using a PSA for internal flooding developed to quantify the impact (the base information used to screen the various technical areas before any detail screening is performed). This information is used to identify the impact of postulated flooding scenarios. The remaining conditions are analysed using previous high energy and moderate energy postulated break hazard analyses. The indirect effects to be considered can include the following:

— Failures that may disable a single train or system;
— Failures that may disable multiple trains or systems;
— Failures that may cause an initiating event such as a reactor trip or a loss of coolant accident;
— Failures that may cause any combination above.

The indirect effects are usually evaluated both without operator action and with operator action to mitigate the consequences of a piping failure. The consequences without operator action assume that the operators take no action with respect to isolating the piping failure. The consequences with operator action assume perfect operators (no human error probabilities are included) with respect to isolating the piping failure. Furthermore, operator actions are only included if the action can be taken from the control room, with sufficient indication to alert the operators and sufficient time to respond. The case with operator action is only valid for flooding and steam release effects, as these are the only effects that last for a sufficiently long period of time.

Possible actions that are normally considered during walkdowns are the following:

— Assume that breaks may occur at points along the high energy piping runs.
— For each high energy pipeline that has the potential to whip or cause jet impingement as a result of a postulated break, look for the following types of protection in the areas that could be impacted by these effects:
  • Separation distances between required systems and components and piping that are used to mitigate potential core damage effects;
  • Provision of piping enclosures (e.g. sleeves);
  • Provision of component enclosures (e.g. walls, cubicles);
  • Provision of system redundant design features (such as isolation valves);

    - Design of required systems and components to withstand the effects of the postulated pipe rupture;
    - Provision of additional protection such as restraints and barriers.
- For high energy piping that has the potential to whip following a postulated break, the following points should be considered:
    - The portions of piping that form a hinge will not become missiles.
    - A whipping pipe that has the potential to impact other piping will not rupture lines of equal or greater size. However, it is assumed that a through wall crack will develop in a line that is impacted by a whipping pipe of the same size.
- The evaluation of fluid jets emanating from postulated breaks on nearby SSCs considers the effects of jet loading, fluid temperature and moisture on the targets impinged upon. The jet shape and direction are established using the schematics of jets discharging from various pipe breaks. In some Member States, targets more than ten pipe diameters away from the break location may not need to be considered for jet impingement impacts.

In some Member States, the structure or component that has been identified as vulnerable is managed by elimination of the risk. This can be done by strengthening the anchoring or changing the design. If the risk cannot be eliminated, seismic requirements can be applied to this vulnerable structure or component, and it can be included in the plant classification list of SSCs that are important to safety and need to be included in the LTO assessment. This includes strengthened anchoring since it can be subject to ageing.

A similar process can be applied to other walkdowns, not related to seismic requirements, where the plant can choose either to eliminate the risk or include the vulnerable structure or component identified in the scope of the LTO. In some cases, a plant can choose not to use preventive options on a system. In that case, the consequences are managed using mitigative solutions when the problem occurs. Those mitigative options can also include SSCs not important to safety. Consequently, those SSCs need to be integrated into the scope for criterion B. These SSCs can be part of piping system analysis, structural analysis or civil structures with links to electrical components and I&C if the selected SSCs have to be operable (active). The scope of the linked item can therefore be based on the methodology described in Section 3.2.5.

3.2.7. Structures, systems and components excluded from the scope

This section clarifies the interpretation and application of para. 5.17 of SSG-48 [3], which defines the conditions for SSCs to be excluded from the scope of ageing management or LTO. By following the scope setting process, the list of SSCs that are in the scope for ageing management and LTO assessment is determined. All other SSCs (or their subcomponents) which do not meet the criteria for scope setting in para. 5.16 of SSG-48 [3] and are not required by national regulatory requirements may be excluded. This decision is usually justified and documented in compliance with the scheme presented in figure 3 of SSG-48 [3], but may be reanalysed if, for example, operating experience indicates the need for reconsideration.

Certain components (or their parts) that are part of a system or structure that is in the scope may be excluded from the scope of the AMR. These components include those that are subject to documented periodic replacement or to a scheduled refurbishment plan based on predefined rules, for example an environmental qualification or manufacturer's recommendation, planned within the term of the licence, if the risk of ageing and inability to fulfil its safety related function is eliminated. This can be generalized for all short lived components and consumables (e.g. seals, gaskets, filter elements) which are not considered in the AMR, since they are replaced before ageing can occur. Replacement programmes may be based on vendor recommendations, operating experience, maintenance strategy or other means that establish a specific service life, qualified life or replacement frequency. If the replacement strategy is changed and a particular component is not replaced based on an environmental qualification or specified time period, it is included in the scope of the AMR.

Components subject to replacement on the basis of condition monitoring are not excluded from the scope. In some Member States, periodic replacement or refurbishment is not used as the justification for exclusion from the scope of ageing management and LTO assessment, since it is considered part of ageing management activities.

3.3. CONSISTENCY CHECK

The scope setting methodology can include a requirement to perform a consistency check of the results. This check is to ensure that various team members interpret and apply the guidance in the scope setting methodology in the same manner and that the conclusions of the reviewers in various areas (i.e. mechanical, electrical, I&C and civil structures) are consistent at points where the various areas interface (e.g. at pump motors). This approach ensures that cross-checking between different technical areas is performed and that all SSCs have been assessed during the scope setting process. The subject of the interaction of the reviews in various areas is addressed in Sections 3.2.1–3.2.7. The methodology could include similar references. The documentation of the scope setting methodology and results is described in Section 6.5.

3.4. COMMODITY GROUPS

This section focuses on the interpretation and application of para. 5.20 of SSG-48 [3]. Structures and components within the scope of ageing management and LTO assessment can be grouped into structure or component commodity groups. These are groups of components with similar functions, materials and environment. The criteria for grouping can be different for different types of structure and component. Structures and components within the same commodity group have the same ageing effects and degradation mechanisms and are subjected to the same ageing management activities. The main purpose of commodity groups is to maximize work efficiency during the AMR and to link identified ageing effects and degradation mechanisms with appropriate ageing management activities. The use of commodity groups also allows condition assessment for each group. In practical terms, this results in the possibility of issuing one AMR for a specific commodity group instead of handling each in-scope structure or component individually.

Groups of structures and components which do not fulfil the objective mentioned above are usually broken down into smaller groups. For example, a group of pipelines made of both carbon steel and stainless steel and operated in treated water are usually divided into two commodity groups because different potential degradation mechanisms are postulated for carbon steel and stainless steel.

Different approaches can be applied for an AMR with regard to the use of commodity groups:

- *Commodity group based approach*. Structures and components are grouped for an AMR on the basis of similar characteristics.
- *Structure or component based approach*. The AMR is performed for each structure or component individually (e.g. pressurizer).
- *Subcomponent based approach*. For major, complex structures and components (e.g. reactor pressure vessel, containment) the AMR is performed for defined subcomponents.

In some Member States, passive and active components are grouped differently. Therefore, components that have both an active and a passive function are typically assigned to a commodity group for the passive function as well as to a commodity group for the active function. The criteria for assignment of in-scope structures and components to commodity groups for the passive function and the active function, respectively, can also differ among Member States.

For structures and components with a passive function, the typical criteria for commodity grouping are the following:

- Type of structure or component (e.g. valve body, pump casing, tank, concrete bases, cables);
- Material of structure or component;
- Working environment (internal or external).

For components with an active function, the typical criteria for commodity grouping are the following:

- Type of component (e.g. motors, moving parts of pumps or valves);
- Intended function of component;
- Mode of operation (i.e. continuous, intermittent or standby).

Examples of commodity grouping for different technical areas are presented in Annex IV.

4. REVIEW AND IMPROVEMENT OF PLANT PROGRAMMES

4.1. GENERAL INFORMATION FOR REVIEW OF PLANT PROGRAMMES

This section examines the application of SSG-48 [3] with regard to the following:

- Paragraphs 4.16–4.53, addressing plant programmes essential to ageing management and evaluations for LTO;
- Paragraphs 7.26 and 7.27, addressing the review of plant programmes and AMPs for LTO.

It does not address the application of paras 5.54–5.63 of SSG-48 [3] on the review and improvement of AMPs, which is described in the Safety Report on IGALL [20] along with AMR and revalidation of TLAAs.

An AMP covers the systematic arrangements which are aimed at the consideration of ageing management measures, specifically engineering, operations and maintenance actions, to control the ageing degradation of SSCs within acceptable limits.

The AMR process (see figure 4 of SSG-48 [3]), including an assessment of the actual condition of structures and components, leads to the identification or the review of relevant (actual and potential) ageing effects and degradation mechanisms for each in-scope structure or component and of the programmes to manage them. These programmes can be of a different nature as long as they are consistent with the nine attributes presented in table 2 of SSG-48 [3]. Examples of programmes are the following:

— IGALL based AMPs, either fleet-wide or NPP specific;
— Plant specific AMPs;
— Plant specific maintenance strategies and programmes, including active components;
— Activities resulting from revalidation of TLAAs;
— Activities for preserving the equipment qualification of structures and components in the scope;
— Plant specific programmes and procedures.

Finally, the AMR results in the following:

— Confirmation that current activities are effective for ageing management;
— Enhancement of current activities to make them more effective;
— Definition of new activities in line with the referenced programmes.

These ageing management activities can be specific to the SSC or commodity group and are typically included in the following plant programmes:

— Maintenance programmes;
— Equipment qualification programmes;
— ISI programmes;
— Surveillance programmes;
— Water chemistry programmes.

Initially, in most of the plants, the key objectives of these plant programmes were not formally associated with ageing management. By establishing an ageing management process supported by an appropriate CAP (see Section 5), the capability of these plant programmes to manage ageing, especially for long lived passive components, and their effectiveness can be continuously verified and improved. This process can be represented by the 'plan–do–check–act' cycle (figure 1 of SSG-48 [3]). It is a recommended practice to check the application of this process for the listed plant programmes and to assess their consistency with the nine generic attributes presented in table 2 of SSG-48 [3]. In this context, the term ‘plant programme’ refers to an overall programme, such as the overall maintenance programme that covers the systematic maintenance arrangements, processes and activities for ageing management.

The links between the AMPs and the actual plant programme activities need to be clearly identified, including the frequency of activities and information on the tasks and confirmation processes. The programme documentation provides technical references to support the findings and conclusions.

Close cooperation among personnel responsible for design, implementation and evaluation of the existing plant programmes and ageing management is essential to coordinate the requirements from each programme to prevent conflicts and duplication and to facilitate continuous improvement.

A systematic review of the existing plant programmes ensures that all required activities related to the ageing management of in-scope SSCs are correctly implemented and effective. Information on documentation of this review is provided in Section 6.3.

The following description of the nine generic attributes (see table 2 of SSG-48 [3]) that can be used as a framework for evaluation may be applied to any plant programme that is applied in ageing management and LTO:

(1) *Scope.* The scope of existing plant programmes may be very different from the scope as required in the AMP. The focus of existing plant programmes is generally not only on nuclear safety but may also take many other aspects into account, such as availability, environmental aspects, insurance and economic aspects. A review of this attribute covers the following:
    — SSCs in and out of the scope for ageing management;
    — Prioritization of SSCs to enable a graded approach;
    — Programme essential elements credited for managing ageing effects;
    — Interaction with ageing management processes.
(2) *Preventive actions.* Preventive actions as part of existing plant programmes may already be embedded in the programmes themselves. It is important to have a clear definition of these activities in order to be able to credit them for the prevention of degradation mechanisms. A review of this attribute includes the following:
    — Strategy and policy for preventive approach;
    — Basis, origin and assumptions made for defining preventive activities within the programme;
    — Application of specific methodologies for preventing degradation.
(3) *Detection of ageing effects.* If an existing plant programme contains activities that can be used to detect ageing effects, it is important to clearly specify the

parameters to be monitored or inspected. This includes defining effective technology used for performing these detection activities and recognizing the limits and sensitivity of the technique to ensure that ageing effects will be detected before the failure of an SSC.

(4) *Monitoring and trending.* Monitoring and trending of data from plant programmes are particularly important for ageing management. While existing plant programmes may perform monitoring and inspection activities, the results of these activities may only be intended to be used as confirmation of the current status of the plant. Trending activities may already be part of the existing plant programme but are not used for ageing management purposes. It is important for these parameters to be recognized as ageing relevant and to be trended. Storage and accessibility of the data used for trending is commonly regarded from a long term perspective. A review of this attribute includes the following:
   — Strategy and approach for monitoring and trending, including data analysis and storage;
   — Application of specific methodologies;
   — Interaction with other assessments, such as health reporting and PSR.

(5) *Mitigation.* Mitigating activities may be temporary or permanent to respond to deviations detected by plant programmes. A clear definition is important to assess whether these activities address the monitored ageing effects, including clear links between the activity, the ageing phenomena intended to be mitigated and the expected results. The review focuses on the applicability of these activities in the programme and their effectiveness. A review of this attribute includes the following:
   — Temporary modification or adaptation of the operating conditions of the plant (e.g. power reduction);
   — Temporary modifications installed in the plant (e.g. shielding, additional monitoring systems).

(6) *Acceptance criteria.* Acceptance criteria for potential anomalies or deviations are important to confirm the capability of an SSC to perform its intended function or functions. If deviations are confirmed as being acceptable, it is recommended to define the appropriate follow-up actions with regard to trending, monitoring and mitigation activities consistent with the objectives of the AMP. If deviations are confirmed as being unacceptable, other actions, including corrective actions, may be required.

(7) *Corrective actions.* In the review of corrective actions in plant programmes, it is important that the actions be clearly defined to determine if they are compatible with the requirements of ageing management. As an example, it may be customary for a maintenance department to perform a one by one

replacement activity, while in the course of the AMP it was established that a design update would be more effective in the long term.

(8) *Operating experience feedback and feedback of R&D results.* This feedback is essential for effective ageing management. The plant usually has a generic programme for the feedback of internal and external operating experience and the results of R&D. The plant can also rely on the CAP as part of the operating experience feedback. The CAP may be generally used for existing programmes and ageing management. Synergy may be obtained when specific activities conducted by experts responsible for the plant programme can be combined with the requirements for ageing management. Recommendations on the overall management of operating experience are provided in IAEA Safety Standards Series No. SSG-50, Operating Experience Feedback for Nuclear Installations [26]. A review of this attribute includes the following:
    - — Exchange of experience within a given organization or entity;
    - — Exchange of operational experience between different entities;
    - — Collection of national and international operating experience.

(9) *Quality management.* Review of the quality management attribute for specific plant programmes commonly includes specific quality aspects that would need to be in place, such as quality requirements for dedicated procedures, measurement activities, instrumentation to be used, as well as personnel conducting the activity. It would not be sufficient to refer only to generic requirements for the plant management system.

Performance indicators that are dedicated to the individual plant programmes may also be used to facilitate evaluation and improvement of the programme. Plant programmes may be used in ageing management, provided they fulfil the requirements of an effective AMP. The Safety Report on IGALL [20] provides several examples of plant programmes as AMPs, which can be used as relevant information.

Ageing management of SSCs needs to provide sufficient assurance that both active and passive SSCs are capable of fulfilling their intended functions. For passive (i.e. long lived) SSCs, typically the intended functions can be preserved by the implementation of AMPs for the specific SSCs and specific degradation mechanisms. The implementation of these AMPs typically includes the definition of activities to enhance the effectiveness of current plant programmes for the ageing management of passive structures and components.

In some Member States, ageing management for active components is based on the application of IGALL practices, where the same AMP approach is applied as for passive components. The approach used to establish an ageing management strategy for active components, specifically the use and integration of AMPs in maintenance, ISI, testing and surveillance activities, can depend on national regulatory requirements. In some Member States, the reliability of active components is addressed by current requirements in the maintenance regulations for LTO, which provide a performance based approach to ensure component reliability and include maintenance, testing and surveillance activities. It could be recommended to check the compliance of these activities with the IGALL AMPs for active components, keeping in mind their relevant characteristics for ageing management, in order to verify or enhance the overall effectiveness of the plant programmes for ageing management.

The above paragraphs refer to the nine generic attributes of effective AMPs, which are applicable to plant programmes in general. In the following sections, a more detailed description is provided of how these attributes are addressed for the five plant programmes essential to ageing management and LTO.

Annex II provides examples of approaches to the review and improvement of plant programmes relevant to ageing management and LTO in Member States.

4.2. MAINTENANCE PROGRAMME

Maintenance programmes sustain the intended functions of SSCs. The type and frequency of maintenance activities applied to each SSC are commensurate with the SSC's importance to safety, design function and required performance. Maintenance programme activities are derived from design or reliability requirements (e.g. reliability centred maintenance), codes and standards, and operating experience and are performed on the basis of service time, actual condition or predicted condition. Typical maintenance strategies are as follows:

— *Preventive maintenance.* Actions that detect, preclude or mitigate degradation of a functional SSC to sustain or extend its service life by controlling degradation and failures to an acceptable level. Specific types of preventive maintenance programme include the following:
  - *Periodic maintenance.* Consists of servicing, parts replacement, surveillance or testing at predetermined intervals of calendar time, operating time or number of cycles.
  - *Planned maintenance.* Consists of refurbishment or replacement that is scheduled and performed prior to unacceptable degradation of an SSC.
  - *Predictive maintenance.* Is performed continuously or at intervals governed by observed condition to monitor, diagnose or trend an SSC condition indicator. Results indicate current and future functional ability or the nature of, and schedule for, planned maintenance.

— *Corrective maintenance.* Actions that restore — by repair, overhaul or replacement — the capability of a failed or degraded SSC to function within acceptance criteria. Performance of corrective maintenance may be necessitated by an unforeseen failure of components in a preventive maintenance programme. Corrective maintenance may even be chosen as maintenance concept (run to failure) for components where failure would result in a very low risk for nuclear safety.

Maintenance activities are commonly conducted in accordance with maintenance descriptions. The latter may describe and justify any decisions made regarding the selection of SSCs in the scope of the programme, functions to be maintained, maintenance strategy to be followed, and frequency of maintenance activities making up the maintenance programme.

For a maintenance programme that is intended to be credited in the AMP, it is important to understand its consistency with the nine attributes of an effective plant programme. To review this consistency, the following approach is typically used. In some cases, one or more attributes might not apply to a given type of maintenance programme. For example, preventive actions would typically not be addressed by a corrective maintenance programme.

4.2.1. Scope

The scope of the maintenance programme needs to be reviewed to ensure that it includes all SSCs within the scope of ageing management and LTO. A verification is also required of whether the programme covers the relevant ageing effects and degradation mechanisms and susceptible locations.

Reliability centred maintenance is a commonly used approach for systematic preventive maintenance to avoid potential failures or to control the failure modes of structures and components important to safety. It utilizes a decision tree to identify the maintenance requirements for SSCs in the scope of the programme according to the safety and operational consequences of each failure and the degradation mechanism responsible for the failures.

The relation between the activities of a maintenance programme and ageing management may be clearly specified by tagging the ageing management related activity in the maintenance management system. Tagging can be done, for example, in the work order, written down in procedures or in the instructions. If properly implemented, the programme provides the technical basis that demonstrates whether proposed maintenance activities in the AMP will be adequately managed.

Structures and components subject to planned or periodic maintenance, involving replacement or refurbishment based on a qualified life or specified time period, may have been removed from the scope of an AMR, as described in Section 3.4.

4.2.2. Preventive actions

The majority of maintenance activities are traditionally preventive. The maintenance programme is reviewed to ensure that specific preventive maintenance actions are appropriate to minimize and control ageing effects where credited for ageing management or LTO.

SSCs important to safety are to be maintained using a preventive maintenance strategy. Depending on their failure mode, preventive maintenance may consist of the following:

- Periodic replacement;
- Time based maintenance, where maintenance is conducted following a period of use expressed in units such as time, operating hours or cycles;
- Condition based maintenance, where maintenance is initiated after measurements that show that the condition of a technical system follows a trend that implies that it falls outside the norm or will do so soon.

4.2.3. Detection of ageing effects

Predictive and condition based maintenance (e.g. using thermography and vibration analysis, which provides early detection of degradation prior to failure of the SSC), is now an integral part of maintenance programmes. It is also reviewed to ensure detection, and subsequent monitoring and trending, of ageing effects, including specification of parameters to be monitored or inspected, condition indicators, data to be collected and methods for predictions or assessments.

4.2.4. Monitoring and trending

Maintenance trending generates a range of reports on malfunctions, mean time between failures and mean time to repair, which may be used on a regular basis to evaluate failure behaviour of components. Furthermore, it is important to register and evaluate unusual events or findings with regard to preventive maintenance to be able to identify initial symptoms, failure mechanisms with common cause, design flaws or any plant deficiencies, thereby being able to improve the preventive maintenance programme.

The effectiveness of the maintenance programme is improved by continuous monitoring of the performance indicators, failure analysis and reliability data, and the implementation of the related action plans. Specific performance indicators can be established to analyse the effectiveness of the programme. Such indicators can include, for example, the following:

- — Corrective maintenance backlog.
- — Deficient maintenance backlog, which includes any work on a component with a potential or actual deficiency that does not threaten the component's design function or performance criteria. A backlog in this type of maintenance may provide an indication of a lack of prescribed maintenance tasks.
- — Deferral of preventive maintenance tasks.
- — Trends observed from testing the performance of a safety system.
- — Preventive maintenance completion ratio.

Risk and reliability analyses can also be included. These analyses can provide information on the following items:

- — Changes in the list of systems important to safety or their reliability targets;
- — Overall performance of structures and components, including statistical summary of performance;
- — Changes having major impact on reliability models;
- — Major update of reliability or unavailability models for structures and components;
- — Number of initiating events;
- — Major changes in failure modes or failure rates;
- — Action plans and implementation status for improving the reliability of structures and components.

The effectiveness of the maintenance programmes can be further improved by integrating results from benchmark analyses from similar plants.

4.2.5. Mitigation

The maintenance programme is typically reviewed for operation and maintenance actions to mitigate ageing effects and degradation of the SSCs. Mitigating activities in a maintenance programme typically include the recommendations that result from predictive maintenance activities.

4.2.6. Acceptance criteria

Acceptance criteria in a maintenance programme typically indicate levels of degradation at which repair or replacement activities are to be initiated as corrective actions. The maintenance programme is typically reviewed to ensure that it identifies acceptance criteria against which the need for corrective actions is evaluated.

4.2.7. Corrective actions

Where the performance or condition of an SSC does not allow it to fulfil its intended function or functions, or does not meet the acceptance criteria, a corrective action is described in the maintenance programme. To ensure a proactive ageing management strategy, the review of the maintenance programme establishes the priority to ensure that the volume of corrective maintenance tasks remains low, so that important preventive maintenance programmes can be conducted and system redundancy maintained.

After corrective maintenance of SSCs that need to be maintained preventively, it is often recommended that a report is prepared, indicating the faulty component, the nature of the defect, the repair measure, the time to repair, the total duration of the outage, and the condition of the system or structure after the corrective maintenance activities. These failure analysis reports may be reviewed on a regular basis to identify any new or repetitive failures. Upon identification of these potential deficiencies, the preventive maintenance programme may be modified accordingly.

4.2.8. Operating experience feedback and feedback of R&D results

The review of the maintenance programme confirms that mechanisms are in place that ensure timely feedback of operating experience and R&D results, and provides objective evidence that the operating experience and R&D results are considered in the programme. The results of all maintenance activities are fed back through an optimization process that enables continuous improvement of the programme.

4.2.9. Quality management

Examples of quality management requirements for the maintenance programme include requirements with regard to the following:

- Administrative controls that document the implementation of the programme and actions taken;
- The confirmation (or verification) process for ensuring that preventive actions are adequate and appropriate, that all corrective actions have been

completed and are effective, and that record keeping practices have been followed.

4.3. EQUIPMENT QUALIFICATION PROGRAMME

In this publication, 'environmental qualification' means the part of equipment qualification that focuses on temperature, pressure, humidity, contact with chemicals, radiation exposure, meteorological conditions, submergence and ageing mechanisms as conditions that could affect the proper functioning of the equipment. Environmental qualification establishes that SSCs, while subject to environmental conditions, are capable of performing their intended safety functions during the required mission time under postulated service conditions. The qualification of SSCs is established considering normal environmental conditions (e.g. dose rates, temperature, humidity) as well as the service environmental conditions resulting from design basis accidents or, if applicable, from design extension conditions. Harsh service environmental conditions typically include the resulting environment during and after a loss of coolant accident and high energy line breaks.

A review of the equipment qualification programme is performed to demonstrate that the environmental qualification of equipment will remain valid over the intended period of operation. The demonstration supports the technical justification that the material degradation mechanisms and ageing effects will be managed effectively, or that the equipment will be replaced or repaired so that its intended safety functions will not be compromised during the planned period of LTO. To review the equipment qualification programme for consistency with the nine attributes of an effective plant programme, the following approach is typically used.

4.3.1. Scope

The scope of the programme is reviewed to ensure that it includes all SSCs within the scope of ageing management and LTO that are managed by the equipment qualification programme. Reviewers verify that the programme covers the relevant ageing degradation mechanisms at the susceptible locations.

The master list of qualified equipment is established based on the plant's exhaustive list of SSCs. This master list gives an overview of all SSCs required to perform an intended safety function. The list of qualified equipment includes mechanical, electrical, I&C, and civil structures and components. Based on the intended functions of the SSCs, the qualification requirements are also indicated. The master list can be managed using a specific equipment qualification master database or hard copies of the lists and can be confirmed by the plant's employees. The equipment qualification master list typically contains the following information:

- Identification of the SSC;
- Technical area of the SSC (i.e. mechanical, electrical, I&C or civil);
- Required qualification (including intended function, postulated initiating events, mission time, targeted qualified life);
- Reference installed qualified equipment and its qualification documentation.

4.3.2. Preventive actions

Preventive actions and periodic inspections to guarantee the SSC's level of qualification are generally embedded in the maintenance programmes. Preventive actions, such as service conditions (i.e. environmental conditions and operating conditions) to be maintained and operating practices aimed at precluding potential degradation of the structure or component, are verified [27].

4.3.3. Detection of ageing effects

In addition to environmental monitoring, condition monitoring can be implemented as a means of detecting ageing effects. Condition monitoring assesses variables that indicate the physical state of the equipment as well as its ability to perform its intended functions or functions during the period of observation. Condition monitoring can include activities such as the following:

- Visual inspection of the physical state of SSCs;
- Functional testing of SSCs;
- Testing of surveillance specimens (e.g. cable deposits);
- Verification that the installed SSCs correspond to the equipment described in the qualification documentation.

4.3.4. Monitoring and trending

Monitoring of the environmental conditions to which the SSCs are exposed is an important input for retaining the equipment qualification and is reviewed for LTO. In many Member States, specific surveillance programmes are established to follow up the evolution of the environmental stressors. These programmes verify compliance of the environmental conditions with the original design parameters (e.g. dose rate, integrated dose, maximum environmental temperature) as marked in the design specifications. The results are used to update the calculation of the qualified life of the concerned SSCs.

Typically, areas with higher values of temperature and radiation (‘hot spots’) are identified in NPPs. Degradation of SSCs is monitored on a regular basis and the qualified life is verified, if needed. The location of hot spots and their characteristics are stored in accordance with applicable guidelines.

The effectiveness of the equipment qualification programme can be ensured and further improved by continuous monitoring and trending of the indicators related to the implemented action plans. These indicators can involve the tracking of the following activities:

— Implementation of the preventive actions (e.g. actions to be performed to retain qualification).
— Analysis and implementation of significant operating experience feedback.
— Implementation of the CAP. All activities related to qualified equipment, implemented in the course of its life, are documented and archived. Specific actions can be implemented in order to verify consistency. These actions can include the following:
    - Verification that the installed equipment corresponds to the equipment described in the qualification documentation;
    - Checking of the availability and completeness of the qualification documentation;
    - Review of the qualification documentation concerning mandatory inspections, tests and surveillances.

4.3.5. Mitigation

Mitigative measures for equipment qualification may include the reduction of exposure of the relevant components to stressors that influence the qualified life. These measures could include application of radiological shielding or thermal insulation, relocation or improving the environmental conditions.

4.3.6. Acceptance criteria

Acceptance criteria, against which the need for corrective actions is evaluated, are specified. In the case of non-compliance, the ability of the SSC to perform the defined qualification requirements is assessed. Several follow-up actions may be recommended, such as increased surveillance or replacement, maintenance and inspection, or qualification extension assessment.

4.3.7. Corrective actions

For the repair of defective components or the replacement of qualified equipment, the applicable basis specifications are used. If no component that conforms to the initial qualification is available, an alternative solution can be chosen, corresponding to at least the same qualification level and subject to the change management procedures of the plant. This aspect also covers obsolescence and the availability of qualified manufacturers and products.

Corrective actions that require replacement or modification of SSCs important to safety follow the change management procedure, a process that controls the entire chain from initiation of an engineering change, design review, requalification process, installation, approval of the test results, and document control. These actions and their implementation may be managed and followed up by the CAP, which includes the following:

- — Repair and replacement actions;
- — Integration of internal and external operating experience (e.g. failure rates, maintenance findings, information from the original equipment manufacturer);
- — Actions for establishing qualification of new SSCs due to obsolescence.

4.3.8. Operating experience feedback and feedback of R&D results

The review of the equipment qualification programme ensures that mechanisms are in place for timely feedback of operating experience and R&D results, and provides objective evidence that these are considered in the programme. Aspects typically covered by operating experience and R&D results are synergies and interactions between ageing mechanisms, reassessment of ageing simulations methodologies, and dose rate aspects. Further information about sources of operating experience can be found in Ref. [20].

4.3.9. Quality management

The equipment qualification documentation is updated and maintained in an auditable and retrievable form for the entire period during which the covered item is installed in the NPP. This documentation typically covers the following items:

- — The original qualification requirements;
- — Qualification programmes and documentation;
- — Assessment results;

— Maintenance activities, test, inspections and surveillance activities, demonstration of the qualification status.

4.4. IN-SERVICE INSPECTION PROGRAMME

The ISI programme is a condition monitoring programme intended to verify the condition or to detect deterioration of structures and components within the scope. The purpose of the programme is to assess the pressure retention or structural integrity of the structures and components within the scope. For ageing management, the programme provides the technical basis that demonstrates whether ageing effects will be detected by the inspections applied or monitoring activities. For LTO, a review of the ISI programme is performed to assess whether it will remain effective for managing ageing over the expected period of LTO.

Guidelines for NPPs to conduct ageing management or perform an AMR for LTO generally consider design data, failure risk analysis, operating conditions and feedback, enabling an objective assessment of the occurrence of failure mechanisms. If possible, ageing effects or degradation mechanisms are identified (e.g. fatigue, cracking, corrosion). If a location is subject to particular attention in terms of defence in depth, additional inspections may be proposed for the ISI programme, defining its objective and frequency (e.g. nature of damage, minimum flaw dimensions and location), along with the inspection technique to be used. A review of the ISI programme, with the objective of ensuring consistency with the nine attributes of an effective plant programme, will identify how these aspects are addressed and may be used in ageing management. This may be applicable to areas subject to inspection, responsibilities, examination methods and procedures, frequency of inspection, record keeping and report requirements, procedures for evaluation of inspection results and subsequent disposition of results of evaluations, and repair or replacement activity requirements. The following approach can be used to review the programme against the nine attributes.

4.4.1. Scope

For ageing management purposes, it is important to understand how the scope of the ISI programme is defined. The scope of the ISI programme generally follows the mandatory requirements of applicable codes and standards based on safety significance and may be supplemented by non-mandatory manufacturer specifications, recommendations by the supplier, and operational, maintenance and inspection experience. The scope specifies the extent and schedule of the inspection and examination methods for the structures and components included in the ISI programme. The programme may contain inspection requirements for unique design aspects of the plant that are under consideration.

4.4.2. Preventive actions

Since ISI is a condition monitoring programme, it is not used to implement preventive actions to control ageing effects.

4.4.3. Detection of ageing effects

The extent and schedule of the programme generally include periodic visual, surface and volumetric examinations and leakage tests of all safety class 1, 2 and 3 pressure retaining components and their integral attachments, but can also include other structures and components depending on national requirements or plant specific needs. The intent is to inspect and verify the pressure retention and structural integrity of relevant structures and components, and to ensure that ageing effects are detected and addressed before loss of the intended function of the structure or component.

In addition to the structures and components in the scope and the frequency and type of inspection to be performed, the ISI programme generally includes information concerning inspection methodology, the required equipment and personnel, and qualification information, for example that the inspection methods are qualified in compliance with national standards. A plan for ISI activities is usually drawn up for a longer term, for example to perform the complete scope of inspections over a fixed period of time.

The ISI programme (procedures and instructions) commonly includes the following:

- Requirements for preparatory activities for the inspection;
- Material and documentation conditions and requirements for the inspection;
- Special aspects of the inspection of the equipment in its assembled state;
- Operating conditions applicable when carrying out a periodic test or inspection;
- Management of non-compliance;
- Requirements for qualification and documentation of the inspection.

Detailed instructions can be developed to meet specific needs. Instructions primarily define the special conditions for inspections and aspects of evaluation and documentation. Some of these instructions are specific to the NPP’s design:

— Inspections:
  - Instructions for the inspection of the reactor pressure vessel, internals (e.g. BWR, PWR), fuel channels and feeder piping (e.g. CANDU, pressurized heavy water reactor (PHWR));
  - Instructions for steam generator inspection;
  - Technical and safety inspection of pressure retaining equipment and pipelines.

— Support activities:
  - Assessment of the conditions required by the inspection, namely verification of the availability of the necessary personnel, material, and organizational and other conditions;
  - Preparatory actions and execution of inspections to be performed, including special requirements for any inspection equipment such as assembly, cabling, calibration and programming of automated equipment;
  - Execution of technical support activities (i.e. development of new inspection methods, preparation of inspection procedures for qualification, preparation of action plans for meeting the regulatory requirements, and data analysis and storage).

4.4.4. Monitoring and trending

The ISI programme specifies parameters to be monitored or inspected, condition indicators, data to be collected, and methods for trending, predicting or assessing degradation. The extent and schedule of the inspection and test techniques prescribed by the programme are reviewed for the period of LTO to ensure that ageing effects will be detected and repaired or dealt with before the loss of the intended functions of the SSC. Inspection can reveal cracking, loss of material due to corrosion, leakage of coolant, and indications of degradation due to wear or stress relaxation. Examples of issues that may be observed are changes in clearances, settings, physical displacements, lost or missing parts, debris, wear, erosion, or loss of integrity at bolted or welded connections.

The ISI programme provides guidance concerning the manner in which inspection results are reported and managed, for example in an ISI database. Such a database may consist of an information system for recording, reference planning and documentation of ISIs on the structures and components important in terms of legislative requirements and the operational safety of NPPs. It may also be used as a tool to provide oversight of the operational safety of an NPP. Some dedicated ISI databases have trending analysis capabilities.

The ISI programme may also specify documentation and registration requirements of test results. Apart from indications that are above the registration and acceptance level, other useful data and information gained from the inspection may be recorded, such as data for indications below the registration limits, and photographs and videos taken during the inspection.

The resulting documentation from the ISI programme needed for trending contains all relevant information for the unique identification of the area under inspection, methods used, procedure, evaluation and inspection results. The ISI programme, its activities and frequencies, as well as longer intervals are incorporated in a long term inspection plan. ISI results are documented in a way that enables a comparative analysis of the inspection results obtained, especially when the inspections are performed in separate areas and at different periods of time.

4.4.5. Mitigation

As a condition monitoring programme, the ISI programme is not used to implement mitigating activities. Degradation may be monitored, which in turn may initiate mitigating actions in the AMP before acceptance criteria are exceeded.

4.4.6. Acceptance criteria

The ISI programme is designed and periodically reviewed to ensure that examination results, including indications or relevant conditions of degradation, are evaluated in accordance with established acceptance criteria provided in regulations or in accepted codes and standards.

Examination results are evaluated by comparing them with the acceptance standards. SSCs with flaws or degradation that do not meet acceptance criteria may be subject to corrective actions or further evaluation of fitness for purpose.

The ISI programme may include requirements that the inspection results be evaluated by personnel with appropriate qualifications for the methodology, in accordance with the relevant evaluation and acceptance criteria. The ISI programme typically provides guidance for when and how indications are sized.

4.4.7. Corrective actions

If notable flaw conditions or relevant indications of degradation are detected while the component is still qualified as acceptable for continued service, the ISI programme may specify follow-up inspections with shorter inspection intervals. For examinations that reveal indications exceeding the acceptance criteria, the ISI programme generally expands the scope of inspection to include additional components made of similar materials and exposed to similar conditions. This type of internal operating experience is then commonly documented in an ageing analysis. Corrective actions often include the need for in-depth evaluation of the observed ageing, which may result in important measures such as repair and replacement of equipment.

4.4.8. Operating experience feedback and feedback of R&D results

The ISI programme may include specifications for feedback resulting from the inspections and their results. This enables the performance of the inspection processes to be periodically assessed and updated as necessary.

In addition to addressing feedback from internal sources, the ISI programme typically features processes for periodically assessing external operating experience. The ISI programme may also include requirements for the periodic review and, as needed, revision of the programme.

While evaluating the ISI programme for longer intervals, all individual inspections are considered. Any changes in the inspection codes and standards, operating experience and the results of R&D, such as in the area of inspection technology, that may have become available are considered for inclusion into the programme, and a schedule for inspections over the full interval to come is drawn up, as far as possible, taking account of the nature of future refuelling outages.

Changes to the ISI programme may be initiated by (i) experience from different testing disciplines; (ii) introduction of new test methods with higher testing sensitivity; (iii) application of new technologies or inspection procedures (qualification); and (iv) operating experience in other NPPs.

The latest technologies and procedures in the area of non-destructive testing may be used in the process of updating the programme in order to achieve maximum reliability of the results of ISI with regard to nuclear safety.

4.4.9. Quality management

The ISI programme identifies quality management requirements, including administrative controls that document the implementation of the programme and actions taken, the confirmation (verification) process for ensuring that necessary actions have been completed and are effective, and the record keeping practices to be followed. The records of inspections typically include the following:

- Drawings of the inspected SSC;
- Historical results of the inspection;
- Operational history of the structure or component to be inspected, such as repair or replacements, or any history of defects to be handled, with special attention during the inspection (e.g. surface damage, any damage to the corrosion protection, mechanical damage, weld defects, integrity of welds,

geometric deviations, corrosion or erosion material defects, deformations, loss of pre-tension of tendons or anchorage bolting);
— Acceptance criteria or non-acceptable defects and conditions;
— Identifiers of the inspection to be implemented;
— Conditions for, and sequence of, the inspections.

Plants periodically review their inspection qualifications as well as the regulatory qualification requirements to ensure that they are up to date and provide for timely detection of ageing effects during the period of LTO. Inspection qualification is a systematic evaluation that includes the methods that can be used to demonstrate the compliance of the inspection system (the elements of the non-destructive test that influence the quality and results of the test, including the equipment, procedure and personnel to be used) with the requirements under actual inspection conditions. The qualification process demonstrates that an inspection procedure is capable of detecting, and potentially characterizing and sizing, an indication created by an applicable degradation mechanism. The requirements for inspection qualification are typically provided in national standards or internationally accepted codes, for example the ASME (American Society of Mechanical Engineers) code or ENIQ (the European Network of Inspection Qualification) documents. IAEA Safety Standards Series No. NS-G-2.6, Maintenance, Surveillance and In-Service Inspection in Nuclear Power Plants [4], provides additional recommendations on the qualification methodology for ISI.

4.5. SURVEILLANCE PROGRAMME

The objective of the surveillance programme, in accordance with Ref. [4], is to provide independent monitoring of the operating modes of the NPP so that the production facility is able to manage abnormal and emergency states. The surveillance programme confirms the provisions for safe operation that were considered during the design phase, checked during construction and commissioning, and verified throughout operation. SSCs credited in the safety analysis need to be identified and periodically tested to ensure that they will function as required. This is done to verify system availability (ready for operation) in all operating modes and conditions and to manage the plant in a safe manner in case of disturbances or accidents for which the plant is designed.

The programme supplies data that can be used to assess the service life of SSCs. The programme also verifies that safety margins are adequate and provide a high tolerance for anticipated operational occurrences, errors and malfunctions. The following aspects require particular attention:

- Availability of the intended functions of active components in the scope of ageing management and the evaluations for LTO;
- Integrity of the barriers between radioactive material and the environment.

Material surveillance monitoring is also commonly implemented under the heading of the surveillance programme. However, this aspect is normally covered under specific AMPs and will not be covered in this section.

A review of the surveillance programme is performed to demonstrate that it will remain effective for managing ageing and valid over the expected period of LTO. To review the surveillance programme for consistency with the nine attributes of effective plant programmes, the following approach is typically used.

4.5.1. Scope

The scope of the surveillance programme is reviewed to ensure that it covers all systems that have been identified in the technical specifications and operational limits as important to safety, including auxiliary systems essential for the functioning of the SSCs important to safety. The safety functions of the SSCs to be tested are described, so that the operational limits, system settings and test frequencies that are given in the technical specifications will be better understood.

The establishment, use and maintenance of a surveillance programme is usually a regulatory requirement. The compliance of methods, extent, implementation, codes and standards to be used and the organization with the regulatory requirements are to be properly documented, for example in a surveillance strategy document. The surveillance programme is usually based on international practices and rules for the functional testing of mechanical systems and components; for maintenance, calibration and testing of electrical and I&C systems and components; and for examination and testing of civil structures and components. The programme will typically contain requirements for unique design aspects of the plant under consideration. The surveillance documentation explains how the different requirements are grouped, considering different functions to be tested, test parameters and test criteria, leading to a complete set of surveillance procedures.

A surveillance programme may include the following activities:

- Monitoring and trending of important operational limits and conditions (technical specifications) in nominal operation and during outage.

Furthermore, transients and important parameters are evaluated in the case of abnormal or failure state in all modes of the NPP.

- Analysis of operational events as a result of which proposals of measures are made and feedback is provided in the form of training.
- Examination and testing of SSCs in the NPP. Providing technical support in the implementation of tests — for example by preparing the relevant instructions and regulations — in updates and the development of examinations and tests and their assessment in terms of operating modes.
- Assessment of modifications, where personnel can provide comments regarding prepared modifications having direct impact on the NPP operation or operating modes.
- Carrying out independent control of compliance with local operating regulations, operating instructions and valid control documentation by operating personnel.
- Performance of continuous checks on the most important parameters of the NPP in all operating modes.
- Provision of feedback and reporting to operating personnel.

The surveillance programme ensures that deterioration of the SSCs is detected before it can lead to an unacceptable condition.

4.5.2. Preventive actions

Since the surveillance programme is essentially a condition monitoring programme, it is not used to implement preventive actions to control ageing effects.

4.5.3. Detection of ageing effects

The programme is reviewed to ensure that all surveillance tests, examinations, detection and monitoring activities are described and documented in a set of periodic examinations or test procedures, walkdown and monitoring sheets, and the results are electronically gathered in a surveillance database. The following general procedures apply:

- Inspections are performed by operational personnel or systems engineers in the form of operator routines or rounds.
- Checklists or data sheets are used if data are needed to confirm that requirements are met or to detect trends to predict deterioration.
- Examination and testing results are used for identification of possible causes of degradation (including ageing mechanism and stressors).

— Results are used in SSC health monitoring.

4.5.4. Monitoring and trending

The programme is reviewed to ensure that surveillance planning is prepared and scheduled for a defined interval, considering the extent and frequency of surveillance and monitoring activities (i.e. tests and checklists), the operational status of the plant, the maintenance activities and possible extra tests and checks introduced by the CAP. The frequency of monitoring activities is related to the results of reliability analysis and operational experience.

In addition to inspections, field inspections and periodic tests, operating conditions may be monitored as part of the surveillance programme, specifically through the following:

— Monitoring of the chemical and radiochemical parameters (see Section 4.6).
— Counting of the operational transients to check compliance with design transients. To this end, counting reports may be periodically produced and analysed to monitor the occurrence of sensitive situations.
— Monitoring of behaviour parameters for some SSCs, such as pumps, with permanent instrumentation providing vibration levels, bearing temperatures, flow, pressure and other parameters. Inspections can be scheduled based on this information.
— Instrumentation of some lines and pipes to measure the occurrence of operating situations and to verify their ability to deal with the risk of fatigue.
— Continuous monitoring of ambient environment parameters in some areas (e.g. temperature, radiation dose) to verify compliance with operating technical specifications.
— Calibration activities on plant components. These may also be regarded as pre-planned, repetitive tasks in the surveillance programme.

Parameters to be monitored and inspected are documented in the testing and monitoring procedures. They are based on the requirements for availability as defined in the technical specifications. Additional parameters and monitoring or increased frequency may be identified through the evaluation process of the surveillance programme.

Trend monitoring, which involves comparison of measured data with established acceptance criteria and preceding evaluations to confirm the continued ability of structures and components to meet design requirements, is part of the surveillance activities. Trending of the results allows for timely detection and mitigation of ageing effects. It permits the analysis of measurements and conditions of periodic tests, enabling evaluation of the long term availability of a structure or component and the implementation of corrective measures as necessary. Based on the results of the activities, extra surveillance tests can be performed or the test or monitoring frequency can be augmented.

4.5.5. Mitigation

As a condition monitoring system, the surveillance programme is not used to implement mitigating actions. Degradation may be detected or monitored, which in turn may initiate mitigating actions in the AMP before acceptance criteria are exceeded.

4.5.6. Acceptance criteria

The surveillance programme is reviewed to ensure that it identifies acceptance criteria against which the need for corrective actions is evaluated. Acceptance criteria are established in accordance with technical specifications, operational limits, and appropriate codes and standards.

4.5.7. Corrective actions

The programme is reviewed to ensure that, where the performance or condition of an SSC does not allow it to fulfil its intended function, the results of surveillance activities lead to appropriate corrective actions. Any reported failures from functional testing need to be documented. A defect cause analysis or root cause analysis may be performed as a result. A well defined surveillance programme ensures that all ageing related results and conclusions from these analyses are documented as such.

For surveillance activities that reveal indications exceeding the acceptance criteria, the surveillance programme usually expands the scope of surveillance to include additional components made of similar materials and exposed to similar conditions.

4.5.8. Operating experience feedback and feedback of R&D results

The review of the surveillance programme confirms that mechanisms are in place to ensure timely feedback of operating experience and R&D results and provides objective evidence that the operating experience and R&D results are considered in the programme. The results of all surveillance activities are fed back through an optimization process that enables continuous improvement of the programme. Special attention is given to the following:

- — Failure frequencies of the components;
- — Internal and external experience with failure mechanisms;
- — Changes in design or safety functions;
- — Ageing effects of SSCs.

Surveillance activities, such as test requirements, are re-evaluated following a modification or are based on relevant operational experience, for example when performance is noted to be inconsistent with what was assumed in the safety analysis.

4.5.9. Quality management

The surveillance programme is reviewed to ensure that it identifies quality management requirements. These include the following:

- — Administrative controls that document the implementation of the programme and actions taken;
- — Confirmation (verification) process for ensuring that preventive actions are adequate and appropriate and that all corrective actions have been completed and are effective;
- — Record keeping practices to be followed.

4.6. WATER CHEMISTRY PROGRAMME

The main objective of the water chemistry programme is to maintain the quality of water (e.g. primary reactor coolant, moderator water for CANDU/PHWR, treated water) and conditioning products within limits of the requirements; minimize contaminant concentration; and mitigate the effects of degradation of SSCs important to safety due to ageing. The water chemistry programme also provides chemical and radiochemical assistance to ensure safe operation and to control and reduce radiation levels in work areas.

A review of the water chemistry programme is performed to demonstrate that it will remain effective for managing ageing over the expected period of LTO. To review the water chemistry programme for consistency with the nine attributes of effective plant programmes, the following approach is typically used.

4.6.1. Scope

The scope of the water chemistry programme is reviewed to ensure that it includes all SSCs and activities within the scope of the ageing management and LTO assessment which include the chemistry programme for ageing management. Ageing effects that are managed directly or indirectly by the water chemistry programme are identified, including loss of material due to corrosion, cracking due to stress corrosion cracking and related mechanisms, and reduction of heat transfer due to fouling in components exposed to a treated water environment.

A water chemistry programme specifies processes, specifications, parameter monitoring, data trending and evaluation to ensure effective control of plant chemistry during operational, shutdown and layup conditions. The review verifies that the programme includes specifications for the acceptable level of specific chemical species, impurities and additives, sampling and analysis frequencies, and corrective actions for control of water chemistry. The technical basis documents for chemistry control and monitoring play an important role in supporting this programme.

4.6.2. Preventive actions

The water chemistry programme is reviewed to ensure that specific preventive actions are appropriate to minimize and control ageing effects where it is applied for ageing management and LTO. For example, the reactor coolant chemistry programme serves to minimize the level of transported activity, to prevent deposition on the out of core regions, and to prevent corrosion by ensuring that chemical conditions in the reactor coolant maintain the optimal pH value and electrochemical potential.

4.6.3. Detection of ageing effects

The water chemistry programme is reviewed to ensure that sampling frequencies and chemistry specifications are documented, with action levels for deviation from parameters to detect potential ageing effects. The frequency of sampling (e.g. continuous, daily, weekly or as needed) varies, based on plant operating conditions and relevant guidelines. Degradation in the form of cracking or loss of material in the tubing of heat exchangers and steam generators are some of the examples that can be detected by sampling.

4.6.4. Monitoring and trending

The water chemistry programme is reviewed to ensure that it includes periodic monitoring of important chemistry parameters, sampling from the reactor coolant, moderator (CANDU/PHWR), steam generator blow down, the water–steam circuit, the makeup water preparation, oil examinations and other assessments (such as examination of ion exchange resins) to minimize degradation, such as loss of material or cracking.

The water chemistry may be monitored by on-line monitoring or manual analysis. Chemistry management systems use databases where chemistry and operational data with potential impact on ageing can be collected and stored. These data can be trended with applicable process information. The programme identifies data to be registered during the performance of chemical or radiochemical analysis and calibration activities, and how these are recorded on analysis measurement charts and calibration logs.

These activities usually involve methods of analysis and equipment imposed by the technical specifications of the plant. All required system parameters for chemical operation of the relevant treated water systems are specified in these documents, which would also define measures to be carried out in the event of deviations.

The programme is reviewed to ensure that long term chemistry trending is also performed to identify any potential negative impact of the chemistry on SSCs. These trends may be helpful in the identification of potential risks well before any serious degradation occurs. Trends, evaluations and recommendations are commonly documented in an annual chemistry report.

4.6.5. Mitigation

The water chemistry programme is aimed at mitigating the corrosion of the main equipment of the reactor coolant circuit, including the integrity of fuel cladding and the observation of surface deposits. The optimization of protection and safety (the as low as reasonably achievable (ALARA) principle) is an important consideration to manage the buildup of radioactive material and limit occupational exposure to radiation.

In the water–steam cycle, the main attention of the chemistry programme focuses on the mitigation of flow accelerated corrosion of low alloy steels. In NPPs with steam generators, specific chemistry issues include minimizing degradation of the steam generator tubing to ensure primary to secondary circuit integrity, and decreasing the deposition of secondary circuit corrosion products on the steam generator tubing to maintain heat transfer capacity and limit steam generator clogging.

4.6.6. Acceptance criteria

Acceptance criteria, against which the need for corrective actions is evaluated, are specified in programme documents. Methodologies to be adhered to for maintaining the water chemistry within desired boundaries may be provided by the designer in the technical specifications of the plant, in national and international standards and regulatory guidance, or as developed by user groups of similar NPP designs. Deviations may occur between the NPP's specifications and international guidelines owing to plant specific conditions. Gap analyses, including the justification for the deviations, are documented and attached to the strategic water chemistry plan.

4.6.7. Corrective actions

The water chemistry programme is reviewed to ensure that it defines and applies corrective actions when chemistry specifications or action levels are exceeded. Deviations in results recorded in the chemistry database are used to define immediate corrective actions or to document and subsequently handle the issue within an acceptable time frame. If there is any deviation from the required water quality norms, the chemistry programme prescribes the necessary corrective actions to be taken and the preparation of an event report on the deviation of chemical parameters.

Chemistry specifications and analysis frequencies are validated periodically to verify the existing inspection programmes and operating conditions. Whenever corrective actions are taken to address an abnormal chemistry condition, relevant procedures usually require increased sampling frequency to be utilized to verify the effectiveness of these actions.

4.6.8. Operating experience feedback and feedback of R&D results

The water chemistry programme is reviewed to ensure that internal and external operating experience is documented in an experience feedback database, as described in Section 2. Reporting of the water chemistry programme includes documenting historical events with an impact on chemistry. The content of such a report includes background information and bases for historical changes in chemistry regimes and strategies, sampling frequencies, recommendations from ageing analyses, and future predicted actions. It contains information about the reasoning behind past decisions and justification for future actions.

The review of the chemistry programme ensures that the results of all activities are fed back through an optimization process that enables continuous improvement of the programme. The water chemistry programme is commonly optimized according to SSC design, construction and used materials. It considers the plant operational experience regarding fuel performance, radiation build up and environmental impact. International industrial guidelines, together with additional fuel vendor requirements and ongoing R&D activities, provide guidance for continuous update and improvements of the chemistry programme. The effectiveness of the chemistry programme is improved by continuous monitoring of performance indicators, failure analysis and reliability data and the implementation of the related action plans.

Interdisciplinary cooperation between personnel in the areas of ageing management, maintenance and plant operation and the chemistry department is important to obtain optimal results. Examples of NPPs with effective AMPs show that the chemistry department takes part in multidisciplinary working groups such as for the reactor vessel and internals, steam generators, fuel performance analyses and source term evaluation. This interaction has proved to be fundamental for the identification and successful management of degradation mechanisms.

4.6.9. Quality management

The water chemistry programme is reviewed to ensure that it identifies quality management requirements. These include the following:

- Administrative controls that document the implementation of the programme and actions taken;
- Confirmation (verification) process for ensuring that preventive actions are adequate and appropriate and that all corrective actions have been completed and are effective;
- Record keeping practices to be followed.

To maintain a high level of safety and quality, short term self-assessments are performed regularly. This includes the evaluation of the performance and chemistry analysis quality in the laboratories as well as in on-line monitoring devices. For example, intercomparison analyses are performed frequently.

Recommendations for the NPP's water chemistry programme are provided in IAEA Safety Standards Series No. SSG-13, Chemistry Programme for Water Cooled Nuclear Power Plants [27]. These are intended to be used by plant personnel to maintain a high level of quality of the water chemistry programme and to identify areas for improvement.

5. CORRECTIVE ACTION PROGRAMME

The need for effective corrective actions is clearly established in the requirements in IAEA Safety Standards Series publications. In particular, Requirement 9 (Monitoring and review of safety performance), Requirement 24 (Feedback of operating experience) and Requirement 31 (Maintenance, testing, surveillance and inspection programmes) in SSR-2/2 (Rev. 1) [2] identify the implementation of corrective actions necessary to ensure continued safe operation of the plant. For example, para. 5.30 of SSR-2/2 (Rev. 1) [2] states that "Corrective actions shall be prioritized, scheduled and effectively implemented and shall be reviewed for their effectiveness."

The CAP is typically part of a plant's operating experience programme within the plant's management system to ensure continued safe operation of the plant. Corrective actions are triggered when a condition adverse to quality or safety is identified, evaluated and entered into the CAP. Such conditions include, for example events, including low level events and near misses [28]; potential problems with equipment; conditions that need to be addressed to prevent undesired ageing effects; failures; malfunctions; deficiencies; deviations; defective material and equipment; and non-conformance.

An effective CAP fulfils the following functions:

- Identifies the specific cause of the condition negatively impacting quality or safety (i.e. cause determination);
- Implements actions to address the adverse condition (i.e. remedial actions);
- Assesses other similar locations to see if the condition exists (i.e. extent of condition);
- Performs a root cause analysis;
- Identifies and implements actions to prevent recurrence (i.e. corrective actions).

In addition to the review of plant specific operating experience or internal findings, another key part of the CAP is the review of external operational experience to prevent similar events or reduce the likelihood of their occurrence at the plant [26]. The consideration of external operational experience is important to leverage the greater industry wide experience as well as that from the plant. When assessing the applicability of external operating experience, an effective CAP focuses on how the lessons learned from the external event could be beneficial to the plant and does not seek to justify why the experience is not applicable.

As described in Ref. [29], the role of management is a key component of an effective CAP. Management at all levels demonstrates ownership of the CAP by directing, promoting, prioritizing and sufficiently staffing programme activities. The success of the CAP depends, to a large extent, on the leadership for safety demonstrated by the management of the operating organization. However, effective management goes beyond this principle by closely following the thoroughness with which events are reported, the depth of event analysis, the scope of the corrective actions and the timeliness and quality of the implementation of corrective actions. In general, frequent management involvement is required for the CAP to remain forceful, productive and efficient.

An effective CAP ensures that corrective actions commensurate with the significance of the issue are specified and implemented. The implementation of corrective actions can occur on two different timescales. The first is the implementation of immediate or interim actions to recover from the event, restore the situation and repair the deficiencies. Short term actions may be needed to correct immediate problems, repair the deficiency, recover functionality or reach a stable state. In addition, short term actions evaluate the extent of the condition and take appropriate actions as needed, such as additional examinations or other activities to ensure that similarly situated equipment maintains functionality.

Once the short term actions have been implemented and equipment functionality has been restored, a root cause analysis can be conducted to provide for long term corrective actions to prevent recurrence of the original event, if warranted. Identification and selection of corrective actions that directly address the root causes of the event are important to ensure continued safety, reliability and performance of the affected equipment and to prevent further events.

The CAP is periodically assessed for effectiveness, in particular the timely completion of corrective actions and recurrence prevention aspects. The periodic assessment includes all stages of the corrective action process to ensure that all elements are being performed effectively [29].

Specific to ageing management, the CAP has an important role to ensure continued safe plant operation. A corrective action is initiated when, for example, a finding by an AMP does not meet the acceptance criteria within the programme. In this case, CAP activities are used to manage the resolution of the adverse condition of the affected SSC.

In addition, the CAP is used when unexpected significant degradation is identified by an AMP [30]. In this case, the CAP evaluation focuses on the need to modify existing ageing management practices (e.g. different examination technique, more frequent examinations, expanded examination scope) or to develop a new AMP. Modifications to AMPs, as well as system configuration or plant operations that are made to manage the occurrence or the severity of the ageing effect, are documented in the CAP.

When the operating organization evaluates the effectiveness of its AMPs, the results of this assessment may also indicate the need to modify existing AMPs or to develop a new AMP [20]. These results are entered into the CAP for appropriate tracking and implementation.

In order to effectively use operating experience to manage and improve AMPs for nuclear installations, an effective CAP and administrative procedures are required. The operating experience programme provides the information needed to be processed and analysed by the CAP. Useful information and good practices for improving the processes of developing, implementing and assessing the effectiveness of corrective actions for issues that have been identified in the operating experience programme are available in Ref. [29]. An example of a typical CAP is illustrated in Fig. 2. Annex III provides an example of a CAP from the United States of America.

6. DOCUMENTATION OF AGEING MANAGEMENT AND LONG TERM OPERATION

The objective of this section is to clarify the application of SSG-48 [3] regarding the following:

— Paragraphs 5.70–5.74, addressing documentation of ageing management;
— Paragraphs 7.29–7.38, addressing documentation in support of LTO.

The plant's quality assurance programme complies with the regulation of the Member State when documenting items discussed in this section. The documentation complies with the established management requirements and quality assurance procedures, and is included in the documentation management systems to ensure that documents are kept up to date.

6.1. DOCUMENTATION OF PLANT LEVEL AGEING MANAGEMENT PROGRAMME

The plant's AMP can be documented in a high level document or manual where fundamentals, strategies and procedures required for the effective ageing management of the plant are established. This plant level AMP usually defines the basis and responsibilities for the different programmes and areas within the plant, as well as the activities required to achieve effective ageing management.

The typical content of the plant level AMP is provided in the IGALL database, which is a part of the Safety Report on IGALL [20].

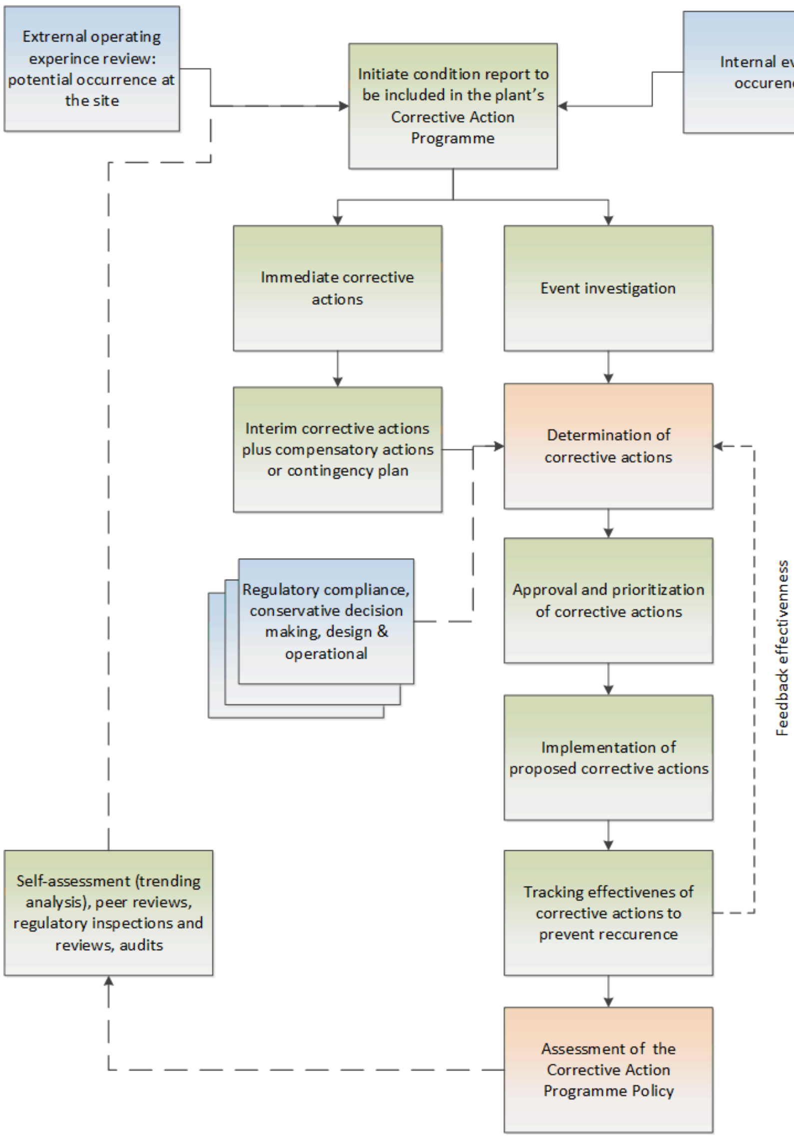

FIG. 2. Example of a typical corrective action programme.

6.2. SAFETY ANALYSIS REPORT AND OTHER LICENSING DOCUMENTATION

The safety analysis report and other licensing documentation are important sources of information for the development of the plant's AMP. They are periodically updated to reflect the current configuration of the plant. Relevant modifications, and the implementation of ageing management and LTO activities, are reflected in licensing documentation. These updates include, but are not limited to, design changes, including replacements and upgrades of plant systems, new analyses and calculations using ageing related data, revalidation of TLAAs, and other time limited assumptions (e.g. update of pressurized thermal shock analysis).

These reports and licensing documents on ageing management typically contain the following:

- The goal of ageing management;
- Regulatory requirements for ageing management;
- The concept and strategy of ageing management;
- Justification of the completeness of ageing management;
- Consideration and identification of degradation mechanisms and ageing effects;
- Details of design and construction (e.g. dimensions, materials used, stress concentration locations, corrosion locations, strength, toughness and corrosion characteristics);
- Manufacturing and installation specifications;
- Characteristics of material properties;
- Strength analyses;
- Principles for scope setting for SSCs subject to the AMP;
- List of SSCs for ageing management and LTO;
- Results of implemented AMPs for main components and other SSCs important to safety;
- Condition monitoring programme;
- Periodic and functional tests;
- Description of other plant programmes;
- AMPs;
- Evaluation and results of TLAAs;
- Use of databases for ageing management;
- Use of the ageing management operating experience in the improvement of maintenance and other plant programmes;
- Evaluation of the physical status of in-scope SSCs;

— Evaluation of the ageing management administration (e.g. reporting system, organization aspects);
— Summary of results of the plant level AMP.

6.3. DOCUMENTATION OF PLANT PROGRAMMES FOR AGEING MANAGEMENT

As described in Section 4, an important part of ageing management is documentation with guidance on how the plant programmes are reviewed to verify that they effectively manage the ageing effects of the structures and components included in the scope of ageing management. The evaluation is performed against the nine attributes of an effective AMP as described in SSG-48 [3].

This evaluation can be documented in text format or as a checklist for each of the nine attributes for each plant programme. As a result of this evaluation, gaps are usually identified and specific corrective actions to address these gaps are proposed, documented and incorporated into the CAP. These actions constitute a set of commitments which usually have different priority levels, time schedules and constraints. In addition, they generally require different levels of approval depending on the relevance of the proposed improvements. When new AMP development needs are identified, the scope and purpose of the new programme are described among the commitment tasks. It is necessary to allocate appropriate resources (i.e. staff and funding) to accomplish the objectives of the commitments.

6.4. DOCUMENTATION OF THE PROGRAMME FOR LONG TERM OPERATION

If the operating organization decides to pursue LTO, a comprehensive safety assessment is performed to demonstrate safety. As in the case for the establishment of a plant programme for ageing management, high level documentation is usually prepared to describe the plant's overall approach to LTO. This can take the form of a general self-contained manual or a set of cross-referenced documents. In both cases, the documentation usually contains important information on the plant policy and strategy for LTO, the regulatory framework and codes and standards to be followed, the intended period of LTO, expectations and requirements of the regulatory body, and organizational aspects and division of responsibilities, as well as a list of the activities included within the programme for LTO. However, an economic evaluation and the expected benefits from LTO may or may not be part of this documentation.

The following items and actions are typical elements of LTO programme documentation:

— Definition of plant policy for LTO, including the period of intended plant operation;
— Description of national regulations for LTO;
— Methodology for the implementation of LTO (e.g. licence renewal or detailed PSR);
— Detailed technical content of the actions planned for implementing the LTO programme (such as scope setting, AMR, AMPs and other plant programmes, TLAA identification and revalidation, documentation for licence approval and commitments for implementing the necessary plant modification and refurbishments, introducing the R&D programmes, and extending the scope of the previously applied condition monitoring programmes);
— Assurance that the necessary resources for the period of LTO exist;
— Update of the safety analysis report.

6.5. DOCUMENTATION OF THE SCOPE SETTING METHODOLOGY AND RESULTS

The methodology used for deciding which SSCs are subject to AMR is usually defined in plant documents, which are reviewed and approved by the responsible personnel. These documents define the scope of the ageing management and plant LTO programme and are usually part of the ageing management and LTO documentation (see figure 8 of SSG-48 [3]).

Documentation of the methodology clearly defines the criteria used for scope setting, by using either a decision chart type document or a fixed set of questions. Decision charts form a map tree that leads each SSC under evaluation to a set of possible outcomes, depending on the parameters of the SSC.

If commodity groups are defined during scope setting, the basis and instructions are defined in the methodology documentation. Similar procedures are used for cables, I&C components, cable trays, civil structures, and supports. Detailed instructions are generally included in the reports, indicating how to process each type of SSC.

Once the methodology for the scope setting process is fixed, it is not recommended to implement changes in the methodology because the entire scoping process would have to be repeated to ensure consistency of results. If there is a need to change the methodology during the scoping process, addenda to methodology or deviations or interpretation are reported in the scoping results.

The information that is documented for scope setting includes designation of the plant SSCs that meet the requirements of paras 5.16 and 5.17 of SSG-48 [3]. The plant retains all information and documentation to document the results of the scope setting procedure described in Section 3 in an auditable and retrievable form.

The results of scope setting are documented in a format consistent with other plant documentation practices. The information is maintained as a hard copy or in electronic format. If available and appropriate, the information is incorporated into an existing plant database, as described in Section 2.

The output of the scope setting process can typically be a list of SSCs, and includes the following:

— Identifier of SSCs in the scope for criteria A to C (according to Section 3) and out of scope;
— Criterion used for inclusion of all SSCs in the scope;
— Identification of intended functions of in-scope SSCs (active and passive functions);
— Breakdown of structures and components into subcomponents, if applicable;
— Other information connected with in-scope SSCs needed for possible identification of commodity groups (e.g. material, temperature, environment).

Drawings, photographs and other relevant information that present the results of dedicated walkdowns are typically provided in specific reports (see Section 3.2.6). These usually include the list of structures and components under evaluation and the reasons to include or exclude them from the scope of the ageing management and LTO programme.

Establishing a clear definition of the boundaries of the SSCs in and out of scope is important to ensure that each part is evaluated, as stated in para. 5.21 of SSG-48 [3]. A useful tool for reporting the boundaries is the use of marked P&IDs or other drawings, such as for civil structures, cables or fire barriers. A colour code could also be applied to indicate which parts are scoped in or out, and even the reasons behind the decision. If such a colour code is used, it is generally clearly defined in the methodology and explicitly reported in the corresponding documentation. These marked drawings are usually attached to the scoping reports and can be created either manually or with the help of graphical IT tools.

If the master list of plant SSCs is in the form of a ‘living’ database, it is desirable to transfer the results of the scope setting process from the different lists generated into a set of attributes that will be added to the master list for each SSC evaluated. Typical attributes are the following:

— In the scope of ageing management (yes or no);
— Reason for inclusion or exclusion (short free text or, preferably, a selection from the decision charts or the fixed set of questions);
— Function used for inclusion (active or passive);
— Commodity group (a choice from the list of defined commodity groups).

The advantage of this approach is that having these results in the master list database simplifies the process to ensure the completeness and consistency of the scope setting process.

It is important to recognize that regardless of whether they are included in the plant master list database or as stand-alone documentation, the results of the scope setting process are 'living' documents that are to be kept updated. This is especially important in the case of modifications, replacements and upgrades of plant SSCs that are reflected in the results of the scope setting process.

6.6. DOCUMENTATION OF AGEING MANAGEMENT REVIEW METHODOLOGY AND RESULTS

According to SSG-48 [3], an AMR should be performed for each in-scope structure or component or commodity group to demonstrate that ageing will be effectively managed. The AMR methodology is documented in a dedicated plant procedure or is part of a plant programme for ageing management or for LTO. Documentation of the AMR methodology is discussed to a level of detail that is sufficient to ensure consistency among the reviews performed by different reviewers.

AMR is discussed in section 2 of the Safety Report on IGALL [20]. The AMR tables in the IGALL database provide applicable review attributes and other technical information. These ATs include PWR (including water cooled, water moderated energetic reactor), BWR and CANDU/PHWR designs.

AMR is documented on a system level basis (i.e. reporting results for each in-scope system), on a commodity group basis (one report for each group of components), using a combination of several commodity groups, or on a component level.

For example, in the case of mechanical and process systems, a system based approach for documentation is more efficient, whereas for evaluation of electrical systems, it is usually more convenient to use commodity group based reports (e.g. transmitters, electrical penetrations, motors, switches).

For AMR, documented information typically includes the following aspects:

- AMR tables (see section 2 of Ref. [20]);
- Plant specific AMP consistency with proven IGALL AMPs, such as those described in table 2 of Ref. [20];
- Identification of the ageing effects and degradation mechanisms requiring management for in-scope structures and components;
- Identification of the specific programmes or activities which will address the effects of ageing for each structure, component or commodity group listed (AMPs, TLAA and plant programmes);
- Description of how the AMP and other relevant programmes or activities will manage the effects of ageing;
- Discussion of how the above mentioned determinations were made;
- A list of substantiating references and source documents;
- A discussion of any assumptions or special conditions used in applying or interpreting the source documents;
- A description of other relevant plant programmes for LTO.

6.7. DOCUMENTATION OF AGEING MANAGEMENT PROGRAMMES

An AMP is a set of plant activities relating to the understanding, prevention, detection, monitoring and mitigation of a specific ageing effect on a structure, component or group of components. The documentation details for AMPs are provided in SSG-48 [3] and section 3 of Ref. [20].

6.8. DOCUMENTATION OF AGEING MANAGEMENT IMPLEMENTATION

A systematic approach is applied when the plant implements ageing management of SSCs according to Deming's 'plan–do–check–act' cycle, as illustrated in figure 1 of SSG-48 [3], to ensure that required intended functions are maintained at all times during the operation stage of the NPP. The tasks and actions performed are typically based on the content of plant AMPs or other plant programmes (see Section 4).

The following documentation is used typically for implementation of ageing management:

- Scheduled plan for implementation of AMPs and verification of other plant programmes;
- Documentation of functional testing data;
- Maintenance and documentation of ISI history data;
- Documentation of structure or component condition monitoring data, including the system health report;
- Failure data documentation;
- Preventive action documentation;
- Corrective action documentation;
- Documentation of modifications performed;
- Collected industry and plant specific operating experience information;
- Ageing management annual report;
- Modification in the ageing management documentation (e.g. AMPs and other plant programmes, TLAAs);
- Documentation of new AMPs;
- Documentation of modifications in data collection and record keeping systems (e.g. software modification in the system, data structure modification);
- Documentation (results) of self-assessments, internal audits and external reviews.

Results of the assessments and evaluations performed in the framework of ageing management are usually recorded in plant documents or managed within a dedicated data collection and record keeping system.

6.9. DOCUMENTATION OF IDENTIFICATION AND REVALIDATION OF TIME LIMITED AGEING ANALYSES FOR LONG TERM OPERATION

The scope of TLAAs is determined by the application of the six criteria defined in para. 5.64 of SSG-48 [3]. The TLAA documentation typically includes the following:

- The methodology applied to develop the TLAA list;
- A list of the TLAAs applicable to the plant;
- A description of the evaluation performed or to be performed on each plant specific TLAA;

— A general discussion of how the determinations were made;
— A list of substantiating references and source documents;
— A discussion of any assumptions or special conditions used in applying or interpreting the source documents.

The results of the identification and revalidation of TLAAs is documented in a format consistent with the plant's documentation practices. The information is maintained as a hard copy or in electronic format. If available and appropriate, the information is incorporated into the existing plant database, as described in Section 2.

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Annex I

EXAMPLES OF THE CONTENTS OF DATA COLLECTION AND RECORD KEEPING SYSTEMS

This annex provides an overview of data required for AMP and LTO assessment and examples of relevant data management in the Czech Republic.

I–1. CONTENT OF DATA COLLECTION AND RECORD KEEPING SYSTEMS — CZECH REPUBLIC

I–1.1. General data systems

I–1.1.1. Central technical archive

All of the documents within the range specified in the register of the application ‘Browser of Technical Documentation EDU’ are stored in the central technical archive of the NPP (e.g. as-built drawings, technical specifications, initial design and safety analyses, and original TLAAs, including information on changes made in these documents).

I–1.1.2. Asset Suite (Enterprise Asset Management system)

Asset Suite is a software system for the performance of asset management processes and all programmes included in that process (including maintenance and ageing management). In Asset Suite, maintenance parameters are set (identification of all maintenance activities, assigning inspections to the SSCs, including the period of their performance) and work orders for inspection implementation are created. Part of Asset Suite is a module with a register of SSCs which covers the following:

— The SSCs in the NPP, the conditions under which SSCs operate, grouping of SSCs into logical and technological groups, making further activities on the SSCs (e.g. maintenance) more efficient.
— Register of documents (e.g. the technical specifications, individual quality assurance programmes and other documentation necessary for SSC operation and maintenance).
— Work orders.

— Database called ‘memory of maintenance’. This is an essential tool for recording all activities performed on the SSCs (including building objects). It documents activities, their evaluation and optimization.

I–1.2. Ageing management and long term operation databases

I–1.2.1. Scoping database

A special database which contains the results of the scoping process. It contains the list of SSCs in the scope for ageing management. For each SSC, this information contains the following:

— Component identifier;
— Technological system;
— Safety classification;
— Scoping criteria and identification of those used for scoping.

I–1.2.2. Catalogue (database) of degradation mechanisms

This database contains the list of degradation mechanisms potentially occurring for the SSCs of the plant, including the major characteristics of each mechanism.

I–1.2.3. Database which contains the results of the ageing management review

The database contains the following information:

— Component identifier;
— Location of the component;
— Material information;
— Working environment;
— Potential ageing effects and degradation mechanisms;
— Real degradation mechanisms and ageing effects;
— Identification of AMPs to cover ageing effects and degradation mechanisms.

I–1.2.4. Specific ageing management programme databases

Several databases store all necessary data for specific AMPs (e.g. database TNR for the reactor pressure vessel, CHECWORKS for flow accelerated corrosion, BPWORKS for buried pipelines, Dialife for low cycle fatigue, VVK for cables and KOHOZ for welds). As an example, VVK, which contains all data connected with cable AMP, is a software tool composed of three main programme applications:

- — Calculations and assessment of the lifetime of safety cables;
- — Environmental parameters monitoring;
- — Visual inspection reports.

The database provides information on:

- — Cable features (e.g. identifier, type, producer, properties);
- — Cable topology (e.g. input and output devices, location, cable tracking);
- — Information about connected devices;
- — Environmental parameters (i.e. temperature, dose rate, humidity and neutron fluxes at each location);
- — Parameters for lifetime calculation (i.e. master curve for each cable, including the information on the influence of temperature and dose rate);
- — Information on connectors, penetrations and cable deposits;
- — Results of lifetime calculations.

I–1.2.5. LTO Suite

This specially developed application works over the register of SSCs (Asset Suite) and serves as an integrator of the sub-databases mentioned above and expert applications. Figure I–1 shows how data for ageing management and LTO are integrated.

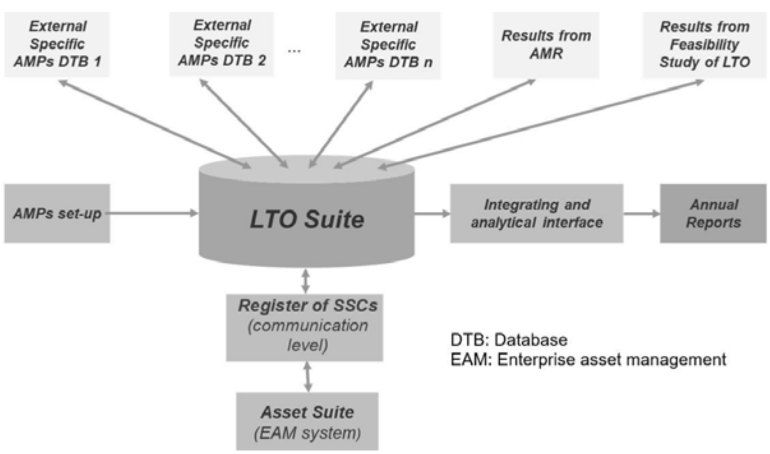

FIG. I–1. LTO Suite: software support for ageing management and long term operation.

Annex II

EXAMPLES OF REVIEW AND IMPROVEMENT OF PLANT PROGRAMMES RELEVANT TO AGEING MANAGEMENT AND LONG TERM OPERATION

This annex provides examples of approaches to reviewing and improving plant programmes relevant to ageing management and LTO in selected Member States.

II–1. LIVING AGEING MANAGEMENT PROCESS FOR REVIEW AND IMPROVEMENT OF PLANT PROGRAMMES AT THE RINGHALS NUCLEAR POWER PLANT

The basic objective of the ageing management process at the Ringhals NPP in Sweden is to describe the links between the object specific ageing analysis, relevant AMPs and detailed ageing management activities. This is done in one single document, also known as the strategic ageing management document (SUP), for each commodity group or set of commodity groups. The aim is to have a unique document which contains embedded references and links to relevant documents, with important data for ageing management (e.g. baseline information, operating history data and maintenance history data) and technical references to support new findings and conclusions. Most of the documents referred to in the SUPs can be retrieved from the NPP document management database or from the plant register. The fact that all relevant information is gathered in one document has a clear benefit over having it dispersed in numerous reports. It also facilitates the implementation of a living process for the review and improvement of existing plant programmes. Figure II–1 shows the typical content of an SUP at the Ringhals NPP.

As stated above, ageing analyses are embedded in the SUPs, are object specific and a ‘static’ part of the SUPs. As an example, the reactor pressure vessel is defined as a component that consists of a number of objects (e.g. upper shell, intermediate shell, outlet nozzles, bottom penetrations). The object specific ageing analysis contains very detailed information about design, manufacturing (e.g. material certificates, welding procedures, weld material, repairs, pre-service inspection), ISI results and operating information (e.g. transients, chemistry, repairs), operating experience, R&D, evaluation of potential degradation mechanisms and conclusions after the analysis. When the understanding of ageing is documented down to the object level, it is possible to connect a combination of

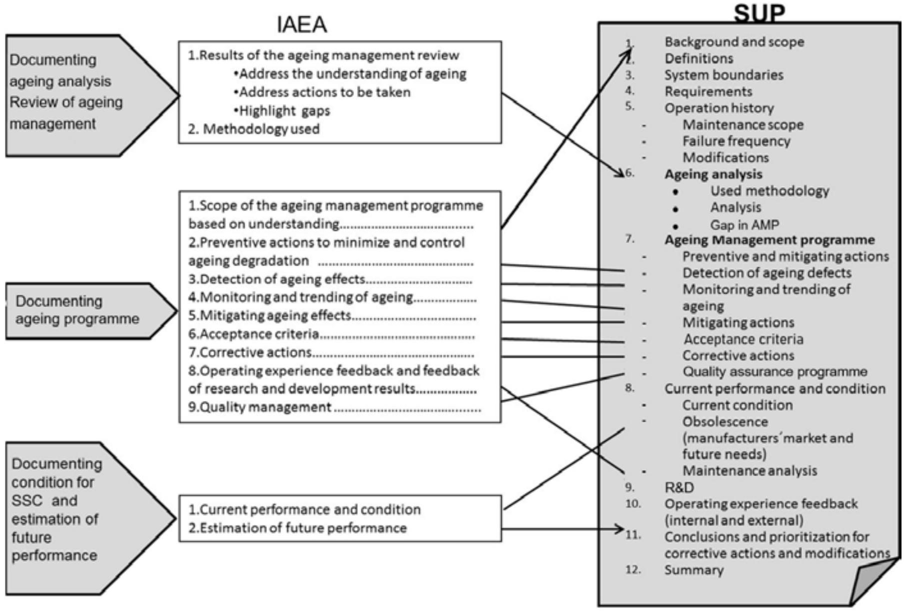

FIG. II–1. Structure of the strategic ageing management document (SUP) used at the Ringhals nuclear power plant. The SUP is used as a hub for record keeping in ageing management and facilitates the review and improvement of existing plant programmes.

AMPs to each object. When new internal or external operating experience needs to be considered for the understanding of ageing, these ‘static’ ageing analyses are updated, and the need for corrective actions is assessed.

Part of the AMPs which have been developed at the Ringhals NPP were based on a selection of the AMPs listed in chapter XI of Ref. [II–1] and the IGALL AMPs in Ref. [II–2]. The AMPs contain the listed attributes according to Ref. [II–3] and have been adapted to the Swedish regulatory requirements and circumstances specific to Ringhals. In addition to the selection of AMPs from Refs [II–1, II–2], additional programmes have been developed to fulfil the needs specific to Ringhals when identified in the ageing analysis. Figure II–2 shows examples of internationally accepted documents which are used as a reference for the development of ageing analysis and AMPs in the SUPs.

The SUPs are periodically assessed and updated to ensure that in-scope SSCs are capable of performing their intended functions throughout operation, including the planned period of LTO. New relevant internal or external operating experience is assessed and used to update SUPs. This can result in new ageing mechanisms that are considered in the ageing analysis or even new recommendations that need to be implemented to improve the existing

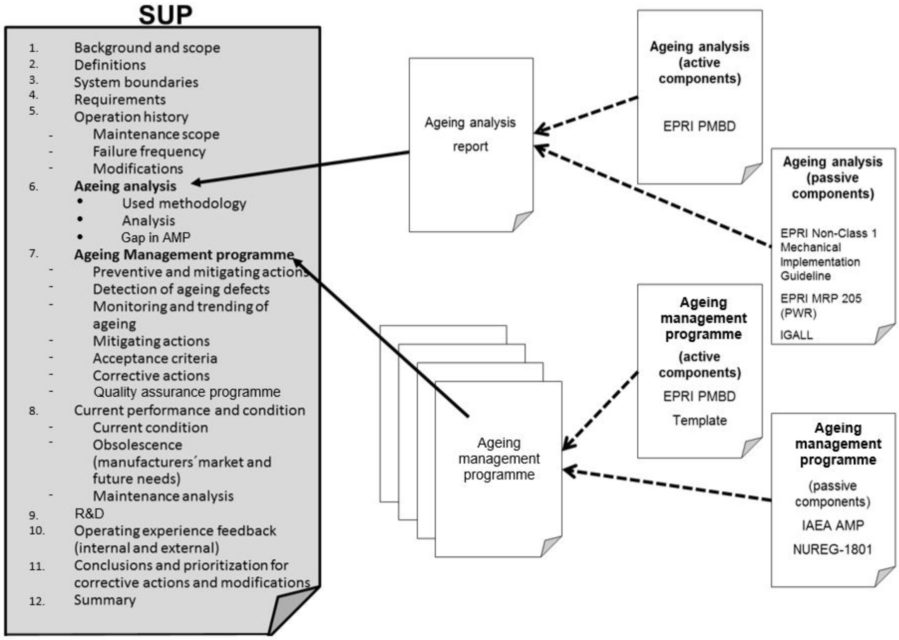

FIG. II–2. Example of international documents used for the creation of ageing analysis and ageing management programmes for mechanical components at the Ringhals nuclear power plant.

maintenance programmes. Deficiencies found after plant activities, such as ISI, function testing and maintenance activities, are summarized in annual reports for each technical area. Analyses of deficiencies are carried out as well as safety assessments, when required, and an action plan which defines corrective actions is drawn up. Actions in the plan are then broken down to lists at the component level, which are prioritized, scheduled and referred in the SUPs. Annual reports are also used to assess the current condition of the object and estimation of future performance. Figure II–3 illustrates the living ageing management process for review and improvement of plant programmes at the Ringhals NPP.

A comprehensive Streamlined Reliability Centred Maintenance programme (SRCM) is in place in the plant. SRCM has been complemented by a living SRCM programme based on failure monitoring and including long term trending over a ten year period. Reports are developed every two years for each unit that form the basis for decisions on which systems are given priority for maintenance analysis that year.

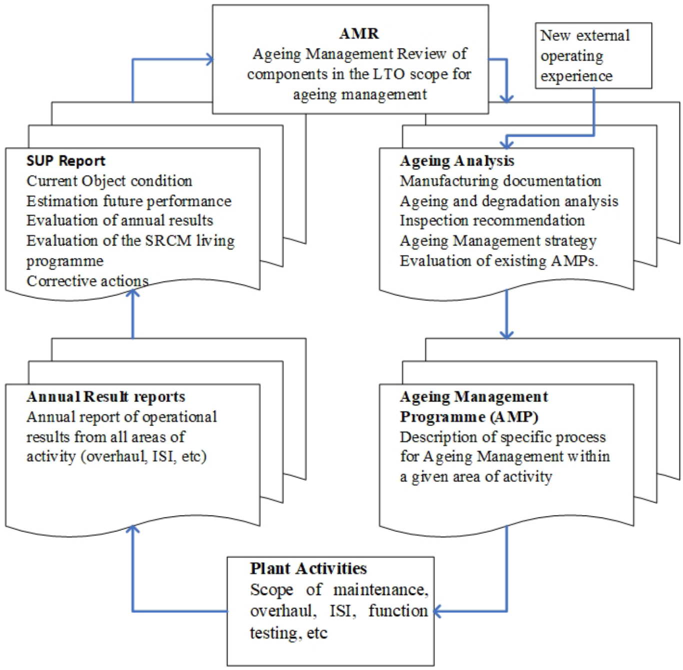

FIG. II–3. Living ageing management process for review and improvement of plant programmes for structures and components in the long term operation scope at Ringhals nuclear power plant.

Three main criteria are applied when prioritizing which systems are analysed:

(1) Is there a problem related to safety in any system that could be resolved with the correct maintenance method or correct interval?
(2) Which systems have the most service requests or orders during a three year period?
(3) Which systems exhibit the clearest increasing trend of service requests or orders during a ten year period?

Based on these criteria, an assessment is performed to determine for which systems it is possible to improve maintenance activities. This is then documented in the applicable SUPs, which results in corrective actions performed within a scheduled time frame and documented in the SUPs.

II–2. REVIEW AND IMPROVEMENT OF PLANT PROGRAMMES AS PART OF A LIVING AGEING MANAGEMENT PROGRAMME AT THE BORSSELE NUCLEAR POWER PLANT

The Borssele NPP in the Netherlands is a two loop PWR designed and built by Siemens/KWU in Germany. Construction started in 1969 and the plant went into commercial operation in 1973. The operating life assumed in the design was 40 years, reflected in TLAAs in the design basis documentation. The plant has conducted PSRs since the 1980s, which resulted in numerous safety upgrades. This enabled the plant to manage conceptual ageing throughout the years. Since 2014, the plant is in LTO with an operating licence until 2034. The owner and operator of the plant is the Elektriciteits-Produktiemaatschappij Zuid-Nederland (EPZ) company.

To obtain regulatory approval to operate beyond its originally assumed operating life, the Borssele NPP conducted its LTO project using the recommendations in the IAEA Safety Standards. An AMR was conducted on passive structures and components in the scope. The safety function of active components would be adequately maintained during LTO by performing an assessment of the existing maintenance and surveillance programmes. The TLAAs have been revalidated for the longer period of operation.

The Borssele NPP decided to maintain the knowledge of ageing management gained by performing these projects by developing an overall, living AMP using all the elements of the LTO project. The basis of the overall AMP was to have a clear definition of the tasks and responsibilities in the organizational structure of the NPP. The responsibilities and activities of the ageing management process owner, defining ageing management, were to be clearly separated from the activities of the existing plant programmes.

The first step was to verify how existing plant programmes essential to ageing management comply with the nine attributes of an effective AMP, which would form the basis for conducting the physical activities needed for ageing management. This verification would provide a clear overview of how these programmes could be integrated into the overall AMP, clarifying the means of detection available in the programmes, the history and trending information available and the corrective actions applied by the programmes. Communication between ageing management and the existing plant programmes was then initiated.

Next, the living AMP was defined, as shown in Fig. II–4. The objectives and requirements of the overall AMP were laid down by means of regulatory compliance requirements and existing plant responsibilities, policies and procedures. Although safe LTO (with respect to nuclear and radiation safety) is the primary objective of the AMP, EPZ also takes into account industrial safety, environmental consequences, legal compliance, loss of production, financial consequences and employee satisfaction when making business decisions by applying its risk matrix.

With the objectives and requirements set, the scope for the AMP was determined using the scope setting process for the AMR in a manner that could remain valid after plant modifications, repair and replacement activities. Having collected all of the necessary information, the plant held 'scope setting workshops' with the original equipment manufacturer, who would also play an important role in conducting the AMR. Specialists in accident analysis, protection systems, plant system knowledge and materials science participated in these workshops, where checklists were used to obtain a clear insight of the intended safety functions of SSCs and to define, on a system level, what systems are included in the scope of the LTO project and ageing management. This facilitated identification of individual structures and components at a later stage. P&IDs were highlighted during the workshops to record decisions on scope setting at this level. Spreadsheets were developed where the responses to the checklists were recorded for the mechanical, electrical, I&C and civil disciplines, containing the justification to include or not include the system. In addition to these scope setting workshops, it was necessary to conduct further activities to expand and refine the scope to include and identify other SSCs whose failure

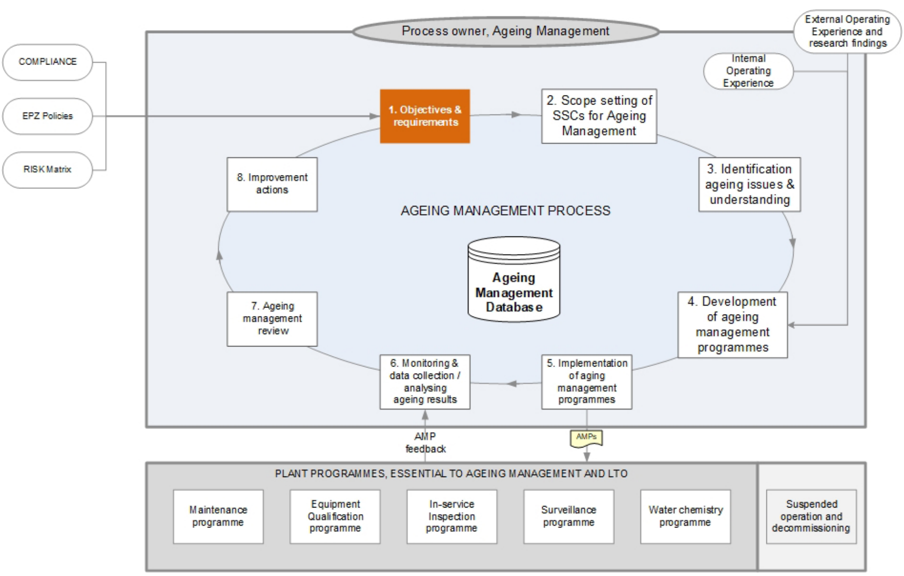

FIG. II–4. Example of a living ageing management programme at the Borssele nuclear power plant, Netherlands.

could prevent SSCs important to safety from fulfilling their intended function, as described in Section 3 of this report.

The next step in the AMP is to identify ageing effects and to understand the affected degradation mechanisms. For this step, it is essential to collect data and identify the sources and record keeping of design information and fabrication methodologies, configuration and modification management, and operational conditions. To facilitate understanding of the degradation mechanisms, experts from the original equipment manufacturer developed catalogues of degradation mechanisms for the three different disciplines. These catalogues provide information on issues to consider when determining the applicability of degradation mechanisms to specific plant conditions so that consistent AMR results could be achieved, and also if different engineers evaluate different sections of the plant. These issues are the following:

- Conditions that need to be considered to understand the ageing mechanism;
- Components or areas where these conditions of concern typically apply in a PWR;
- Examination and detection of the effects of the mechanisms;
- Prevention, mitigation measures and remedies or corrective actions;
- Examples from LWRs in general, and the Borssele NPP specifically.

With all aspects of the relevant ageing mechanisms well understood, existing activities to manage them were identified using the results of the verification of the plant programmes against the nine attributes of an effective AMP. In the majority of cases, it could be demonstrated that relevant ageing mechanisms were already adequately managed by existing plant programme activities. If that was not the case, activities in plant programmes were to be modified or newly introduced.

AMPs were developed using the experience of the AMR. It appeared that the traceability of ageing management activities was improved by defining AMPs. Ageing degradation mechanisms for SSCs or groups of SSCs are determined, based on the following:

- Design and fabrication information;
- Materials used;
- Environmental and operating conditions;
- Operating experience;
- International experience.

These documents show, at a high level, how the ageing degradation mechanisms are to be managed at Borssele. They are based on the AMR project documents, written in Dutch, and provide the basis for the lower level plant programmes (AMPs).

Coordination between disciplines has improved by creating ageing management working groups for major components. The steam generator working group has around eight members, representing the ageing management team with material expertise: the maintenance department, ISI, production and the chemistry department. The working group meets three to four times per year and discusses improvements in all relevant aspects of steam generator ageing, for example tube plate cleaning issues, tube inspection procedures, water quality aspects including the effect of condenser leakages, operating procedures to improve hide-out return, blow-down optimization and international operating experience.

The AMPs have an IGALL based document format and implementation specific to Borssele. They provide the link to (often existing) activities. The completeness of the resulting AMPs is verified by drawing up a matrix of ageing mechanisms, as shown in Fig. II–5. Activities are coordinated with the operational departments responsible for executing the existing plant programmes. Owing to the improved coordination between departments, the clarity of the requirements for the activities to be conducted has also improved a great deal, as has the traceability. Communication of the AMP is managed by issuing one-off or periodic work orders. The work orders have a mark, indicating their relationship with the AMP.

Internal operating experience, external operating experience and the results of research findings are available to the ageing management team in the form of notices. The team evaluates these notices, decides on their applicability to ageing management and decides if additional requirements from the plant programmes are required. In such cases, the overall AMP provides the opportunity to include these activities in the individual AMPs.

Plant programmes were improved by introducing new or modified work orders with a direct relationship to ageing management, on the one hand, and by identifying activities that did not have the same purpose as when they were introduced and, thus, could be optimized or combined with other activities. The results from the activities that were identified in the AMPs are then fed back into the AMP. The information is analysed, the results are reviewed, and conclusions may be drawn in the periodic AMR.

The insights gained from the AMR are used to initiate subsequent activities or modification of the AMP. This concludes the Deming cycle of plan (scope setting, understanding ageing mechanisms), do (developing the AMPs and introducing them to the plant programmes), check (data collection and monitoring, periodic AMR) and act (implementation of improvement actions)

Component \ Ageing mechanism	BAC	Intergranular SCC	Pitting	Stress relaxation	Wear/fretting	PWSCC	Crevice corrosion	Thermal Ageing	Transgranular SCC	Fatigue
Outside area steam generator	BCD		ABC							
Primary chambers and nozzles			ABC						A	
Division sheet			ABC						A	
Tube bundle			ABC		I				A	
Tube sheet						AD				FGH
Rolled plugs					I					
Explosion welded plugs			ABC				A		A	
Welded plugs						AD				
Manhole cover			ABC					DJ		
Nozzle dam bolts			ABC						A	
Dewatering lines		ABC	ABC						A	
Closure bolting	BCD		BC	E						F

PWSCC: primary water stress corrosion cracking SCC: stress corrosion cracking BAC: boric acid corrosion

A	Water chemistry
B	Leakage walkdowns
C	Leak monitoring
D	ISI
E	Preventive tensioning
F	Fatigue analysis
G	Managing transients
H	Fatigue Monitoring
I	Loose Parts monitoring
J	Preventive replacement

FIG. II–5. Mechanism matrix for the primary side of steam generators.

for ageing management (see figure 1 of Ref. [II–3], of which the review and improvement of plant programmes is an important part.

REFERENCES TO ANNEX II

[II–1] NUCLEAR REGULATORY COMMISSION, Generic Aging Lessons Learned (GALL) Report, NUREG-1801, Rev. 2, Office of Nuclear Reactor Regulation, Washington, DC (2010).

[II–2] INTERNATIONAL ATOMIC ENERGY AGENCY, Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL), Safety Reports Series No. 82, IAEA, Vienna (2015).

[II–3] INTERNATIONAL ATOMIC ENERGY AGENCY, Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants, IAEA Safety Standards Series No. 48, IAEA, Vienna (2018).

Annex III

EXAMPLE OF A CORRECTIVE ACTION PROGRAMME

This annex provides an example of a CAP from the United States of America. Following the flow chart in Fig. 2, an example of an event occurrence (external or internal event) related to an AMP would be a component failure due to an ageing effect. A situation where a piping system was leaking would require documentation in the CAP. The leaking pipe is the event that resulted in a condition report being written. The event investigation would identify the root cause of the leaking pipe and would include the identification of the pipe material (e.g. carbon steel), the environment to which the pipe material was exposed (e.g. raw water) and the ageing effect that resulted (e.g. general corrosion).

The corrective action options needed to address the leaking pipe would include looking at the existing AMP to determine if changes were needed. In addition, the 'extent of condition' would be evaluated to determine if additional inspections were needed for other piping in a similar material and environment combination that may also be degraded, but not yet leaking.

Once the corrective actions were approved and implemented (e.g. further inspections, repair of the leak and changes to the AMP), the piping system and the AMP would be monitored to ensure the effectiveness of the corrective action to prevent recurrence of the ageing effect. If the ageing effect was determined to be appropriately managed, the AMP would be confirmed to be effective. However, if the ageing effect continued to impact the integrity of the piping system (e.g. additional pipe leaks occurred), the AMP would be found to be ineffective and additional corrective action would be needed. The example discussed here demonstrates how the CAP is used to continuously monitor and evaluate the effectiveness of all AMPs needed for LTO.

III–1. PURPOSE AND SCOPE

This procedure provides instructions for the administration of a CAP, including the identification, reporting, evaluation and correction of a broad range of conditions. Issues addressed in the CAP include conditions adverse to quality. The process can include identification and disposition of minor conditions that may be precursors to more significant events, areas for improvement and standards performance deficiencies (i.e. deficiencies in performing according to standards) identified during assessments and other activities (e.g. operating experience feedback).

III–2. REFERENCES

This section includes references to regulatory requirements for a CAP, management system documents and related procedures that provide inputs to the CAP (e.g. the operating experience procedure, the self-assessment procedure, oversight procedures).

III–3. DEFINITIONS

This section includes definitions for the following terms:

— Administrative action;
— Adverse condition;
— Augmented quality related;
— Condition;
— Condition adverse to quality;
— Condition report;
— Corrective action;
— Corrective actions to preclude repetition;
— Effectiveness reviews;
— Non-adverse condition;
— Non-conformance;
— Quality related activities;
— Repair;
— Reject;
— Repeat event;
— Rework;
— Safety related;
— Significant conditions adverse to quality;
— Use as is;
— Verification of acceptability evaluation.

III–4. RESPONSIBILITIES

This section includes a summary of responsibilities for personnel involved in the CAP process, such as the following:

— All personnel working at the nuclear installation are responsible for the following:
  - Identifying and reporting conditions;
  - Documenting conditions by initiating condition reports in accordance with this procedure;
  - Assigning a corrective action code in accordance with this procedure;
  - Completing assigned corrective actions as written.

— Management (supervisor and above) is responsible for the following:
  - Ensuring that personnel are familiar with the requirements of the CAP;
  - Ensuring the conditions are reported;
  - Trending is conducted as required;
  - Ensuring that required actions are determined, implemented, and adequate to resolve the condition;
  - Ensuring performance of effectiveness reviews as assigned;
  - Ensuring that non-conforming items are controlled within the guidance of the CAP;
  - Approving root cause evaluations and apparent cause assessments.

— All other personnel responsibilities at the nuclear installation are defined, such as site managers responsible for security, safeguards, licensing, operation and maintenance.

III–5. INSTRUCTIONS

This section includes instructions on the following:

— Precautions and limitations, such as how to handle safeguards information, as well as proprietary and confidential information.

— General requirements, such as the following:
  - Listing of trend codes for condition reports to ensure consistent use and effective trending of conditions;
  - Templates for performing root cause and apparent cause evaluations;
  - Listing of examples of adverse conditions that are reported;
  - Instructions on how to identify immediate actions to minimize the condition consequences;
  - Guidance on whom to notify when an adverse condition is found;
  - Guidance on handling of safeguards, proprietary or confidential information;
  - Guidance on classification of non-conforming items (e.g. use as is, reject, repair, rework);

  - Guidance on how to document the condition report (e.g. in an electronic database) and what information is required to be provided, level of detail and immediate and interim actions taken.
- — Operability, functionality and immediate reportability instructions, such as the following:
  - When to notify the operations department to make an operability determination;
  - When to notify the regulatory body if required by regulations.
- — Condition report screening, to ensure appropriate oversight, classification, identification of corrective actions, timeliness of actions to be taken and consistency.
- — Condition report disposition requirements, such as categories or significance level for the condition reports; for example:
  - Category A — significant conditions adverse to quality;
  - Category B — adverse conditions that warrant additional analysis;
  - Category C — adverse conditions (e.g. broken, fixed) that do not warrant additional analysis;
  - Category D — adverse conditions that are being addressed by other efforts or systems;
  - Category NC, NA or N — non-adverse conditions that need additional analysis (NC), have been addressed (NA) or are closed to other processes (N).
- — Corrective actions instructions, such as general instructions on assigning corrective action type codes, documentation of actions (via electronic system), handling of assignments to another department, assignment of due dates for actions and how to close an action.
- — Periodic review instructions, such as categories of condition reports to be reviewed and the frequency of the review to ensure the corrective action has been effective and the condition has been addressed.
- — Programme oversight instructions, such as which organization performs the oversight of the CAP, the frequency of audits and sample size, and the sharing of audit results.

III–6. RECORDS

This section provides the instructions for maintaining the condition report and corrective action documents in accordance with records management and document control requirements.

Annex IV

EXAMPLES OF COMMODITY GROUPING FOR EACH TECHNICAL AREA

This annex provides examples of commodity grouping for different technical areas.

IV–1. TECHNICAL AREA OF MECHANICAL COMPONENTS

Grouping of passive mechanical components can be performed on the basis of the following features of the equipment:

- Commodity classification (e.g. valve bodies of one type series, pump casings, tanks of similar technical type);
- Material (e.g. stainless steel, carbon steel);
- Manufacturing technology (e.g. forged material, cast material);
- Mode of operation (continuous, intermittent, standby);
- Physical parameters of the medium (e.g. pressure, temperature);
- Chemical composition of the medium.

Table IV–1 shows an example of how commodity grouping can be performed with the use of codes typically used in some Member States. For example, primary water pumps, which are made of corrosion resistant steel, would be denoted D112, while reactor cooling water pumps made of carbon steel would be denoted D311. In the case of heat exchangers, an extra code can be used to denote the second medium, such as W1112 for the regenerative heat exchangers in the chemical and volume control system. It is also possible to break down heat exchangers into the shell side (pressure retaining parts including shell and shell inlet and outlet nozzles, shell side of tube sheet, tube (outside), baffle plates (tube supports)) and the tube side (tubes (inside), channel head including inlet and outlet nozzles, channel cover, divider plate, tube side of tube sheet) since the internal and external medium is different and, thus, different degradations mechanisms can occur.

Grouping of active mechanical components can be performed based on the following:

- Type of component (e.g. valves, pumps, fans);
- Intended function;

— Design (if applicable):
  - Mode of operation (e.g. continuous, intermittent, standby);
  - Environment (e.g. mild, harsh).

TABLE IV–1. EXAMPLE OF COMMODITY GROUP CODES FOR PASSIVE MECHANICAL COMPONENTS

Format of the code: $AN_1N_1N_2N_3$					
Character in the format	A	N_1	(N_1)	N_2	N_3
Meaning	Type of equipment	Medium 1	(Medium 2)	Environment	Component material
Possible values	B — Vessel or tank D — Pump DV — Fan N — Filter S — Valve W — Heat exchanger Z — Pipeline, plate line	1 — Primary water 2 — Primary steam 3 — Treated water 4 — Water steam 5 — Raw water 6 — Other contaminated solutions 7 — Oil 8 — Gas 9 — Acid/alkali 10 — Steam–gas mixture		1 — Air, indoor, controlled 2 — Air, indoor, uncontrolled 3 — Air, outdoor 4 — Air, moist 5 — Buried and underground	1 — Carbon steel, non-corrosion-resistant steel 2 — Corrosion resistant steel 3 — Other alloys 4 — Mixture (carbon steels, non-corrosion-resistant steels/corrosion resistant steels) 5 — Mixture (corrosion resistant steels/other alloys) 6 — Mixture (carbon steels, non-corrosion-resistant steels/other alloys) 7 — Mixture (carbon steels, no-corrosion-resistant steels/corrosion resistant steels/other alloys)

A typical case can be described for active mechanical components in valves. Valves can be divided into different subgroups: motor operated, air operated, check and manual. In the case of check valves, for instance, there are different designs such as double disc, in-line and piston, which are thus subject to different degradation mechanisms. The mode of operation and environment are also typically considered for commodity grouping since they might affect ageing and therefore different ageing management activities can be applicable.

Table IV–2 shows basic examples of how the division of component types into subgroups can be done before commodity groups are created.

TABLE IV–2. BASIC DIVISION OF ACTIVE MECHANICAL COMPONENTS BEFORE COMMODITY GROUPING

Main group based on component type	Subgroups
Valves	Motor operated valves
	Air operated valves
	Check valves
	Manual valves
	Safety relief valves
	Pressure reducing valves
	Solenoid valves
Pumps	Axial flow pumps
	Radial flow pumps
	Piston flow pumps
Compressors and fans	Piston compressors
	Centrifugal compressors
	Axial flow compressors
	Centrifugal fans
	Axial flow fans

IV–2. TECHNICAL AREA OF CIVIL STRUCTURES

Grouping for passive civil structures can be performed based on the following features:

- Type of building (e.g. containment, water cooling supply structures or building, other types of building);
- Type of structure (e.g. liner, penetration, concrete structure, steel structure, hatch);
- Environment (e.g. indoor, outdoor, raw water, underground).

Table IV–3 shows basic examples of commodity groups for civil structures.

IV–3. TECHNICAL AREA OF ELECTRICAL AND INSTRUMENTATION AND CONTROL COMPONENTS

Passive electrical and I&C structures and components can be grouped on the basis of the type of component, such as cable penetrations, cabinets, racks and the lightning protection system. In some cases, the material and working environment (mild or harsh) can be relevant to form commodity groups such as for cables. In the specific case of cables, even voltage can be relevant for commodity grouping.

Active electrical and I&C components can be grouped solely on the basis of the type of component and the intended function. Examples of commodity groups can be batteries, rectifiers, actuators, electrical heaters, oil filled transformers, dry type transformers, the reactor protection system, and the rod control system. In some cases, the working environment (mild or harsh) and mode of operation can be used to create different commodity groups within the same type of component and intended function.

IV–3.1. Examples of commodity groups for electrical and instrumentation and control components from the Netherlands

After scope setting for electrical and I&C systems, potential active and passive commodity groups for these systems were identified using international guidelines [IV–1]. These potential commodity groups were fine-tuned to fit the ageing management and maintenance programmes at the plant. This resulted in the definition of seven passive and 14 active plant specific electrical and I&C commodity groups. The passive commodity groups were divided between electrical and I&C components and structural parts used in the electrical and I&C systems.

TABLE IV–3. EXAMPLES OF COMMODITY GROUPS FOR CIVIL STRUCTURES

Building	Type of structure	Intended function	Material	Environment	Commodity group
Containment	Foundations	Supporting	Reinforced concrete	Soil Groundwater	CF1 CF2
	Underground structures	Supporting	Reinforced concrete	Soil Groundwater	CU1 CU2
	Interior reinforced concrete structures	Shielding Supporting	Reinforced concrete	Containment interior environment	CI1 CI2
	Exterior reinforced concrete structures	Shielding Supporting	Reinforced concrete	Climate conditions	CE1 CE2
	Pre-stressed concrete structures	Radiation protection Missile impact shielding Supporting Protection against outdoor environment	Reinforced concrete	Containment interior environment Air — outdoor	CP1 CP2 CP3 CP4
	Pre-stressing tendons	Pre-stressing of concrete structure	Steel	Internal environment (uncontrolled)	CT1

TABLE IV–3. EXAMPLES OF COMMODITY GROUPS FOR CIVIL STRUCTURES (cont.)

Building	Type of structure	Intended function	Material	Environment	Commodity group
Diesel generator, compressor and pumping station buildings	Foundations	Supporting	Reinforced concrete	Soil Underground water	DB1 DB2
	Reinforced concrete structures	Supporting, shielding[a]	Reinforced concrete	Air — indoor Air — outdoor[b]	DR1
	Coating	Protection against outdoor environment	Painted coating	Air — outdoor	DC1

[a] In some cases, different intended functions do not result in different degradation mechanisms and different AMPs. Therefore, it is possible to have one commodity group for both functions.

[b] In this case, different environments do not result in different degradation mechanisms, because the structure is protected against the outdoor environment by a coating.

The intended functions of the seven passive commodity groups are presented in Table IV–4. Ageing management of these groups was reviewed during the LTO project. Ageing management of the active commodity groups was reviewed in a dedicated assessment of all active components in the scope of the LTO project.

Commodity grouping was aimed at structures and components with similar operating environments and materials of construction. Identifying passive commodity groups in this manner allowed an AMR to be conducted on these groups which was not influenced by cross-system boundaries.

The applicable commodity groups for each system within the scope of the LTO project were initially identified by reviewing the relevant system P&IDs and engineering knowledge by a group of experts. These potential commodity groups per system represented a conservative overview and needed to be investigated in detail during the subsequent LTO assessment. The detailed selection of components or structural parts for each commodity group was part of the LTO assessment.

TABLE IV–4. INTENDED FUNCTIONS OF PASSIVE COMMODITY GROUPS

Commodity group	Intended function
Cables	Insulation
Wires	Insulation
Electrical connectors	Insulation, conductivity
Electrical containment cable penetrations	Insulation, conductivity
Cable penetration (floors, walls)	Protection, support
Cabinets, racks	Protection, support
Cable trays	Protection, support

All the equipment needed for the electrical supply of a system (cables, termination boxes, penetrations) was allocated to the relevant components. This was done for process components and electrical cabinets. Each commodity group was thus allocated to at least one system. The connection from the switchgear breaker to the electrical consumer was allocated to the respective process system.

The signal connection from a sensor or transducer to an I&C cabinet was allocated to the process system in the same manner. Connections between I&C cabinets and control panels were allocated to the panels.

Plant walkdowns were performed to evaluate the determination of commodity groups on site and to verify the completeness of the scope of relevant structures and components in commodity groups. Some structural parts in the scope of ageing management, such as floor penetrations, cable trays and protections, are not listed in the plant's configuration system. Plant walkdowns were therefore essential to be able to identify these structural parts.

The commodity group for cable protections was identified as potentially applicable to the plant in the preparatory phases of scope setting. However, in this case, the plant walkdowns concluded that this commodity group was not applicable to the plant.

IV–3.2. Passive electrical and instrumentation and control commodity groups

Cables. Power and I&C cables and splices may be used in atmospheric conditions or buried (e.g. leading to the cooling water inlet building or laid in conduits between buildings). They are grouped for all voltage levels. The insulation materials are subject to AMR for LTO. Splices are used to connect cable conductors to penetration pigtails or to motor leads, and to connect sections of cables that have been repaired or replaced. The electrical splices (i.e. insulation) review includes heat shrink tubing and insulation tape used for the insulation in electrical splices.

Wires. A wire is defined as a single conductor with a single layer of insulation. Wires can be outside or inside components or cabinets. Examples are wires on cable spreaders in spreader rooms (outside) or wires in I&C cabinets (inside). They are grouped for all voltage levels. The insulation materials are subject to AMR for LTO.

Connectors and terminals. Electrical connectors are used to connect cable conductors to other cables or electrical devices or to the grounding system. The connectors in the grounding system contain terminal blocks, consisting of an insulation base with fixed metallic points for earthing wires and cables (conductors). The insulating material parts and their electrical conductivity are under review in this electrical commodity group. Terminal blocks are installed in enclosures (i.e. panels, control boards, motor control centres, terminal boxes and junction boxes). Terminal blocks in passive enclosures are in the scope of the AMR. Three main types of connector are: compression, fusion and plug-in (mated) connectors. A brief description of each is provided below:

- *Compression connectors.* Fittings (e.g. ring lugs, barrels) that are bolted, physically crimped or mechanically swaged to connect cable conductors. The bolted connections are used in metal enclosed buses, large fuses and internal equipment connections.
- *Fusion connectors.* Cable connections made by welding, brazing or soldering where a permanent conductor connection is desired.
- *Plug-in (mated) connectors.* Connectors with one or more electrical contacts that plug or screw into a mating receptacle; useful where ease and frequency of separation of an electrical connection are desired, for ease of mating specific types of equipment, and where multiple simultaneous electrical connections need to be made.

Fuse holders outside the metal enclosed buses (battery fuse holders) in the scope of an AMR are located in passive assemblies or enclosures. These are considered as connectors and therefore allocated to this commodity group.

The connector insulation material may be of a variety of organic polymers. Its insulating properties and the electrical conductivity behaviour of the connection are subject to AMR in this electrical commodity group.

Electrical penetrations (containment and annulus). Electrical penetration assemblies are provided as a means of passing electrical circuits through the containment building wall, while maintaining the integrity of the containment pressure barrier. Electrical penetrations entering the containment are handled as an entire assembly (i.e. structural and electrical portions) in the electrical and I&C scope. However, the AMRs of the respective portions are addressed by the relevant discipline. The electrical portions of the electrical penetration assemblies are the internal conductors (electrical), insulation materials (e.g. glass) and the connector insulation materials.

Cable penetrations through walls and floors are placed in the scope of a commodity group for passive structural parts for electrical and I&C if they fulfil the function of 'fire protection' or 'tightness against ingress' (of water, steam).

Two other passive structural commodity groups for electrical and I&C consist of the following:

— Cabinets, racks and other enclosures;
— Cable trays and tubes for cable routing and protection.

It is not possible to allocate elements in these commodity groups to specific systems. These structures and components are therefore grouped on the basis of used materials and environmental conditions only. Racks and cabinets exist in all electrical, I&C and process systems except those which are contained in cabinets only, such as switchgears, busbars and rectifiers.

IV–3.3. Active electrical and instrumentation and control commodity groups

The following active commodity groups were identified:

— *Power transformers.* Including protection equipment, measuring devices, isolators, current transformers, voltage transformers.
— *Power supply distribution systems*. 6 kV AC, 380 V AC, 220 V DC and 24 V DC systems, including isolators, breakers, measuring transformers and transmitters, relays, protection relays, fuses, indication meters and lights, power supply decoupling.

— *Battery chargers, static converters.* 220 V DC and 24 V DC.
— *Batteries*. 220 V DC and 24 V DC, including isolators and fuses.
— *Rotating converters*. Including controllers, measurement, indication.
— *Generators and motors.* Emergency diesel generators, 6 kV AC, 380 V AC, 220 V AC and 220 V DC motors. Electrical motors of actuators are allocated to the commodity group 'Actuators'.
— *Actuators.* Including motor operated valves and solenoid drives.
— *Control circuits*. Loop controllers, including solid state devices, indicators and meters.
— *Emergency diesel equipment*. Including control circuits, protection relays and indicators.
— *Instrumentation.* Including process instrumentation (e.g. pressure, temperature, flow, frequency, speed, voltage) sensors, transducers, transmitters, analysers and monitors (e.g. radiation monitors).
— *Panel assemblies.* Main and emergency control room panels and emergency diesel panels, including switches, indicating lights and meters, alarm equipment and recorders.
— *Electrical heaters.* Electrical heaters and heat tracing.
— *Electronic cabinets*. Cabinets, including fuses, surge arresters, solid state devices and power supply decoupling.
— *Non-process systems with safety significance*. Communication systems, fire detection, lightning protection and earthing.

REFERENCE TO ANNEX IV

[IV–1] AREVA, Screening of Relevant Structures and Components in the Frame of the KCB Long-Term Operation Process, Rep. NTCM-G/2009/en/0144, Rev. B, Erlangen (2011);
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ABBREVIATIONS

AMP	ageing management programme
AMR	ageing management review
BWR	boiling water reactor
CANDU	Canada deuterium–uranium (reactor)
CAP	corrective action programme
I&C	instrumentation and control
IGALL	International Generic Ageing Lessons Learned
IRS	International Reporting System for Operating Experience
ISI	in-service inspection
LTO	long term operation
P&ID	process and instrumentation diagram
PHWR	pressurized heavy water reactor
PSR	periodic safety review
PWR	pressurized water reactor
SSC	structure, system and component
TLAA	time limited ageing analysis

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In recent decades, the number of IAEA Member States planning to extend the operation of their nuclear power plants (NPPs) beyond the time frame originally anticipated has steadily increased. These decisions have been influenced by the significant economic advantages offered by the long term operation (LTO) of existing NPPs. This Safety Report complements IAEA Safety Standards Series Nos SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation, and SSG-48, Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants. It provides information on selected topics from the latter, and specifically, it addresses data collection and record keeping, scope setting for structures, systems and components, plant programmes, corrective action programmes, and documentation of ageing management and LTO assessment. The publication focuses on NPPs throughout their lifetime, including operation beyond the time frame originally established for their operation and decommissioning, while considering the different reactor designs that exist around the world. It is also relevant for facilities for spent fuel storage and radioactive waste management at NPPs. It may also be used as a basis for managing the ageing of other nuclear installations and for radioactive waste management facilities. This Safety Report is intended to provide information for operating organizations but may be also used by regulatory bodies.

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